

**Development of a Systemwide Program:
Stepwise Implementation of a Predation Index, Predator Control Fisheries,
and Evaluation Plan in the Columbia River Basin**

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VOLUME I

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INDEX, PREDATOR CONTROL FISHERIES, AND
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I. IMPLEMENTATION

Cooperators

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Columbia River Inter-Tribal Fish Commission

University of Washington

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EXECUTIVE SUMMARY

by Charles F. Willis

We report our results from the second year of a basinwide program to harvest northern squawfish (*Ptychocheilus oregonensis*) in an effort to reduce mortality due to squawfish predation on juvenile salmonids during their emigration from natal streams to the ocean. Earlier work in the Columbia River Basin suggested predation by northern squawfish on juvenile salmonids may account for most of the 10-20% mortality juvenile salmonids experience in each of eight Columbia and Snake River reservoirs. Modeling simulations based on work in the John Day Reservoir from 1982 through 1988 indicated it is not necessary to eradicate northern squawfish to substantially reduce predation-caused mortality of juvenile salmonids. Instead, if northern squawfish were exploited at a 10-20% rate, reductions in their numbers and restructuring of their populations could reduce their predation on juvenile salmonids by 50% or more.

Consequently, we designed and tested a sport-reward angling fishery and a commercial longline fishery in the John Day pool in 1990. Based on the success of these limited efforts, we implemented three test fisheries on a multi-pool or systemwide scale in 1991: a tribal longline fishery, a sport-reward fishery, and a dam-angling fishery. The sport-reward and dam-angling fisheries were continued in 1992 together with an investigation of the feasibility of implementing a commercial longline fishery in the Columbia River below Bonneville Dam.

In addition, we examined several alternative harvest techniques to determine their potential for use in systemwide test fisheries. Evaluation of the success of the two test fisheries conducted in 1992 in achieving a 20% exploitation rate on northern squawfish, together with information regarding the economic, social, and legal feasibility of sustaining each fishery, is presented in Section II of this report.

The implementation team consists of the Oregon Department of Fish and Wildlife Columbia River Coordination Section (ODFW), S.P. Cramer and Associates, Inc. (SPCA), the Washington Department of Wildlife (WDW), the Columbia River Inter-Tribal Fish Commission (CRITFC), the University of Washington (UW), the National Marine Fisheries Service (NMFS), and the Pacific States Marine Fisheries Commission (PSMFC). ODFW, with assistance from SPCA, is responsible for the coordination and administration of the entire program and has subcontracted various tasks and activities to WDW, CRITFC, UW, NMFS, and PSMFC based on expertise each brings to the tasks involved in implementing the program. Objectives of each cooperator related to fishery implementation are as follows.

1. ODFW (Report A): Investigate the feasibility of implementing a commercial longline fishery in the Columbia River below Bonneville Dam.
2. WDW (Report B): Implement a systemwide sport-reward fishery.

3. CRITFC (Report C): Implement a systemwide angling fishery at eight mainstem Snake and Columbia River dams.
4. UW (Report D): Examine and summarize information regarding alternative harvest techniques to determine their utility for harvesting northern squawfish in mainstem reservoirs of the Snake and Columbia rivers.
5. NMFS (Report E): Investigate differences in juvenile salmon survival associated with releases from Bonneville Hatchery at alternative release locations and following removal of northern squawfish by electrofishing.
6. PSMFC (Report F): Process and provide accounting for reward payments and compensation payments to participants in the sport-reward and commercial longline fisheries, respectively.

Background and rationale for the study can be found in Report A of our 1990 annual report (Vigg et al. 1990). Highlights of the results of our work by report are as follows.

Report A
Feasibility Investigation of a Commercial Longline Fishery
for Northern Squawfish in the Columbia River Downstream from Bonneville Dam

1. A commercial longline fishery for northern squawfish was conducted in the Columbia River downstream from Bonneville Dam. The purpose of this test fishery was to improve gear effectiveness, to assess catch efficiency, and to evaluate the potential for a self-sustaining commercial longline fishery.
2. Commercial fishers used various longline, hook set, and bait types. The fishing season lasted from April 1 to August 14, 1992. A total of 1,755 longline sets were deployed and fished for a total of 2 1,997 hours. Commercial fishers caught a total of 6,035 fish.
3. Northern squawfish were caught at a rate of 36% (2,158 fish) or 0.1 northern squawfish per hour fished. Nearly all incidentally caught species were released alive. White sturgeon comprised 61% (3,660 fish) of the total catch.
4. Most longlines (1,015 lines, or 58%) were baited with fresh, frozen coho smolts and accounted for 70% (1,530 fish) of the total northern squawfish catch and 53 % (1,934 fish) of the white sturgeon catch.

5. When considering catch, effort, and cost collectively, we concluded that a commercial longline fishery was ineffective for harvesting large numbers of northern squawfish. It may, however, be useful for harvesting localized concentrations under special conditions.

Report B
Evaluation of the Northern Squawfish Sport-Reward Fishery
in the Columbia and Snake Rivers

1. Objectives for 1992 were to implement the sport-reward fishery for northern squawfish in the lower Snake and Columbia rivers, to conduct a survey to assess impacts of the fishery on non-target fish species, and to report on the inseason dynamics of the fishery.
2. The northern squawfish sport-reward fishery was conducted from May 18 through September 27, 1992. Twenty registration stations were located throughout the lower Snake and Columbia rivers. The area serviced by registration stations was increased by approximately 50% over that serviced in 1991, with the placement of five additional stations below Bonneville Dam.
3. A total of 186,904 northern squawfish 11 inches or longer were caught by 35,128 anglers, which represented 39.7% of the total number of registered anglers that participated in the fishery in 1992. Harvest of northern squawfish increased 15% over that observed in 1991 with an increase in participation of 24%. The catch per unit effort (CPUE) decreased 10.6% in comparison to 1991, yielding 2.11 fish per angler day in 1992.
4. Fork lengths of northern squawfish averaged 346 mm and 93% of those measured were over 250 mm (11 inches) total length.
5. A T-test indicated a statistically significant decrease in mean fork length of total northern squawfish catch from 1991 to 1992.
6. A total of 2,349 fish other than northern squawfish were returned to the registration sites comprising 1.24% of the total catch. Smallmouth bass, walleye, channel catfish, and peamouth comprised the majority of other fishes caught.
7. A portable computerized data collection station was tested during the last month of the season. Modifications to the software are in progress and evaluation will continue in 1993.

8. We recommend that the 1993 sport-reward fishery start in early May and extend through mid-September. Fish licenses should be required for residents of both Oregon and Washington. Regulations specific to the sport-reward fishery should be developed. Some registration stations should be relocated to areas where high predation index values indicate the potential for greater reduction of predator impacts on juvenile salmonid survival. Additional incentives and aggressive media coverage should be used to promote participation in the fishery. The use of computerized data collection stations should continue to be investigated.

Report C
Controlled Angling for Northern Squawfish at Selected Dams
on the Columbia and Snake Rivers in 1992

1. Dam angling at eight dams on the lower Snake and Columbia rivers during 1992 resulted in 27,868 northern squawfish being caught during a 21-week season.
2. The total catch of northern squawfish in 1992 declined 30% from the 1991 catch. This was largely due to declines in catch at Snake River dams.
3. During 1992, incidental catch was roughly half of that observed in 1991. As in 1991, the majority of incidentally caught fish were taken at Snake River dams, with channel catfish comprising 79% of the incidentally caught fish. Salmonids comprised 1.41 % of the incidental catch and .08% of the total catch in 1992.
4. We recommend that angling at all eight dams be continued in 1993. Fishing effort will be shaped over time and location to increase harvest. A mobile crew will be used to augment resident crew efforts. We will continue to evaluate the contribution and feasibility of angling from boats in boat restricted zones at some dams. We will increase the use of controlled volunteer angling at high-catch dams. We will work with others to relocate bird wires to increase angler access and effectiveness. Biological sampling on incidentally caught channel catfish will be pursued at key dams.

Report D
Evaluation of Harvest Technology for Squawfish Control
in Columbia River Reservoirs

1. We prepared a comprehensive report that summarizes information on harvest methods for squawfish removal. Each type of gear was evaluated with respect to squawfish catch rates, incidental catch rates, ease of deployment, and potential contribution to the overall northern squawfish management program. This report was presented to ODFW in October 1992 as a special issue paper and is available under separate cover from the University of Washington.

2. During 1992, the University of Washington developed and tested two methods for large-scale removal of northern squawfish on the Columbia River -- mobile floating trap nets and boat-based electrofishing. Additionally, potential restrictions and regulations for a large-scale floating trap net fishery were investigated.
3. Over 5,500 northern squawfish were captured during the 1992 season using a stationary Merwin trap. This accounted for 21.5% of the overall catch of all species. Salmonids comprised 3.63% of the total catch, a decrease of over 82.6% from 1991 catch levels, while northern squawfish catches increased by 31.9%.
4. The mean fork length of northern squawfish caught declined from 314 mm in 1991 to 295 mm. A 46% increase from 1991 in northern squawfish that were less than 250 mm long was due primarily to the large numbers of small squawfish captured during the month of August.
5. Mobile Merwin trapping occurred in a variety of locations throughout the Columbia River during the 1992 season. Mobile traps were fished a total of 79 days capturing 1,108 northern squawfish, comprising 21.2% of the total catch. Salmonids accounted for 14.3% of the total catch with nearly 75% of these fish caught in two sets near McNary Dam during the peak of the sockeye run.
6. Electrofishing on the Columbia and Snake rivers accounted for a total of 4,076 northern squawfish taken in 43.16 hours of unit on-time, yielding a CPUE of 94.44 northern squawfish per hour on-time. The overall CPUE for northern squawfish greater than 250 mm long was 18.9 northern squawfish per hour on-time.

Report E
Effectiveness of Predator Removal for Protecting Juvenile
Fall Chinook Salmon Released from Bonneville Hatchery, 1992

1. Subyearling chinook salmon from Bonneville Hatchery released into the midstream Columbia River exhibited significantly higher survival rates than fish released into Tanner Creek at the hatchery. The difference in survival is in part related to predation by northern squawfish on fish released at the hatchery.
2. The predominance of coded-wire tags (CWTs) from Tanner Creek released juvenile salmon in digestive tracts of northern squawfish indicated that juvenile salmon released from the hatchery were more vulnerable to predation by northern squawfish located in the river region near Bonneville Hatchery than juveniles released midstream.

3. The survival difference between midstream Columbia River and Tanner Creek release groups appears to be inversely related to the movement rate of Tanner Creek release groups. Higher movement rates for fish were associated with high river flows and may also have been influenced by smoltification differences between years.
4. It was difficult to determine if the high numbers and catch rates of predators at the transects nearest Tanner Creek occurred in response to the hatchery release or to general high densities of northern squawfish throughout the study area.
5. Electrofishing efforts to remove northern squawfish from the migration route of juvenile salmon released from Bonneville Hatchery did not significantly reduce the survival difference between midstream Columbia River and Tanner Creek release groups.

Report F

Northern Squawfish Sport Reward Payments

1. During 1992, a total of \$537,066 was paid to anglers for 179,022 northern squawfish harvested in the sport-reward fishery. Also, \$52,126.50 was paid as compensation to three individuals under contract to participate in the commercial longline fishery.
2. Payment activity for the sport-reward fishery was highest during June and July, accounting for about 74% of total dollars paid.
3. Vouchers that had missing or incomplete information were returned to anglers for completion, causing delay in payment. A total of 1,736 vouchers were returned.
4. There were several requests by various agencies to withhold payment on anglers suspected of wrongdoing. A total of 14 individuals had their payments withheld or delayed in accordance with these requests.
5. The commercial longline fishery was open for 14 weeks and PSMFC processed 144 vouchers totaling \$52,126.50. Longliners were compensated \$250 per day for a five-day work week or \$312.50 for a four-day work week. Compensation for effort totaled \$48,187.50 and reward payments for 1,313 squawfish caught during the season totaled \$3,939.

REPORT A

**Feasibility Investigation of a Commercial Longline Fishery
for Northern Squawfish in the Columbia River
Downstream from Bonneville Dam**

Prepared by

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Paige M. Pierce**

**Oregon Department of Fish and Wildlife
Columbia River Coordination Section
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1992 Annual Report

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We thank Jack Marenkovich, Columbia River Fishermen Protective Union, and Les Clark, Northwest Gillnetters, for their assistance in soliciting commercial fishing contractors. Special thanks to Wallace Nelson and his crew, Larry Ponn and his crew, and Brian Tarabochia and his crew for their cooperation. We extend our thanks to Sharon L. Conyers, Oregon Department of Fish and Wildlife, for the preparation of related personal service contracts.

We thank Stephen B. Mathews and Thomas K. Iverson, University of Washington; Susan Hanna and Jon Pampush, Oregon State University; and David L. Ward and his staff, ODFW Research and Development, Predator Control Evaluation study, for their help with project coordination.

Matthew M. Marshall and John T. Skidmore, ODFW Columbia River Coordination Section, Commercial Longline project, assisted with overseeing field operations. Seven other seasonal employees monitored fishing activities, and recorded and summarized related data sets.

ABSTRACT

We are reporting progress on evaluating the feasibility of a commercial longline fishery for northern squawfish (*Ptychocheilus oregonensis*) in the Columbia River downstream from Bonneville Dam. The purpose of this test fishery is to improve gear effectiveness, to assess efficiency limitations, and to evaluate the probability of a self-sustained commercial longline fishery for northern squawfish in the lower Columbia River.

Pre-season fishing was conducted from April 1 to May 22 to (1) identify potential fishing locations with high northern squawfish abundance, (2) to determine early season susceptibility of northern squawfish to various longline gear configurations and bait types, and (3) to develop methods to reduce the incidental catch of white sturgeon (*Acipenser transmontanus*). The Oregon Department of Fish and Wildlife (ODFW) contracted with three commercial fishers to maximize catch rates for northern squawfish from May 18 to August 14. In addition, we evaluated the level of public interest in a longline fishery to be implemented in subsequent years for northern squawfish.

Contracted commercial fishers used various longline, hook set, and bait types. ODFW employees observed all fishing activities. From April 1 to August 14, a total of 1,755 longline sets were deployed and fished for 21,997 hours (soaking time). The total catch was 6,035 fish including 2,158 (36% of the catch) northern squawfish, or 0.1 northern squawfish per hour fished. Nearly all incidentally caught species were released alive. White sturgeon catch totaled 3,660 fish (61% of the total catch). Three adult and four juvenile salmonids were also caught. Most longlines (1,015 lines, or 58%) were baited with fresh, frozen coho smolts and accounted for 70% (1,530 fish) of the total northern squawfish catch and 53% (1,934 fish) of the white sturgeon catch.

INTRODUCTION

Water impoundments created by the development of the Columbia River Basin hydroelectric system delay downstream migration of juvenile salmonids and prolong their exposure to predators (Raymond 1988). Resulting habitat changes have enabled some resident, predaceous fish species, particularly northern squawfish (*Ptychocheilus oregonensis*), to increase in abundance (Beamesderfer and Rieman 1988). Predation is an important component of reservoir mortality in migrating juvenile salmonids, and could account for 80% of the reservoir losses (Rieman et al. 1988). Modeling results have suggested a potential 50% reduction in juvenile salmonid losses to predation when resident northern squawfish populations are exploited by sustained fisheries at a rate of 10-20% (Rieman and Beamesderfer 1990).

Previous predator control studies (Vigg and Burley 1989, Vigg et al. 1990) developed a stepwise process for systematic implementation and evaluation of various northern squawfish fisheries in the Columbia River Basin. Angling fisheries (sport-reward fishery and controlled angling at selected hydropower projects) were implemented. In 1989 the University of Washington evaluated longline gear for applicability to commercial harvest using small vessels and manual reels in the John Day Reservoir (Mathews et al. 1989). The use of monofilament groundlines, 3/0 hooks and salmonid smolts for bait was most effective. Catches averaged one northern squawfish per 12 baited hook sets. Total catch was comprised of 72% northern squawfish, 23 % white sturgeon and 5% other species. In 1990 a subsidized commercial, limited entry (three tribal vessels), longline test fishery was implemented in the John Day Reservoir (Vigg et al. 1990). Catches were lower than expected based on 1989 results and averaged one northern squawfish per 22.5 hook sets. Total catch was comprised of 73% northern squawfish, 15% white sturgeon and 12% other species.

Mathews and Iverson (1990) suggested that the effectiveness of longline gear as a predator removal method be tested when applied on a larger scale. Consequently, ODFW implemented a commercial longline fishery in three Columbia River reservoirs in 1991 (Malette and Willis 1991). All members of the four treaty tribes were eligible for

participation in the fishery; however, only four tribal crews fished with regularity (i.e., more than one week). We conducted a phone survey to determine reasons for low tribal participation. The survey revealed that unfamiliarity with locations of northern squawfish concentrations and unfamiliarity with longline gear resulted in low catch rates. Consequently, fishing trip expenses could not be covered by reimbursement of \$4 per qualifying northern squawfish caught. Catches averaged one northern squawfish per 34.7 hook sets. Total catch was comprised of 66% northern squawfish, 22% white sturgeon and 12 % other species.

Due to very low tribal participation in the 1991 longline fishery, and resulting inadequate sample sizes, the effectiveness of a large scale, commercial longline fishery and its relative contribution to northern squawfish management program harvest could not be evaluated conclusively. Based on the 1991 results, we suggested additional subsidies to increase tribal interest and participation. In addition, we recommended to investigate the feasibility of a commercial longline fishery in the Columbia River downstream from Bonneville Dam. In 1992, this recommendation was addressed through the implementation of a limited entry (three vessels) test fishery.

METHODS

The Northern Squawfish Commercial Longline Fishery Investigation Project was implemented in the lower Columbia River from Multnomah Falls, River Mile (RM) 136, downstream to the west end of Puget Island, RM 38. We conducted pre-season fishing tests from April 1 to May 22 (Week 1 through Week 8) to (1) identify potential fishing locations with high northern squawfish abundance, (2) to determine early season susceptibility of northern squawfish to various configurations of longline gear, and (3) to develop methods to reduce the incidental catch of white sturgeon. The fishing season started on May 18 and lasted through August 14 (Week 8 through Week 20).

The ODFW crew fished from Week 1 through Week 17. We used a 1974 Clipper Craft 23-foot wooden dory (FV Grey Ghost) crewed by three ODFW seasonal employees. The crew used a manual reel with drag control and free spooling features, 250-pound test soft monofilament groundline with brass bead stops every three feet, 1/4-inch plastic gangion snaps, 12-inch gangion leaders with test strengths ranging from 6 to 30 pounds, 3/0 Eagle Claw nickel or bronze plated "up-eye" hooks, and numerous bait and lure types to target northern squawfish. During the pre-season, northern squawfish were marked with Floy spaghetti tags and the entire catch was released. The ODFW crew started to remove northern squawfish in Week 8 and continued to do so through the end of the fishing season.

We contacted the Columbia River Fishermen Protective Union in Astoria, Oregon, and the Northwest Gillnetters in Chinook, Washington, to solicit commercial fishers who could assist with harvesting northern squawfish at commercial rates using longline gear. We

received a total of 37 responses from commercial fishers who expressed interest in the project. From these fishers, 22 applied (Appendix Figure A-1) for a total of three available personal services contracts. We graded all applications on a 42-point system (Appendix Figure A-2) and interviewed the 12 highest scoring applicants. We offered personal services contracts to the three highest scoring fishers, Wallace A. Nelson, Larry E. Ponn, and Brian Tarabochia.

These fishers and their crews joined the ODFW crew from May 18 to August 14 to maximize northern squawfish catch using longline gear. Fishing occurred Monday through Friday (except for holidays) for up to 40 hours per week. Contractors were required to (1) set and reset, (2) reset, or (3) reset and remove at least 7,200 feet of groundline and 720 baited hooks within an eight-hour period, or 9,000 feet of groundline and 900 baited hooks within a 10-hour period. Contractors used either 250-pound test soft monofilament groundline with brass bead stops every three feet and 2-inch plastic gangion snaps, or a combination of the monofilament groundline and 3/4-inch braided (halibut) groundline with steel wire gangion snaps. Also used were gangion leaders of 20-pound test strength and ranging from 9 inches to 24 inches in length, 3/0 Eagle Claw nickel or bronze plated "up-eye" hooks, and numerous bait and lure types.

The study area was initially divided into three regions to avoid competition for fishing areas among contractors. The area from the west end of Puget Island (RM 38) upstream to the east end of Cottonwood Island (RM 72) was defined as Region 1 and assigned to Tarabochia. He used a 1989 Modutech 32-foot fiberglass gillnet bow picker (FV OR 247 RZ). The area from the east end of Cottonwood Island (RM 72) upstream to the Interstate 5 (Vancouver) bridge (RM 107) was defined as Region 2 and assigned to Nelson. He used a 1978 Roberts 36-foot fiberglass gillnet/crab stern picker with power block (FV Casino). The area from the Interstate 5 (Vancouver) bridge (RM 107) upstream to Multnomah Falls (RM 136) was defined as Region 3 and assigned to Ponn. He used a 1988 Lührz 30-foot gillnet bow picker (FV Gypsy). On July 20 all three regions were made equally available to the contracted fishers.

The contracted fishers fished from Week 8 through Week 20. An ODFW observer accompanied each crew during each trip. A fishing trip was defined as a calendar day, for a given vessel, during which longlines were set. Longlines were retrieved either on the same day they were set or on the following day.

The ODFW crew and observers recorded information regarding the longline sets in a logbook. Each logbook page (Appendix Figure B-1) contained information on one longline set including location, type of bait used, longline length, numbers of hooks, weights, and floats used, soaking time (the cumulative amount of time that the longline was in the water fishing), time spent working with the gear, and catch. In addition, daily information, including weather conditions, turbidity, water surface temperature, and fishing trip start and end times were recorded on an observation form (Appendix Figure B-2).

ODFW employees processed and released incidentally caught species quickly. Processing consisted of measuring the fork length, checking for tags, and assessing the physical condition of the fish. This information was recorded on a biological data form (Appendix Figure B-2).

At the end of each fishing trip, the fishers received a \$3 voucher (Appendix Figure B-3) in exchange for each northern squawfish harvested that was at least 11 inches in total length. We transported the northern squawfish to local field stations and stored them in chest freezers until collection by Oregon State University personnel.

RESULTS

Effort

All fishing crews combined made a total of 216 fishing trips. The number of trips per boat remained fairly constant through the season, with totals for the season ranging from 52 trips by Tarabochia's crew to 57 trips by Ponn's crew. Table 1 lists the numbers of trips and related northern squawfish catch by week. The majority of the trips (148, or 68%) occurred from mid-May to mid-July.

The ODFW crew set a total of 300 longlines during 54 trips. Only one trip was made during the first and last weeks of fishing. The weekly average number of longlines set per trip ranged from three to 7.3, with an average for the season of 5.6 longlines per trip. An average of 55.2 hooks were set per longline, for a total of 16,551 hooks set during the season. Soaking time averaged 365.0 hours per week, with a season total of 6,205.3 hours.

Nelson set 445 lines with a total of 39,617 hooks during 53 trips, averaging 8.4 longlines per trip and 89 hooks per longline. Nelson's lines soaked for an average of 484.6 hours per week, for a season total of 6,299.9 hours. During 57 trips, Ponn set 405 longlines with a total of 49,776 hooks, averaging 7.1 longlines per trip and 122.9 hooks per longline. Ponn's lines soaked for an average of 384.5 hours per week, for a season total of 4,998.2 hours. During 52 trips, Tarabochia set 608 longlines with a total of 55,831 hooks, averaging 11.7 longlines per trip and 91.8 hooks per longline. Tarabochia's lines soaked for an average of 345.6 hours per week, for a season total of 4,493.3 hours. Appendix Figures D-1 through D-6 illustrate the number of trips, number of lines, number of hooks used, time spent setting gear, time spent retrieving gear, and soaking time, by week for each fisher.

The ODFW crew started longlining earlier in the season than the contracted fishers, and ended earlier. Therefore, the total fishing effort per week is variable. A very small proportion of the lines that were set by the four fishers (12 out of 1,767, or 0.7%) became snagged or lost, or were otherwise not retrievable.

The ODFW crew fished in all three regions of the study area, setting 11% (33 out of 300) of the longlines in Region 1, 37% (112 lines) in Region 2, and 52 % (155 lines) in Region 3. Nelson fished primarily in Region 2, setting 92% (411 out of 445) of the lines there, and the other 8% in Region 3. Ponn fished exclusively in Region 3, and Tarabochia set all but two lines (less than 1%) in Region 1.

Table 1. Number of trips and northern squawfish caught for all fishers combined, by week.

Week	Dates	Trips		Squawfish Caught	
		#	%	#	%
1	Mar 30 - Apr 03	1	<1	9	<1
2	Apr 06 - Apr 10	4	2	28	1
3	Apr 13 - Apr 17	4	2	31	1
4	Apr 20 - Apr 24	4	2	41	2
5	Apr 27 - May 01	4	2	41	2
6	May 04 - May 08	2	1	16	1
7	May 11 - May 15	2	1	11	1
8	May 18 - May 22	16	7	102	5
9	May 25 - May 29	14	6	117	5
10	Jun 01 - Jun 05	18	8	214	10
11	Jun 08 - Jun 12	17	8	153	7
12	Jun 15 - Jun 19	18	8	272	13
13	Jun 22 - Jun 26	17	8	137	6
14	Jun 29 - Jul 03	15	7	190	9
15	Jul 06 - Jul 10	16	7	296	14
16	Jul 13 - Jul 17	17	8	154	7
17	Jul 20 - Jul 24	12	6	82	4
18	Jul 27 - Jul 31	13	6	49	2
19	Aug 03 - Aug 07	11	5	84	4
20	Aug 10 - Aug 14	11	5	131	6
Total		216	100	2,158	100

Northern Squawfish Catch

During the 1992 northern squawfish longlining season, a total of 6,035 fish were caught. Northern squawfish comprised 36% (2,158 fish) of the total catch. This proportion is low compared to previous years. In 1991, northern squawfish comprised 66% of the total catch (Mallette and Willis 1991); in 1990, 73% (Mathews and Iverson 1990); and in 1989, 72% (Mathews et al. 1989).

The weekly northern squawfish catch reflects the number of fishing crews participating. Catch remained low through Week 7, increased in Week 8, stayed high through Week 16, and then dropped off through the end of the fishing season (Table 1). The majority (76%, or 1,635 fish) of the northern squawfish harvest occurred during Weeks 8 through 16, as did the majority of the effort (68% of the trips, 77% of the lines set, 69% of the hooks set, and 76 % of the soak time).

The numbers of northern squawfish caught, tagged, removed, and paid for are listed in Table 2 by fisher and type of groundline used.

Table 2. Numbers of northern squawfish caught, tagged, removed and paid for, by fisher and groundline type.

Fisher	Dates	Groundline Type"	# Caught	# Tagged	# Removed	# Paid
ODFW	03/30-07/31	M	409	164	230	NA
Nelson	05/18-06/12	B	185	NA	170	147
	06/15-08/14	M	557	NA	541	394
Ponn	05/18-06/19	B	147	NA	143	133
	06/22-08/14	M	190	NA	186	144
Taraboc.	05/18-08/14	M	670	NA	534	522
Total			2,158	NA	1,804	1,340

^a B=braided, M=monofilament.

The ODFW crew caught 409 northern squawfish (19% of the total northern squawfish catch), averaging 24 northern squawfish per week of fishing. For the first part of the season, from April 2 to May 22, the majority (87%, or 164 out of 188) of the northern squawfish caught were tagged and then released. Starting in Week 9, all of the northern squawfish caught were kept, for a total of 230 (56% of the total ODFW catch) removed from the system.

Nelson's crew caught a total of 742 northern squawfish (34% of the total northern squawfish catch; Table 2.), averaging 57 per week. Partway through the season, on June 15, Nelson switched from using only braided groundline (Period 1: 4 weeks) to using monofilament groundline for some proportion of sets (Period 2: 9 weeks). During Period 1, Nelson caught 185 northern squawfish (25% of total Nelson catch), removed 170 (92% of the Nelson Period 1 catch), and received vouchers for 147 squawfish (79% of the Nelson Period 1 catch). For Period 1, Nelson's average catch was 46 northern squawfish per week; he removed an average of 42 per week and was paid for an average of 37 per week. During Period 2, Nelson caught 557 northern squawfish (75 % of total Nelson catch), removed 541 (97% of the Nelson Period 2 catch), and received vouchers for 394 squawfish (71% of the Nelson Period 2 catch). For Period 2, Nelson's average catch was 62 northern squawfish per week; he removed an average of 60 per week and was paid for an average of 44 per week.

Ponn's crew caught a total of 337 northern squawfish (16% of the total northern squawfish catch; Table 2), averaging 26 per week. Partway through the season, on June 22, Ponn switched from using only braided groundline (Period 1: 5 weeks) to using monofilament groundline for some proportion of sets (Period 2: 8 weeks). During Period 1, Ponn caught 147 northern squawfish (44% of total Ponn catch), removed 143 (97% of the Ponn Period 1 catch), and received vouchers for 133 squawfish (90% of the Ponn Period 1 catch). For Period 1, Ponn's average catch was 29 northern squawfish per week; he removed an average of 29 per week and was paid for an average of 27 per week. During Period 2, Ponn caught 190 northern squawfish (56% of total Ponn catch), removed 186 (98% of the Ponn Period 2 catch), and received vouchers for 144 squawfish (76% of the Ponn Period 2 catch). For Period 2, Ponn's average catch was 24 northern squawfish per week; he removed an average of 23 per week and was paid for an average of 18 per week.

Tarabochia's crew caught a total of 670 northern squawfish (3 1% of the total northern squawfish catch; Table 2), averaging 52 per week. Except for the first week of fishing, he used monofilament groundline exclusively. Tarabochia removed 534 (80%) squawfish and was paid for 522, 78% of the northern squawfish he caught. On average, Tarabochia removed 41 and was paid for 40 northern squawfish per week.

Incidental Catch

Table 3 illustrates the incidental catch of the 1992 northern squawfish commercial longline fishery. Most of the white sturgeon (2,179, or 60%) were caught in Weeks 8 through 12, the first five weeks of heaviest fishing effort. The average of 436 white sturgeon per week during this time period dropped to 236 white sturgeon per week for Weeks 13 through 16, although effort did not decrease significantly.

The majority of white sturgeon (3,416, or 93.3%) were released in good condition. Fifty-five white sturgeon (1.5%) were released in fair condition, 44 (1.2%) were in poor condition, and one was dead (Table 4).

Conditions of 144 white sturgeon (3.9%) were not recorded. Most of the white sturgeon (45%) that were in fair or poor condition, and the one dead, were caught in Week 8, the first week of fishing by the contracted boats.

The ODFW boat caught 3% of the total white sturgeon catch, averaging seven per week. Almost all (97%) of the white sturgeon caught by the ODFW boat were released in good condition.

During the first four weeks of fishing (using braided groundline exclusively), Nelson caught 24% of the total white sturgeon catch. The average per week for this period was 217 white sturgeon. Most (89%) were released in good condition, although 2% were in poor condition and one fish was dead (the conditions for 9% were not recorded). During the rest of the fishing season (using monofilament groundline to some degree), Nelson caught 35% of the total white sturgeon catch, averaging 142 fish per week. All of the white sturgeon for which conditions were recorded were released in good condition.

During the first five weeks of fishing (using braided groundline), Ponn's crew caught 26% of the total white sturgeon catch. The average per week was 188 white sturgeon. Most (93%) were released in good condition, although 5% were released as fair, and 2% as poor. During the rest of the fishing season (using monofilament groundline to some degree), Ponn caught 10% of the total white sturgeon catch, averaging 47 per week. Most (96%) were released in good condition, 2% in fair condition, and 1% in poor condition.

Tarabochia caught 2% of the total white sturgeon catch, averaging six per week. All of the white sturgeon caught by Tarabochia were released in good condition.

Fork lengths were measured for 3,636 (99%) of the white sturgeon caught. Almost 80% (2,868 fish) were in the range of 401-600 mm. Only one white sturgeon was less than 200 mm, and only two were greater than 900 mm in fork length. Condition at release does not appear to vary with length (Appendix Figure D-7).

Table 3. Incidental catch and percent of total catch by species.

Species	# Fish Caught	Percent of Total Catch
Sturgeon	3,660	60.6
Sculpin	50	0.8
Peamouth	48	0.8
Catfish	37	0.6
Sucker	37	0.6
Carp	15	0.2
Shad	6	0.1
Bullhead	5	0.1
Flounder	5	0.1
Salmon Smolt	4	0.1
Chiselmouth	3	<0.1
Yellow Perch	3	<0.1
Chinook	2	<0.1
Bass	1	<0.1
Steelhead	1	<0.1
Total	3,877	64.2

Table 4. Number of white sturgeon caught and condition at release, by fisher and groundline type.

Fisher	Dates	Groundline Type ^a	# Caught	# Good	# Fair	# Poor	# Dead
ODFW	03/30-07/31	M	121	118	2	1	0
Nelson	05/18-06/12	B	868 ^b	772	0	20	1
	06/15-08/14	M	1,276 ^c	1,207	0	0	0
Ponn	05/18-06/19	B	942	879	45	18	0
	06/22-08/14	M	374	361	8	5	0
Tarabochia	05/18-08/14	M	79	79	0	0	0
Total			3,660	3,416	55	44	1

^a B=braided, M=monofilament.

^b The disposition at release of 75 of these sturgeon is unknown.

^c The disposition at release of 69 of these sturgeon is unknown.

For incidental species other than sturgeon, average catch per week by fisher ranged from 1.6 fish to 11.5 fish. The ODFW boat caught 14% of the total non-sturgeon incidental catch, averaging 1.8 fish per week. Nelson caught 37%, averaging 11.5 fish per week in Period 1, and 3.9 fish per week in Period 2. Ponn caught 39%, averaging 11 fish per week in Period 1, and 3.6 fish per week in Period 2. Tarabochia had the smallest non-sturgeon incidental catch, with 10% of the total and an average of 1.6 fish per week. Of all the non-sturgeon incidental catch, 75% were released in good condition.

Catch per Unit of Effort

Northern Squawfish

Catch per unit effort (CPUE) was lower in the 1992 season than in 1991 or 1990. For the 1992 season, the overall catch rate was 0.098 northern squawfish per hour, compared to 0.124 fish per hour in 1991 (Malette and Willis 1991). In the 1992 season, an average of 74.9 hooks were set to catch one northern squawfish, compared to 34.6 hook sets per northern squawfish in 1991 (Malette and Willis 1991) and 22.5 hook sets per northern squawfish in 1990 (Mathews and Iverson 1990). The average number of northern squawfish caught on each line in 1992 was 1.23 fish.

The northern squawfish catch rate for the ODFW crew was 0.066 fish per hour. The ODFW crew caught an average of 1.36 northern squawfish per line, and set an average of 41 hooks per fish.

The northern squawfish catch rate for Nelson during Period 1 (using braided groundline) was 0.110 fish per hour. Nelson caught an average of 2.01 northern squawfish per line, and set 68 hooks per fish. During Period 2 (using monofilament groundline to some degree), Nelson's catch rate was 0.12 1. He caught an average of 1.58 fish per line, and set an average of 48 hooks per fish.

The northern squawfish catch rate for Ponn during Period 1 (using braided groundline) was 0.054 fish per hour. Ponn caught an average of 1.03 northern squawfish per line and set 122 hooks per fish. During Period 2 (using monofilament groundline to some degree), Ponn's catch rate was 0.082. He caught an average of 0.73 fish per line and set an average of 167 hooks per fish.

The northern squawfish catch rate for Tarabochia was 0.149 fish per hour. Tarabochia caught an average of 1.11 northern squawfish per line, and set an average of 83 hooks per fish.

Incidental Catch

The overall catch rate for white sturgeon was 0.814 fish per hour. The average number of white sturgeon caught on each line was 2.09 fish; an average of 44 hooks were set to catch each white sturgeon.

The white sturgeon catch rate for the ODFW crew was 0.019 fish per hour. The ODFW crew caught an average of 0.40 white sturgeon per line and set an average of 137 hooks per fish.

The white sturgeon catch rate for Nelson during Period 1 was 0.514 fish per hour. Nelson caught an average of 9.45 white sturgeon per line and set 15 hooks per fish. During Period 2, Nelson's catch rate was 0.277. He caught an average of 3.61 fish per line and set an average of 21 hooks per fish.

The white sturgeon catch rate for Ponn during Period 1 was 0.351 fish per hour. Ponn caught an average of 6.59 white sturgeon per line and set 19 hooks per fish. During Period 2, Ponn's catch rate was 0.161. He caught an average of 1.43 fish per line and set an average of 85 hooks per fish.

The white sturgeon catch rate for Tarabochia was 0.018 fish per hour. Tarabochia caught an average of 0.13 white sturgeon per line and set an average of 706 hooks per fish.

Gear Deployment and Evaluation

Information on the type of longline (monofilament or braided), longline length, gangion leader length, hook spacing, use of floats and weights, position of line relative to the shore, distance of the line from the shore, and water depth was collected for the majority of longlines that were set. In addition, types of baits used were recorded.

Two types of groundline were used, braided and monofilament. Two of the fishers (ODFW and Tarabochia) used monofilament line for the entire season; two (Nelson and Ponn) used braided for the first part of the season and then began using monofilament line for some proportion of the sets in the second part of the season. Overall, 52 % (905 out of 1,755) of the lines set had monofilament groundline, 13% (235 out of 1,755) had braided groundline, and the remaining 35% (615 out of 1,755) of the sets had some proportion of monofilament groundline.

Of the braided lines that were set, 99% (232 out of 235) were horizontal in the water and parallel to the shoreline. The longlines were set from 8-300 yards from the shore, with most of them (61%, 143 out of 233) between 25 yards and 74 yards from the shore. Most of the lines (65%, 152 out of 234) were set in water 10-19 feet deep. The majority of the lines (66%, 155 out of 235) were 1,200 feet long, although lengths varied from 200-4,200 feet. Groundlines were unbranched. The gangion leader length ranged from 10-24 inches, with 10 inches being the most frequent length (60%, 142 out of 235). Hook sets were placed from 8-20 feet apart, primarily at 10 feet apart (62%, 147 out of 235). None of the longline sets employed weights, although 76% (175 out of 229) did use floats spaced along the line to achieve buoyancy. For these lines, float spacing ranged from 50-750 feet. For 51% of the lines (89 out of 175), the float spacing was from 200-299 feet; for an additional 35% (62 out of 175), spacing was between 100 and 199 feet.

Of the longline sets that used monofilament groundline in some proportion, 77% (1,149 out of 1,496) were set horizontal in the water and parallel to the shoreline, and 22% (330 out of 1,496) were set "vertical" in the water column (with one end anchored and the other end floating, also called "Portuguese" longlines). Longlines were set 4-200 yards from the shore, with 47% (710 out of 1,509) between 25 and 49 yards. Most of the lines (60%, 913 out of 1,515) were set in water that was 10-19 feet deep, although water depth ranged 6-70 feet. The horizontal lines ranged 250-7,200 feet in length, with 25% (298 out of 1,183) at 600 feet, 22 % (259 out of 1,183) at 1,200 feet, 18 % (219 out of 1,183) at 250 feet, and 17% (199 out of 1,183) at 1,800 feet. The vertical lines ranged 20-40 feet, with the majority (88%) at 40 feet. All of the lines were unbranched.

The length of the gangion leaders ranged 9-24 inches, with 39% (585 out of 1,488) at 12 inches and 23% (348 out of 1,488) at 20 inches. On the horizontal lines, the hook sets were spaced 7-20 feet apart. The majority of the horizontal lines had hook sets spaced 10 feet (35%; 413 out of 1,183) and 11 feet (32%; 380 out of 1,183) apart. On the vertical lines, the hook sets were placed 1-4 feet apart, with the majority (56%; 188 out of 333) at 2 feet apart. Only a few of the horizontal longlines (96 out of 1,178, or 8%) had weights in

addition to the anchors, and none of the vertical longlines did. Most of the horizontal lines (75 %, 865 out of 1,158) employed floats to achieve buoyancy. The number of floats used ranged from 1-23 per line. The most frequent spacing between floats was from 100-199 feet (47%, or 409 out of 865), and an additional 32% of the lines (281 out of 865) had floats spaced 200-299 feet apart. All of the vertical lines employed at least one float, and 13% (44 out of 337) employed more than one.

The ODFW crew tested different types of hook sets. The contracted fishers consistently used 20-pound test line for gangion leaders, while ODFW used 6-, 10-, 20-, and 30-pound test (Appendix Figure D-8). The ODFW boat also set a very small proportion of lines using hose gear and suspension gear. The term “hose gear” is used to describe a hook set that has a gangion leader of minimal test strength (6 pounds in this case) encased within a piece of surgical tubing. The surgical tubing prevents the gangion leader from coiling and snagging. “Suspension gear” incorporates a piece of surgical tubing between the snap and the gangion leader, allowing for more flexibility than in the standard hook set (where the gangion leader is attached directly to the snap).

There is no apparent association between the gangion leader length and the number of northern squawfish or white sturgeon caught (Appendix Table C-1).

All of the longliners used a variety of baits. The ODFW boat used primarily steelhead chunks (62 %, or 186 out of 300, of the line sets), but also tried coho (fresh and salted), worms and lures (Appendix Figure D-9). Fifty-six percent (229 out of 409) of the northern squawfish catch and 65% (79 out of 121) of the white sturgeon were caught using steelhead chunks for bait (Appendix Table C-2). Fresh coho smolts were used on 24 % (73 out of 300) of the line sets, catching 34% (139 out of 409) of the northern squawfish and 20% (24 out of 121) of the white sturgeon (Appendix Table C-2).

For all of the fishers combined, 58% of the lines (1,015 out of 1,755) were baited with fresh coho smolts or a combination of bait types including fresh coho smolts (Appendix Table C-3). These lines accounted for 70% of the total northern squawfish catch (1,530 out of 2,158) and 53 % of the white sturgeon catch (1,934 out of 3,660). Worms were used on 16% of the lines (281 out of 1,755), accounting for 5 % of the total northern squawfish catch (99 out of 2,158) and 4% of the total white sturgeon catch (151 out of 3,660). Steelhead chunks were used on 11% of the lines (196 out of 1,755), accounting for 12% of the total northern squawfish catch (255 out of 2,158) and 4% of the total white sturgeon catch (153 out of 3,660).

Weather and River Conditions

Weather, wind and river conditions were recorded for each fishing trip during the 1992 season (for this analysis, a “trip” is defined as a fishing day, for a given fisher, during which lines were pulled). Appendix Table C-4 summarizes the proportions of different conditions within these three categories. Since a trip may have been described by more than

one type within a category (i.e., the weather may have been sunny for part of the trip and overcast for part of the trip), the proportions do not sum to 100%. The data indicate that most trips were made on sunny days, when the river was smooth and the wind was from the northwest or the southwest.

The ODFW crew recorded daily readings of water surface temperature. The weekly mean water surface temperature rose fairly steadily through the fishing season, from a low of 49° Fahrenheit in the second week of the season, to a high of 71° F in the 18th week (Appendix Figure D-10; temperature readings were not available for Weeks 17, 19 and 20). All four participating fishers measured turbidity once or twice each trip. The weekly mean turbidity ranged from approximately 125 cm to slightly more than 275 cm (Appendix Figure D-11).

DISCUSSION

Catch and Effort

Participating commercial fishers complied with contract conditions and cooperated at satisfactory levels. In general, effort obligations were exceeded by the contracted fishers, who were motivated by the monetary incentive offered per qualifying northern squawfish harvested. The overall number of northern squawfish that were removed from the system by the 1992 Commercial Longline Fishery Investigation Project was higher than the northern squawfish catch of previous longline fishery implementations (Vigg et al. 1990, Mallette and Willis 1991). However, catch per unit of effort (CPUE) was disappointingly low in 1992, as was the percentage of northern squawfish in the total catch. The average northern squawfish catch rate for all participating fishing crews and for all longline gear types and hook set assemblies used was lower than catch rates that were achieved in previous longline fisheries. Several reasons may have contributed to the low catch rate, as discussed in the following paragraphs.

The ODFW crew sought to improve longline gear effectiveness by testing numerous hook set assemblies, gangion leader lengths and test strengths, and bait types. Due to the experimental nature of this assignment, resulting northern squawfish catch and effort rates were expectedly lower than catch and effort rates for contracted commercial fishers and lower than catch rates achieved in previously conducted fisheries.

In mid-July, the ODFW vessel developed a leak in the hull. Necessary repairs, related dry dock time, and the unavailability of an alternative vessel prevented the crew from expending fishing effort and from conducting further meaningful gear tests through the last four weeks of the fishing season.

In addition to using the recommended 250-pound test monofilament groundline, two of the contracted commercial fishers deployed braided (halibut) groundline to some proportion. Monofilament groundline is best retrieved manually; braided groundline, on the other hand, is easily retrievable with commercial, hydraulic reel systems. Use of braided groundline resulted in significantly increased bycatch of white sturgeon and reduced catch rates for northern squawfish.

The availability of the most effective bait type (fresh, flash frozen salmonid smolts) was limited, especially during Weeks 8 to 12, the first month of maximized fishing effort. Although a total of 106 federal, state, and private fish culturists in Oregon and Washington were contacted several months prior to the start of the fishery, only two orders for relatively small quantities of adequately sized coho smolts could be placed. The availability of this bait type depends on the timely coordination of project needs with interested fish culturists no later than the preceding fall season. At that time hatchery managers identify production needs for the subsequent year. Without having specific orders for smolt bait in place, fish culturists are understandably hesitant to purchase large quantities of eyed eggs. The managers' decisions are especially critical if spatial accommodations of the hatchery facilities are limited; the option of rearing surplus fish beyond bait size to facilitate alternative end uses is not provided. Upon the start of the 1992 longline season, it was apparent that fishers would have to utilize secondary bait types, since the quantities of ordered coho smolts, delivery dates, and the volume of otherwise obtained salmonid bait (hatchery donations, surplus of cured smolts from previous longline fisheries, etc.) would only cover a fraction of the projected bait need for the 1992 longline fishery investigation.

The very high incidental catch of small sized white sturgeon constitutes the most limiting, single factor to a successful commercial longline fishery for northern squawfish in the Columbia River below Bonneville Dam. In addition to a higher susceptibility of white sturgeon to the gear type used, as opposed to other resident fish species, white sturgeon of these smaller size classes are distinctly more abundant in the study area than in other Columbia River reaches (Devore et al. 1992). Furthermore, low gear efficiency may be magnified by the considerable amount of time that fishing crews spent to (1) assess relative gear impact on, and physical condition of, incidentally caught white sturgeon, and to (2) release the captured specimens appropriately.

Gear Deployment and Evaluation

The contracted fishers were encouraged to test commercial (braided) longline gear and compare its effectiveness to the recommended monofilament groundline. Although fishing effort could have been maximized to a higher degree by using braided groundline, the related catch composition, comprised primarily of white sturgeon, was undesirable. It has not been determined whether the catch composition was solely a result of the type of groundline used or the type of bait used (smelt, worms, etc.) or a combination of both. However, unacceptably high bycatch rates for white sturgeon did not occur in catches of fishers who used monofilament groundline exclusively. Therefore, it appeared that the type of

groundline used had a more significant impact on catch composition than the type of bait used. One possible explanation for the experienced low northern squawfish and high white sturgeon catch rates associated with braided groundline deployment might be that this groundline type is highly visible, even under marginal water clarity conditions. Northern squawfish have been described as visual feeders (Eggers et al. 1978). Therefore, foraging northern squawfish could easily detect and avoid this type of groundline regardless of the type of bait used. Consequently, available baited hooks attract more of the other resident fish, and in particular white sturgeon, who probably locate food by olfaction rather than vision (Brannon et al. 1987).

Comparisons between the two groundline types used and between related catch rates for northern squawfish and white sturgeon suggest that deployment of monofilament groundline generally yields comparable or higher northern squawfish catch and significantly lower incidental bycatch of white sturgeon. However, the decline in bycatch rates for white sturgeon that occurred as the season progressed may equally be a result of fishers' increasing levels of experience in avoiding white sturgeon by (1) adjusting the position of the groundline relative to the water column (lines were set to achieve buoyancy at a minimum of six feet off the river substrate), and (2) avoiding sites with known high abundance of white sturgeon, as well as increasing availability of preferred bait types.

The use of 40-foot long monofilament, Portuguese longline sets yielded desirable catch compositions in terms of depressed white sturgeon bycatch and elevated northern squawfish catch. The floating end of the groundline appears to provide additional movement to the hook set assemblies, which attracts northern squawfish, while bottom fish are less susceptible to this groundline type. However, deployment is more labor intensive and not as uniformly applicable to varying river conditions as groundlines that are set horizontally.

Analyses of hook set assembly test results suggest that the most efficient hook set assembly, with regard to highest catch rates for northern squawfish and minimal bycatch of white sturgeon, consists of 20-pound test gangion leader, spaced approximately 10 feet apart on monofilament groundline, and 3/0 eagle claw hooks baited with whole, fresh frozen, coho smolts that are 8-10 cm in total length.

The ODFW crew attempted to minimize the incidental bycatch of white sturgeon by testing the effectiveness of gangion leaders of less than 30-pound test strength (30-pound test leaders were used in previous northern squawfish longline fisheries). Gangion leaders of 10-pound test and less tended to coil around the groundline, resulting in additional labor expended in setting and retrieving longlines, and generally lower catch rates. Use of 20-pound test leaders, however, yielded comparable northern squawfish catch rates with a lesser likelihood of capturing white sturgeon (of 50-80 cm in total length) compared to catch rates that were achieved by using leaders of 30-pound test strength.

Various types of salmonid bait were made available to the longline fishers. Most effective were whole smolts of 8-10 cm in total length that were starved for three to five days prior to processing. Bait quality was preserved best by instant, postmortem flash

freezing and packaging in small batches of not more than five pounds each. Bait processed in this fashion maintained its quality grade beyond thawing, however, the consistency of this bait type was fairly soft, resulting in losses from the hook set assemblies after prolonged exposure to regular river conditions. The effectiveness of bait types that did not comply with the above bait specifications decreased with the increasing number of bait and processing criteria that were not met. However, longlines that employed hook set assemblies with scented or unscented, white or fluorescent green lures alternating with high quality salmonid bait demonstrated comparable, high efficiency attributes.

CONCLUSIONS AND RECOMMENDATIONS

Deployment of longline gear could be effective in removing population concentrations of northern squawfish if the following gear and deployment specifications are met:

1. Selection of fishing locations should primarily depend on criteria regarding the avoidance of white sturgeon bycatch.
2. Monofilament, 250-pound test strength groundline should be deployed manually, and set vertical (Portuguese style) or horizontal to the water column.
3. Hook sets should be fished a minimum of six feet off the river substrate.
4. Hook set assemblies should consist of 20-pound test strength gangion leaders with 3/0 eagle claw hooks baited with fresh, starved, flash frozen salmonid smolts of 8-10 cm in total length; baited hook sets could be alternated with lures.

Although northern squawfish abundance is relatively high in the lower, free-flowing reach of the Columbia River compared to the impounded reaches above Bonneville Dam, large northern squawfish aggregations could not be identified. Therefore, longline fishing effort could not be focused on localized concentrations. Furthermore, capture and handling of abundant, small white sturgeon was cumbersome and time-consuming. Use of automated fishing techniques could yield economic harvest of northern squawfish in commercially valuable quantities. However, the most effective longline gear is too light to be set and retrieved hydraulically. Consequently, a self-sustaining commercial fishery with a monetary remuneration of fishing effort that is solely based on qualifying northern squawfish catch, is not feasible in the study area. Manually deployed longline gear could possibly be effective in removing localized northern squawfish population concentrations where they exist (i.e., in boat restricted areas of hydropower projects).

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APPENDIX A
Selection of Fishers

ODF&W
 Northern Squawfish Management Program
 Commercial Longline Test Fishery
 Fishers Application Form

Your Name	Address
Daytime Phone #	

Boat Name	Are You the Boat Owner?
Type of Boat	# Years Fishina Experience
Model and Make	# Years Longline Experience
Length	What Fish Species?
Engine (hp)	
Type of Reel	Where?
Size of Fishlocker	
Other Fish Handling Facilities?	
	Crew Size

Preferred Fishing Areas

Are You Able To Fish Other Areas?

Are you interested in serving on a fishery design/oversight committee?

Date:

Signature:

COMMERCIAL FISHER GRADING FORM

FISHER Name:
VESSEL Name:

CATEGORY	DESCRIPT.	POINTS	MAX. POINTS	CATEGORY	DESCRIPT.	POINTS	MAX. POINTS
VESSEL Type	Nonaccept.	0		OTHER Fac.			
	Accept.	1	1	Trailer	No	0	
Length	< 20ft.	0			Yes	1	1
	20-30ft.	1		Subst. V.	None	0	
Engine	> 30ft.	2	2		Suit.Poor	0	
	< 200hp.	0			Suit.Fair	1	
Gen.Cond.	< 300hp.	1			Suit.Good	2	2
	> 300hp.	2	2		Needs Reloc.	1	
	Poor	0			Needs Gear	1	
	Fair	1			Is Ready	2	2
	Good	2		EXPERIENCE			
	Excellent	3	3	Comm.	< 4 years	0	
Safety	Poor	0			< 9 years	1	
	Fair	1			> 9 years	2	2
	Good	2		Col.Riv.	< 4 years	0	
	Excellent	3	3		< 9 years	1	
Obs.Space	Poor	0			> 9 years	2	2
	Fair	1		Longline	< 1 year	0	
	Good	2			< 5 years	1	
	Excellent	3	3		> 5 years	2	2
FACILITIES				LL Sturg.	No	0	
Reel	Non-Hydraul	0			Yes	1	1
	Hydraulic	1		REFERENCE			
	Single	0		ODFW	Poor	-1	
	Sing./Div.	1			No Op.	0	
	Twin	1			Good	1	
Fishlocker	Dual	2	2		Very Good	2	2
	< 1000lbs.	0		Pers.Ref. 1	Poor	-1	
	< 2000lbs.	1			No Op.	0	
	> 2000lbs.	2	2		Good	1	
	No Insulat.	0			Very Good	2	2
Live Tank	Insulation	1	1	Pers.Ref.2	Poor	-1	
	No	0			No Op.	0	
	Yes	1	1		Good	1	
Hyd.Fi.pick.	No	0		LOCATION	Very Good	2	2
	Yes	1	1		Washington	0	
Roller	No	0			Oregon	0	
	Yes	1	1		Upper Riv.	0	
Davit/ Snatchblock	No	0			Mid River	0	
	Yes	1	1		Lower Riv.	0	0
Powerblock	No	0		TOTAL			42
	Yes	1	1				

COMMENTS:

APPENDIX B

Data and Voucher Forms

Fisherman's Name:						Long-line no. :		
Fisherman's ID no.:				Location:				
Distance to nearest shore point [yards]:								
Line length [feet]:						No. of hooks:		
Line depth [feet] min - max:						Bait type:		
	Line set			Line pulled			ODFW Verification Location ID: Comments: Clerk No.:	
Date YY/MM/DD								
Gear work start		am	pm		am	pm		
Gear work stop		am	pm		am	pm		
Species	# caught	# lost		# kept		# released	and condition was	
						good	poor	dead
Squawfish								
Sturgeon								
Catfish								
Bass								
Walleye								
SalmonEteelhead								
Other (specify)								

Fisherman's comments:

Appendix Figure B-1. Logbook Data Form.

1992 NSQF LONGLINE OBSERVATION FORM

Page of _

Fisherman's Name		Date(YY/MM/DD)							
Fisherman's ID no.		Boat Name							
Launch Site		Start Time (military)							
Fishing Location		ID #				Stop Time (military)			
Distance to nearest shore point (yrds)				Time on Water (min)					
Weather/Wind: <input type="checkbox"/> N <input type="checkbox"/> NE		River:		Comments					
<input type="checkbox"/> Sun <input type="checkbox"/> S <input type="checkbox"/> NW		<input type="checkbox"/> Smooth							
<input type="checkbox"/> Overcast <input type="checkbox"/> E <input type="checkbox"/> SE		<input type="checkbox"/> Swells < 2"							
<input type="checkbox"/> Rain <input type="checkbox"/> W OSW		<input type="checkbox"/> Swells > 2"							
<input type="checkbox"/> Fog		Temp. (F)							
How many hooks were empty?		< 30%		< 50%		> 50%			
INCIDENTAL CATCH									
Fish no	Species	Fork lgth. (mm)	Disci	Tag No.	Color	Mark	Comments		
1									
2									
3									
4									
5									
6									
7									
8									
9									
0									

Observer's Comments

Appendix Figure B-2. Observation and Incidental Catch Form.

OREGON DEPT. OF FISH AND WILDLIFE
PACIFIC STATES MARINE FISHERIES COMMISSION
1992 NSQF LONGLINE VOUCHER

Date: _____

Fisherman's Name: _____

Last

First

Middle

Fisherman's ID No.: _____

No. of NSQF: _____

Amount \$ _____

Fisherman

ODFW Clerk

APPENDIX C

Result Tables

Appendix Table C-1. Gangion leader lengths and associated northern squawfish and white sturgeon catch.

Gangion Leader Length (in)	<u>Longline Sets</u>		<u>Squawfish Catch</u>		<u>Sturgeon Catch</u>	
	#	%	#	%	#	%
9	1	<1	0	0	1	<1
10	335	19	309	14	1,253	34
12	601	34	865	40	188	5
14	2	<1	2	<1	13	<1
15	280	16	133	6	11	<1
18	4	<1	4	<1	22	1
20	438	25	734	34	2,109	58
24	2	<1	2	<1	0	0
Unknown	92	5	109	5	63	2
Total	1,755	100	2,158	100	3,660	100

Appendix Table C-2. Bait types used on longlines set by the ODFW crew, and associated northern squawfish and white sturgeon catch

Bait	<u>Longline Sets</u>		<u>Squawfish Catch</u>		<u>Sturgeon Catch</u>	
	#	%	#	%	#	%
Steelhead Smolts	186	62	229	56	79	66
Fresh Coho Smolts-SF1 ^a	67	22	137	33	23	19
Mixed-Smolts and Lures ^b	27	9	34	8	3	2
Fresh Coho Smolts-SF2 ^c	6	2	2	<1	1	1
Mixed-Smolts ^d	5	2	7	2	6	5
Worms	5	2	0	0	9	7
Mixed-Lures ^e	3	1	0	0	0	0
Salted Coho Smolts	1	<1	0	0	0	0
Total	300	100	400	100	121	100

^a From Sea Fresh Co.; used from May 19 through July 15.

^b More than one type of bait, including smolts and lures.

^c From Sea Fresh Co.; used after July 15.

^d More than one type of **bait**, including smolts.

^e More than one type of bait, including lures.

Appendix Table C-3. Bait types used on longlines set by all fishers combined, and associated northern squawfish and white sturgeon catch.

Bait	<u>Longline Sets</u>		<u>Squawfish Catch</u>		<u>Sturgeon Catch</u>	
	#	%	#	%	#	%
Fresh Coho Smolts-SF1 ^a	449	25	671	31	741	20
Worms	281	16	99	5	151	4
Steelhead Smolts	196	11	255	12	153	4
Fresh Coho Smolts-SF2 ^b	192	11	242	11	189	5
Mixed-Smolts ^c	168	10	238	11	526	14
Other ^d	129	7	95	4	647	18
Fresh Coho Smolts-FP ^e	126	7	262	12	281	8
Mixed-Smolts and Lures ^f	80	5	117	5	197	5
Mixed	59	3	69	3	510	14
Salted Coho Smolts	49	3	79	4	176	5
Mixed-Lure ^g	16	1	15	1	44	1
Lures	1	<1	0	0	1	Cl
Unknown	9	1	16	1	44	1
Total	1,755	100	2,158	100	3,660	100

^a From Sea Fresh Co.; used from May 19 through July 15.

^b From Sea Fresh Co.; used after July 15.

^c More than one type of bait, including smolts.

^d Anchovies, apples, marshmallows, potatoes, sand shrimp, shrimp, smelt, and squid.

^e From Fish Pro Co.

^f More than one type of bait, including smolts and lures.

^g More than one type of bait, including lures.

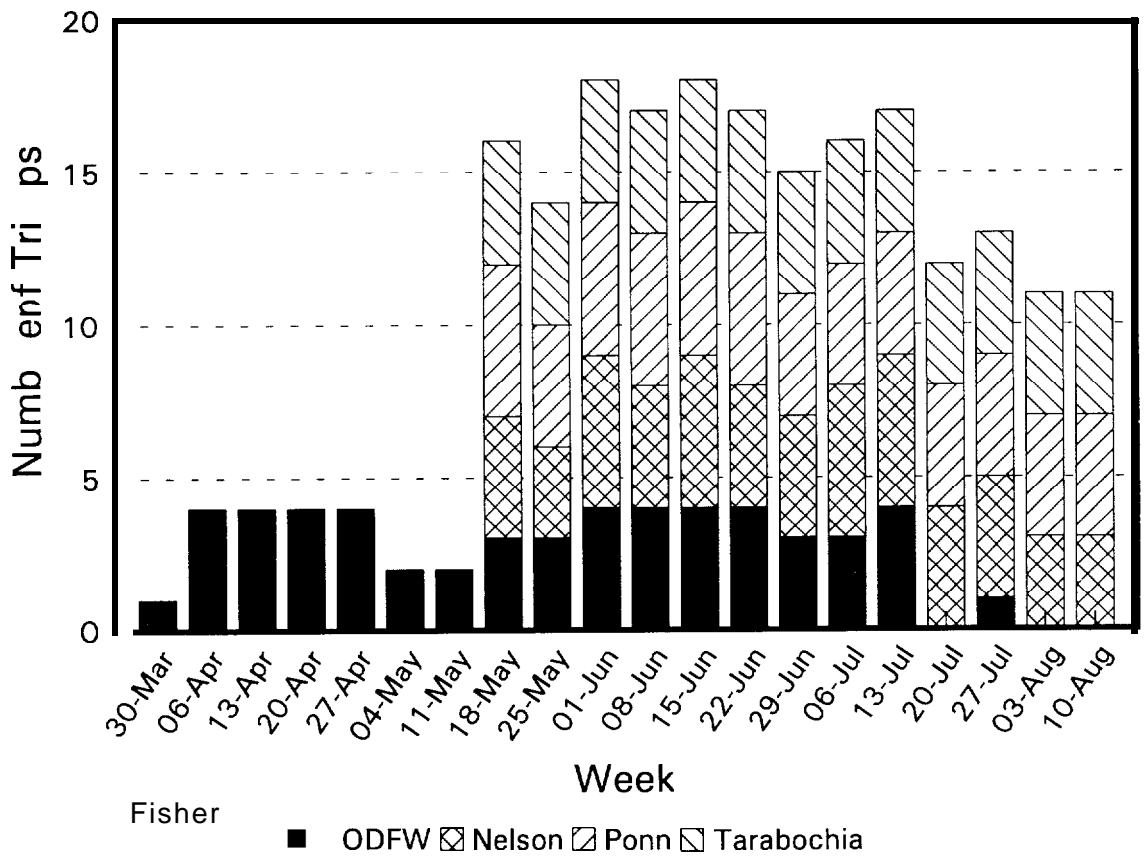
Appendix Table C-4. Categorized weather and river conditions by percent of total fishing trips".

Weather				Wind							River		
Sun	Over- cast	Rain	Fog	NW	SW	N	S	NE	SE	W	Smooth	Swells	
												<2ft	≥2ft
60	47	7	1	30	29	0	1	14	7	16	56	46	2

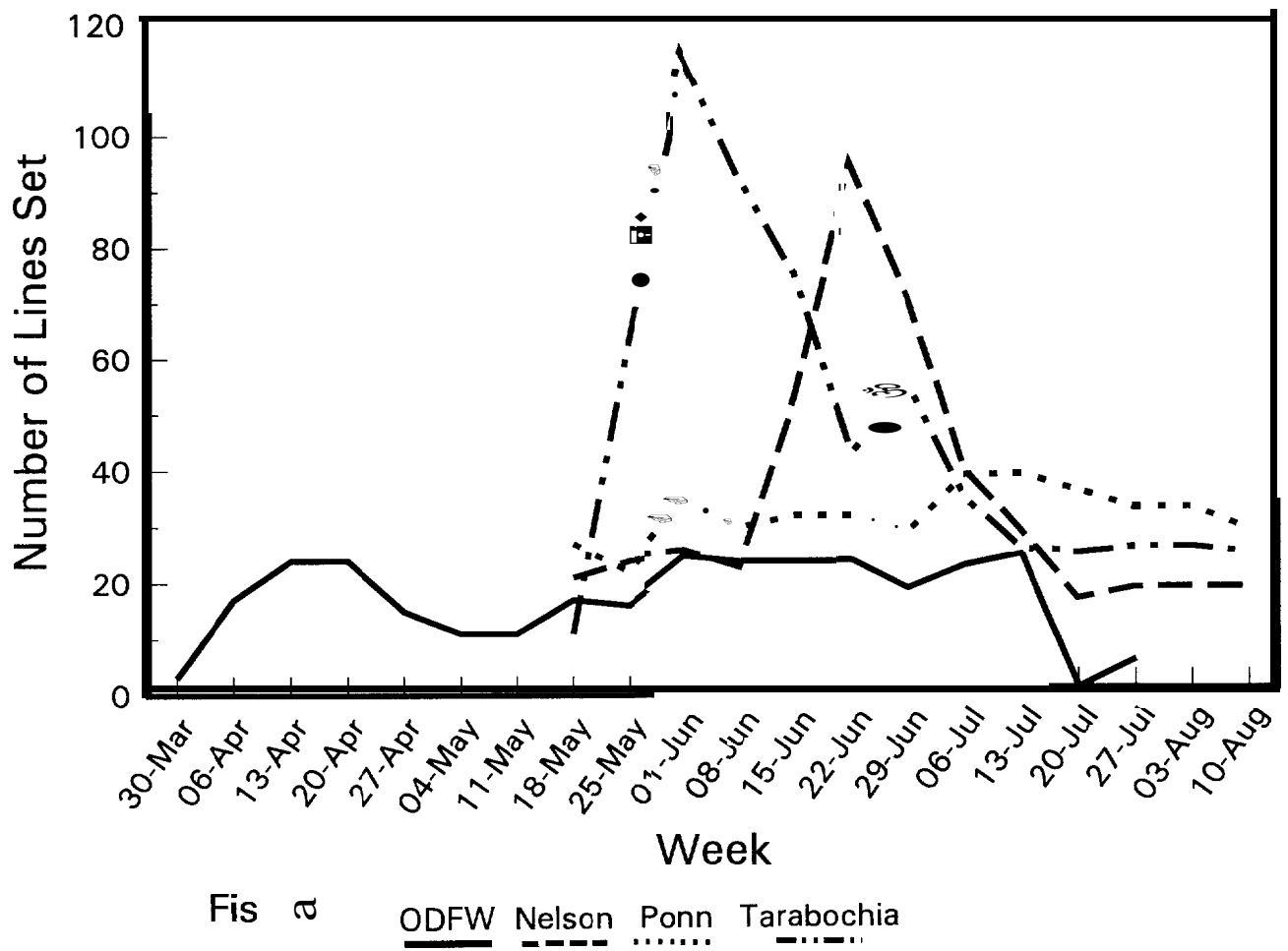
^a The total percent for each category is greater than 100%, since **more** than one condition for a category was **sometimes** recorded on a given trip (i.e., weather during a trip **may** have been described as both sunny and overcast).

APPENDIX D

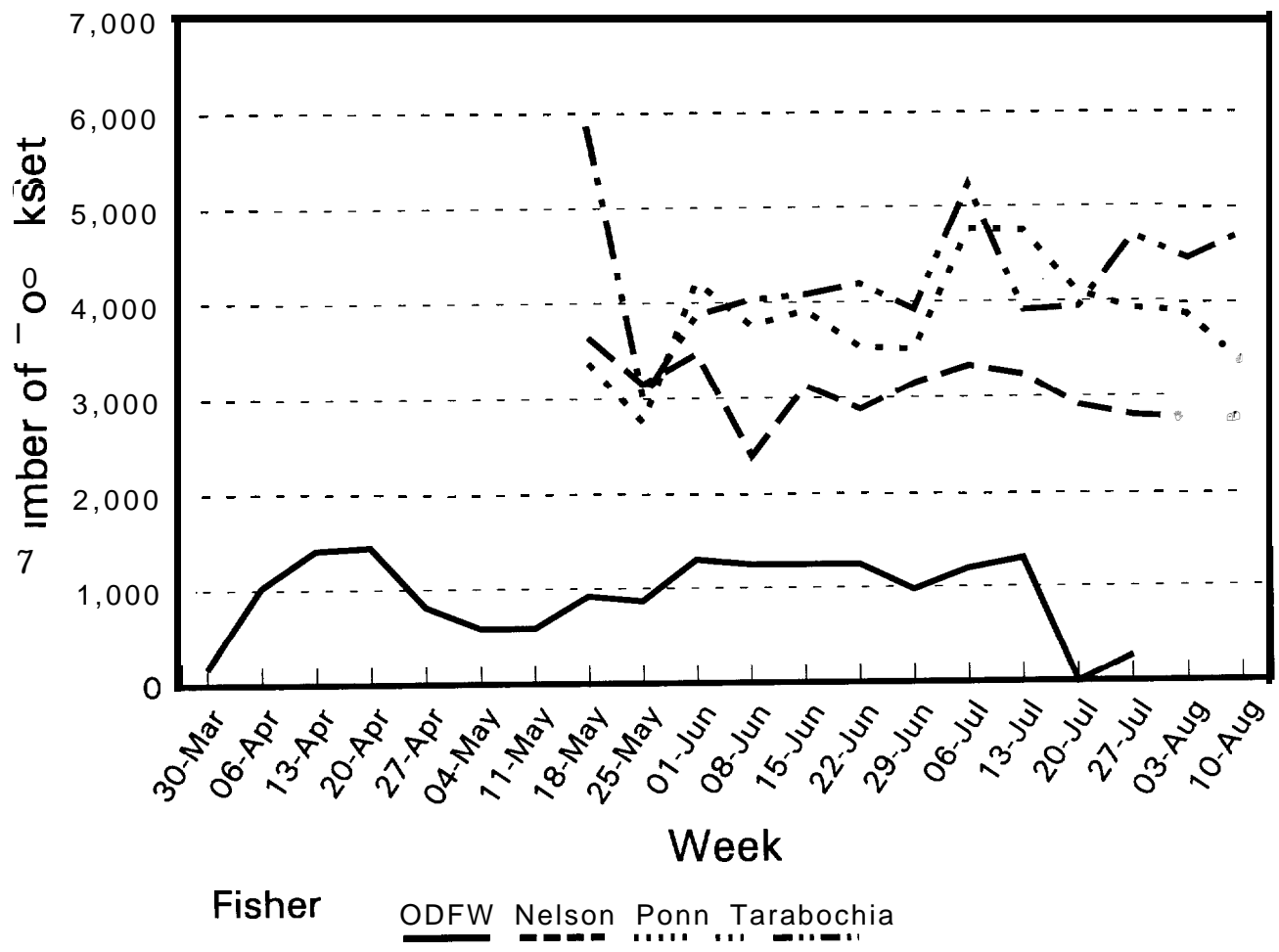
Result Figures



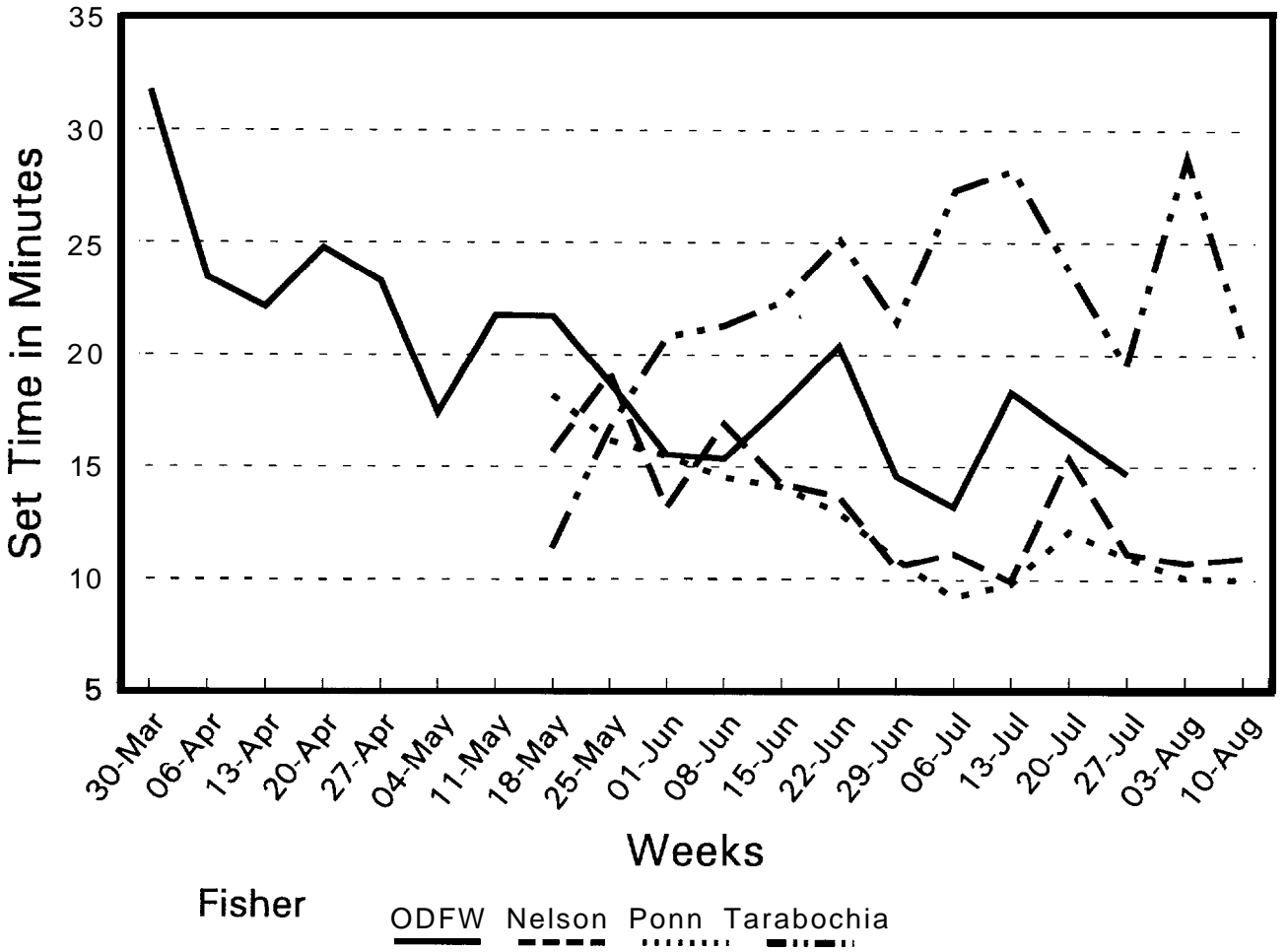
Appendix Figure D-I. Number of Trips per Week by Fisher.



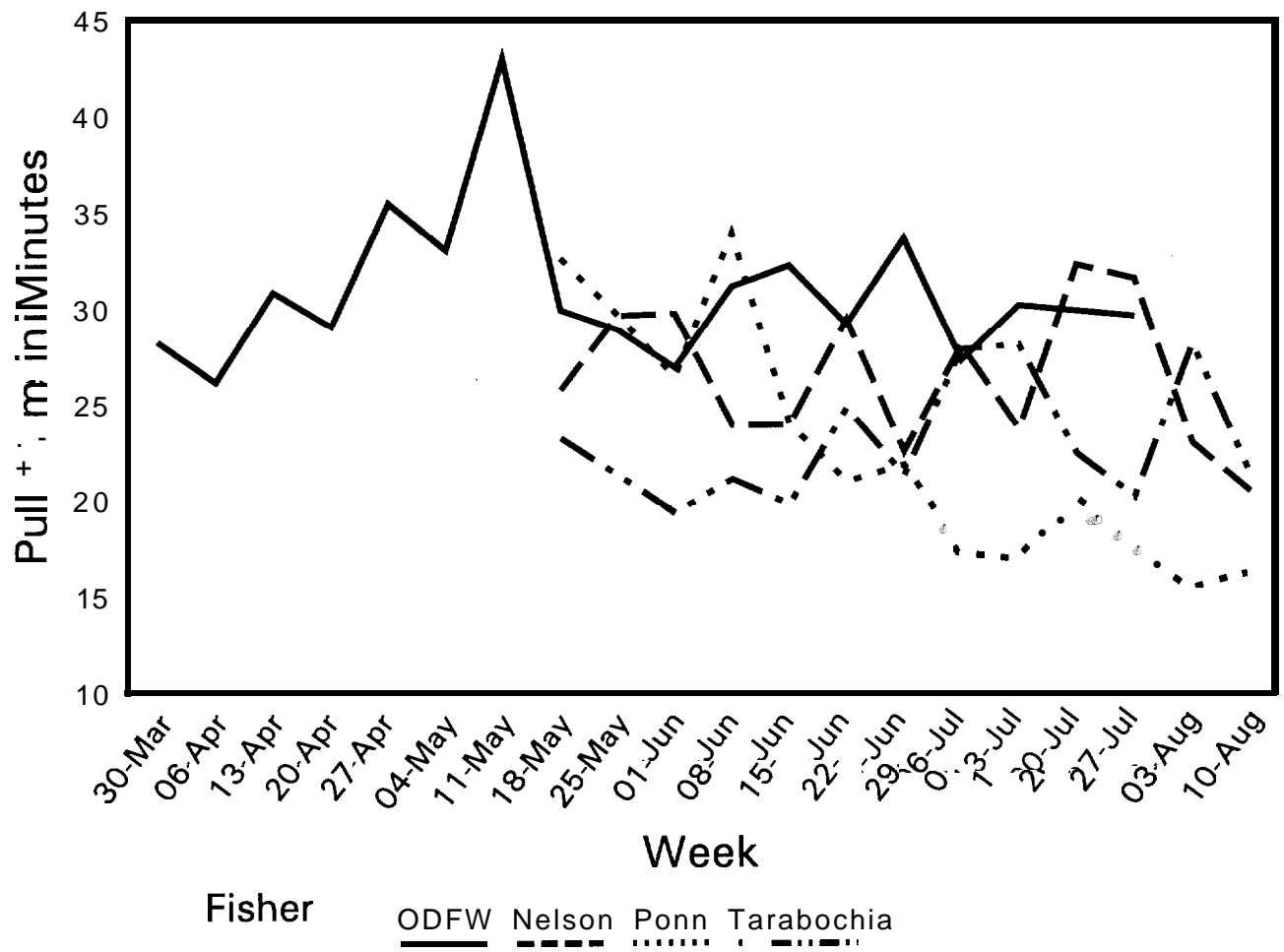
Appendix Figure D-2 Number of Lines Set per Week by Fisher



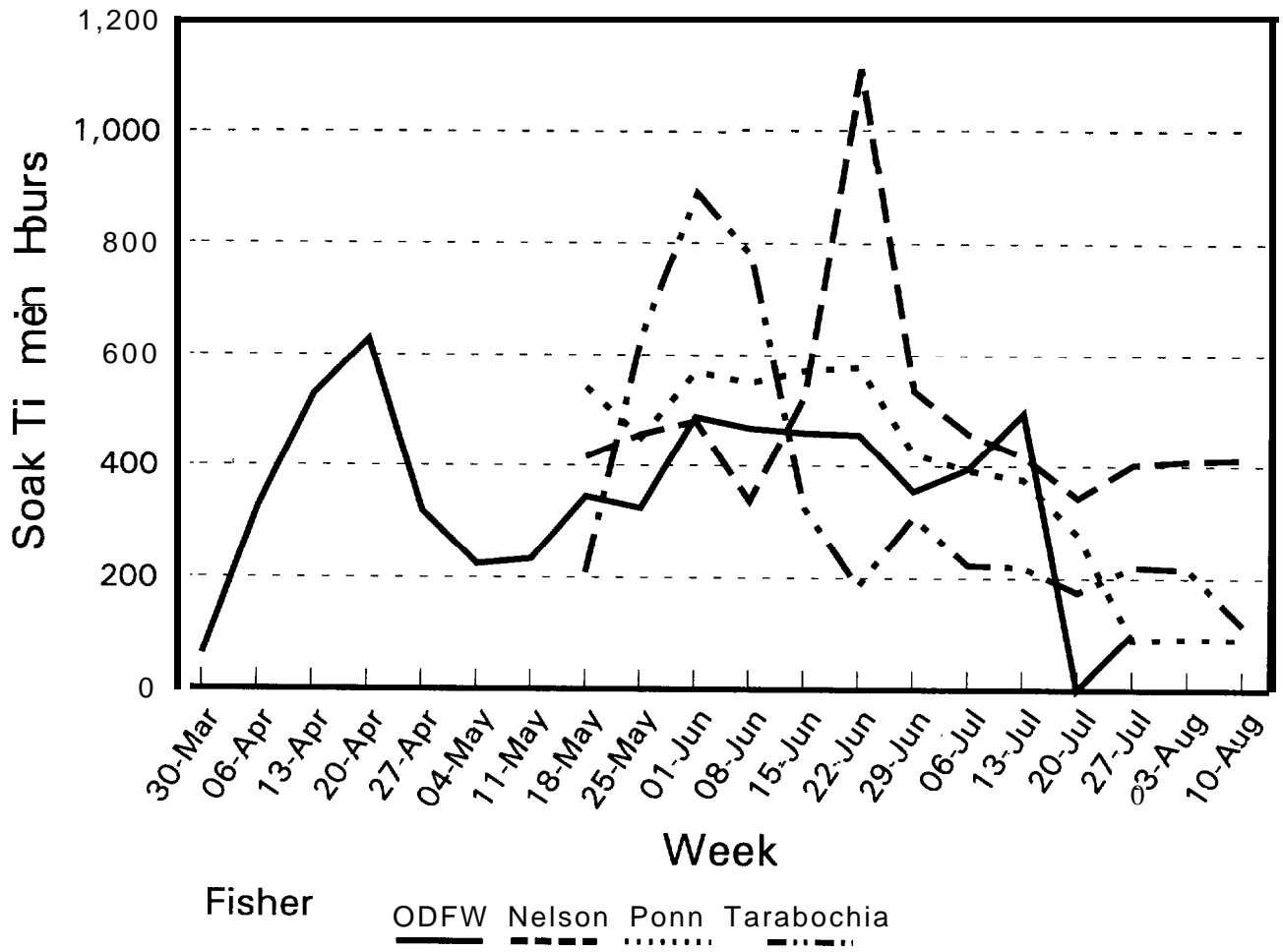
Appendix Figure D-3. Number of Hooks Set per Week by Fisher.



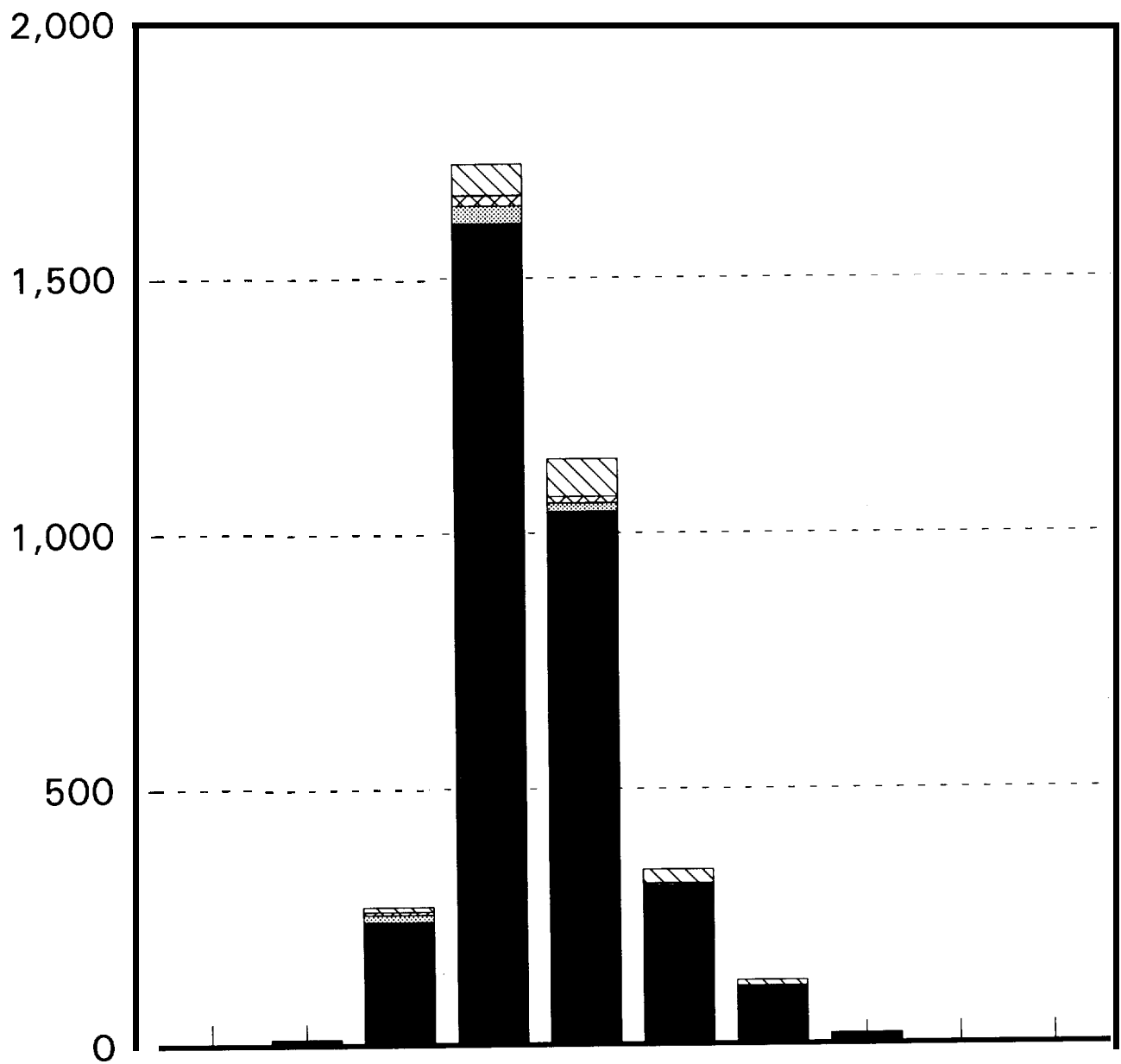
Appendix Figure D-4. Set Time per 120 Hooks by Week and Fisher.








Appendix Figure D-5. Pull Time per 120 Hooks by Week and Fisher.

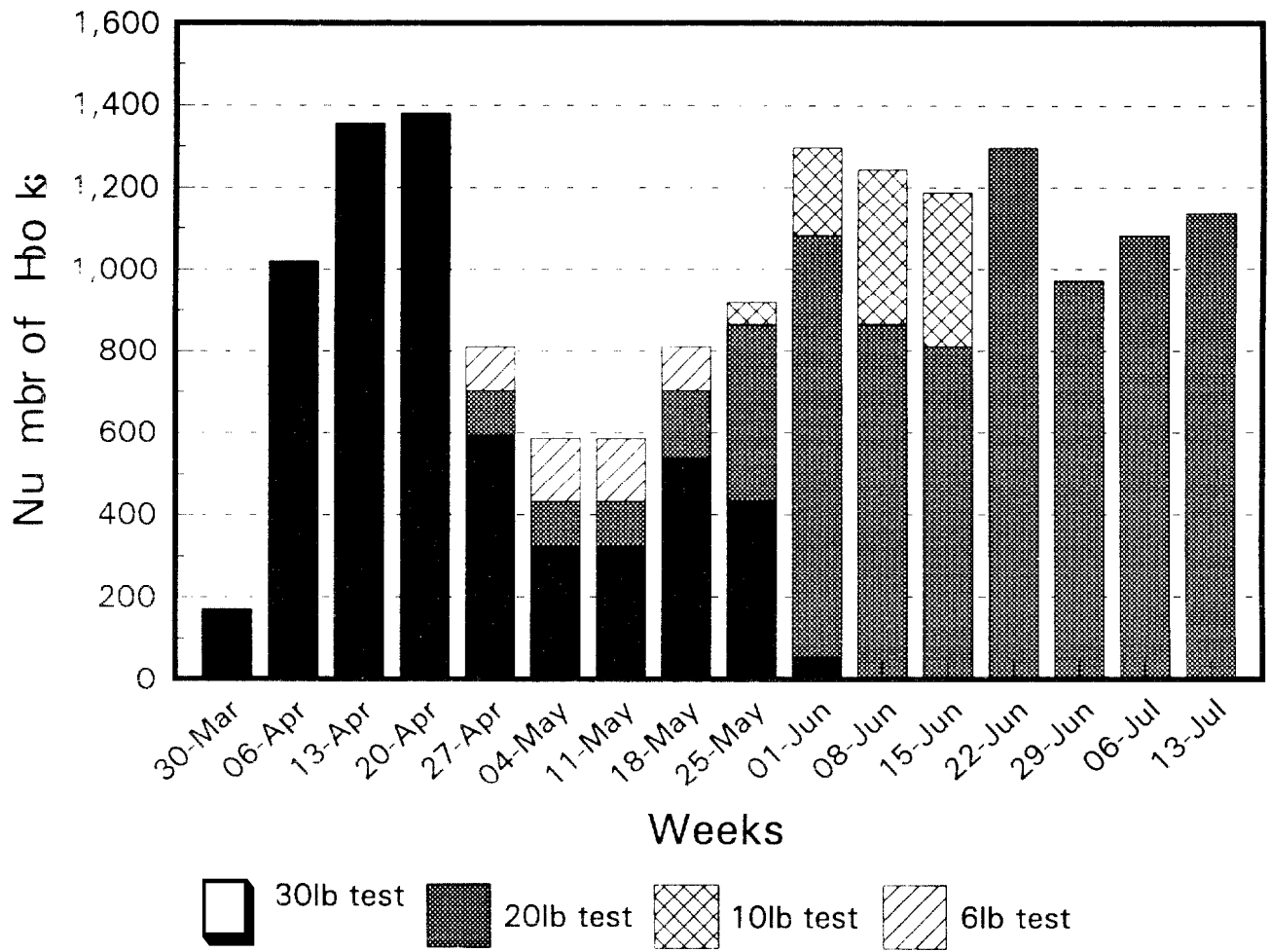


Appendix Figure D-6. Longline Soak Time per Week by Fisher.

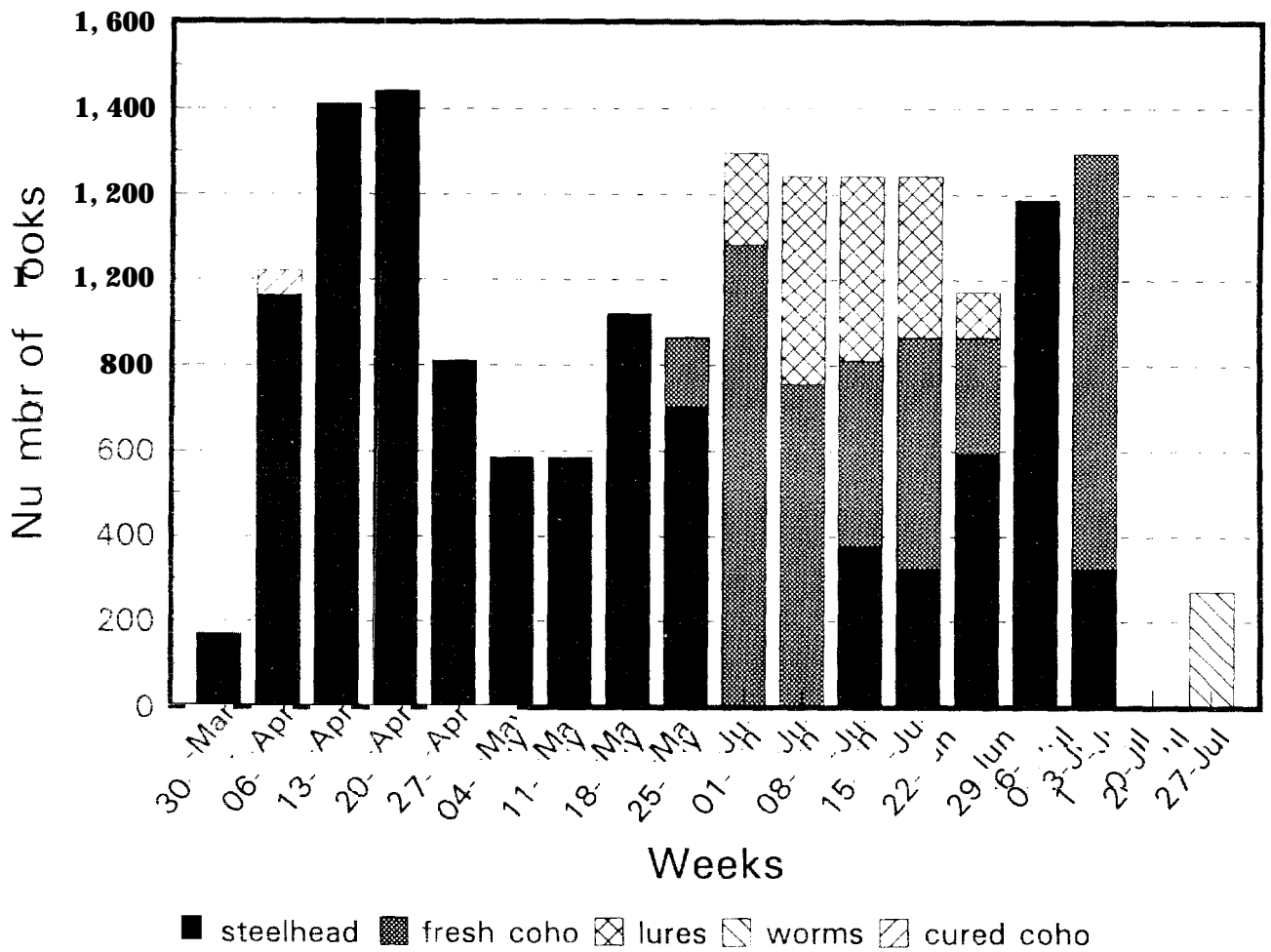


	101-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-1000	1001-1100
Good 	1	12	239	1,606	1,042	307	108	18	1	1
Fair 	0	0	14	34	18	2	3	0	0	0
Poor 	0	0	6	20	13	4	2	0	0	0
Dead 	0	0	0	1	0	1	0	0	0	0
Not recorded 	0	0	9	61	73	27	11	2	0	0

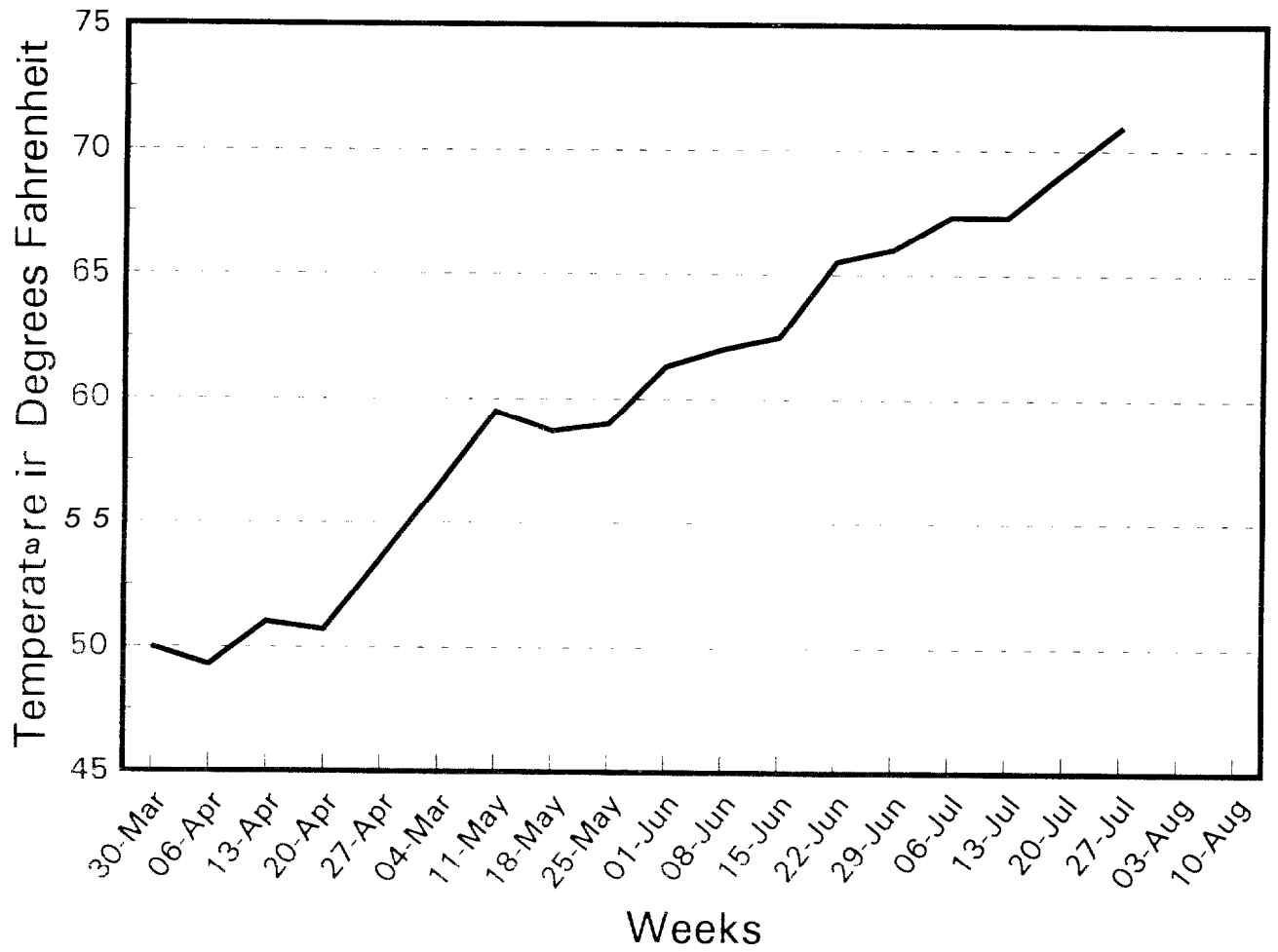
Appendix Figure D-7. Number of White Sturgeon by Length and Condition.



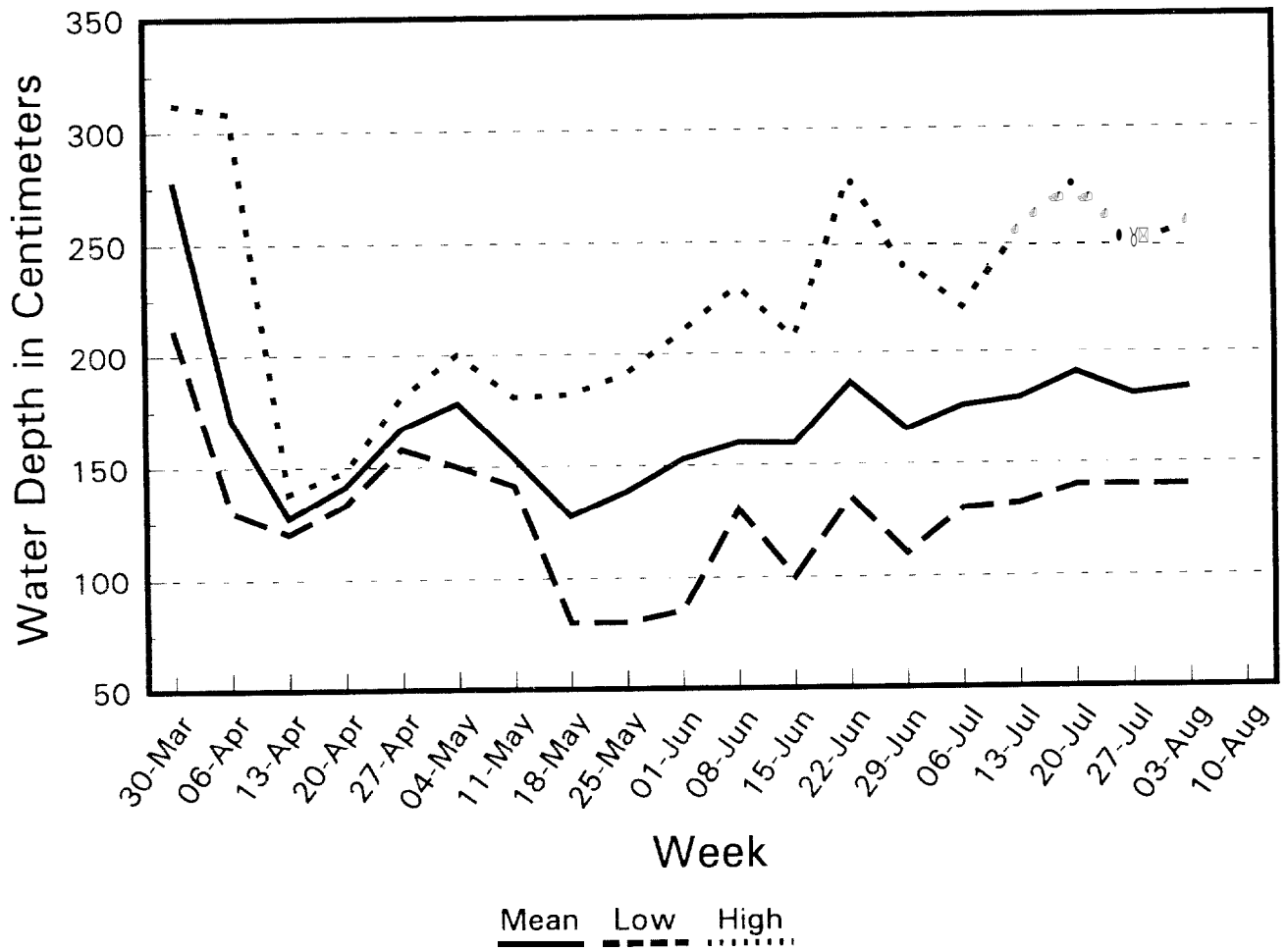
Appendix Figure D-8. Use of Gangion Leader Test Strengths by Number of Hooks per Week for ODFW Vessel.



Appendix Figure D-9. Use of Bait Types by Number of Hooks per Week for ODFW Vessel.



Appendix Figure D-10. Weekly Mean Water Surface Temperature.



Appendix Figure D-11. Weekly Turbidity.

REPORT B

**Evaluation of the Northern Squawfish Sport-Reward Fishery
in the Columbia and Snake Rivers**

Prepared by

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1992 Annual Report

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We thank the U.S. Army Corps of Engineers for the use of its project facilities at Hamilton Island Ft. Rains outlook, LePage Park, Plymouth Boat Ramp, Hood Park, Windust Park, and the Greenbelt Boat Ramp. We thank the Washington State Parks and Recreation Commission for the use of its facilities at Maryhill State Park. We thank the City of Longview for the use of Willow Grove Park, the City of Vancouver for the use of Portco Park, the City of Bingen for the use of Bingen Marina, the City of The Dalles for the use of Dalles Boat Basin, the City of Richland for the use of Columbia Point Park, the Port of Kalama for the use of Kalama Marina, the Port of Cascade Locks for the use of Cascade Locks Marina, the Port of Whitman County for the use of Boyer Park, the Port of Columbia County for the use of Lyons Ferry Marina, and Multnomah County Parks for the use of their facilities at M.J. Gleason Park. We thank Sheila Cannon for coordinating the use of The Fishery At Covert's Landing, and Jan Gronholm for the use of the facilities at Bayport Marina.

We thank Robert Adamsen, John Aleckson, Lianne Anderson, Jack Anderson, Peter Bergman, Tony Blaine, Monte Busselman, Kathleen Byrd, Scott Clark, Floyd Culpepper, Mike Dawkins, John Delaney, James Dewilde, Thu Doan, Patrica Dogherra, Angela Duling, Scott Fielding, Beverly Frantum, Andrew Fritz, Kristi Gadwa, Erich Gaedeke, James Galbreath, Barbara Griggs, Matt Gustafsen, Evelyn Haase, Bob Haley, Darrell Haley, Eric Hobbs, Maria Holmes, John Hone, Kurt Hubbard, Tammy Kapron, Jon Kohr, Mark Kramer, Brad Littlefield, Scott Longnecker, John Mahan, Dale Markel, Matthew Marshall, JoEllen Marshall, Steve Martin, Merl May, Ken McGee, Derrick Meagers, Luther Miller, Jess Mings, Molly Monroe, Kathleen Moyer, Larry Nash, Travis Nelson, Brian Pederson, Marc Petersen, Robert Phelps, Bill Purcell, Tom Quinn, Nate Reagan, Joseph Repp, Bill Rogers, Sarah Rowley, Jeanne Rust, Heidi Ruthhardt, Dave Schultz, Catherine Smith, Paul Smith, Denny Snyder, John Songster, Joe Steele, Joe F. Steele, Shannon Stein, Lynn Stewart, Morgan Strayer, Greg Taylor, Steve Terrell, Mark Thompson, Vicky Troastle, David Van Schoiak, Jeff Vass, Carrie Vestal, Mark Wachtel, Erik Wasankari, Meri-Lynn Weeks, Eric Wilson, Thomas Wood, Pat Wright, and Sile Zacharias for their work conducting the sport-reward fishery registration stations, and collecting the data necessary for the success of this program. We thank Eric Gower, Stacie Kelsey, Robert Morgan, Dave Phinney, Greg Short, Glenn Snodgrass, Connie Stevens, and Fredrick Watson for their

outstanding efforts in the field collecting quality data during the creel survey, We thank Dennis Gilliland, Conrad Dickson, Randy Drew, Diane DuCommun, Melanie Greer, Cynthia Rief, and April Stedronsky for entering the volumes of data collected during the sport-reward fishery into the computers accurately. We thank Dan Fender for the creel survey computer program development and Pete Hahn for assisting with the creel survey analysis design. We give special thanks to Janice Orr for her contributions in completing the annual report.

ABSTRACT

We are reporting on the progress of the Northern Squawfish (*Ptychocheilus oregonensis*) Sport-Reward Fishery in the Columbia River Basin for April 1 through September 30, 1992. The objectives of this project were (1) to implement the Sport-Reward Fishery for northern squawfish at 20 registration stations on the Washington and Oregon shores in the lower Columbia River and Snake River; (2) to register anglers to participate in the program; (3) to collect biological data on northern squawfish and other fish species caught and turned in to the registration stations; (4) to conduct a roving creel survey to assess impacts of the fishery on other fish species; and (5) to report on the inseason dynamics of the fishery.

The Northern Squawfish Sport-Reward Fishery was conducted during May 18 through September 27, 1992. A total of 88,494 angler days were spent fishing for northern squawfish. A total of 35,128 (39.7%) anglers returned to the registration stations and turned in 186,904 northern squawfish 11 inches or longer for the \$3 reward. An additional 13,892 northern squawfish less than 11 inches were turned into the stations (no reward was issued for northern squawfish less than 11 inches). The catch per unit effort (CPUE) for the season was 2.11 fish per angler day (northern squawfish 11 inches or longer).

The harvest of reward-size northern squawfish was 15% greater in 1992 than in 1991, with an increase in participation of about 24%. From 1991 to 1992, the CPUE decreased (10.6%) from 2.36 fish per angler day in 1991 to 2.11 fish per angler day in 1992.

Fork lengths were collected from 128,510 northern squawfish, 119,437 were from northern squawfish with a fork length of 250 mm or longer (approximately 11 inches total length). The overall mean fork length of the northern squawfish greater than 250 mm was 346 mm (SD = 59.7 mm). We used a t-test to compare the mean fork length of northern squawfish between 1991 and 1992. We found a statistically significant decrease in mean fork length for all reservoirs combined.

Fish species other than northern squawfish turned into the registration stations totaled 2,349 fish (1.24% of all fish species returned). Smallmouth bass (*Micropterus dolomieu*) had the highest reported harvest of 693 fish. A total of 231 walleye (*Stizostedion vitreum*) and 141 channel catfish (*Ictalurus punctatus*) were observed in the catch. Peamouth

(*Mylocheilus caurinus*) had the highest harvest of 588 fish for unclassified species (non-game or non-food).

The portable computerized data collection station was field tested during the last month of the field season at the Hamilton Island boat ramp. Modification of the software is in progress and the unit will continue to be evaluated in 1993.

The roving creel survey interviewed a total of 6,754 angling parties in nine reservoirs during the 1992 fishery. The percent harvest by registered anglers encountered in the creel survey by reservoir ranged from 2.3 % in the Lower Monumental Reservoir to 42.8 % in The Dalles Reservoir. A positive correlation was observed between the harvest of northern squawfish calculated by reservoir turned into the registration stations and the estimated harvest of northern squawfish calculated by the roving creel survey.

INTRODUCTION

Predation on outmigrating juvenile salmonids (*Oncorhynchus spp.*) by northern squawfish (*Ptychocheilus oregonensis*) in the Columbia River Basin has been identified as a major concern of the Columbia River Basin Fish and Wildlife Program (NPPC 1987). Predator control of northern squawfish on the Columbia and Snake rivers has developed in recent years to the extent that multiple fisheries now exist that target northern squawfish (Nigro 1990). The goal of the predator control program is to achieve a sustained harvest of 10-20% of the larger northern squawfish in the population (250 mm or longer). This could restructure the population and reduce the impacts of predation on the outmigrating juvenile salmonids by as much as 50% (Rieman and Beamesderfer 1990).

One component of the program is a test fishery, paying the public a reward of \$3 each for northern squawfish 11 inches or longer (Burley et al. 1992). The sport-reward test fishery began in 1990 in the John Day Reservoir (Vigg et al. 1990) and expanded to include multiple reservoirs in the Columbia and Snake rivers in 1991 (Burley et al. 1992).

The objective of this project was to implement the sport-reward fishery for northern squawfish at 20 registration stations on the Washington and Oregon shores in the lower Columbia and Snake rivers from May 18 through September 27, 1992. Specifically, the project called for registering anglers to participate in the fishery, issuing vouchers for payment to successful anglers, collecting biological data on northern squawfish and other fish species caught and turned into the registration stations, and reporting on the inseason dynamics of the fishery. The feasibility of using a roving creel survey to assess the impact of the sport-reward fishery on game, food, and other unclassified fish species, was also tested.

METHODS

Study Area

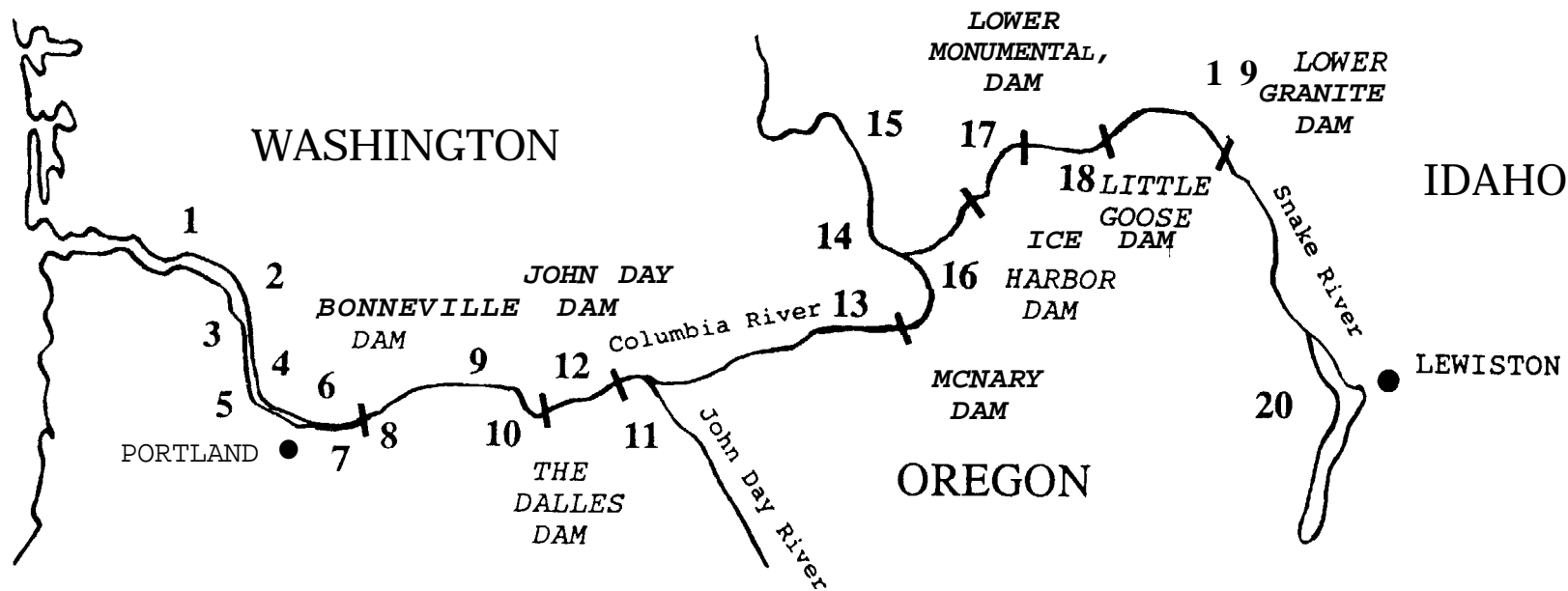
The sport-reward fishery for northern squawfish was conducted from the mouth to the tailrace of Priest Rapids Dam on the Columbia River, and from the mouth to the Hells Canyon Dam on the Snake River. Backwaters, sloughs, and up to 400 feet inside the mouth of tributaries along the above mentioned reaches of the Columbia and Snake rivers were also open for harvest of northern squawfish for payment.

Twenty registration stations were located on the lower Columbia and Snake rivers (Figure 1). The stations on the Columbia River were located below Bonneville Dam at Willow Grove Park, Wash.; Bayport Marina, Ore.; Kalama Marina, Wash.; M.J. Gleason Park, Ore.; Portco Park Marina, Wash.; The Fishery at Convert's Landing, Ore.; and Hamilton Island Ft. Rains Outlook, Wash.. In the Bonneville Reservoir, stations were at Cascade Locks Marina, Ore.; Bingen Marina, Wash.; and The Dalles Boat Basin, Ore.. Stations were located in The Dalles Reservoir at Maryhill State Park, Wash., and in the John Day Reservoir at LePage Park, Ore., and Plymouth Park, Wash.. In McNary Reservoir, stations were at Columbia Point Park, Wash., and Ringold Boat Ramp, Wash.. On the lower Snake River, registration stations were located in McNary Reservoir at Hood Park, Wash., and in the Ice Harbor Reservoir at Windust Park, Wash. In the Lower Monumental Reservoir, a station was located at Lyons Ferry Marina, Wash. In the Little Goose Reservoir, the station was at Boyer State Park, Wash. The station in the Lower Granite Reservoir was located at the Greenbelt Boat Ramp, Wash.

Field Procedures

Registration Interview

Washington Department of Wildlife (WDW) technicians were present to register anglers from 9 a.m. to 9 p.m. Anglers could self-register at a registration box near the site between 9:01 p.m. and 8:59 a.m. A short interview was conducted to record information pertinent to the anglers fishing day and tiled by last name.



- | | | |
|---------------------------------|---------------------------|-------------------------|
| 1. Willow Grove | 8. Cascade Locks Marina | 15. Ringold Access Site |
| 2. Kalama Marina | 9. Bingen Marina | 16. Hood Park |
| 3. Bayport Marina | 10. The Dalles Boat Basin | 17. Windust Park |
| 4. Marine Park | 11. LePage Park | 18. Lyons Ferry Marina |
| 5. M. James Gleason | 12. Maryhill State Park | 19. Boyer Park |
| 6. The Fishery Island Boat Ramp | 13. Plymouth Boat Ramp | 20. Greenbelt Boat Ramp |
| 7. The Fishery Island Boat Ramp | 14. Columbia Point | |

Figure 1. Location of the northern squawfish sport-reward fishery check stations on the Columbia and Snake rivers during May 18-September 27, 1992.

Exit Interview

Upon completion of fishing, anglers were requested to return to the same station that they registered. A WDW technician then retrieved the anglers registration form and conducted the exit interview. All fish turned in were inspected and counted by technicians. This included the number of northern squawfish 11 inches or greater (\$3 reward per fish) and their total weight (\pm 0.2 lbs), the number of northern squawfish turned in less than 11 inches, and the number of northern squawfish lost or released. Other fish species harvested were also recorded.

The qualifying northern squawfish were totaled and the angler was issued a pay voucher. The technician and angler each signed the pay voucher to verify the number of northern squawfish eligible for the reward. The angler was required to complete the inside questionnaire on his or her own and mail to the Pacific States Marine Fisheries Commission (PSMFC). Sport-reward payment was funded by the Bonneville Power Administration.

Biological Data Collection

Fish brought to the registration station by registered anglers were sampled for biological data by a scientific technician. These data were recorded on the back portion of the original angler registration form. During periods when large numbers of fish were being turned in or people were in line to register or exit, a subsampling regime was conducted.

Complete biological data was collected for northern squawfish catches numbering 30 or less. Catches greater than 30 fish were subsampled (fish species and fork length). Complete biological data was collected on every fifth fish. All qualifying northern squawfish returned to the check station were tail-clipped to indicate a voucher had been issued for these fish. Other fish species brought to the site were processed for biological data then returned to the angler. If time allowed during the shift, technicians would process any fish not previously sampled for a more complete biological profile.

Northern Squawfish Processing

After WDW technicians collected the biological data, each northern squawfish was graded according to guidelines provided by Oregon State University (OSU). These guidelines outlined specific instructions for technicians to determine whether a fish would be processed as "food-grade" or "fertilizer-grade" fish. Food-grade fish were placed on ice in red insulated coolers while fertilizer-grade fish were placed on ice in blue insulated coolers. At the end of each shift, technicians delivered the iced fish to a designated facility for fish processing or storage. Empty coolers and ice were picked up by technicians for the next day. This routine was repeated daily at each site for the duration of the Northern Squawfish Sport-Reward Fishery.

Computerized Data Collection

During September 10-27, 1992, a computerized data collection station was tested at the Hamilton Island registration site. This water-resistant work station incorporated an electronic balance, metric length measurement scale, a digitizer, multiplexer, an external computer keyboard, a laptop computer, and a 12-VDC power source. A customized software package developed by the work station manufacturer, Biomark Inc., enabled WDW technicians to enter registration, exit interview, and biological data directly onto a computer diskette in lieu of hand recording this information. This data was audited by the software upon entry, alerting the technicians to errors or omissions in the data while the registrant and specimens were still at hand. At the end of the evening shift, WDW technicians would remove the labeled computer diskette that included all data from both shifts. A new diskette was used to record the data for each day.

Roving Creel Survey

A roving creel survey was conducted concurrently with the Northern Squawfish Sport-Reward Fishery from May 18-September 27, 1992, to assess the impact of the sport-reward fishery on fish species other than northern squawfish. The creel survey was conducted on about 500 miles of the Columbia and Snake rivers (Figure 1). The area encompassed the free-flowing section of the Columbia River (Puget Island to Bonneville Dam) and several reservoirs on the Columbia and Snake rivers (Columbia River -- Bonneville, The Dalles, John Day, and McNary reservoirs; Snake River -- Ice Harbor, Lower Monumental, Little Goose, and the Lower Granite reservoir to the mouth of the Grande Ronde River).

The design was based on an adaptation of Malvestuto et al. (1978) and Von Geldern and Tomlinson (1973) using a roving creel survey to estimate harvest on large impoundments with multiple access points, and structured around a 10-hour work day.

The study area was divided into approximately 10-mile sections and each section assigned a unique code. The field season consisted of 19 weeks with 95 weekdays and 43 weekend days (including holidays) for a total of 138 days. Every weekend and holiday was sampled as well as two randomly selected weekdays each week. This resulted in 38 weekdays and 43 weekend days for a total of 79 sampling days. The sample day was defined as a 10-hour period from 8 a. m. to 6 p. m. The sample day was further divided into two time periods, early and late. Angler counts and angler interviews were assigned using a stratified random design without replacement. Each cell (geographic section, day type, and time period) was given equal weight.

Through the randomization process some cells were not represented at a satisfactory sample size to determine probability of angler encounter for future sample design

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refinements. Supplemental sampling were randomly assigned within a strata to meet the predetermined minimum sample size per cell.

Angler Counts

Counts were stratified by anglers fishing from shore and anglers fishing from boats. Only people actually in the process of fishing were included in the counts. An angler count was conducted once at the beginning and once at the end of the sampling period by traveling the entire section at a constant rate and observing anglers at strategic vantage points using binoculars (10 X 70). The direction traveled was randomly determined and angler counts were completed in less than one hour. The data collected were river section, date, start time, number of anglers fishing from shore, number of fishing boats, and number of anglers in the fishing boats.

Angler Interviews

Angler interviews were conducted in the assigned section giving equal time to all access points where anglers could be encountered. Angler interview data were recorded using the "Angler Fish Data Base" form and associated codes. All anglers encountered were interviewed as time permitted, however, at heavy use areas a subsampling regime was used. In this case, every fourth angler was interviewed and catch cohort data collected (fork length and weight from every fourth fish). The angler interview data collected were river section, date, number of anglers in fishing party, time fished (start and stop time), complete or incomplete effort, registered in sport-reward fishery or not, angler type, gear type, target species, and catch cohort data [species, origin, marks, fork length (± 1 mm), and weight (± 1 g)].

Data Analysis

Sport-Reward Fishery

Computer programs were written using SAS Version 6.04 statistical software to retrieve subsets of data for analysis of the Northern Squawfish Sport-Reward Fishery.

Roving Creel Survey

The roving creel survey data was calculated using methodologies similar to Malvestuto et al. (1978). Daily calculations were made. They were combined by strata and expanded for a reservoir.

Daily Calculations

The fishing effort was calculated from angler count data. The effort in angler hours was determined by multiplying the mean number of anglers per count by the total number of fishing hours for each day (Neuhold and Lu 1957; Malvestuto et al. 1978):

$$F_i = h_i X_i \quad (1)$$

where

F_i = fishing effort (hours) for the i^{th} day,
 h_i = number of total possible fishing hours for the i^{th} day, and
 X_i = mean number of anglers per count for the i^{th} day.

The daily fishing effort was kept separate by strata (reservoir section, angler type, and day type).

The harvest per unit of effort (fish * angler hour⁻¹) was calculated for each day using the equation:

$$r_i = \frac{\sum h_{ij}}{\sum t_{ij}} \quad (2)$$

where

r_i = Harvest per unit of effort (HPUE) for the i^{th} day,
 h_{ij} = harvest of all species for the j^{th} angler, and
 t_{ij} = the fishing time for the j^{th} angler.

The daily HPUE were kept separate by strata.

The harvest for each day (by strata) was calculated using fishing effort (F_i , angler hours) from Equation 1 multiplied by the HPUE (r_i , fish * angler hour⁻¹) from Equation 2:

$$H_i = r_i F_i \quad (3)$$

Calculations By Strata

A mean daily angler effort was calculated for each stratum:

$$\bar{F}_h = \frac{\sum F_{hi}}{n_h} \quad (4)$$

where n_h is the number of days surveyed.

The total effort for the stratum was calculated by multiplying the total possible fishing days (N_h) in the season by the mean daily fishing effort:

$$F_h = N_h \bar{F}_h \quad (5)$$

The variance of the angler counts for each stratum was calculated using Equations 6 and 7 (Zar 1974; Malvestuto et al. 1978):

$$\text{VAR}(\bar{F}_h) = \frac{\sum F_{hi}^2 - \frac{(\sum F_{hi})^2}{n_h}}{n_h - 1} \quad (6)$$

$$\text{VAR}(F_h) = N_h^2 (\text{VAR}(\bar{F}_h)) \left(1 - \frac{n_h}{N_h}\right) \quad (7)$$

where

- $\text{VAR}(\bar{F}_h)$ = the variance of the mean daily effort,
- $\text{VAR}(F_h)$ = the variance of total effort for the h^{th} stratum,
- n_h = the number of days surveyed in the stratum,
- N_h = the total available days in the stratum, and
- $(1 - (n_h/N_h))$ = the finite population correction (applied when $n/N > 0.05$).

The HPUE for each stratum was calculated by averaging the daily HPUE similar to Equation 4 (Malvestuto et al. 1978). The variance of the HPUE for each strata was calculated using Equation 8:

$$\text{VAR}(r_h) = \frac{\sum r_{hi}^2 - \frac{(\sum r_{hi})^2}{n_h}}{n_h - 1} \quad (8)$$

The harvest for each stratum was calculated by multiplying the total possible fishing days (N_h) in the season by the mean daily harvest estimates similar to Equation 5. The variance of harvest for each stratum was calculated.

Season Calculations

The total fishing effort for the season was calculated by summing the fishing effort of all the strata. The variance for the total fishing effort was calculated using the following equation:

$$\text{VAR}(F_T) = \text{VAR}(F_1) + \text{VAR}(F_2) + \dots + \text{VAR}(F_k) \quad (9)$$

where

k = the number of groups in the stratification, and
 $\text{VAR}(F_1)$ = the variance of the h^{th} stratum, assuming that the fishing effort for each h^{th} strata were independent and that the covariance terms were zero due to random sampling.

The standard error (SE) of the total fishing effort was determined by calculating the square root of $\text{VAR}(F_T)$ in Equation 10:

$$\text{SE}(F_T) = \sqrt{\text{VAR}(F_T)}. \quad (10)$$

The 95% confidence interval for the total fishing effort was determined using Equation 11:

$$95 \% \text{C.I.} = F_T \pm t_{(0.05(2),v)} \text{SE}(F_T) \quad (11)$$

where

- v = the degrees of freedom (approximated by a number midway between the smallest n_h and the sum of the individual strata degrees of freedom), and
 SE(F_T) = standard error of the total fishing effort.

The HPUE for the season was calculated by dividing the total harvest by the total effort. The variance of the HPUE for the season was calculated using Equation 11 (assuming zero covariance, from Hansen et al. (1953) and standard error using Equation 13:

$$\text{VAR}(r_T) = \frac{H_T^2}{F_T^2} * \left(\frac{\text{VAR}(H_T)}{H_T^2} + \frac{\text{VAR}(F_T)}{F_T^2} \right) \quad (12)$$

$$\text{SE} = \sqrt{\text{VAR}(r_T)} \quad (13)$$

The equation used for calculating the 95% confidence intervals for the HPUE was:

$$\text{C.I. } r_h = r_h \pm t_{(0.05(2),v)} \text{ SE}(r_h) \quad (14)$$

We assumed the H_j s were independent and calculated total harvest and the variance of the total harvest as follows:

$$H_T = H_1 + H_2 + \dots + H_k \quad (15)$$

$$\text{VAR}(H_T) = \text{VAR}(H_1) + \text{VAR}(H_2) + \dots + \text{VAR}(H_k) \quad (16)$$

where k is the number of stratifications.

The standard error and confidence intervals were calculated as follows:

$$\text{SE} = \sqrt{\text{VAR}(H_T)} \quad (17)$$

$$95 \% \text{ C.I. } H_T = H_T \pm t_{(0.05(2),v)} \text{ SE}(H_T) \quad (18)$$

RESULTS

Sport-Reward Fishery

Northern Squawfish Harvest Data

The sport-reward fishery had a total participation (effort) of 88,494 angler days. A total of 35,128 (39.7%) anglers returned to the registration stations. Those anglers harvested, and turned in for payment, a total of 186,904 northern squawfish 11 inches or longer. An additional 13,892 northern squawfish less than 11 inches were turned into the registration stations (no payment was issued for northern squawfish less than 11 inches). The overall CPUE for northern squawfish eligible for payment was 2.11 fish per angler day.

The harvest of northern squawfish and effort varied by week during the season (Figure 2). The weekly totals of harvest and effort were calculated showing fairly constant harvest for the first five weeks with a gradual decrease through the rest of the season. The participation showed a gradual decrease during the season. The weekly harvest ranged from 1,802 to 20,572 northern squawfish. The effort ranged from 992 to 10,813 angler days. The average CPUE by week was 1.99 fish per angler day and ranged from 1.48 to 2.59 fish per angler day (Figure 3).

Harvest and effort of northern squawfish varied by reservoir (Figure 4). Harvest ranged from 3,045 fish in Lower Monumental Reservoir to 79,822 fish in the Bonneville tailrace (defined as the reach of the river from Bonneville Dam to the mouth of the Columbia River, and for ease of presenting the results is termed a reservoir). Effort in returning angler days (only anglers returning to the registration stations were asked where they fished) ranged from 779 in the Lower Monumental Reservoir to 16,620 returning anglers in the Bonneville tailrace. The average CPUE by reservoir was 5.34 fish per returning angler day. CPUE ranged from 3.43 to 7.36 fish per returning angler day (Figure 5).

The harvest and effort of northern squawfish varied by registration location (Figure 6). The average catch of northern squawfish was 9,345 fish and ranged from 1,456 fish at Windust Park to 23,851 fish at The Fishery at Covert's Landing. The average effort in angler days was 4,425 and ranged from 1,164 to 10,672 angler days. The average CPUE by registration location was 2.07 fish per angler day and ranged from 0.49 at Bayport Marina to 4.16 fish per angler day at Columbia Point Park (Figure 7).

Fishing location No. 10 (Bonneville tailrace) exhibited the highest harvest of northern squawfish at 42,760 fish (Figure 8A) and effort at 7,834 angler days (Figure 11A). Fishing location No. 25 (McNary Reservoir) and fishing location No. 37 (Ice Harbor Reservoir) showed no harvest (Figure 9B-C) or effort (Figure 12B-C). The CPUE (36 fish per angler day) was highest in McNary Reservoir's fishing location No. 26 (Figure 15B). The majority of harvest and effort appear to be concentrated at the tailrace sections below the hydropower facilities (Figures 8-13). CPUE varied by fishing location (Figures 14- 16).

Fork length measurements were taken from a total of 128,466 northern squawfish. The average length for all locations combined was 337 mm (SD = 66.1; Figure 17). Length frequency distributions were also analyzed by reservoir for the entire season. Mean lengths ranged from 306 mm (SD = 40.8) in Lower Monumental Reservoir to 368 mm (SD = 58.8) in John Day Reservoir (Figures 18-20).

Game, Food, and Unclassified Fish Species Catch Data

Of the game fish turned into the registration stations, smallmouth bass (*Micropterus dolomieu*), channel catfish (*Ictalurus punctatus*), and walleye (*Stizostedion vitreum*) were most often seen. A total of 693 smallmouth bass were harvested and observed in returning anglers' catch. This number was higher than all other species excluding northern squawfish. A total of 141 channel catfish and 231 walleye were also turned into the registration stations (Table 1). Besides northern squawfish, there were more peamouth (*Mylocheilus caurinus*) caught (588) than any other unclassified fish species. We also continued to see individual specimens (125) that appear to be a hybridization between the northern squawfish and chiselmouth, and are referred to as Columbia River chub for reporting purposes in this report (Table 1). Efforts continue to determine whether these fish are hybridized.

Fish species caught by participants in the Northern Squawfish Sport-Reward Fishery were also looked at relative to whether the angler was targeting those species. Of the 693 smallmouth bass that were caught, 50% of those were caught by anglers targeting smallmouth bass (Figure 21). Seventy-one percent of the 231 walleye caught and 57% of the 141 channel cattish were also targeted. All peamouth caught were incidental to the program.

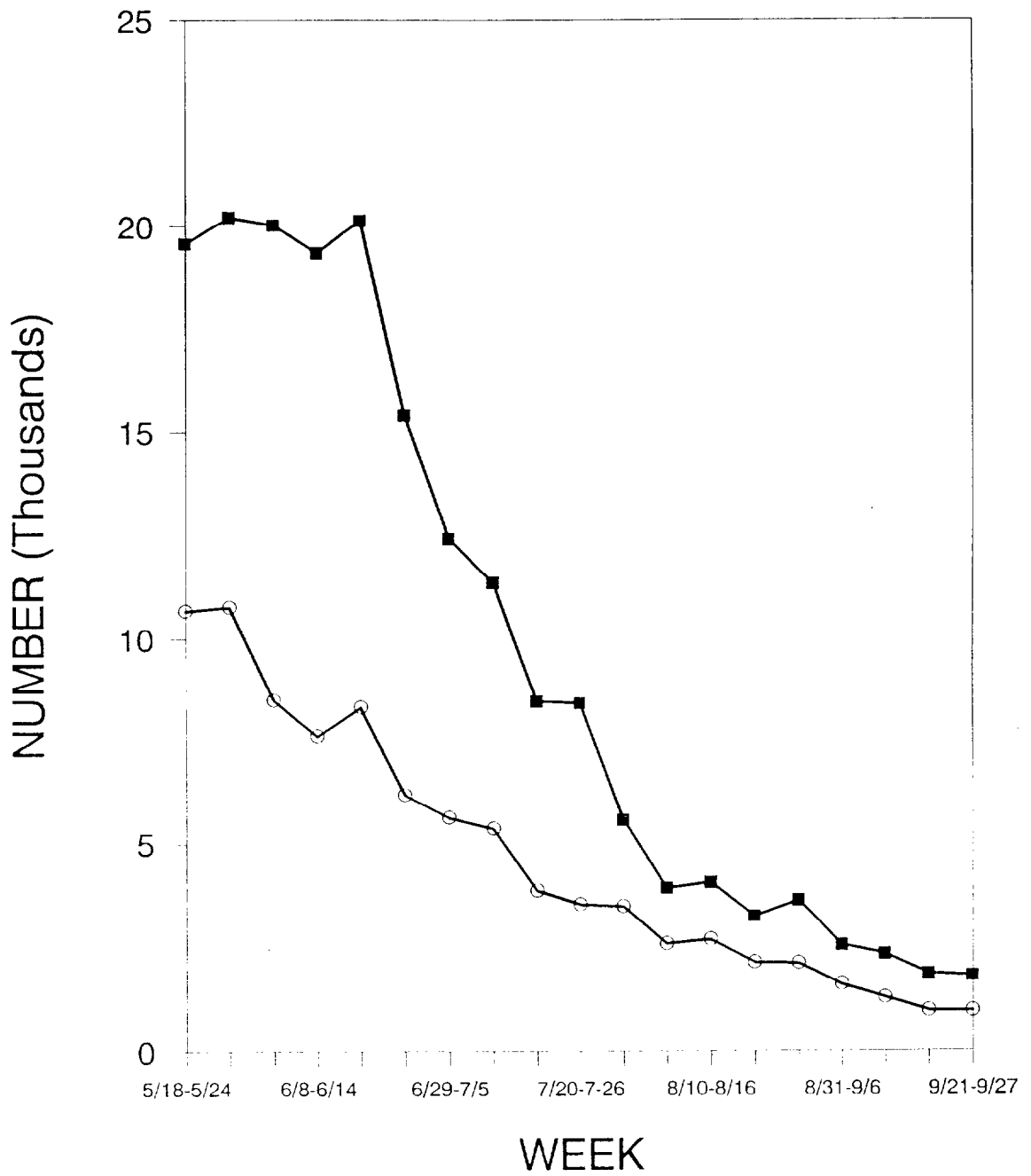


Figure 2. Northern squawfish effort (angler days) and harvest by week (O= angler days and ■= northern squawfish catch), May 18-September 27, 1992.

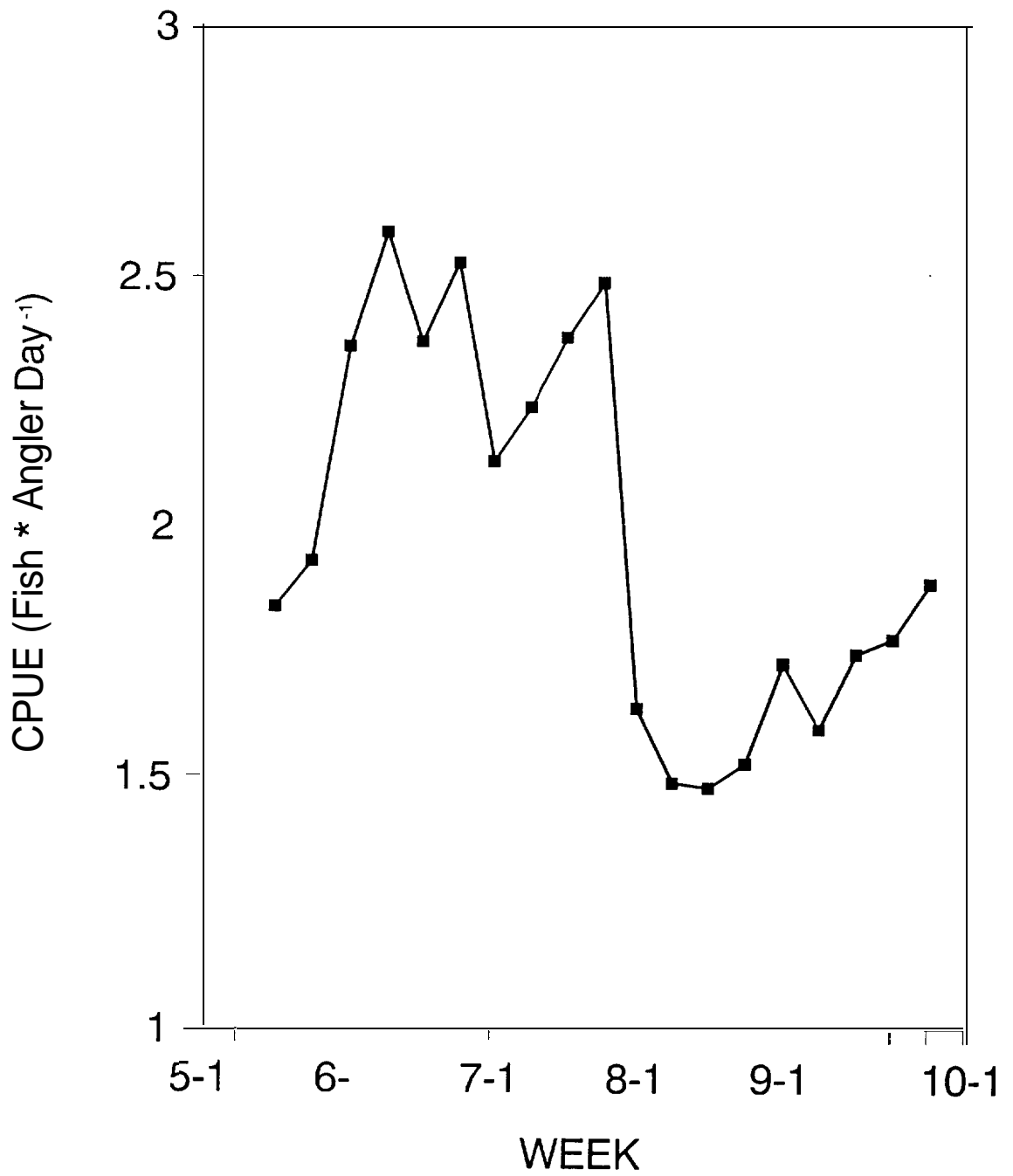


Figure 3. CPUE (fish * angler day⁻¹) for northern squawfish by week, May 18-September 27, 1992.
Figure 3.

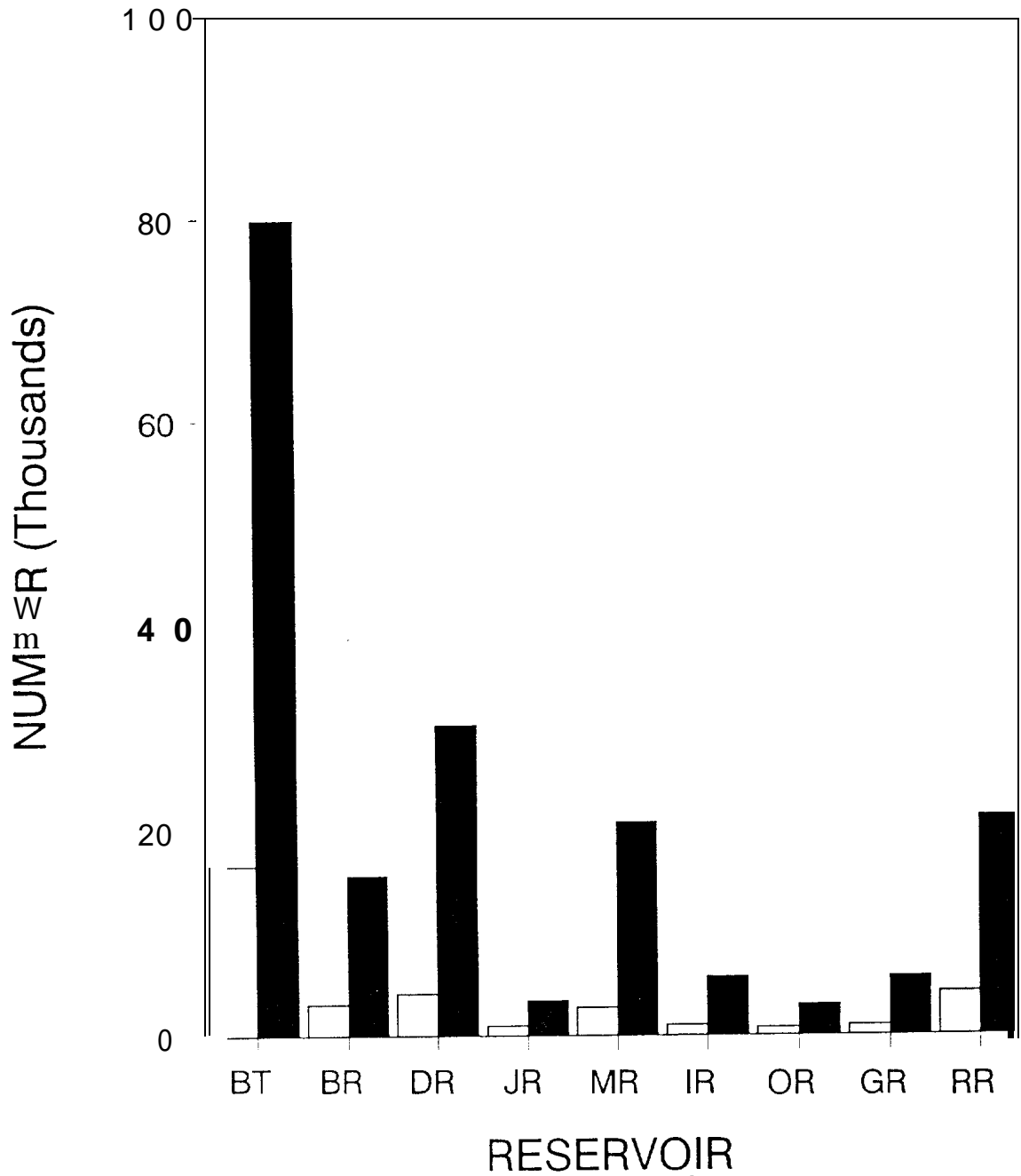


Figure 4. Northern squawfish harvest and effort (returning angler days) by reservoir (only anglers returning to the registration station had location fished recorded); (shaded bar= returning angler days, black bar= northern squawfish harvest); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

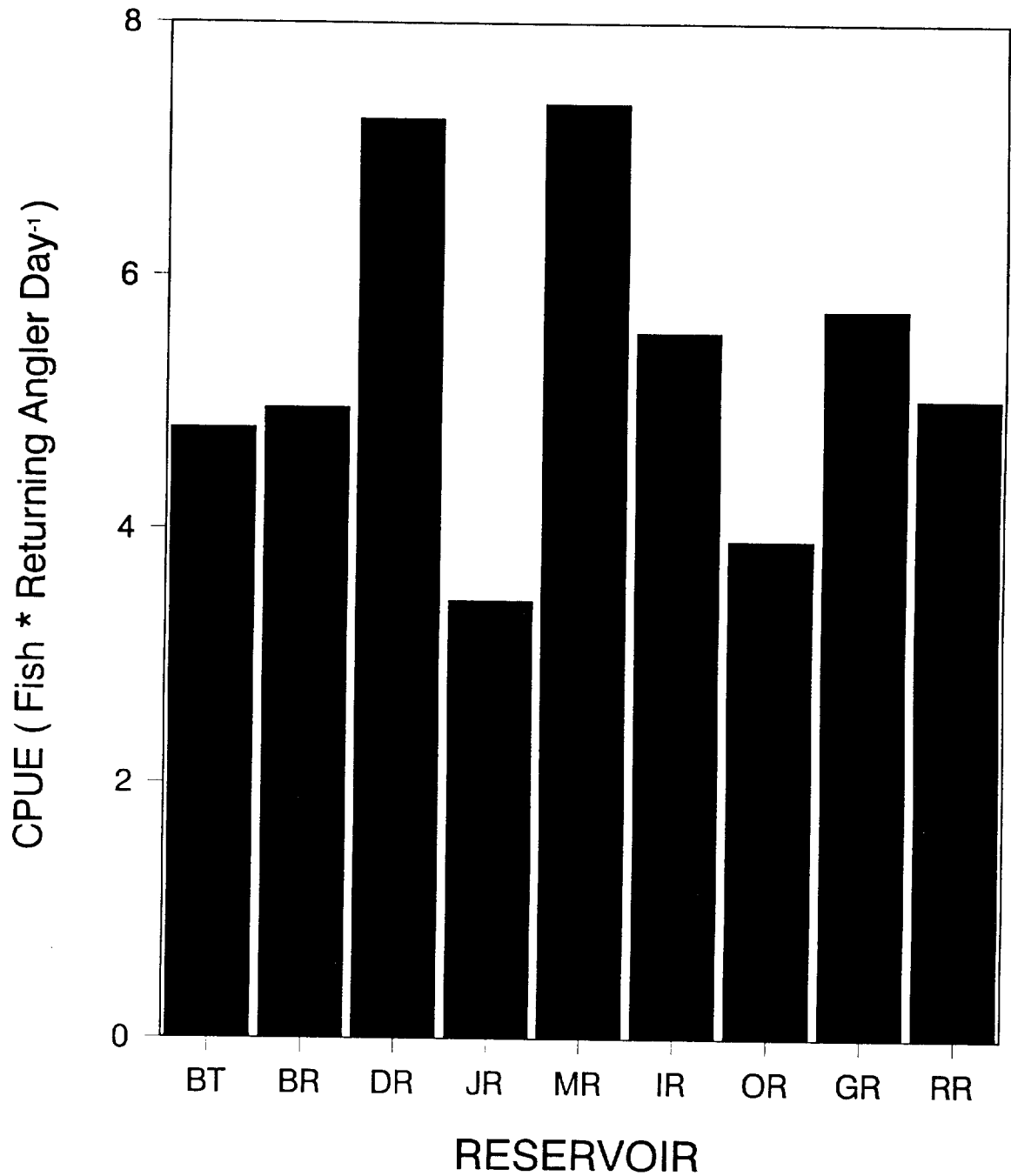


Figure 5. CPUE (fish * returning angler day⁻¹) for northern squawfish by reservoir (only anglers returning to registration stations had location fished recorded); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

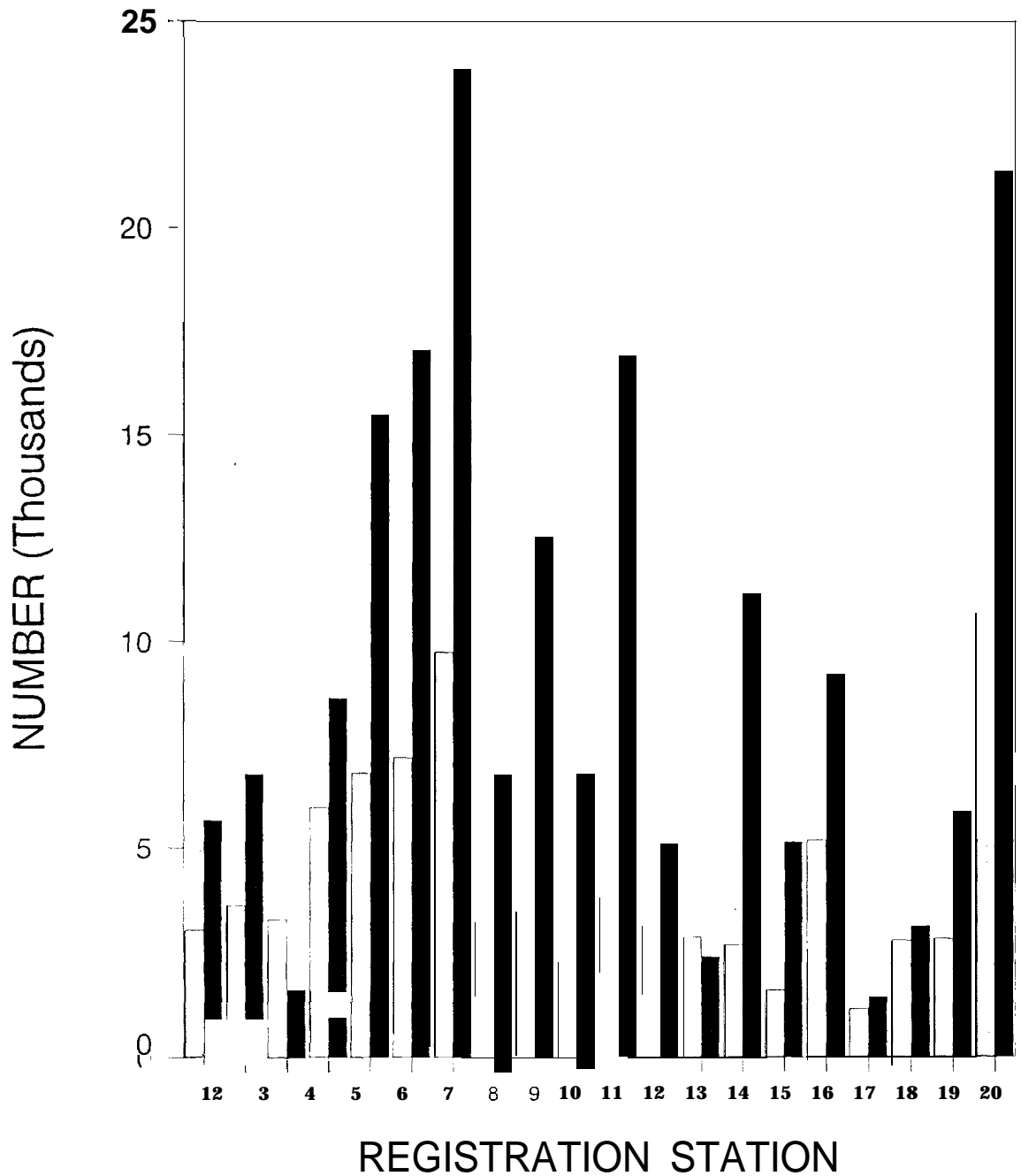


Figure 6. Northern squawfish harvest (dark bar) and effort (shaded bar = angler day) by registration station; 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Point, 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

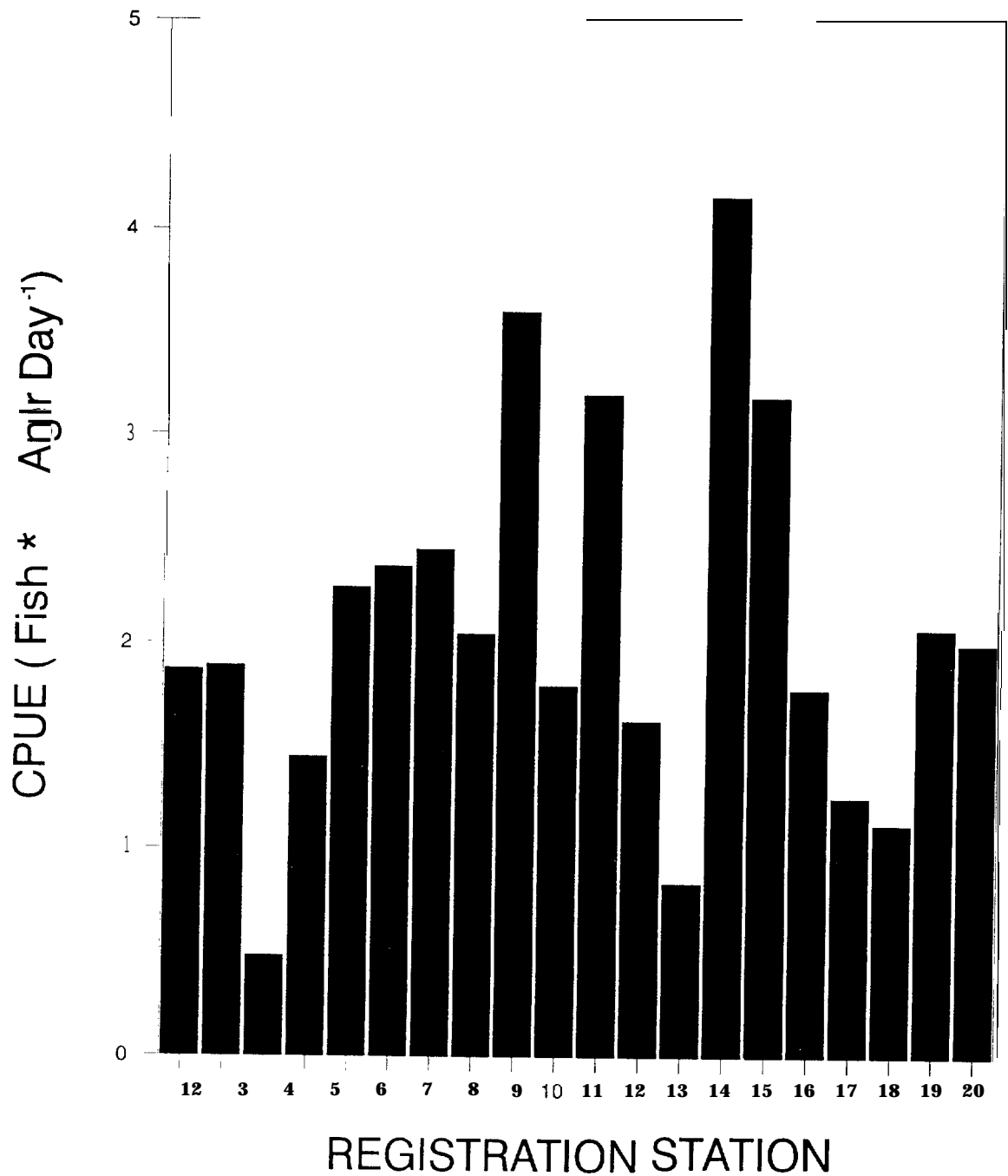


Figure 7. CPUE (fish * angler day⁻¹) for northern squawfish by registration station; 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= M. James Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Point, 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

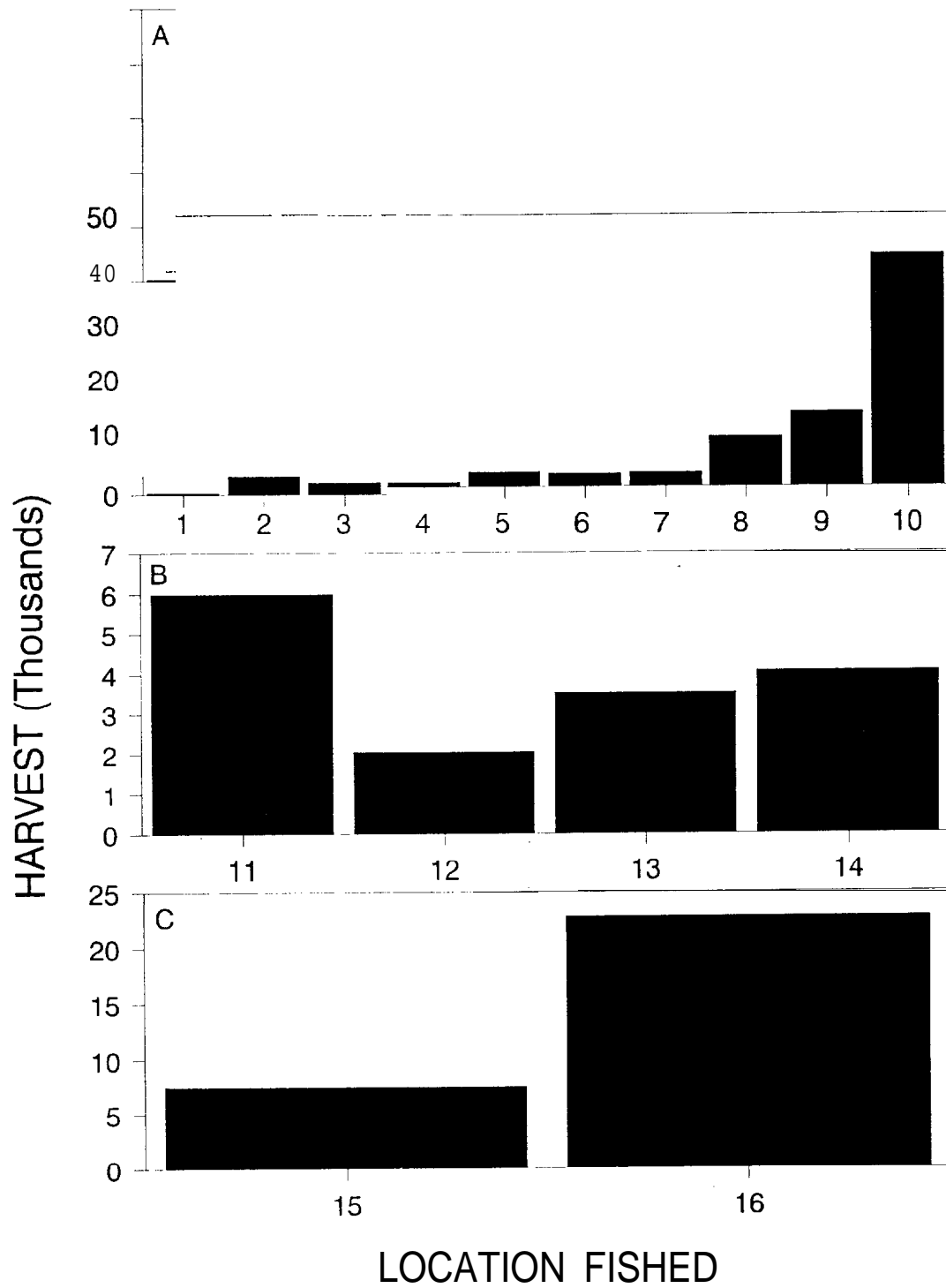


Figure 8. Northern squawfish harvest by reservoir and location fished; (A)= Bonneville Tailrace, (B)= Bonneville Res., (C)= The Dalles Res.

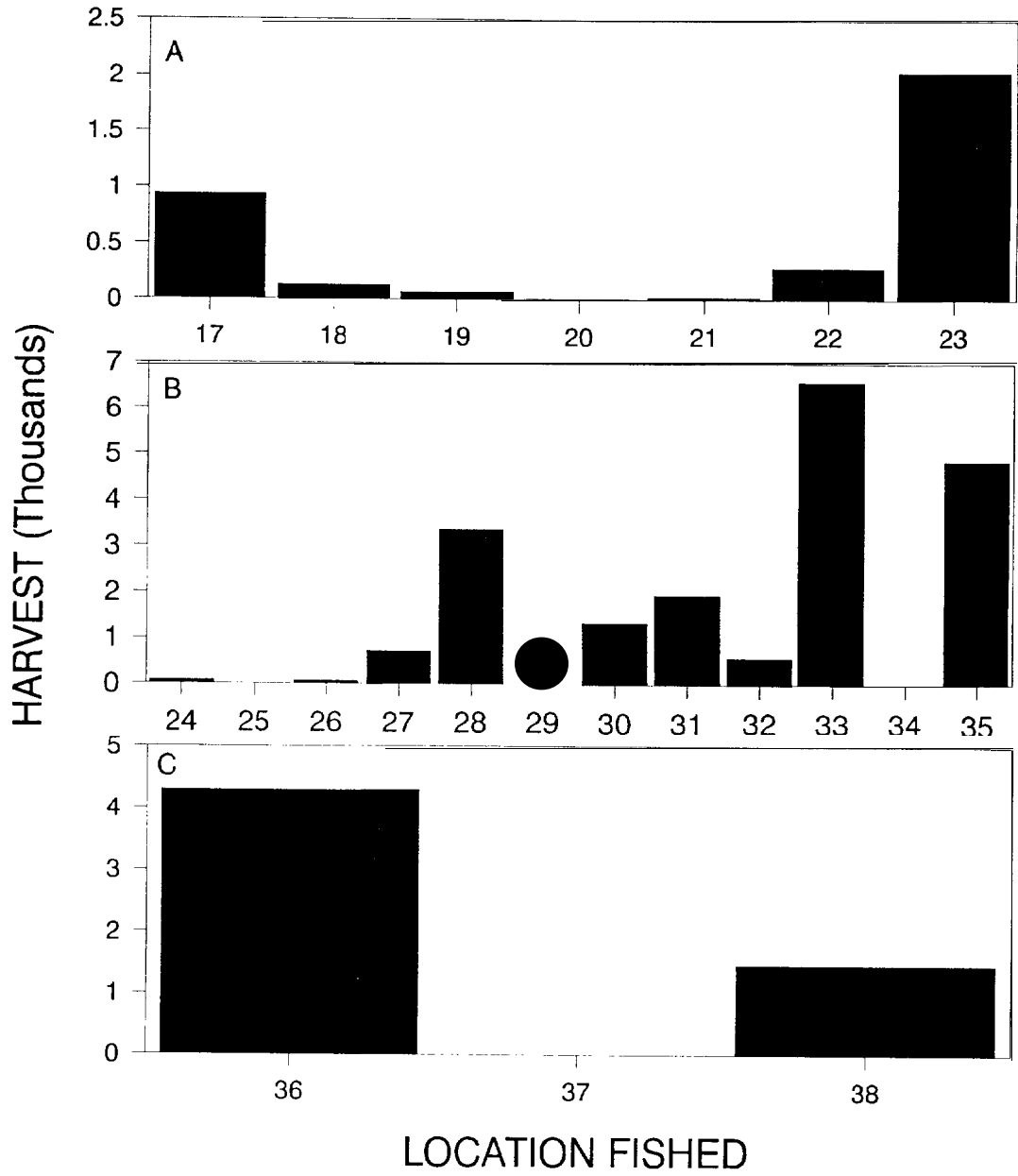


Figure 9. Northern squawfish harvest by reservoir and location fished; (A)= John Day Res. (B)= McNary Res., (C)= Ice Harbor Res.

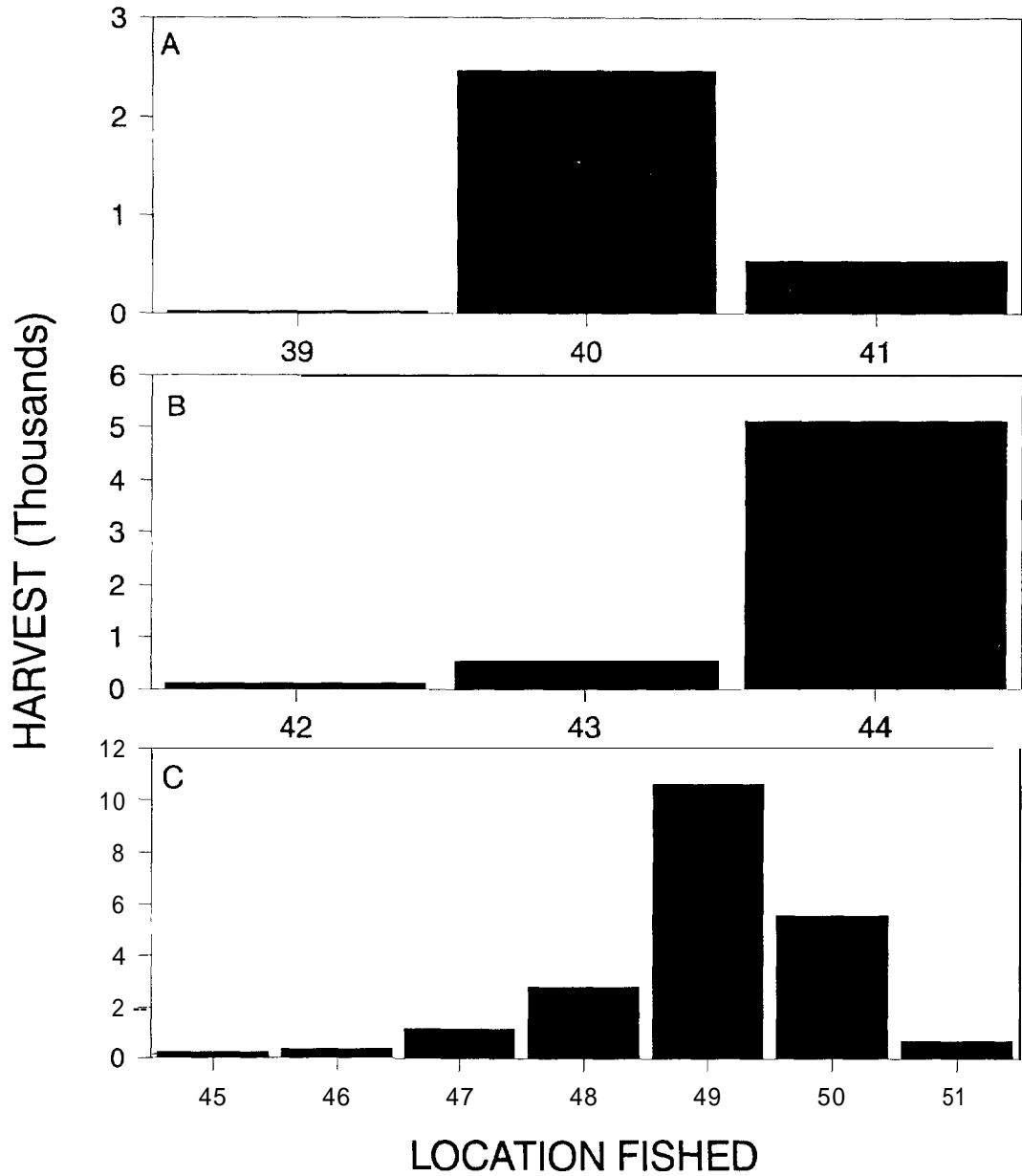


Figure 10. Northern squawfish harvest by reservoir and location fished; (A)= Lower Monumental Res., (B)= Little Goose Res., (C)= Lower Granite Res.

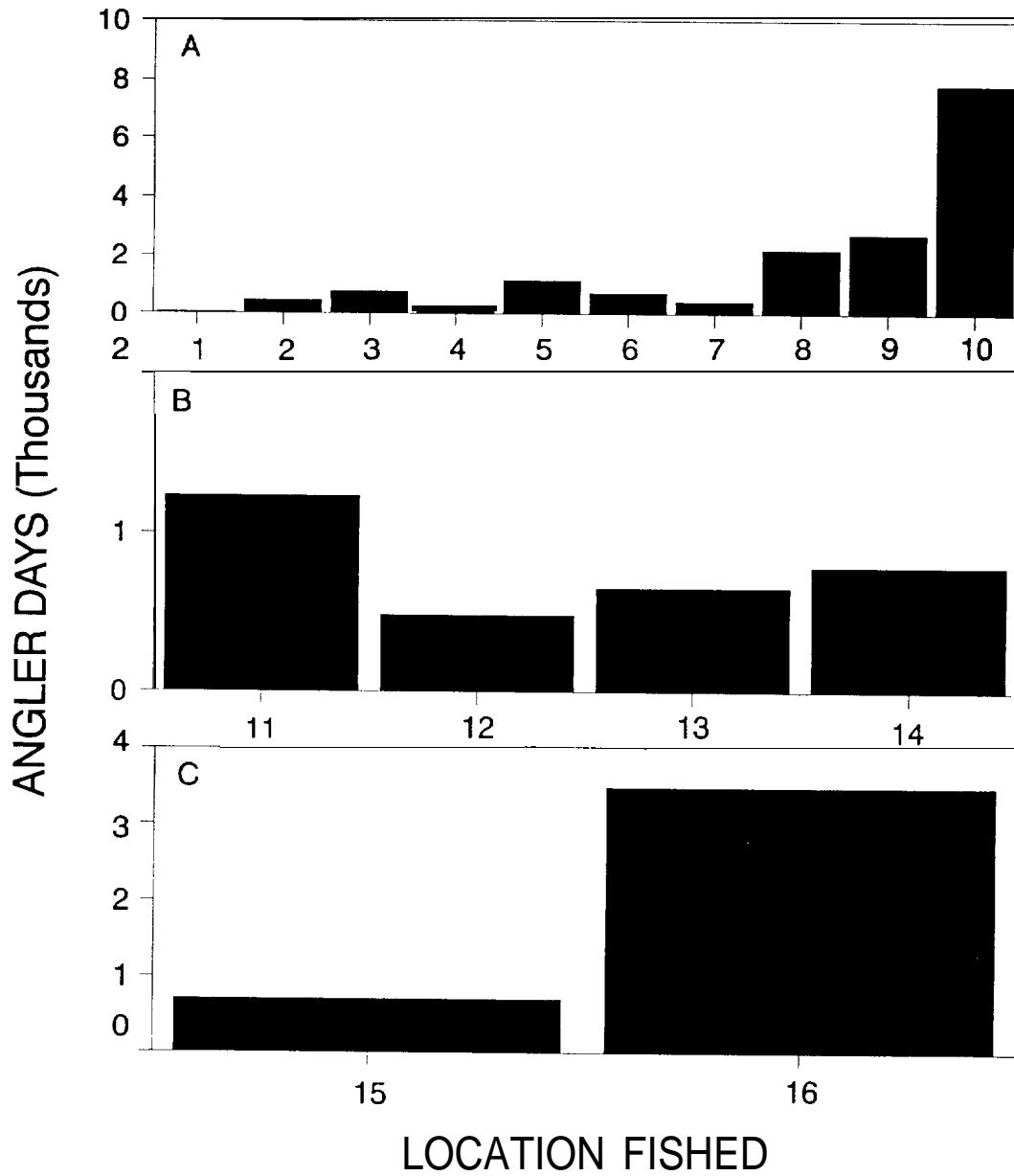


Figure 11. Effort (angler days) by reservoir and location fished; (A)= Bonneville Tailrace, (B)= Bonneville Res., (C)= The Dalles Res.

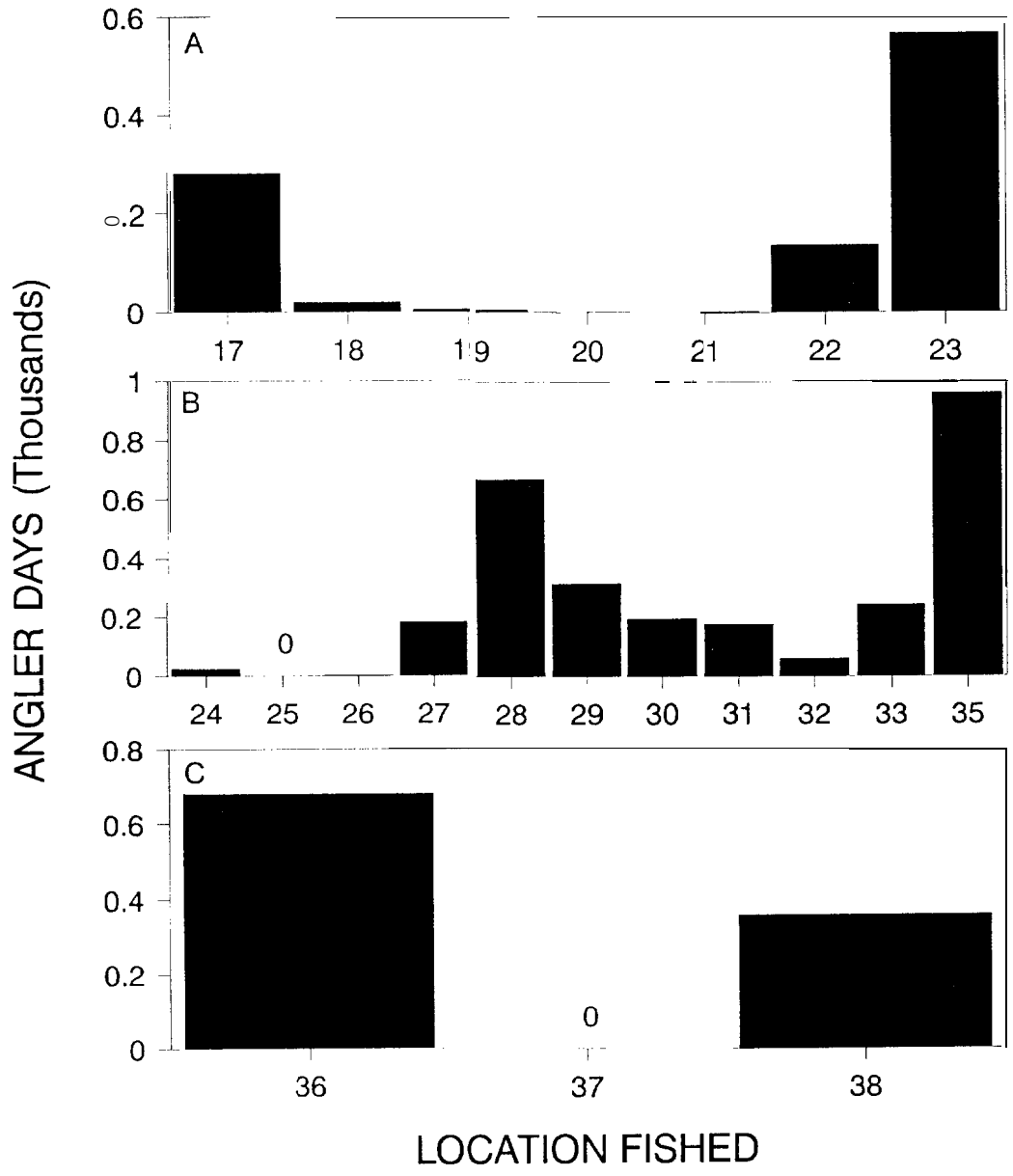


Figure 12. Effort (angler days) by reservoir and location fished: (A)= John Day Res., (B)= McNary Res., (C)= Ice Harbor Res.

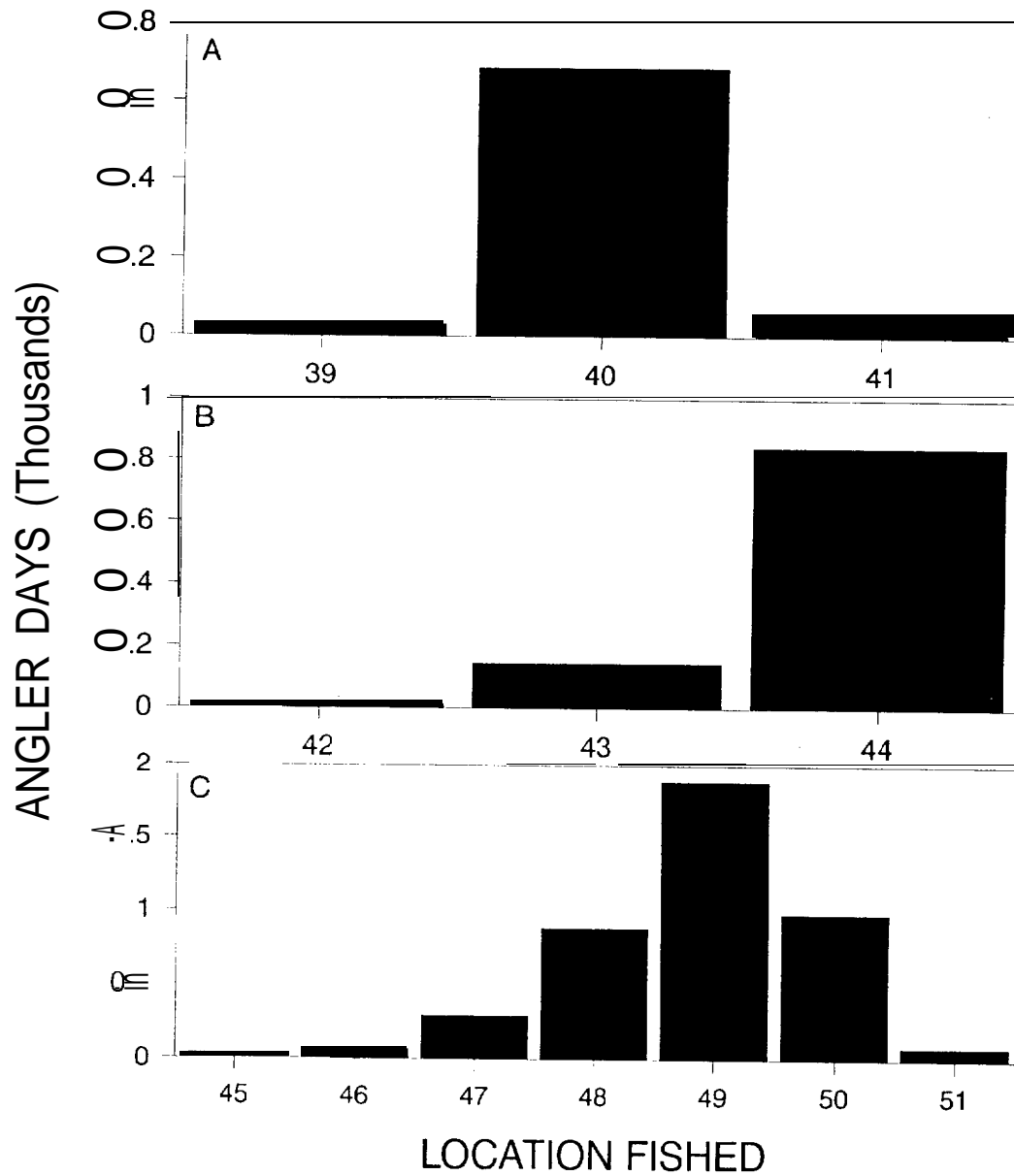


Figure 13. Effort (angler days) by reservoir and location fished; (A)= Lower Monumental Res., (B)= Little Goose Res. (C)= Lower Granite Res.

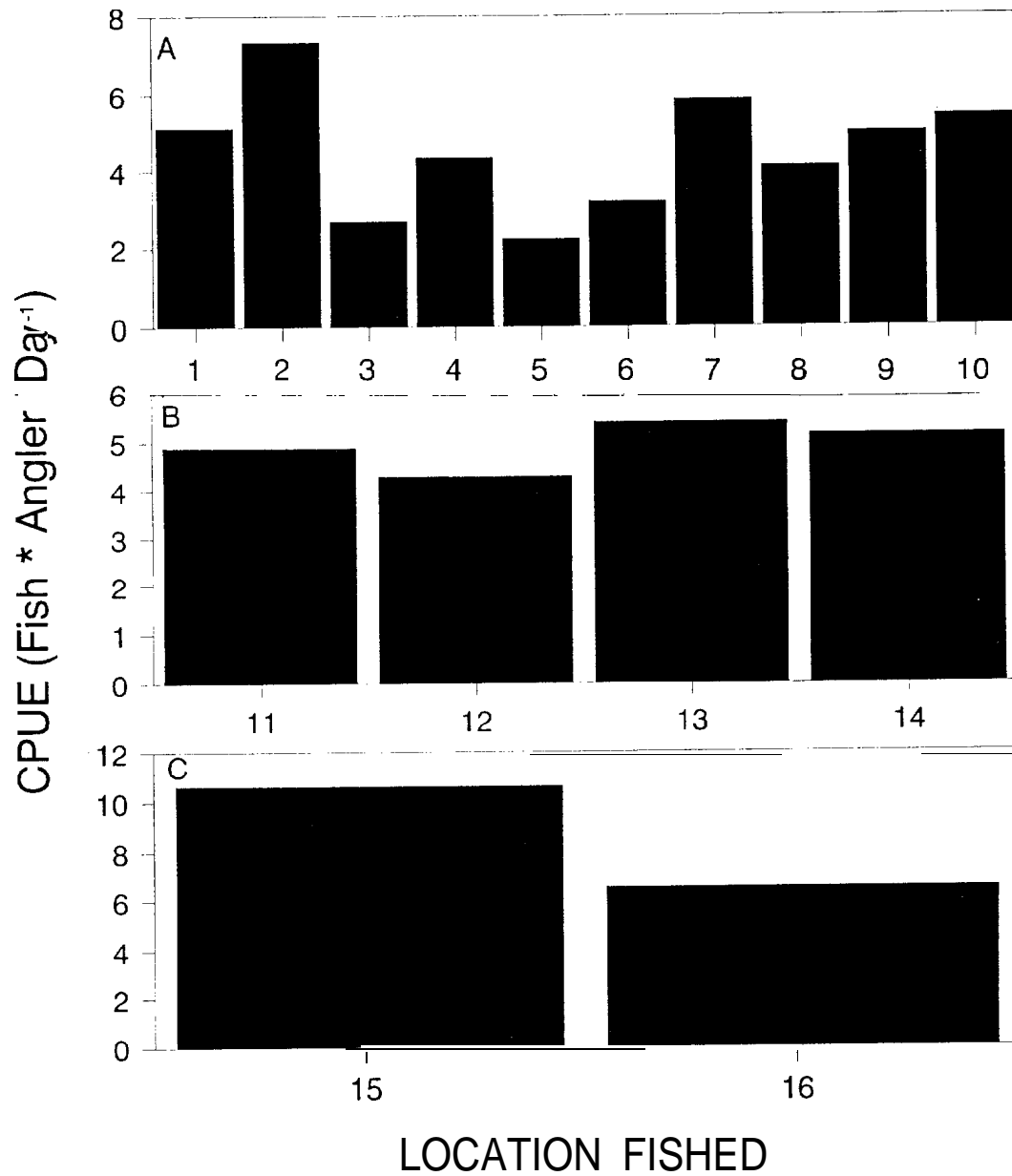


Figure 14. CPUE (Fish * Angler Day⁻¹) by reservoir and location fished; (A)= Bonneville Tailrace, (B)= Bonneville Res., (C)= The Dalles Res.

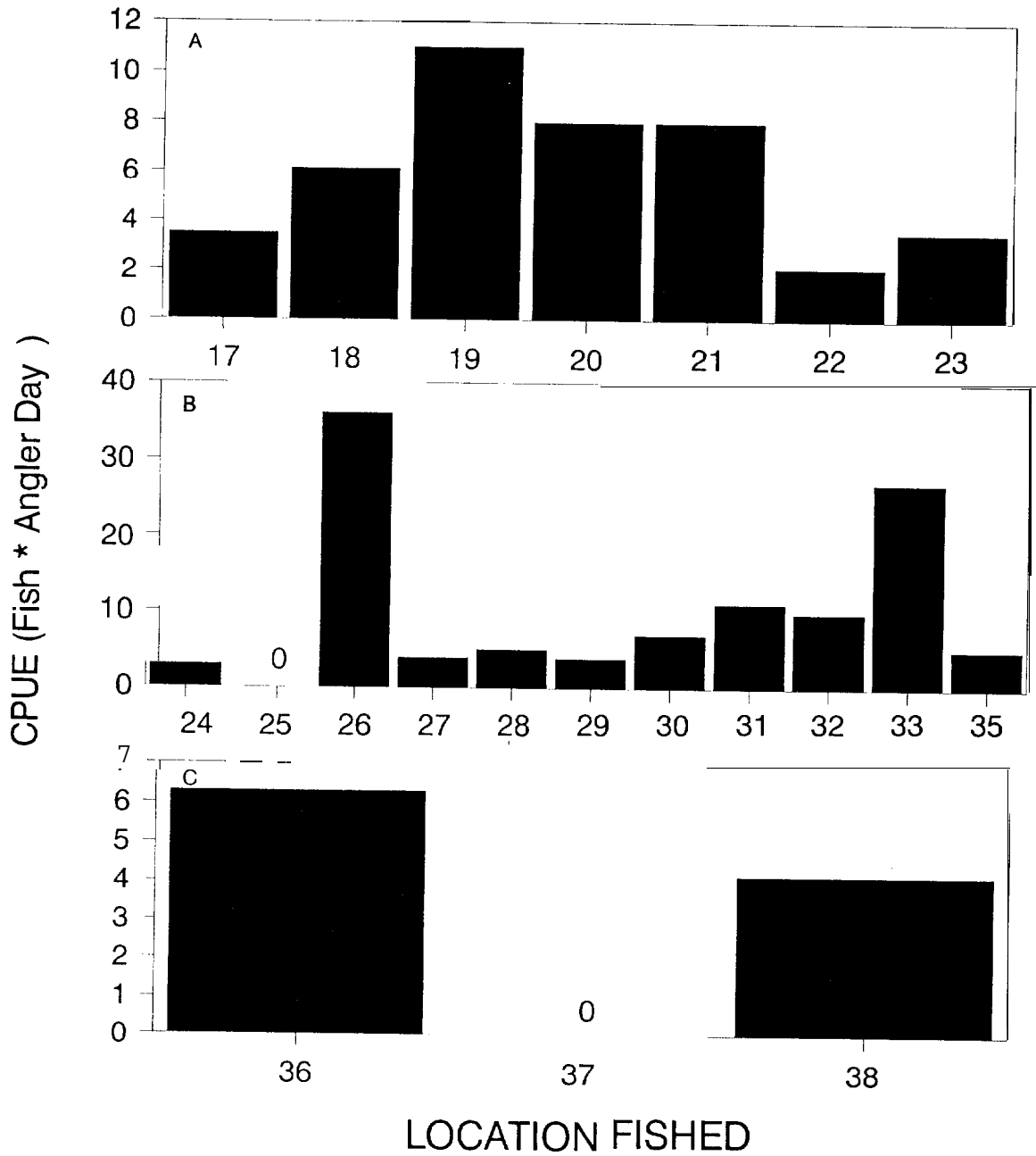


Figure 15. CPUE (Fish * Angler Day⁻¹) by reservoir and location fished; (A) = John Day Res., (B) = McNary Res., (C) = Ice Harbor Res.

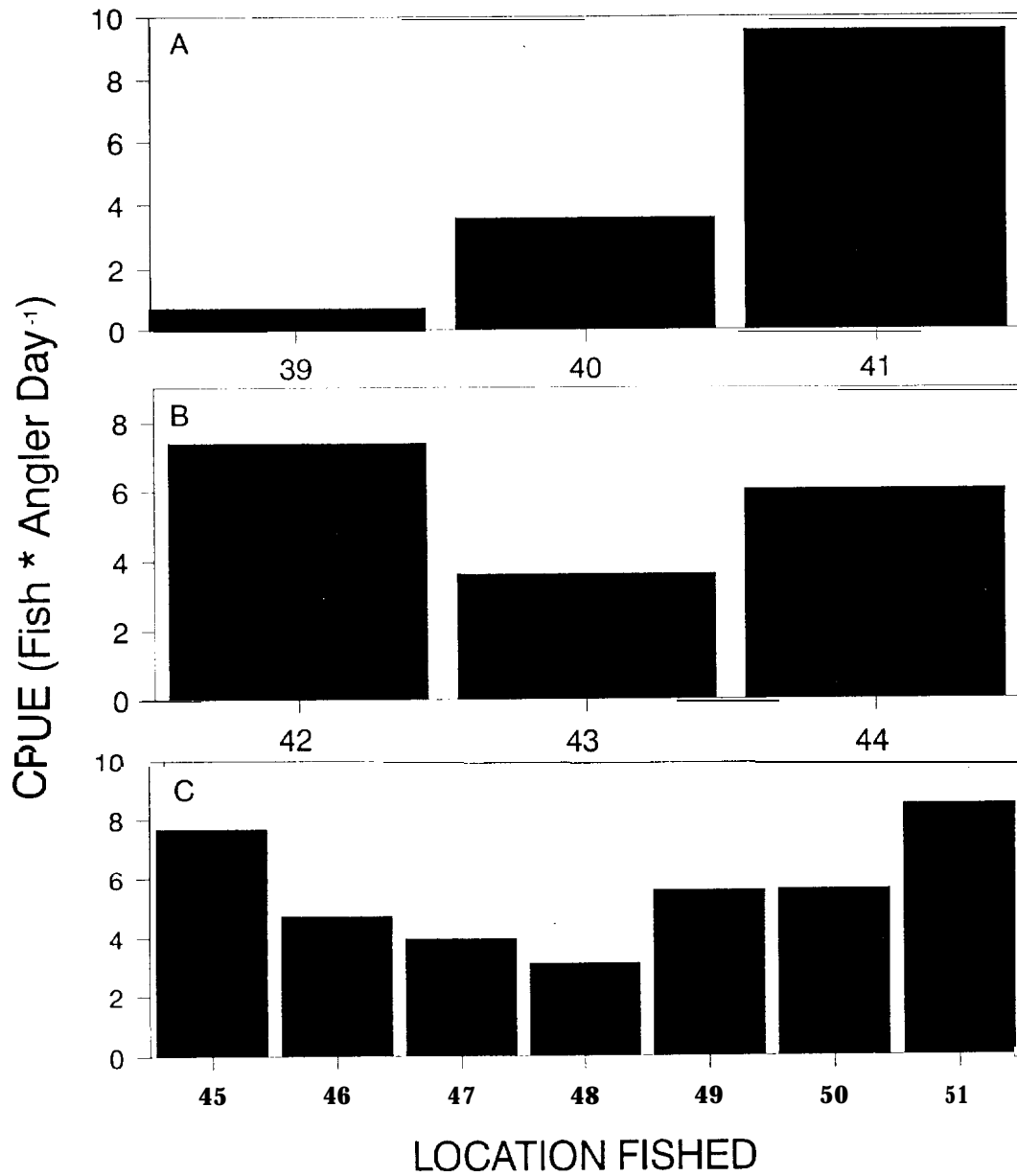


Figure 16. CPUE (Fish * Angler Day⁻¹) by reservoir and location fished; (A)= Lower Monumental Res., (B)= Little Goose Res., (C)= Lower Granite Res.

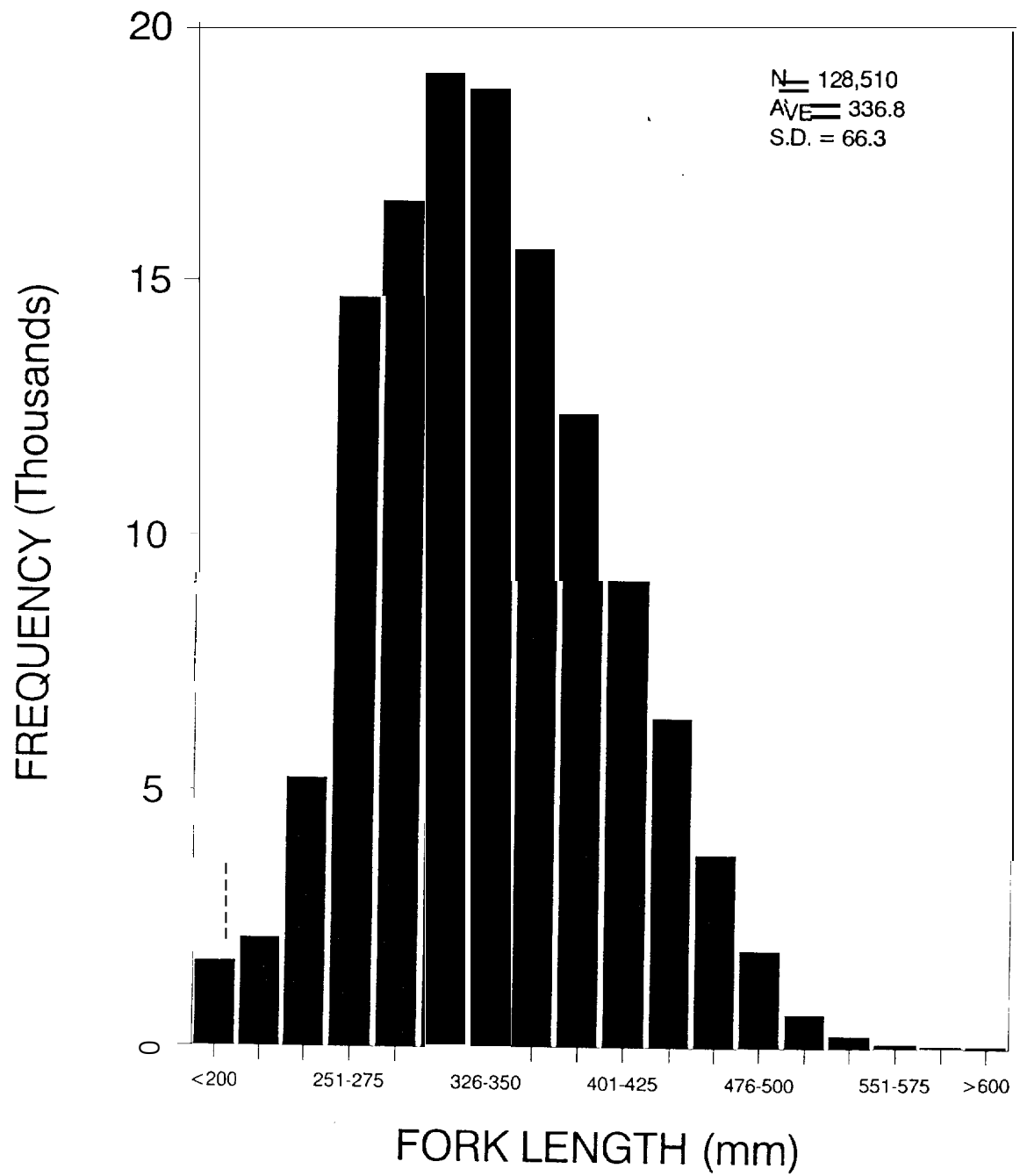


Figure 17. Overall length frequency distribution of northern squawfish caught in the sport-reward fishery.

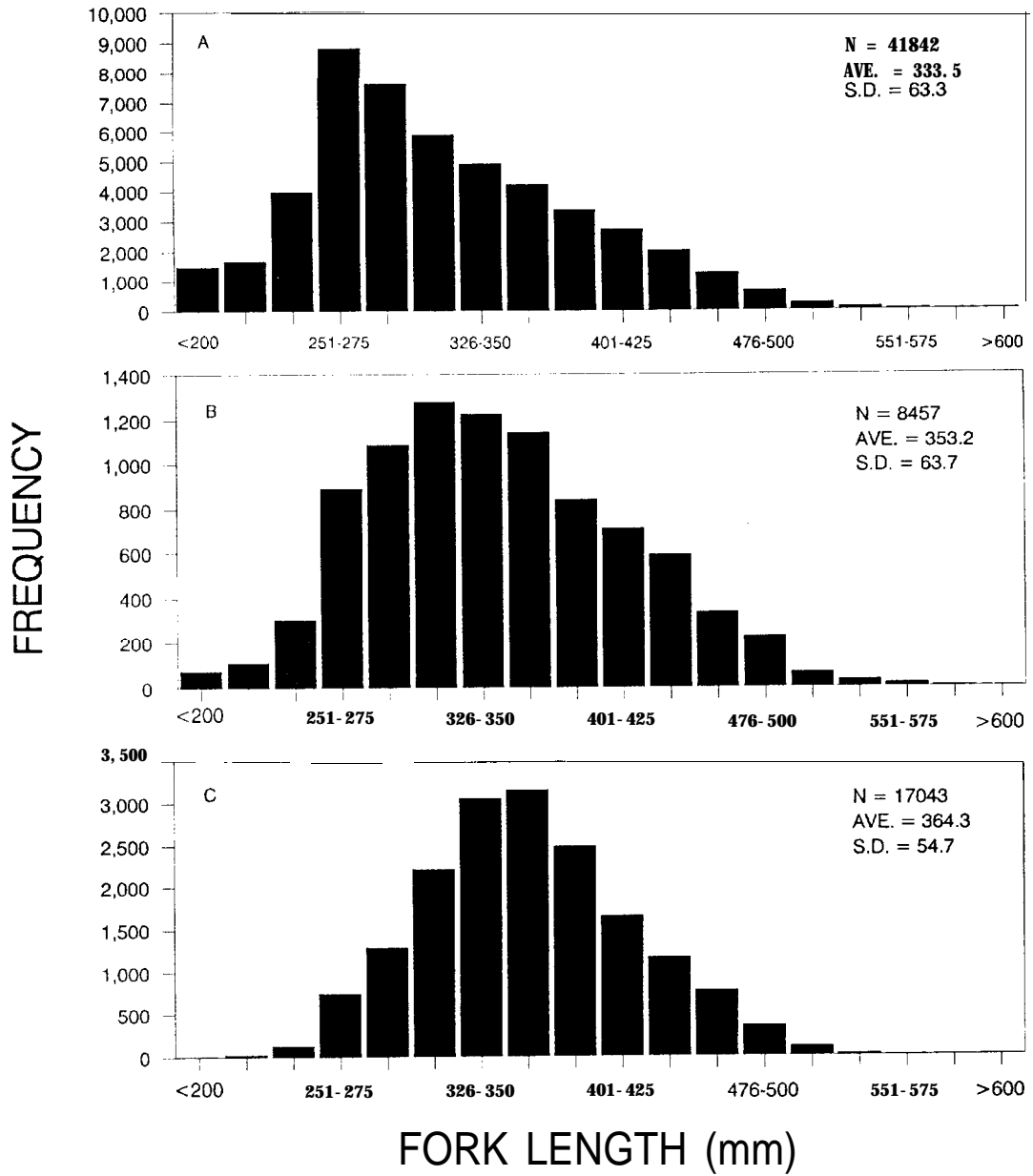


Figure 18. Length frequency distribution of northern squawfish by reservoir; (A)= Bonneville Talirace, (B)= Bonneville Res., (C)= The Dalles Res.

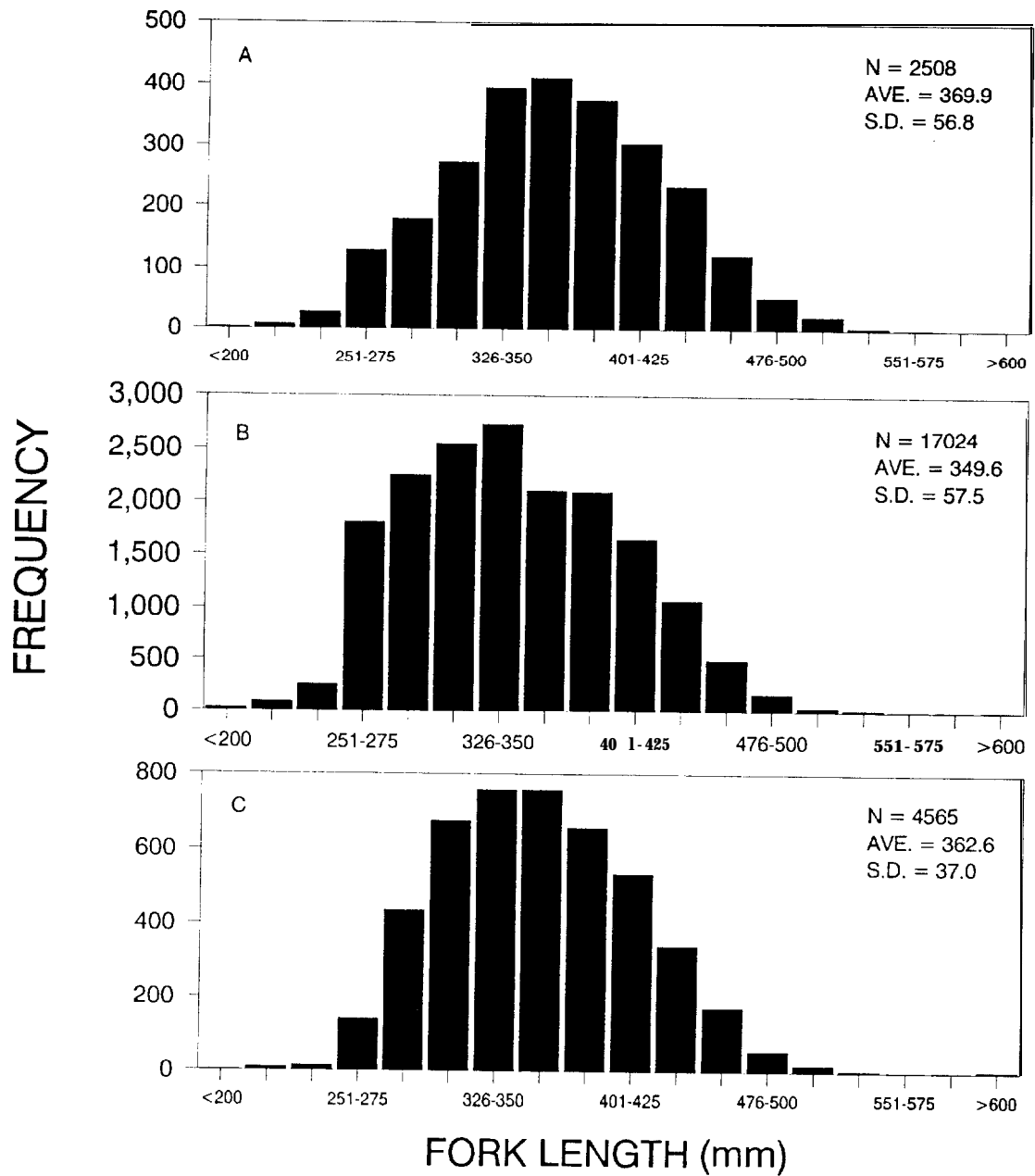


Figure 19. Length frequency distribution of northern squawfish by reservoir; (A)= John Day Res., (B)= McNary Res., (C)= Ice Harbor Res.

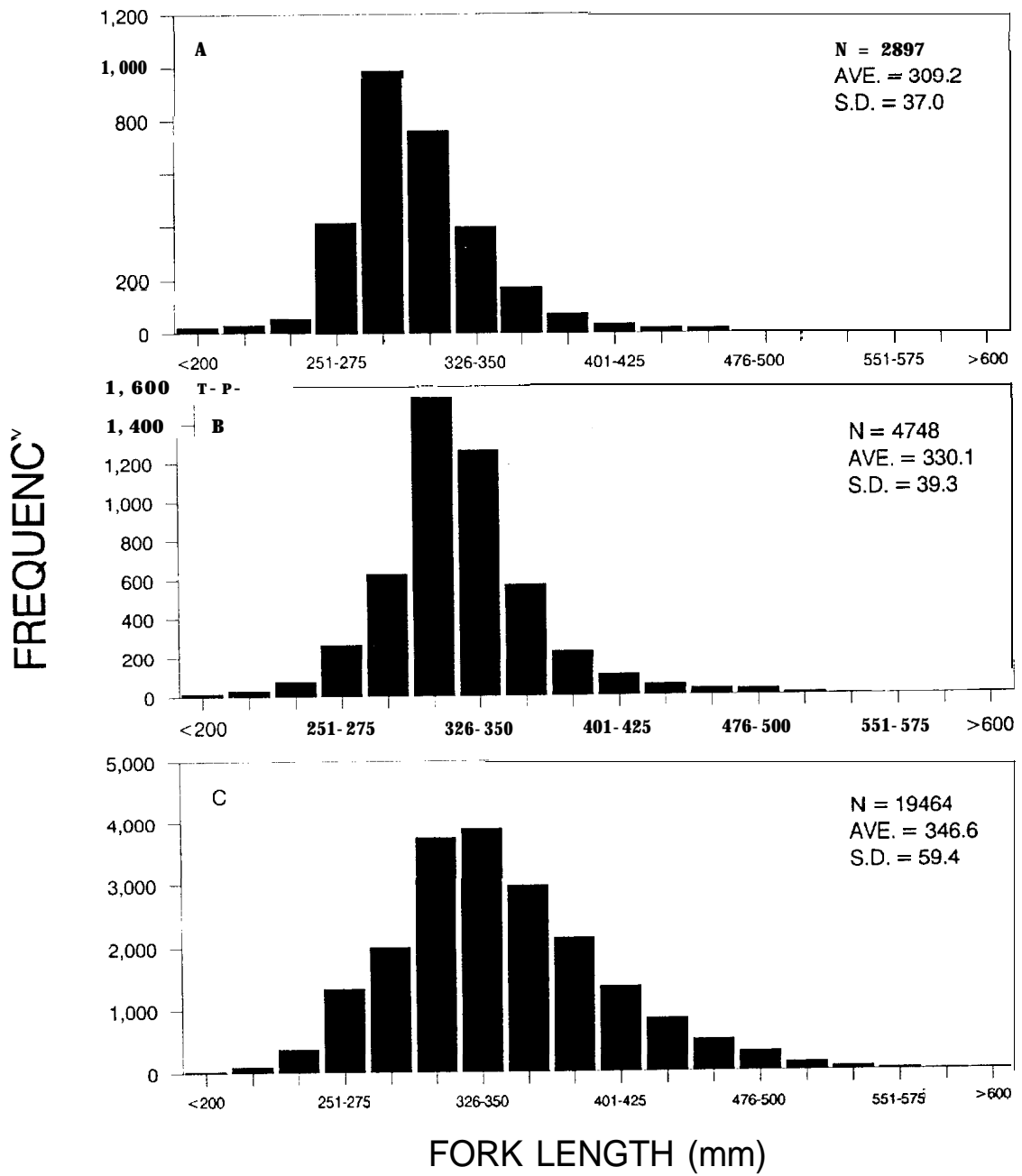


Figure 20. Length frequency distribution of northern squawfish by reservoir; (A)= Lower Monumental Res., (B)= Little Goose Res., (C)= Lower Granite Res.

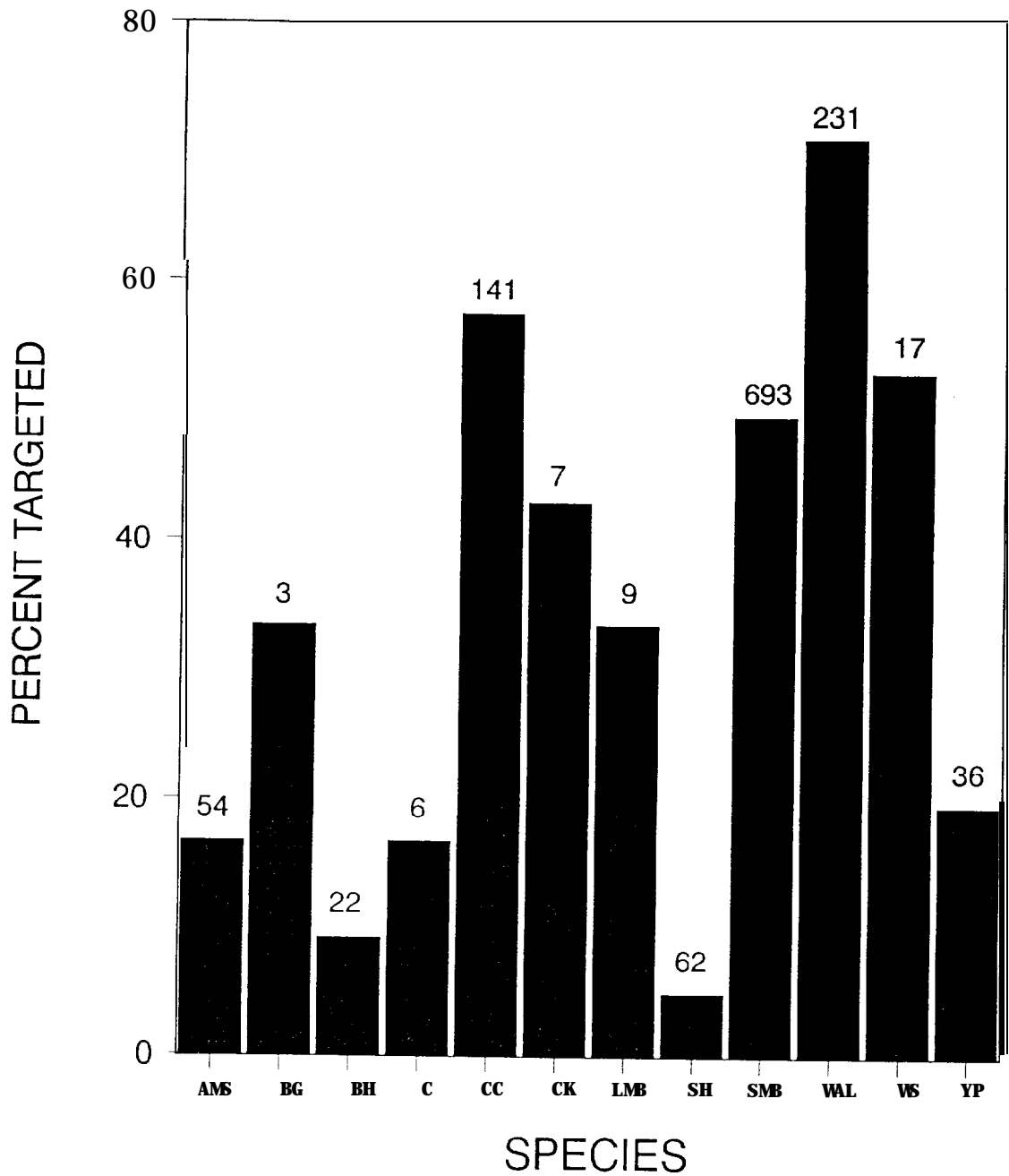


Figure 21. Percent targeted and number of other species turned in to registration stations; AMS= american shad, BG= bluegill, BH= bullhead (general), C= crappie (general), CC= channel catfish, CK= chinook salmon, LMB= largemouth bass, SH= steelhead, SMB= smallmouth bass, WAL= walleye, WS= white sturgeon, YP= yellow perch.

Roving Creel Survey

A total of 6,754 angling parties were interviewed and 1,739 random effort counts were conducted during the 1992 field season. There were a total of 12,110 anglers encountered of which 775 (6%) were registered and 11,335 (94%) were unregistered. The catch, all species combined, kept and released was 14,634 fish (Table 2). Of the total, 1,460 fish (10%) were caught by registered anglers and 13,174 fish (90%) by unregistered anglers.

The number of registered and unregistered anglers varied by reservoir and location fished (Figures 22-24), however, the majority of angling activity was by unregistered anglers. The overall percent harvest by registered and unregistered anglers also varied in this manner, again with the majority of total harvest by the unregistered angler (Figure 25).

The lowest overall catch was in Ice Harbor Reservoir (614 fish); the highest catch was in Little Goose Reservoir (2,912 fish; Appendix A). Total catch for Snake River reservoirs were higher than Columbia River reservoirs.

The overall catch composition for registered and unregistered anglers in all reservoirs show smallmouth bass as the most prevalent fish species (4,256 fish) with lesser catches of rainbow trout (1,392 fish), channel catfish (1,249 fish), northern squawfish (1,222 fish), and white sturgeon (1,221 fish), respectively (Table 2).

When examining the percent harvest of smallmouth bass by registered anglers, we see that Ice Harbor Reservoir was the highest at 21.2%. Registered anglers accounted for 75% of the channel catfish harvested in The Dalles Reservoir; 100% of the observed harvest of walleye were by registered anglers in this reservoir (Figure 26).

High numbers of fish were released by registered (598 fish) and unregistered anglers (7,760 fish) for a combined total of 8,358 fish (Table 1). Smallmouth bass were the dominant fish species released (3,401 fish) followed in ranking order by white sturgeon (1,081 fish), rainbow trout (1,040 fish), channel catfish (327), and steelhead (309 fish).

Expanded harvest estimates (all fish species kept) for registered anglers ranged from 802 (CI= ± 684) fish in Ice Harbor Reservoir to 17,167 (CI= $\pm 12,214$) fish in Lower Granite Reservoir. The range for unregistered anglers was 3,420 (CI= $\pm 1,756$) fish in Bonneville Reservoir and 42,951 (CI= $\pm 27,958$) fish in the Bonneville Dam tailrace (Figure 27).

The comparison of northern squawfish harvested by reservoir in the sport-reward fishery and the estimated harvest of northern squawfish by registered anglers from the roving creel survey (Figure 28) showed a positive correlation using the Spearman Correlation Coefficient (SAS Institute Inc. 1988); $r = 0.733$ ($P = 0.025$).

Table 1. Total of all species of fish turned into the registration stations excluding northern squawfish.

Common Name	Scientific Name	Code	Total 1992
American shad	<i>Alosa sapidissima</i>	AMS	54
Brown bullhead	<i>Ictalurus nebulosus</i>	BBH	18
Black crappie	<i>Pomoxis nigromaculatus</i>	BC	3
Bluegill	<i>Lepomis macrochirus</i>	BG	3
Bullhead (general)	<i>Ameiurus spp.</i>	BH	4
Bull trout	<i>Salvelinius malma</i>	BLC	0
Bridgelip sucker	<i>Catostomus columbianus</i>	BRS	8
Brown trout	<i>Salmo trutta</i>	BT	0
Crappie (general)	<i>Pomoxis spp.</i>	C	3
Channel catfish	<i>Ictalurus punctatus</i>	c c	141
Chum salmon	<i>Oncorhynchus keta</i>	CH	1
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	CK	7
Chiselmouth	<i>Acrocheilus alutaceus</i>	CMO	139
Sculpin (general)	<i>Cottus spp.</i>	COT	10
Carp	<i>Cyprinus carpio</i>	CP	19
Columbia River chub"		CRC	125
Cutthroat trout	<i>Oncorhynchus clarki</i>	CT	0
Largemouth bass	<i>Micropterus salmoides</i>	LMB	9
Longnose sucker	<i>Catostomus catostomus</i>	LNS	1
Largescale sucker	<i>Catostomus microps</i>	LRS	11
Mountain whitefish	<i>Prosopium williamsoni</i>	MW	5
Peamouth	<i>Mylocheilus caurinus</i>	PMO	588
Pumpkinseed	<i>Lepomis gibbosus</i>	PS	2
Rainbow trout (res.)	<i>Oncorhynchus mykiss</i>	RB	9
Redside shiner	<i>Richardsonius balteatus</i>	RS	2
Rainbow trout (unk.)	<i>Oncorhynchus mykiss</i>	RU	113
Sculpin, prickly	<i>Cottus asper</i>	PRS	
Searun cutthroat	<i>Oncorhynchus clarki</i>	SCT	1
Starry flounder	<i>Platichthys stellatus</i>	SF	9
Steelhead (unk.)	<i>Oncorhynchus mykiss</i>	SH	9

Table 1. Continued.

Common Name	Scientific Name	Code	Total 1992
Sucker (general)	<i>Catostomus spp.</i>	SK	21
Smallmouth bass	<i>Micropterus dolomieu</i>	SMB	693
Sockeye salmon	<i>Oncorhynchus nerka</i>	s o	2
Steelhead (summer)	<i>Oncorhynchus mykiss</i>	s s	40
Steelhead (winter)	<i>Oncorhynchus mykiss</i>	s w	13
Tench	<i>Tinca tinca</i>	TNC	0
Walleye	<i>Stizostedion vitreum</i>	WAL	231
White crappie	<i>Pomoxis annularis</i>	w c	0
Warmouth	<i>Chaenobryttus gulosus</i>	WM	0
White sturgeon	<i>Acipenser transmontanus</i>	w s	17
Yellow perch	<i>Per-ca flavescens</i>	YP	36
Total			2,349

^a Probable northern squawfish/chiselmouth hybrid; named Columbia River chub for reporting purposes.

Table 2. Catch composition from the roving creel survey for all reservoirs, 1992 (species codes are listed in Table 1).

Species	Registered Anglers			Unregistered Anglers			Total
	Kept	Released	Total	Kept	Released	Total	
AMS	28	2	30	955	169	1124	1154
B	1	34	35	43	212	255	290
BC	2	7	9	296	22	517	526
BCF	--	--	--	1		1	1
BG	1	10	11	64	83	147	158
BH		3	3	49	88	137	140
BBH	--	--	--	29	--	29	29
BRS	1	--	1	50	11	61	62
C	--	1	1	118	193	311	312
c c	20	27	47	902	300	1202	1249
CMO	1	1	2	8	44	52	54
CYP		3	3		3	3	6
CK	1	--	1	118	24	142	143
c o	--	--		13	--	13	13
COT	--	9	9	1	6	7	16
CP		--		8	15	23	23
GS	--	--		--	20	20	20
LMB		1	1	3	15	18	19
LRS	--	2	2	4	3	7	9
NSF	751	43	794	201	227	428	1222
PK	1	--	1	54	36	90	91
PMO	1	3	4	17	2	19	23
PS	1		1	15	12	27	28
RU		48	48	186	194	380	428
S	3		3	25	35	60	63
SAL	--			13	17	30	30
SCT		--		3	--	3	3
SF	--	--		1	--	1	1
SH	4	45	49	291	310	601	650
SK	--	26	26	13	64	77	103

Table 2. Continued.

Species	<u>Registered Anglers</u>			<u>Unregistered Anglers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
SMB	32	219	251	823	3182	4005	4256
s o	--	--	--	--	2	2	2
s s				227	30	257	257
TR	3	68	71	349	972	1321	1392
TCH	--	--		--	1	1	1
WC	--		--	96	15	111	111
WAL	7	11	18	26	10	36	54
w s	2	29	31	138	1052	1190	1221
YBH	--	--	--	39	15	54	54
YP	2	6	8	235	177	412	420
Totals	862	598	1460	5414	7760	13174	14634

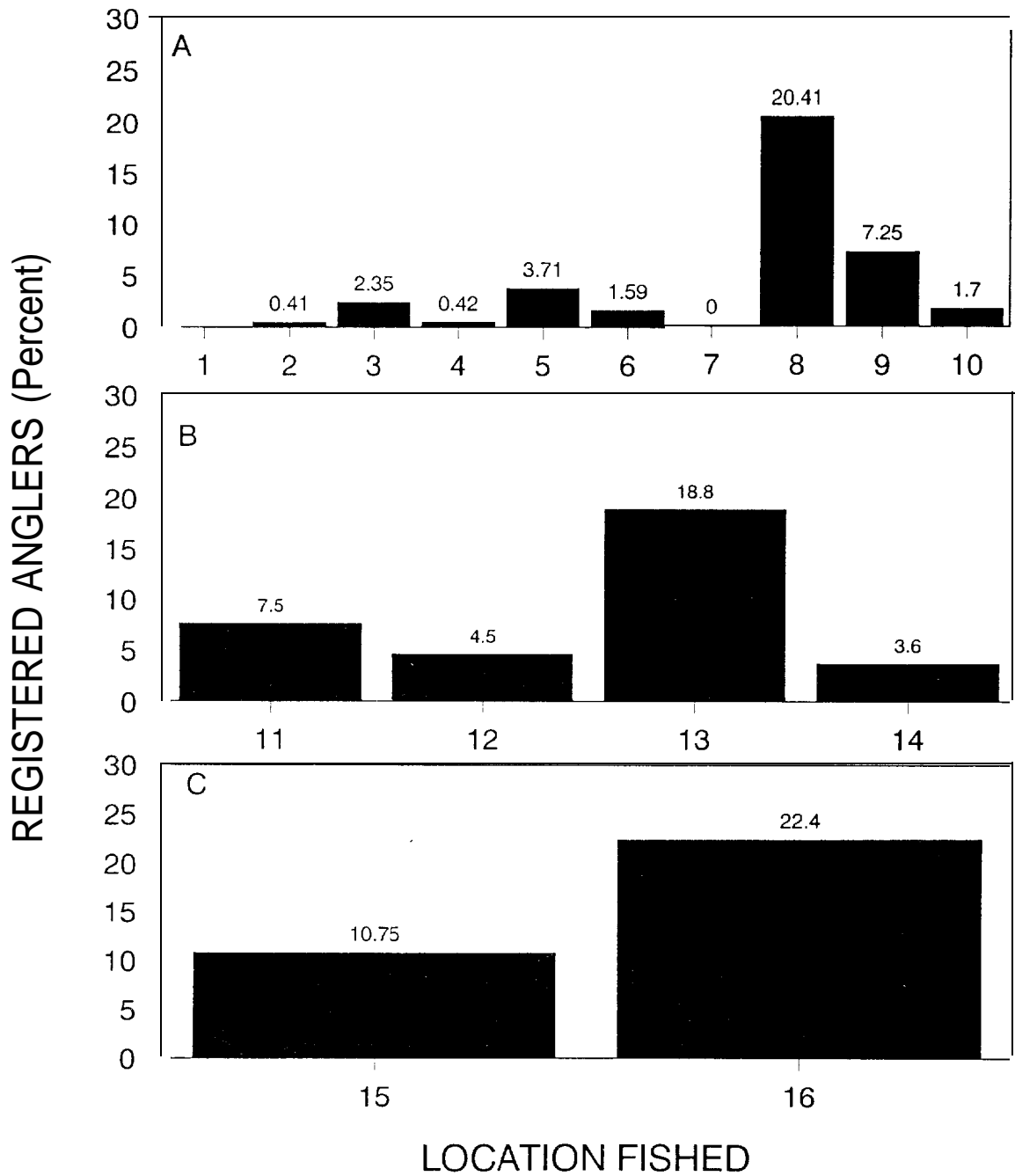


Figure 22. Creel survey percent registered anglers by reservoir and location fished; (A)= Bonneville Tailrace, (B)= Bonneville Res., (C)= Dalles Res.

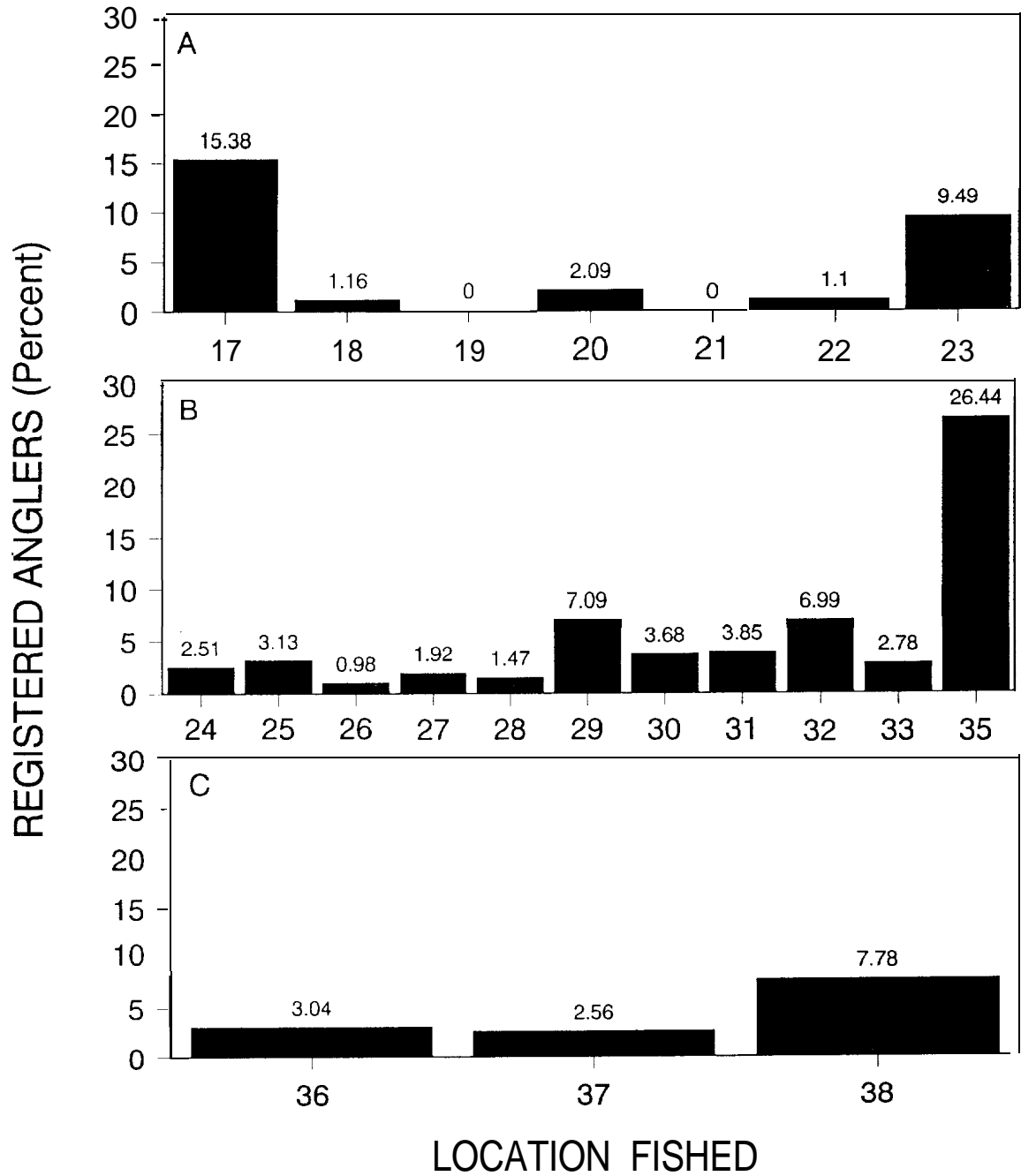


Figure 23. Creel survey percent registered anglers by reservoir and location fished; (A)= John Day Res., (B)= McNary Res., (C)= Ice Harbor Res.

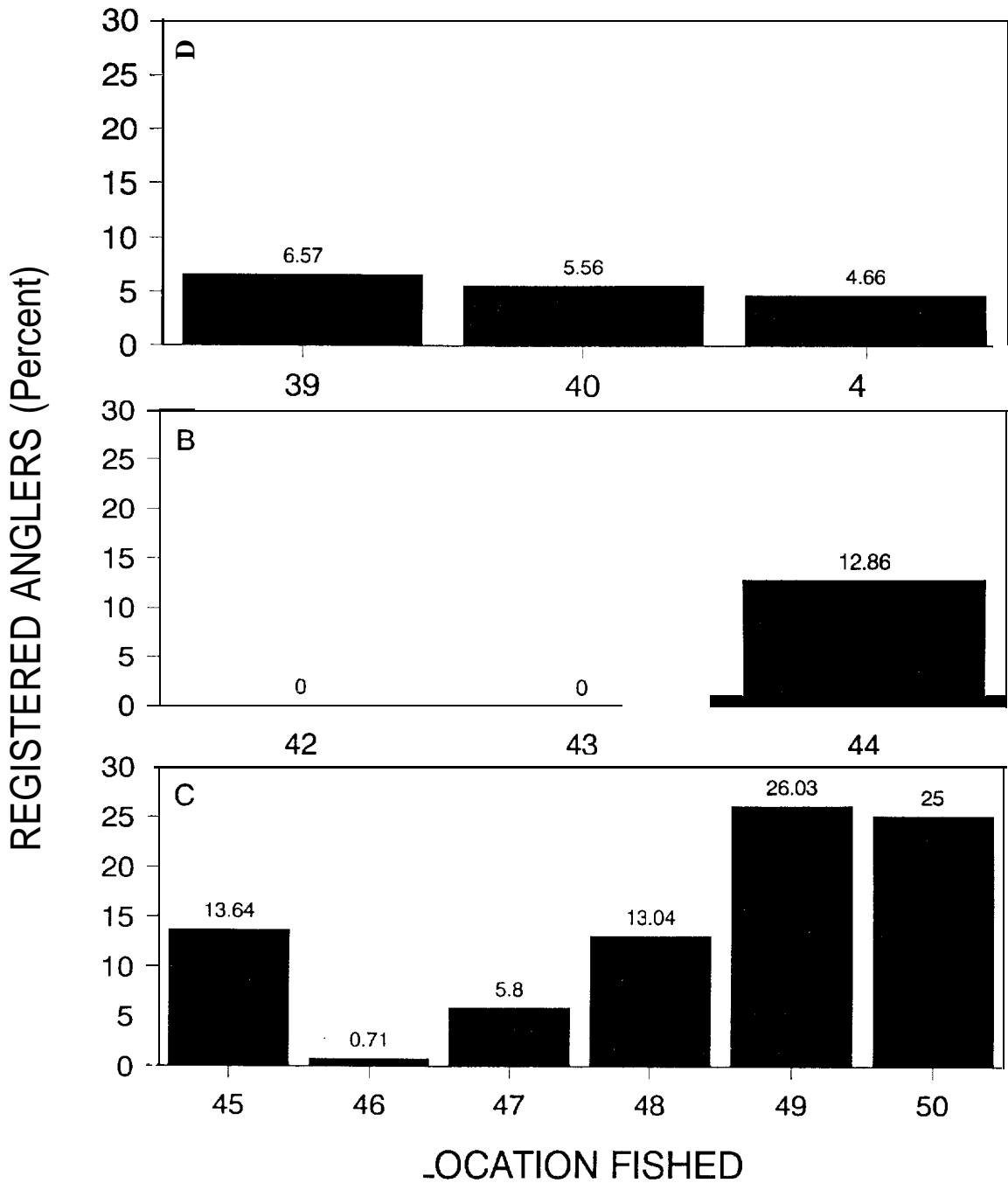


Figure 24. Creel survey percent registered anglers by reservoir and location fished; (A)= Lower Monumental Res., (B)= Little Goose Res., (C)= Lower Granite Res.

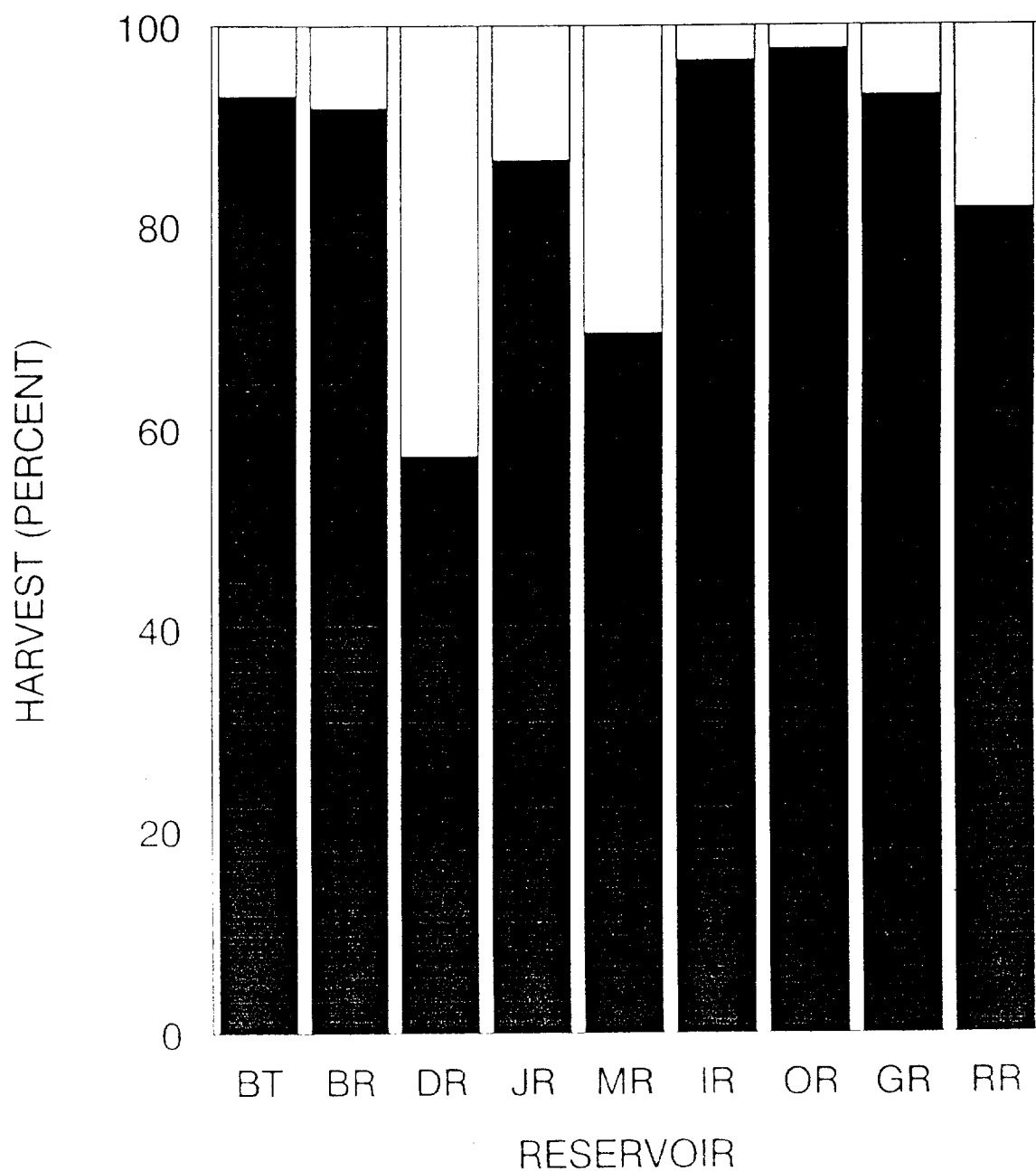


Figure 24. Creel survey percent harvest by reservoir for all species combined; (shaded bar= registered anglers, black bar= unregistered anglers). BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

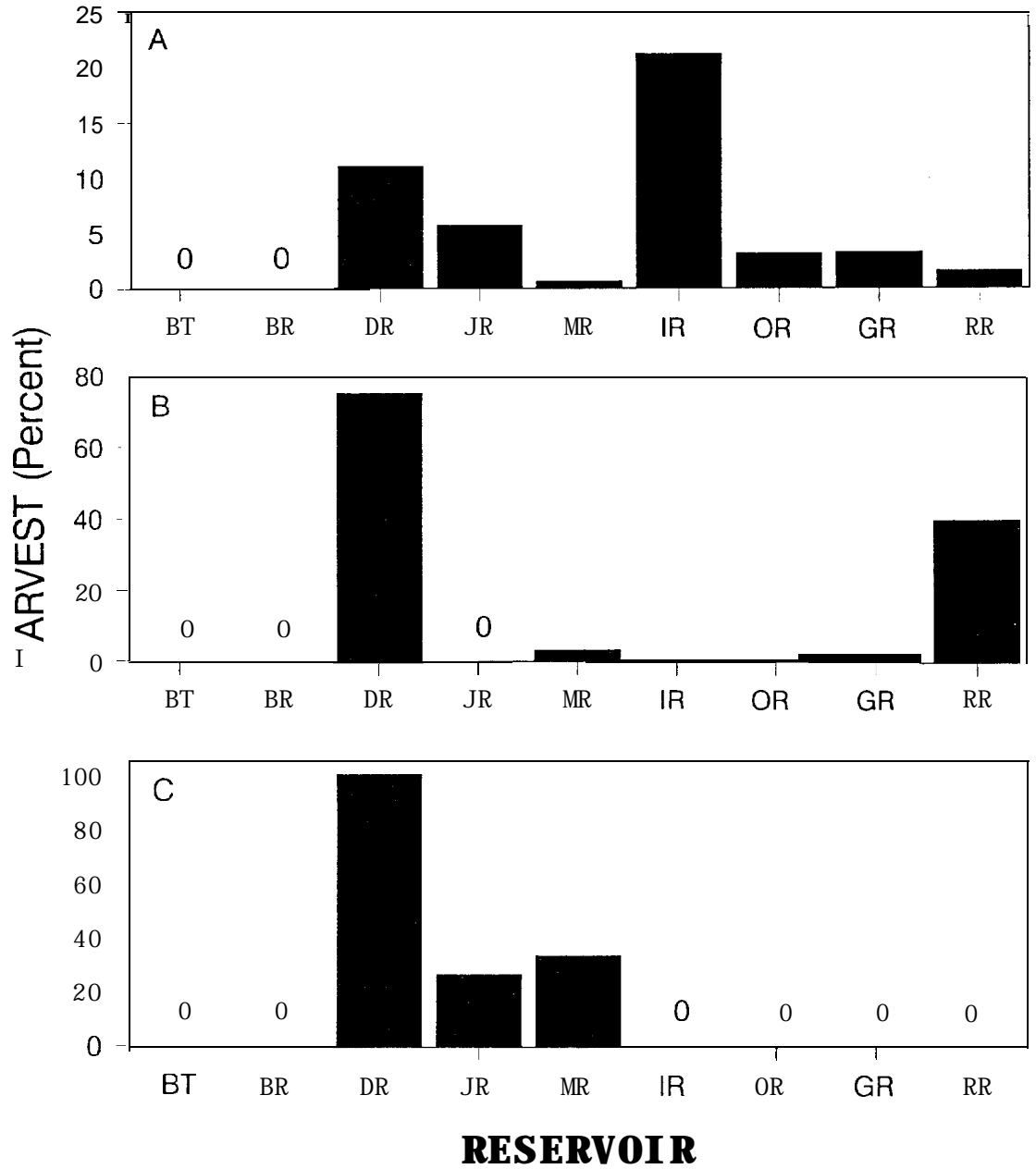


Figure 26. Creel survey percent harvest by registered angler by reservoir; (A)= smallmouth Bass, (B)= channel catfish, (C)= walleye; BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

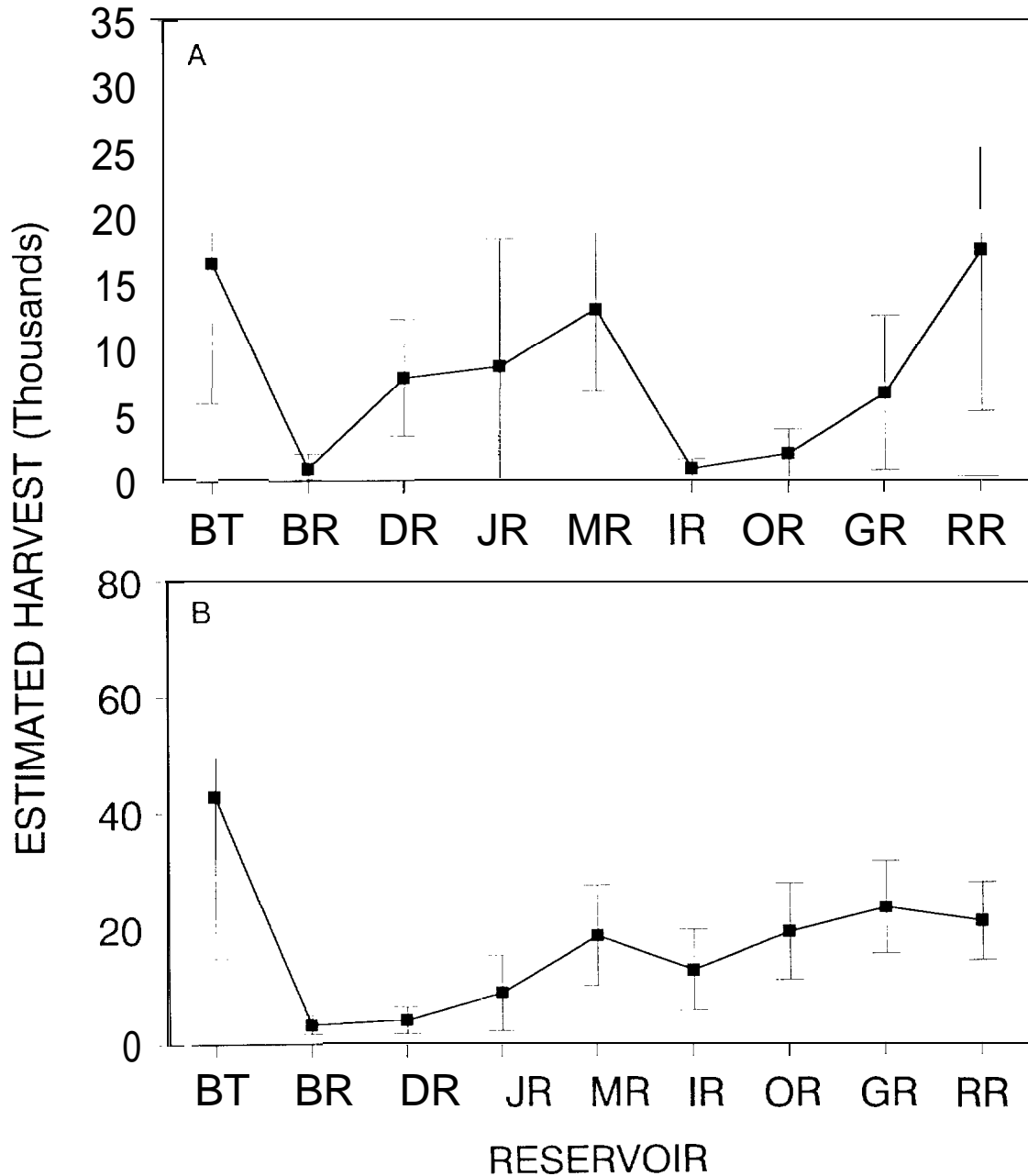


Figure 27. Creel survey estimated harvest for all species combined by reservoir with 95% confidence intervals; (A)= registered anglers, (B)= unregistered anglers; BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

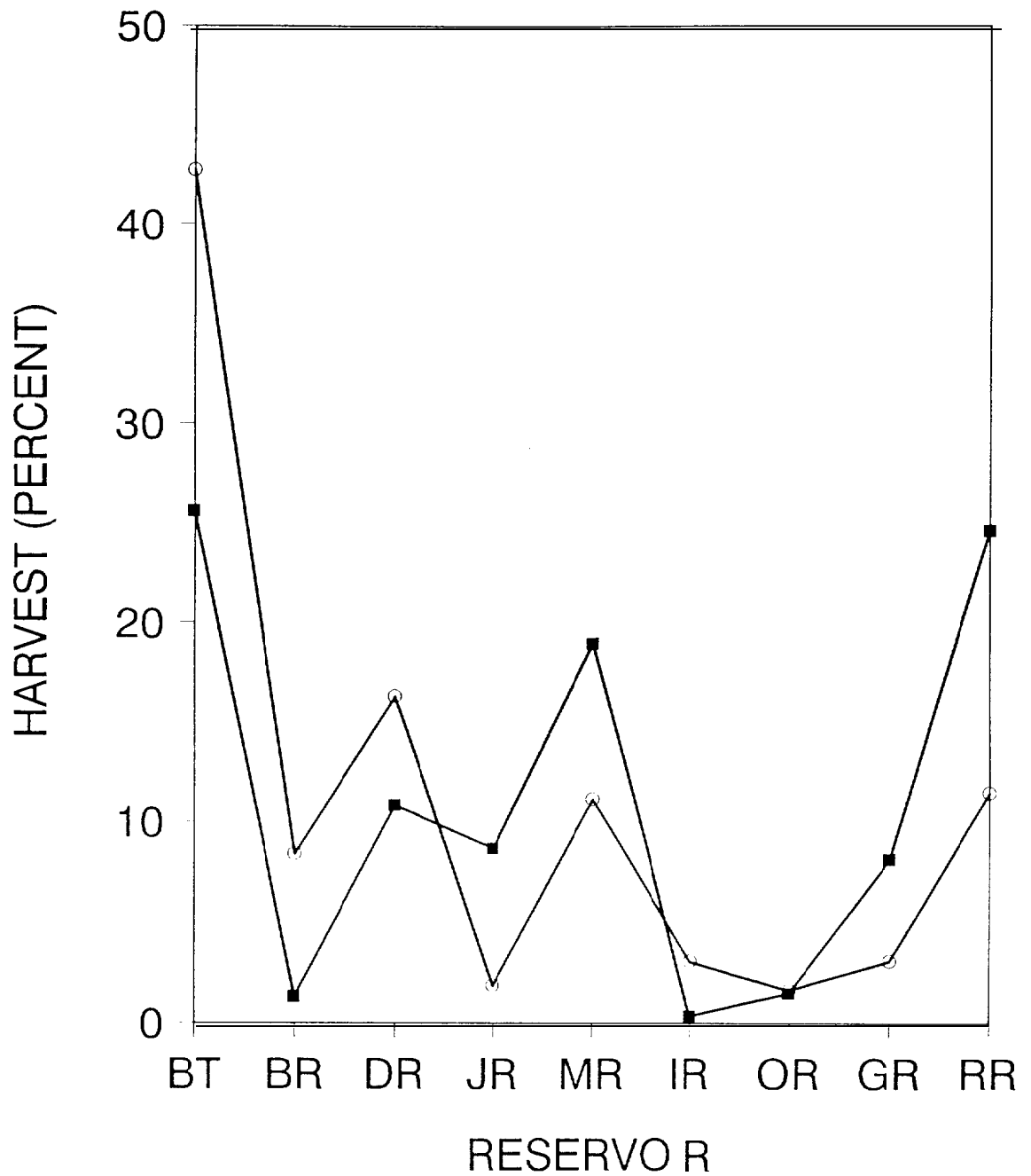


Figure 28. Northern squawfish harvest by reservoir (O= sport-reward fishery-actual, ■= creel survey-registered angler-estimated); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

1991-1992 Comparisons

The overall harvest in 1992 was approximately 15% higher than the sport fishery harvest of 159,162 northern squawfish in 1991. Participation also increased by about 24% from an estimated 67,384 angler days in 1991 to 88,494 angler days in 1992. The CPUE showed a decrease from 2.36 fish per angler day in 1991 to 2.11 fish per angler day in 1992.

A comparison of the harvest data and effort by week for 1991 and 1992 shows a marked difference between years in the early weeks of the season. The two years had similar trends in harvest in the later weeks of the season, however, the 1992 data was shifted approximately three weeks earlier (Figure 29). The comparison of effort data by week between the two fishing seasons showed trends similar to the harvest data (Figure 30). The CPUE values varied more in 1991 than in 1992 (Figure 31). Both years had fairly similar and level CPUE values in the later weeks of the season.

The catch and effort (returning anglers only) data by reservoir between the two seasons showed differences. Five of the nine reservoirs had increased harvests of northern squawfish from 1991 to 1992 (Bonneville tailrace; McNary, Ice Harbor, Little Goose, and Lower Granite reservoirs). The largest increase in numbers of fish harvested was from 58,235 to 79,822 in the Bonneville tailrace. The other four reservoirs (Bonneville, The Dalles, John Day, and Lower Monumental reservoirs) had reduced harvest between the two years (Figure 32). Six of the nine reservoirs had increased effort in 1992 (Bonneville tailrace; The Dalles, McNary, Ice Harbor, Lower Monumental, and Little Goose reservoirs). The other three reservoirs (Bonneville, John Day, and Lower Granite) had reduced effort in 1992 (Figure 33). Five of the nine reservoirs had increased CPUE (fish per returning angler day) values from 1991 to 1992 (Bonneville, John Day, McNary, Ice Harbor, and Lower Granite reservoirs). The other four had reduced CPUE values from 1991 to 1992 (Figure 34).

Catch, effort (angler days), and CPUE (fish per angler day) varied by registration station between the two years. Thirteen of the 20 registration sites were open in both 1991 and 1992. Of the 13 registration stations that were open in both years, six (The Dalles Boat Basin, Maryhill State Park, Columbia Point, Hood Park, Windust Park, and Greenbelt Boat Ramp) had greater catches (Figure 35). Seven (The Dalles Boat Basin, Maryhill State Park, Columbia Point, Hood Park, Windust Park, Lyons Ferry Marina, and Greenbelt Boat Ramp) of the 13 stations had higher participation (Figure 36). Eight of the 13 stations (Cascade Locks, Bingen Marina, The Dalles Boat Basin, Maryhill State Park, Columbia Point, Hood Park, Windust Park, and Greenbelt Boat Ramp) had higher CPUE values in 1992 than in 1991 (Figure 37).

Length measurements were taken from a total of 119,437 northern squawfish with fork lengths greater than or equal to 250 mm (11 inches total length) during the 1992 season and 59,650 northern squawfish during the 1991 season. The average length for all locations combined was 346 mm (SD = 59.7 mm) in 1992, and 350 mm (SD = 59.6) in 1991. We used a t-test to compare mean fork lengths by reservoir to determine whether there was a

statistically significant change in mean fork lengths between 1991 and 1992. We found that the John Day and Ice harbor reservoirs did not show a statistically significant difference in mean fork lengths ($P = 0.05$) while all other reservoirs did show a statistically significant difference. One possible reason for this could be attributed to between-season variability (Table 3).

DISCUSSION

Sport-Reward Fishery

Northern Squawfish Harvest Data

The 186,604 northern squawfish removed systemwide in 1992 accounted for a significant portion of the systemwide exploitation of about 9.8-14.4% (Parker et al. 1992). The upper range of this estimate met the minimum targeted exploitation rate of 10%.

The increase in harvest by 15 % and participation by 24% from the 1991 fishery can partially be attributed to the addition of five registration stations and increased public awareness of the program. However, with CPUE being lower in 1992 than in 1991, our ability to increase the level of northern squawfish harvest will depend primarily on our ability to increase participation in 1993.

When analyzing the sport-reward fishery data to determine how many and where registration stations should be located to achieve the targeted systemwide exploitation rate of 10-20%, we need to focus on three factors: (1) the reservoir specific predation index values, (2) the current annual exploitation of northern squawfish in that reservoir, and (3) the size composition of the northern squawfish being turned in. The reservoir specific predation index values, associated exploitation rates, and size composition indicated that we should increase effort in some reservoirs and reduce effort in others. Specifically, additional registration stations should be opened below Bonneville Dam where there are some of the highest predation index values and exploitation rates (Parker et al. 1992).

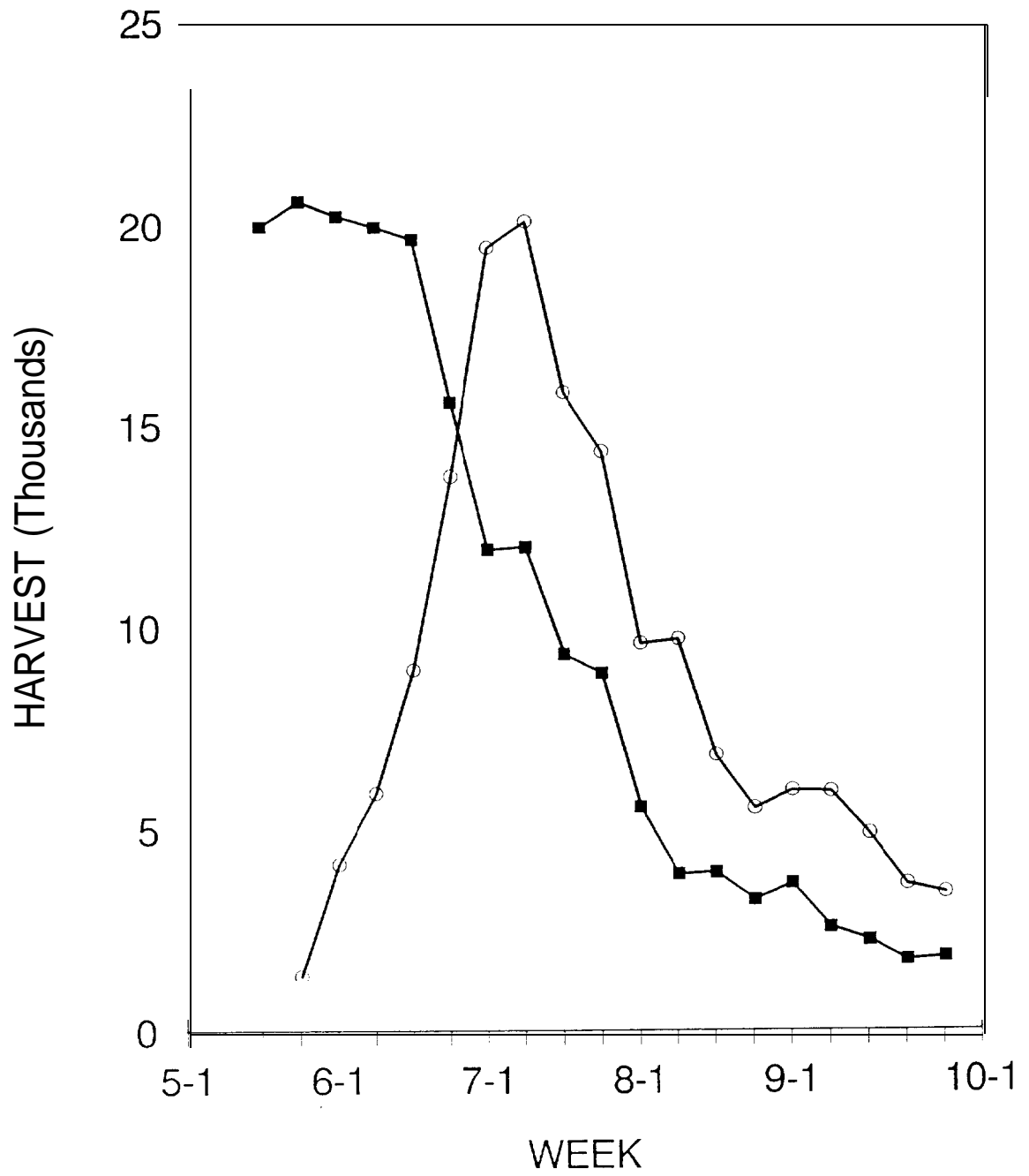


Figure 2». Northern squawfish harvest by week between 1991 and 1992 (○= 1991, ■= 1992).

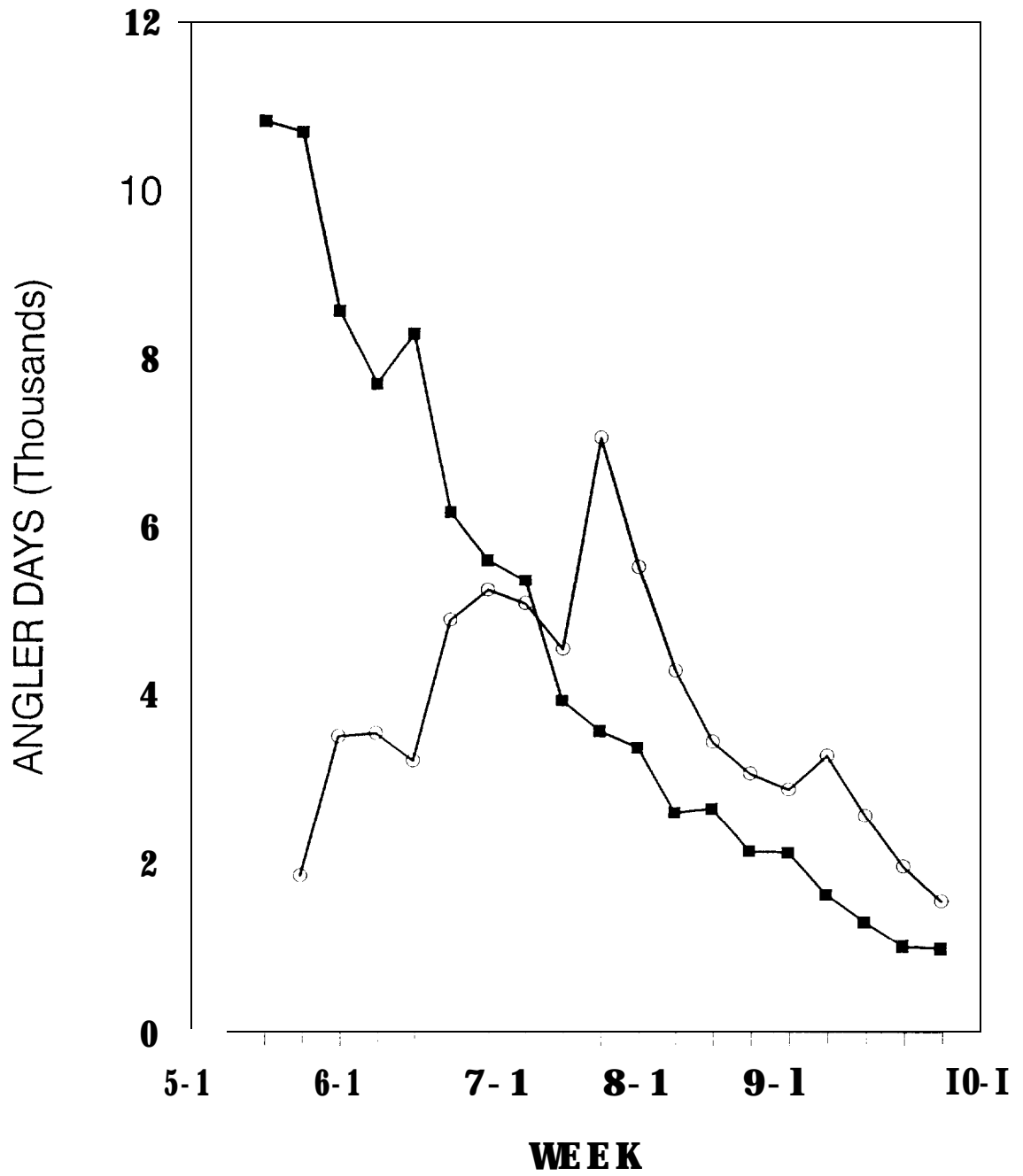


Figure 30. Effort (angler days) by week between 1991 and 1992 (o= 1991, ■= 1992).

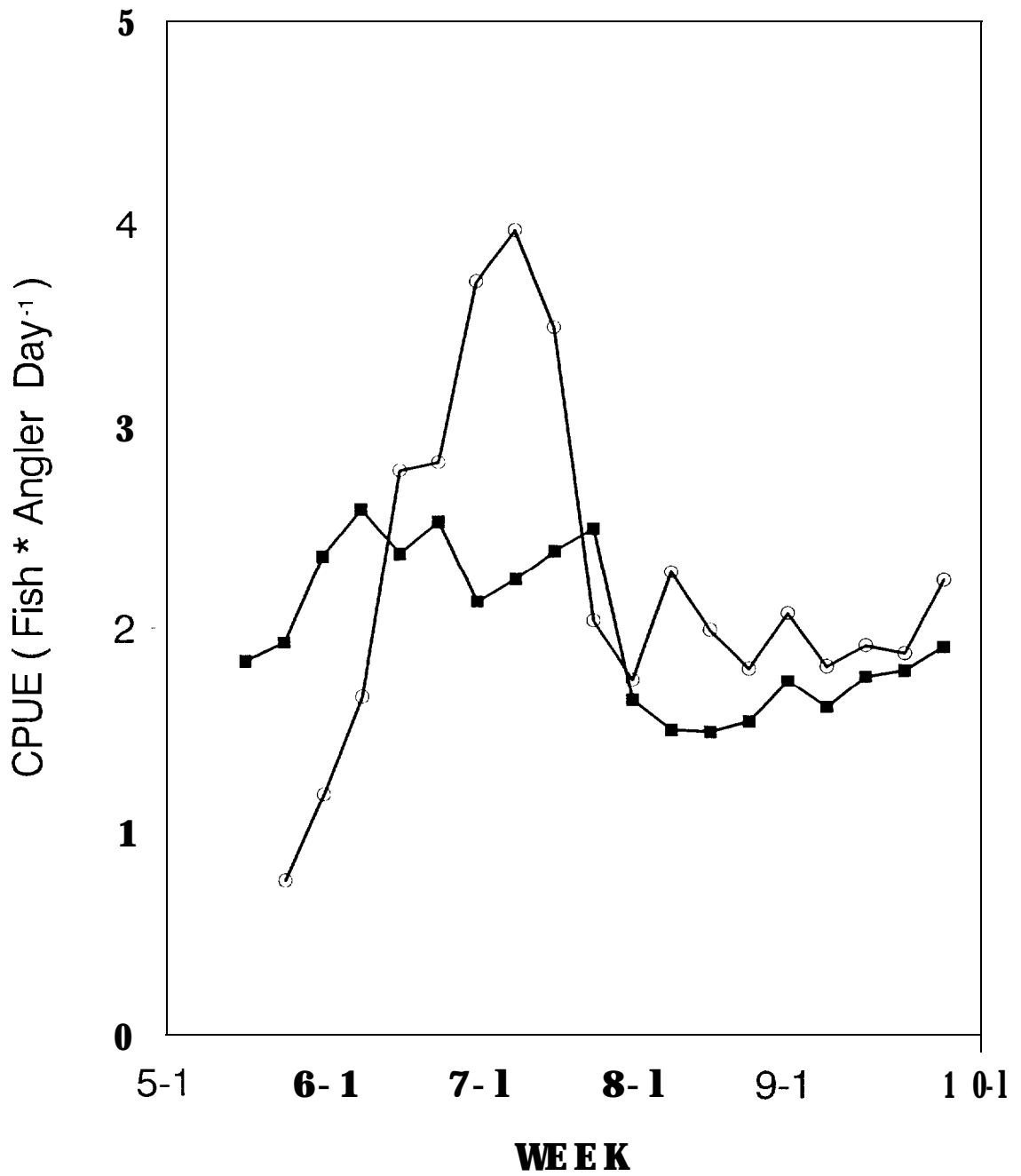


Figure 31. CPUE (fish * angler day⁻¹) of northern squawfish by week between 1991 and 1992 (O= 1991, ■= 1992).

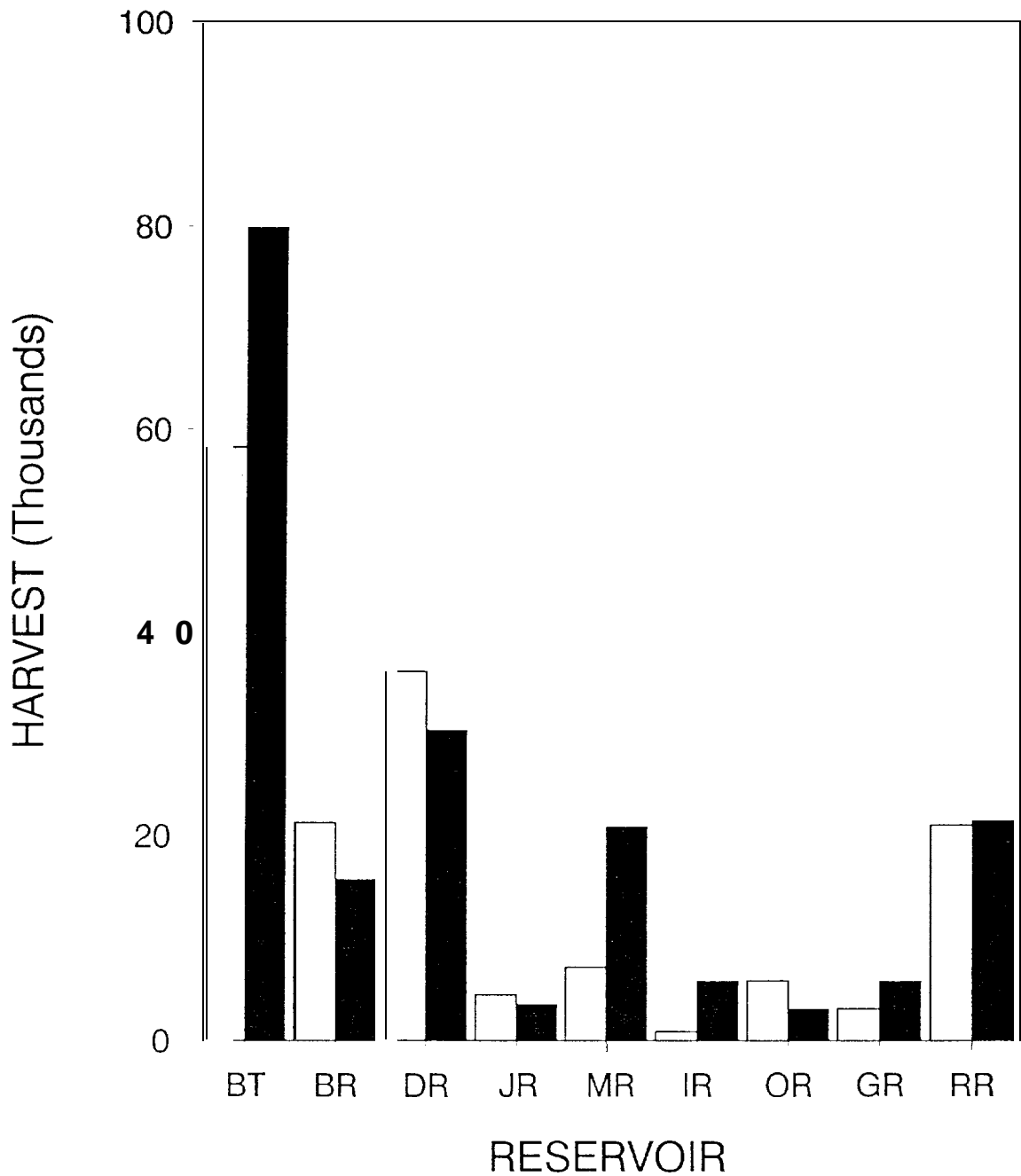


Figure 32. Northern squawfish harvest by reservoir between 1991 (shaded bar) and 1992 (dark bar); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

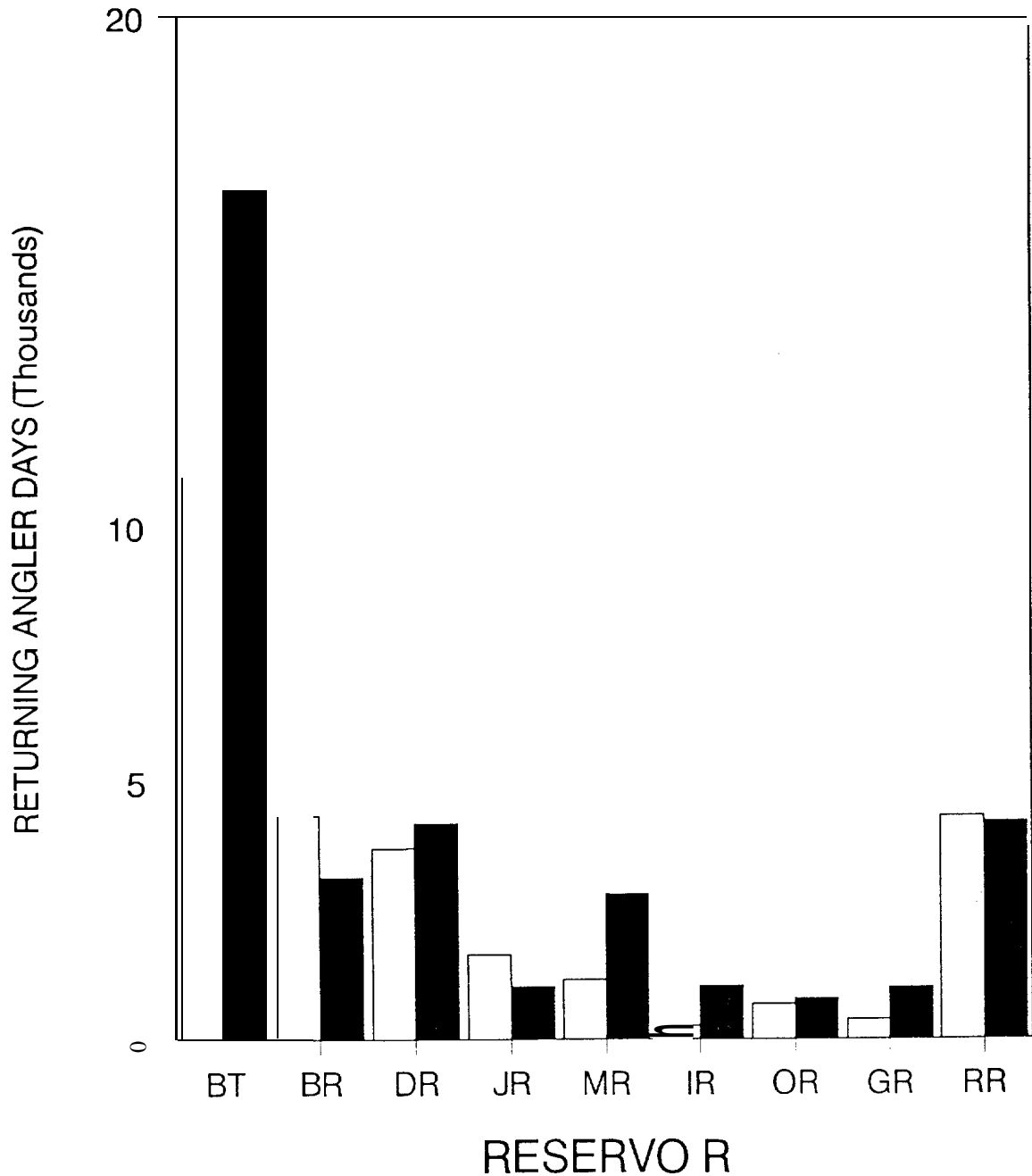


Figure 33. Effort (returning angler days) by reservoir between 1991 (shaded bar) and 1992 (dark bar); (only anglers returning to registration station had location fished recorded); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

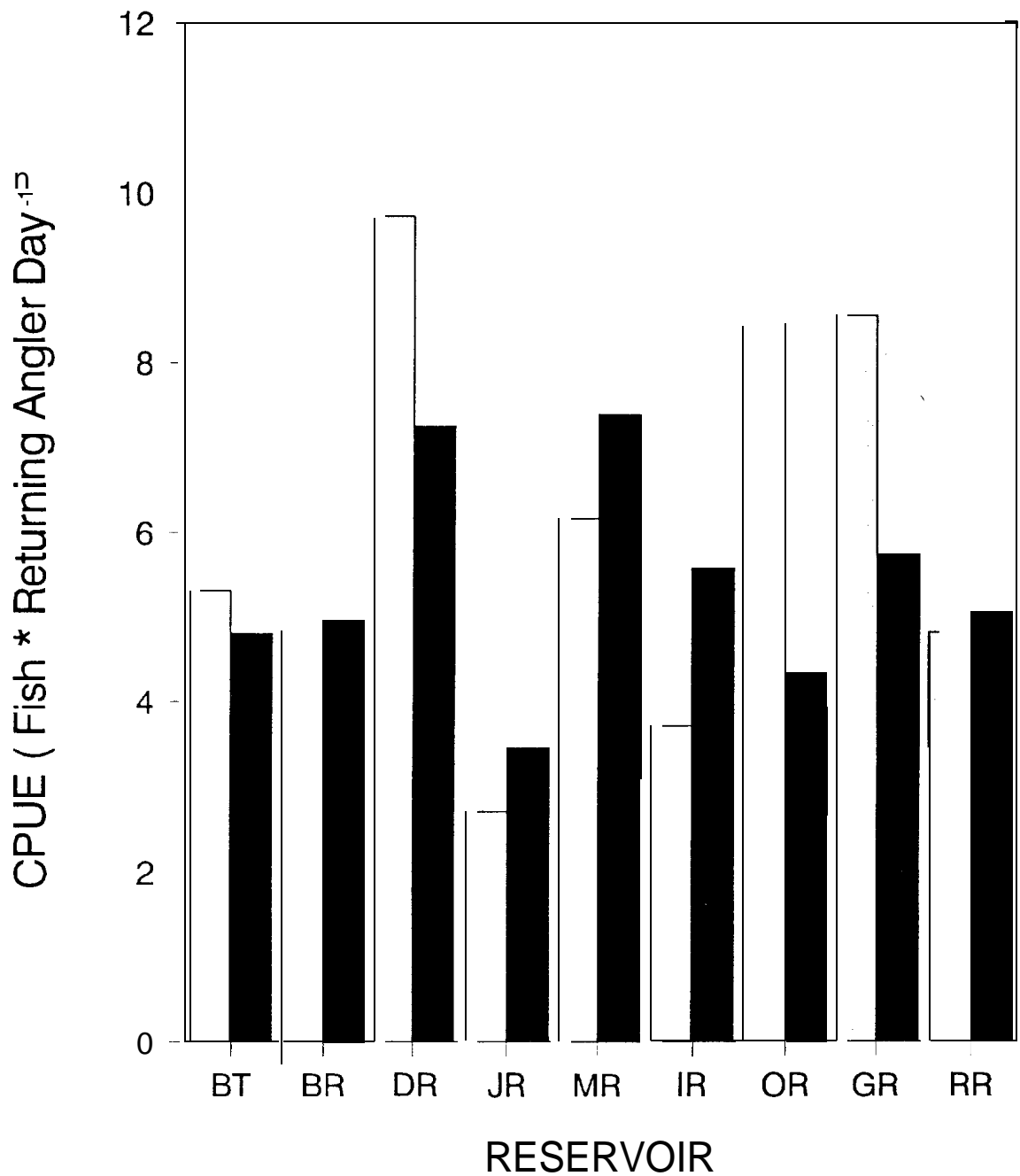


Figure 34. CPUE (fish * angler day⁻¹) of northern squawfish by reservoir between 1991 (shaded bar) and 1992 (dark bar); (only anglers returning to registration station had location fished recorded); BT= Bonneville Tailrace, BR= Bonneville Res., DR= Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Low. Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

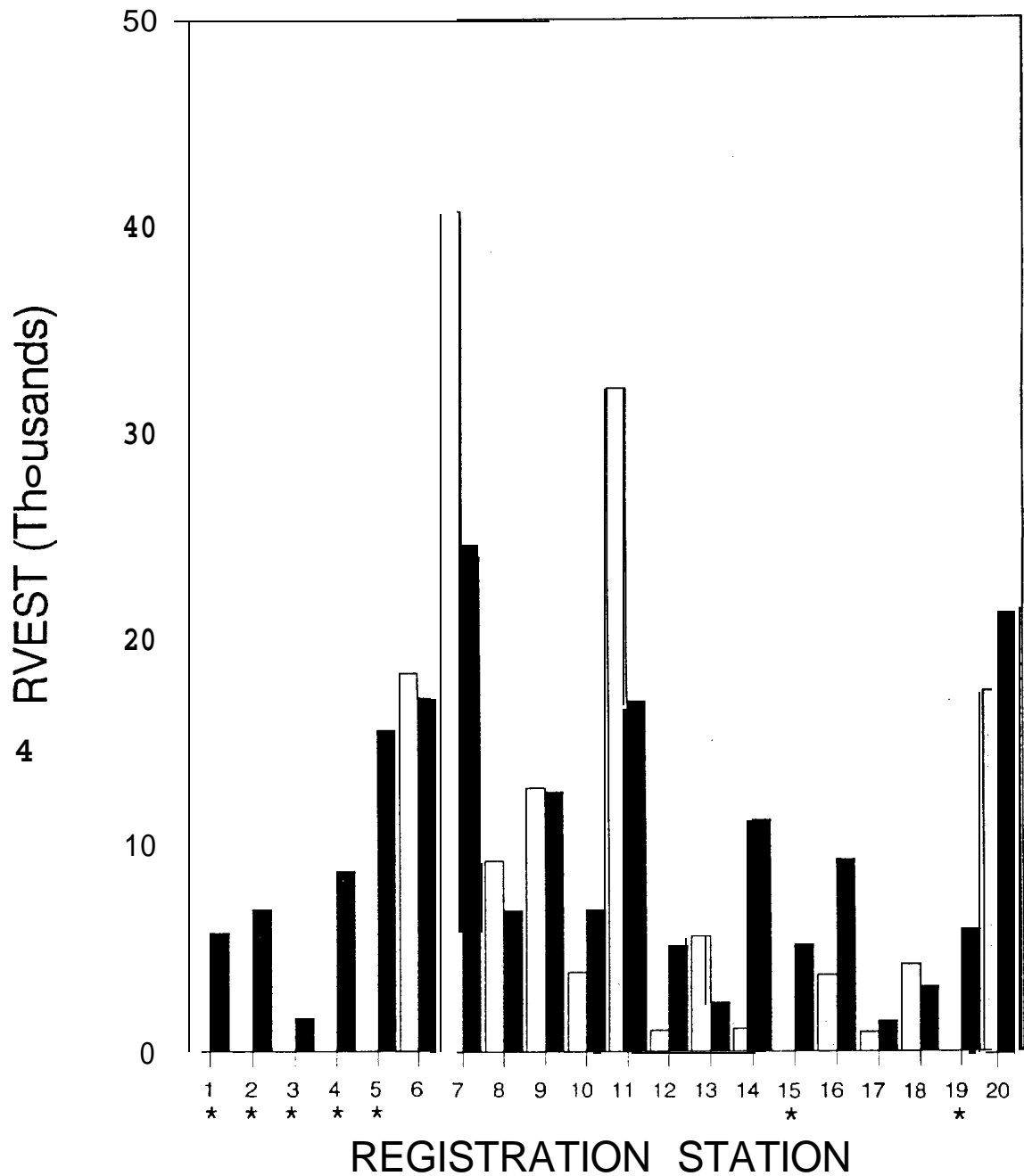


Figure 35. Northern squawfish harvest by registration station between 1991 (shaded bar) and 1992 (dark bar); (*= new stations in 1992, eliminated stations from 1991 not shown); 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Pt., 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

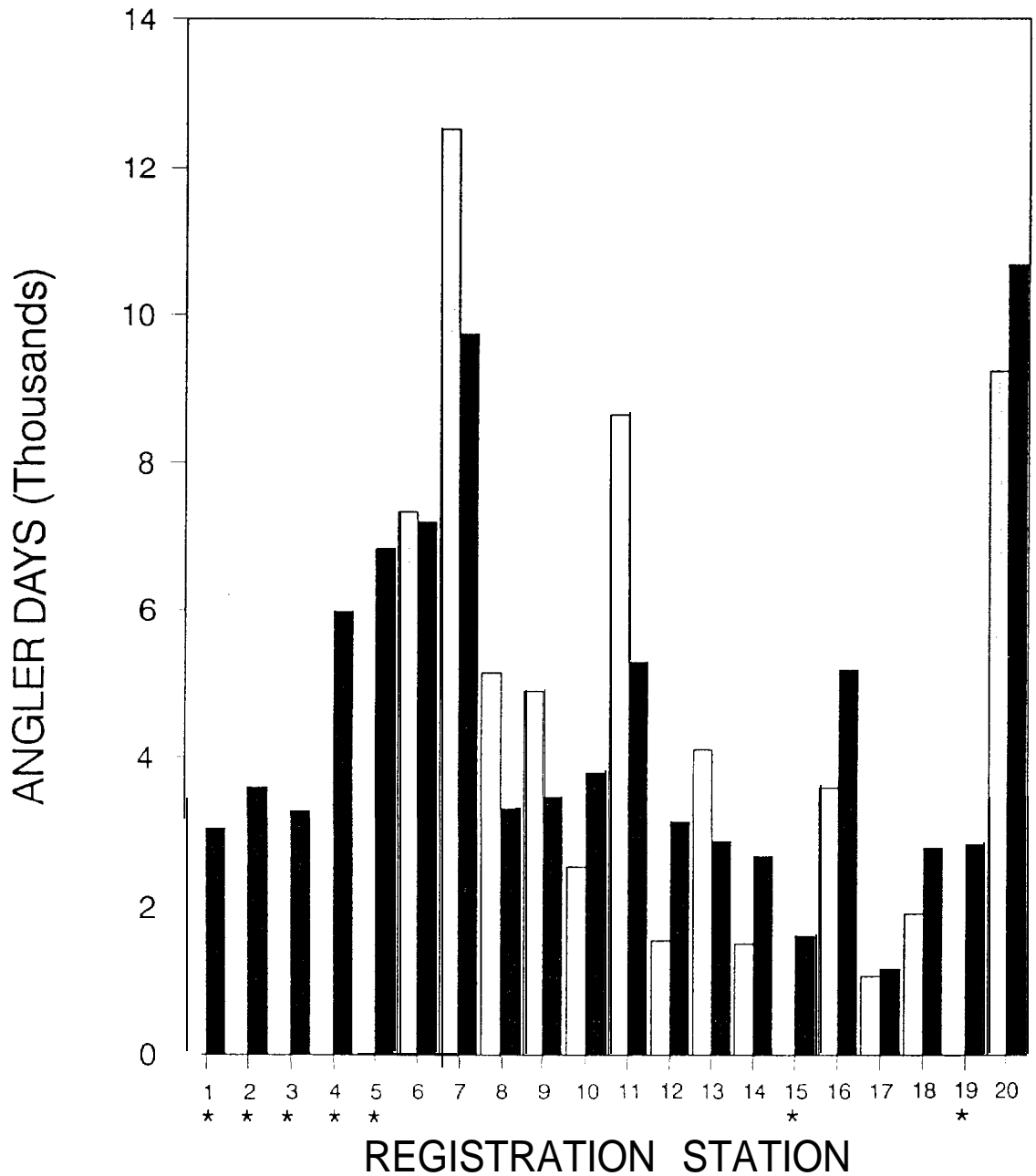


Figure 36. Effort (angler days) by registration station between 1991 (shaded bar) and 1992 (dark bar); (*= new stations in 1992, eliminated stations from 1991 not shown); 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= M. James Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Pt., 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

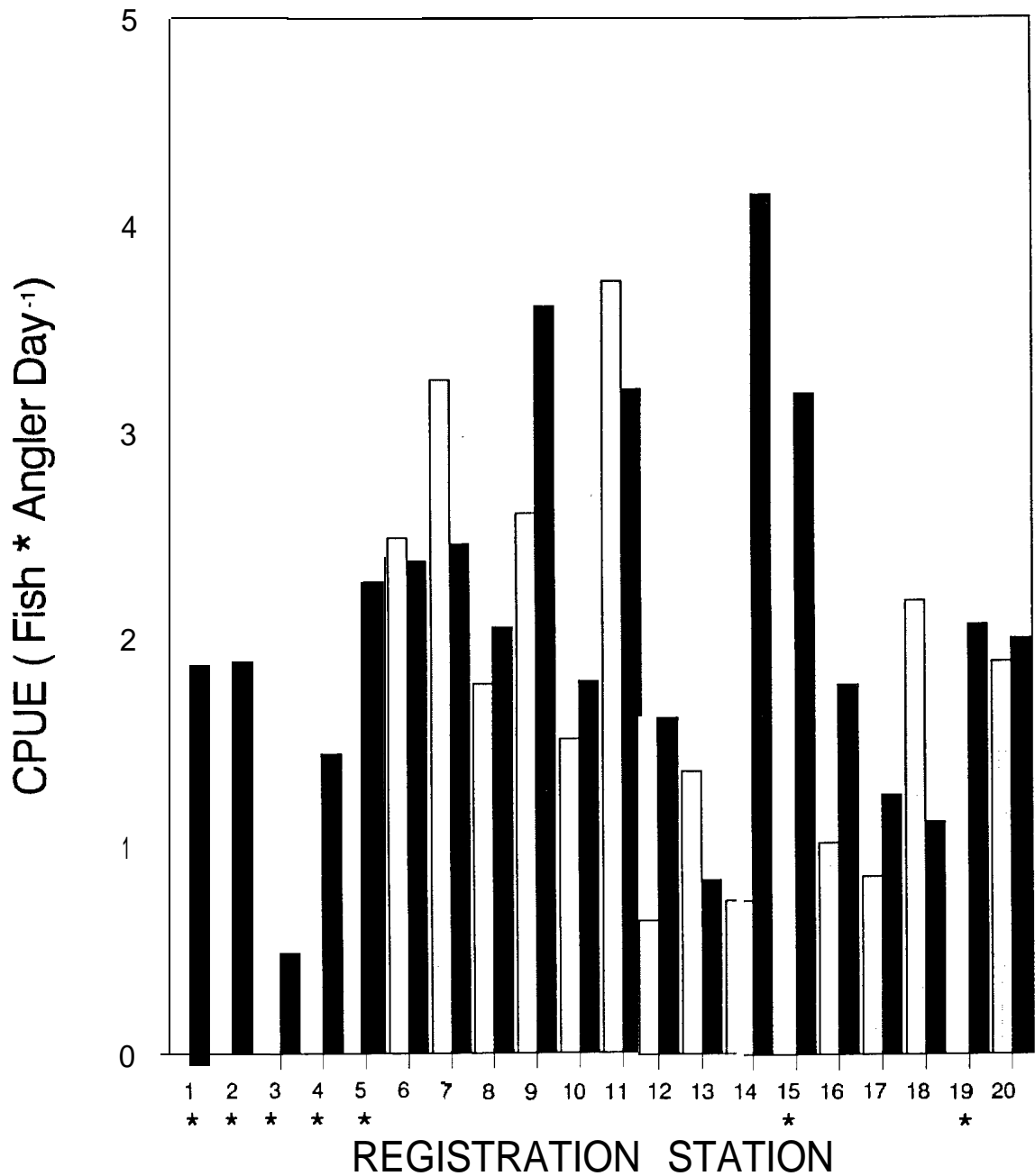


Figure 37. CPUE (Fish * Angler Day⁻¹) of northern squawfish by registration station between 1991 (shaded bar) and 1992 (dark bar); (*= new stations in 1992); 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= M. James Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Pt., 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

Table 3. Mean fork length comparison of 1991 and 1992.

Reservoir	Year	n	Mean	SD	Prob
(1) Below Bonneville	1991	9698	341	64.6	0.0001
	1992	41842	334	63.3	
(2) Bonneville	1991	7550	349	63.9	0.0002
	1992	8457	353	63.7	
(3) The Dalles	1991	8563	371	57.4	0.0001
	1992	7043	364	54.7	
(4) John Day	1991	2821	371	61.6	0.3785
	1992	2508	370	56.8	
(5) McNary	1991	4701	356	53.0	0.0001
	1992	17024	350	57.5	
(6) Ice Harbor	1991	890	361	58.2	0.3069
	1992	4565	363	52.9	
(7) Lower Monumental	1991	3642	319	48.7	0.0001
	1992	2897	309	37.0	
(8) Little Goose	1991	1902	337	50.6	0.0001
	1992	4748	330	39.3	
(9) Lower Granite	1991	19122	348	55.9	0.0001
	1992	19464	350	55.6	
Combined Totals	1991	59650	350	59.6	0.0001
	1992	119437	346	59.7	

The station at Bayport Marina in St. Helens, Ore., should be relocated below St. Helens, Ore., at a higher use site. The predation index value was low in Ice Harbor and the estimate of exploitation was not calculated due to lack of marked fish recovered (Parker et al. 1992); the size distribution of the northern squawfish population showed no change from 1991 to 1992. The registration station at Windust Park should be moved to an area with higher predation (e.g., below Bonneville Dam). The Plymouth boat ramp should be relocated in the John Day Reservoir to a higher use access site to increase the exploitation rate in the John Day Reservoir, where we see a high predation index value, a low exploitation rate, and no significant change in mean length of the northern squawfish. All other registration stations open in 1992 should remain as is to ensure that target exploitation rates are maintained systemwide. The conclusions made to alter registration station sites based on the exploitation rate, the predation index values, and changes in mean length of the northern squawfish between years agree well with each other.

The issue of increasing participation should also be addressed by incorporating an aggressive media campaign as well as with increased incentives to focus harvest effort in areas and times when participation is low. Additional incentives could include organized derbies, tournaments, lottery incentives from the pool of registered anglers, and prizes for recovery of tagged northern squawfish.

There were documented instances of anglers fishing outside the geographic boundary of the program as well as fish being turned in for payment from other components of the predator control program. The Washington Department of Wildlife, in coordination with the Oregon Department of Fish and Wildlife, is taking steps to codify rules and regulations in both states to reduce these types of activities for the 1993 sport-reward fishery.

Game, Food, and Unclassified Fish Species Catch Data

The harvest of other fish species by registered anglers in 1991 and 1992 is similar and accounts for a small percentage of the overall harvest. Warmwater species account for the majority of this harvest. While these fish species are currently being impacted at low levels, monitoring of the impacts of the sport-reward fishery should continue to ensure that this trend continues in future years.

Roving Creel Survey

One concern with the introduction of a new sport fishery is the impacts it could have on other fish species in the system. Specifically, in 1991 there was an estimated 60,000 angler days spent fishing for northern squawfish systemwide. Approximately 60% of the registered participants failed to return to the registration stations to have their catch inspected.

In 1992 we addressed the question of incidental harvest of other fish species by registered anglers (returning and non-returning) using a roving creel survey, and expressed

this impact as a percent of the total harvest by species. This approach had several advantages over other methods; it allowed inspection of the catch in the field, it provided accurate catch and effort information, and it reduced biases associated with angler memory (Malvestuto 1983). This method allowed a quantifiable comparison between the total estimated harvest of other fish species and the percent of that harvest by anglers registered to participate in the Northern Squawfish Sport-Reward Fishery. One disadvantage was its relative cost to other methods, such as telephone surveys. The analysis of the data indicated that the sport-reward fishery did not significantly impact populations of other fish species in 1992.

Monitoring of the sport-reward fishery and the impacts it has on other fish species should continue through data collection at the registration stations and with follow-up phone surveys to ensure that the impacts on other fish species continue to be minimal. If in the future evidence suggests that these impacts are increasing, we recommend implementing a roving creel survey.

Computerized Portable Data Collection Station

The computerized portable data collection station appears to be an efficient way to collect registration and biological data at the registration stations, however, additional software modifications need to be made to the programs and field tested before final recommendations are made.

Although the initial capital costs of the units would be high, the reduction in labor costs associated with entering the registration and biological data, and associated quality control costs, could be greatly reduced with the implementation of these units at all registration stations.

Recommendations for 1993 Sport-Reward Fishing Season

1. Adjust the timing of the fishery to begin in early May and extend through mid-September.
2. Classify the northern squawfish as a game fish in Washington, and codify regulation in Washington and Oregon to increase compliance with program objectives.
3. Add and/or move registration stations to areas with high predation index values (e.g., below Bonneville Dam, McNary Reservoir, etc.).
4. Eliminate and/or move registration stations from areas with low predation index values and exploitation rates (i.e., in Ice Harbor Reservoir, keep the reservoir open to the program, but relocate the registration station to an area with higher predation).

APPENDIX A

Catch Composition for Each Reservoir from the Roving Creel Survey

Appendix Table A-1. Catch composition from the roving creel survey for the Bonneville tailrace, 1992.

Species	<u>Registered Anglers</u>			<u>Unregistered Anglers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
AMS		2	2	724	146	870	872
BBH		--	--	7	--	7	7
BRS			--	1	--	1	1
CK			--	48	6	54	54
CO		---	--	13		13	13
CP		--	--	--	2	2	2
LMB			--	--	5	5	5
LRS			--	1	--	1	1
NSF	93	4	97	37	15	52	149
PK	1	--	1		--	--	1
PMO	--		--	9	--	9	9
PS		--	--	1	--	1	1
SCT			--	3	--	3	3
SF	--		--	1	--	1	1
SH	--	--	--	4	--	4	4
SK	--		--	4	--	4	4
SMB		8	8	13	42	55	63
SO	--	--	--	--	2	2	2
SS		--	--	227	30	257	257
WAL	--	--	--	13	2	15	15
WS	1	5	6	101	481	582	588
YBH		--	--	28	4	32	32
YP	--	--	--	28	5	33	33
Total	95	19	114	1263	740	2003	2117

Appendix Table A-2. Catch composition from the roving creel survey for Bonneville Reservoir, 1992.

Species	<u>Registered Anglers</u>			<u>Unregistered Anglers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
B	--	--	--	--	3	3	3
C	--	--	--	--	1	1	1
cc	--	3	3	--	--	--	3
CK	--	--	--	14	2	16	16
NSF	9	--	9	4	--	4	13
SH	--	--	--	67	18	85	85
SMB	--	4	4	--	9	9	13
TR	--	--	--	18	1	19	19
ws	1	21	22	9	95	104	126
Total	10	28	38	112	129	241	279

Appendix Table A-3. Catch composition from the roving creel survey for The Dalles Reservoir, 1992.

Species	<u>Registered Anglers</u>			<u>Unregistered Anglers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
AMS	20	--	20	157	13	170	190
B	--	--	--	4	12	16	16
CC	3	--	3	1	--	1	4
CK	--	--	--	5	3	8	8
NSF	201	--	201	62	1	63	264
SH	--	--	--	39	14	53	53
SMB	3	3	6	24	25	49	55
WAL	2	8	10	--	--	--	10
ws	--	1	1	12	201	213	214
YP	--	--	--	2	--	2	2
Total	229	12	241	306	269	575	816

Appendix Table A-4. Catch composition from the roving creel survey for John Day Reservoir, 1992.

Species	<u>Registered Anglers</u>			<u>Unregistered Anglers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
AMS	2	--	2	41	2	43	45
B	--	--		27	74	101	101
BC	--	--	--	1	--	1	1
BH		--	--	--	1	1	1
BRS		--	--	--	1	1	1
C	--		--	--	1	1	1
c c	--		--	6	1	7	7
CMO	--	--	--	1	24	25	25
COT	--	9	9		--	--	9
CP	--	--	--		10	10	10
LMB	--		--	1	1	2	2
LRS	--	--	--	2	3	5	5
NSF	26	5	31	24	11	35	66
PS	--	--	--		1	1	1
S	3	--	3	21	10	31	34
SAL	--	--		1	14	15	15
SH	--	--		2	4	6	6
SK	--	--		1	5	6	6
SMB	6	11	17	97	369	466	483
WAL	4	3	7	11	6	17	24
ws	--	--	--	3	119	122	122
YBH	--	--	--	3	8	11	11
YP		--	--	18	21	39	39
Total	41	28	69	260	686	946	1015

Appendix Table A-5. Catch composition from the roving creel survey for McNary Reservoir, 1992.

Species	<u>Registered Anglers</u>			<u>Unregistered Anglers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
AMS	6	--	6	33	8	41	47
B	1	32	33	12	112	124	157
BC	--	--		4	6	10	10
BCF	--	--		1		1	1
BG	--	--		3	13	16	16
BH	--	--	--	--	37	37	37
BRS	1	--	1	41	6	47	48
C	--	--		--	6	6	6
cc	3	5	8	90	59	149	157
CMO	1	1	2	6	17	23	25
CYP	--	--	--	--	2	2	2
CK	1	--	1	51	13	64	65
COT	--	--		--	5	5	5
GS	--	--		--	20	20	20
LMB	--	1	1	2	6	8	9
LRS	--	2	2	1		1	3
NSF	248	10	258	41	138	179	437
PMO	1	--	1	2		2	3
PS	--	--		2	10	12	12
RU	--	--		--	3	3	3
S	--	--	--	4	25	29	29
SAL	--	--		12	3	15	15
SH	3	10	13	111	254	365	378
SK	--	22	22	1	47	48	70
SMB	1	34	35	139	417	556	591
TR	--	--	--	10	86	96	96
TCH	--	--	--	--	1	1	1
WAL	1	--	1	2	2	4	5
ws	--	2	2	7	144	151	153
YBH	--	--		--	1	1	1
YP	--	--		16	19	35	35
Total	267	119	386	597	1458	2055	2441

Appendix Table A-6. Catch composition from the roving creel survey for Ice Harbor Reservoir, 1992.

Species	<u>Registered Anglers</u>			<u>Unregistered Anglers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
BC	--	--	--	1	--	1	1
BG	--	--	--	3	1	4	4
BBH	--	--	--	1	--	1	1
BRS	--	--	--	5	1	6	6
cc	2	14	16	234	117	351	367
CMO	--	--	--	1	--	1	1
NSF	3	--	3	3	3	6	9
PMO	--	--	--	--	2	2	2
PS	--	--	--	--	2	2	2
RU	--	--	--	31	17	48	48
SH	--	--	--	17	6	23	23
SK	--	3	3	--	--	--	3
SMB	7	13	20	26	78	104	124
ws	--	--	--	2	1	3	3
YBH	--	--	--	1	--	1	1
YP	--	--	--	12	5	17	17
Total	12	30	42	337	233	570	612

Appendix Table A-7. Catch composition from the roving creel survey for Lower Monumental, 1992.

Species	<u>Registered Anslers</u>			<u>Unregistered Anslers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
B	--	2	2	--	11	11	13
BC	2	7	9	167	200	367	376
BG	1	--	1	10	3	13	14
BBH	--	--	--	20	--	20	20
BRS	--	--	--	3	3	6	6
C	--	--	--	45	28	73	73
c c	2	3	5	237	73	310	315
CMO	--	--	--	--	2	2	2
CYP	--	3	3	--	1	1	4
CP	--	--	--	--	2	2	2
NSF	11	12	23	18	11	29	52
PMO	--	--	--	1	--	1	1
PS	1	--	1	5	1	6	7
RU	--	33	33	155	162	317	350
SH	--	--	--	42	10	52	52
SMB	3	65	68	89	300	389	457
TR	--	--	--	9	16	25	25
WC	--	--	--	1	--	1	1
ws	--	--	--	1	6	7	7
YBH	--	--	--	4	1	5	5
YP	2	6	8	132	104	236	244
Total	22	131	153	939	934	1873	2026

Appendix Table A-8. Catch composition from the roving creel survey for Little Goose Reservoir, 1992.

Species	<u>Registered Anglers</u>			<u>Unregistered Anglers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
BC	--	--		95	15	110	110
BG	--	--		46	55	101	101
BH	--	--	--	48	47	95	95
BBH		--	--	1	--	1	1
C		1	1	46	126	172	173
c c	8	2	10	331	47	378	388
CMO		--	--	--	1	1	1
COT		--	--	1	1	2	2
CP	--	--	--	1	--	1	1
LMB	--	--	--	--	3	3	3
NSF	71	--	71	7	11	18	89
PK	--	--	--	45	26	71	71
PMO	--	3	3	3	--	3	6
SH	--	--	--	8	2	10	10
SK	--	--		1	8	9	9
SMB	9	28	37	258	873	1131	1168
TR	--	6	6	181	373	554	560
WC		--	--	80	15	95	95
ws	--	--	--	3	5	8	8
YBH	--	--	--	3	1	4	4
YP	--	--	--	8	9	17	17
Total	88	40	128	1166	1618	2784	2912

Appendix Table A-9. Catch composition from the roving creel survey for Lower Granite Reservoir, 1992.

Species	<u>Registered Anglers</u>			<u>Unregistered Anglers</u>			Total
	Kept	Released	Total	Kept	Released	Total	
BC		--	--	28	--	28	28
BG	--	10	10	2	11	13	23
BH	--	3	3	1	3	4	7
C	--	--	--	27	31	58	58
cc	2	--	2	3	3	6	8
CP	--	--	--	7	1	8	8
NSF	89	12	101	5	37	42	143
PK	--	--	--	9	10	19	19
PMO	--	--	--	2	--	2	2
PS		--	--	1	--	1	1
RU	--	15	15		12	12	27
SH	1	35	36	1	2	3	39
SK	--	1	1	6	4	10	11
SMB	3	53	56	177	1069	1246	1302
TR	3	62	65	131	496	627	692
WC			--	15	--	15	15
YP			--	19	14	33	33
Total	98	191	289	434	1693	2127	2416

REPORT C

Controlled Angling for Northern Squawfish at Selected Dams on the Columbia and Snake Rivers in 1992

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1992 Annual Report

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ABSTRACT

The dam angling efforts reported here are part of an ongoing predator control program targeting northern squawfish (*Ptychocheilus oregonensis*), a major predator of juvenile salmonids (*Oncorhynchus sp.*) in the Columbia River Basin. In 1992, technicians stationed at eight U.S. Army Corps of Engineers dams on the lower Columbia and Snake rivers caught 27,868 northern squawfish in a 21-week season, from late April through early September.

The total catch of northern squawfish in 1992 declined 30% from 1991, largely due to declines in catches at Snake River dams. Possible reasons for the overall decline in catch include (1) substantial removals of northern squawfish since program implementation, (2) an early spring combined with a late start on the Columbia River, (3) a reduction in effort at some dams to increase cost effectiveness, (4) reservoir drawdown activities on the Snake River, and (5) reduced access to tailrace angling sites due to newly installed bird wires.

The incidental catch in 1992 was roughly half that of 1991. As in 1991, the majority of incidentally caught fish were caught at Snake River dams, and most of these fish [79.1% (80.2% in 1991)] were ictalurids (primarily channel catfish, *Ictalurus punctatus*). Salmonids (adults and juveniles) composed 1.41% of the incidental catch and 0.08% of the total catch in 1992, down from 1991 (3.29% of incidental catch, 0.26% of total catch). Fewer white sturgeon (*Acipenser transmontanus*) were caught in 1992 (217) than in 1991 (384). The decline in incidental catch was in part due to preventive measures implemented in 1992.

INTRODUCTION

Impoundments created by the construction of hydroelectric dams on the Columbia and Snake rivers have severely impacted anadromous salmonids (*Oncorhynchus sp.*; Raymond 1988). Migrating juvenile salmonids face an increased risk of predation around dams where predators concentrate (Beamesderfer and Rieman 1988, Faler et al. 1988, Raymond 1988). Predation rates adjacent to dams are high, particularly in tailrace areas (Brown and Moyle 1981, Poe et al. 1988). To address this problem, controlled angling from dams was adopted as part of a systemwide predator control program to decrease predation by northern squawfish (*Ptychocheilus oregonensis*) on juvenile salmonids (Nigro 1990).

Previous studies have shown that hook-and-line angling can remove large numbers of northern squawfish (Vigg et al. 1990, Beaty et al. 1991). In 1990, dam angling was among three test fisheries that were investigated to harvest northern squawfish in the Columbia River Basin. Dam angling was conducted at five dams from May through late September, harvesting approximately 11,000 northern squawfish (Vigg et al. 1990). In 1991, the Columbia River Inter-Tribal Fish Commission (CRITFC) and its subcontractors conducted angling operations at eight dams on the Columbia and Snake rivers, catching 39,351 northern squawfish (Beaty et al. 1991).

Results from the 1992 dam-angling season are presented in this report. Our main objectives in 1992 were to (1) remove northern squawfish from areas adjacent to dams where squawfish are abundant and predation rates on juvenile salmonids are high; (2) reduce the incidental catch; and (3) work with the cooperating agencies to develop, implement, and evaluate the program's fisheries.

This report includes preliminary catch and effort data for northern squawfish in 1992; incidental catch data are also presented. Comparisons are made throughout this report to results in 1991, and possible reasons for differences in catch between years are discussed. We also make recommendations for improvements in 1993.

METHODS

In 1992, angling crews worked at eight U.S. Corps of Engineers dams on the lower reaches of the Columbia and Snake rivers (Figure C-1). Crew size and season length were tailored among dams (Table 1) based on results from 1991 (Beaty et al. 1991) and the current year.

Table 1. Distribution of angling effort at Columbia and Snake river dams in 1992.

Dam (river km)	Average crew size ^a	Weeks worked	Season	Supervised by
<u>Columbia River</u>				
Bonneville (233)	4	15	May 28-Sept 3	CTWS ^b , CRITFC
The Dalles (310)	6	18	May 11-Sept 10	CRITFC
John Day (348)	5	19	May 6-Sept 10	YIN
McNary (470)	8	13	June 2-Aug 27	CTUIR ^d
<u>Snake River</u>				
Ice Harbor (16)	3	13	June 3-Aug 27	CTUIR, CRITFC
Lower Monumental (68)	3	16	May 5-Aug 27	CRITFC
Little Goose (113)	5	21	April 2 1-Sept 10	NPT ^c
Lower Granite (172)	5	20	April 20-Sept 3	NPT

^a Average crew size varied according to differences in the initial size of resident crews, attrition, and a tailoring of effort within the season in response to catch rates.

^b Confederated Tribes of the Warm Springs Reservation.

^c Confederated Tribes and Bands of the Yakima Indian Nation.

^d Confederated Tribes of the Umatilla Indian Reservation.

^e Nez Perce Tribe.

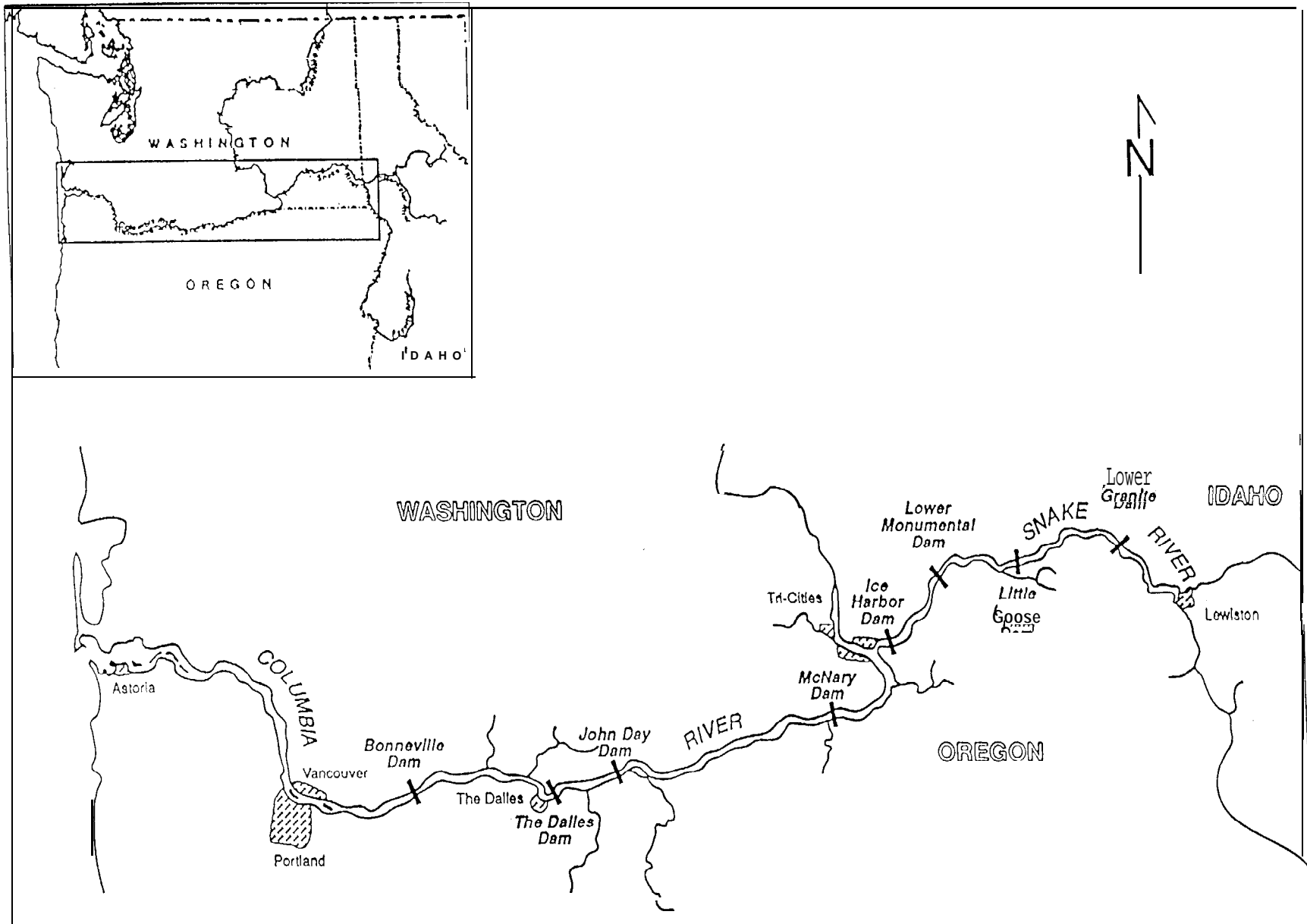


Figure C-1. Dams where controlled angling operations were conducted in 1992.

Resident crew efforts on the dam were supplemented by other angling activities -- a mobile crew, volunteer anglers, and boat anglers -- to improve catches (Table 2). The mobile crew consisted of 4-5 anglers and worked at Snake River dams early in the season and at Columbia River dams from mid- to late-season. The location and dates worked by the mobile crew depended upon the relative catch rates on each river and dam in the previous and current year. However, there were practical limitations to this crew's mobility. For example, travel costs and other constraints precluded moving the crew too frequently and with little advance notice to distant areas, such as between the Snake and Columbia rivers from day-to-day. Therefore, we planned to station the crew on one river for periods of at least one month and to assign it to work at specific dams on that river each day or week depending on where catch rates were best for resident crews.

In 1991, catch rates were higher at Snake versus Columbia river dams early in the season. Based on these data, the mobile crew was first deployed to Snake River dams in 1992. Thereafter, the mobile crew moved between rivers and among dams according to (1) relative catch rates among dams through the season and (2) costs and logistical difficulties involved with moving the crew.

Volunteer anglers, members of The Dalles Rod and Gun Club, supplemented the efforts at Bonneville Dam when catch rates were high later in the season (Table 2). Boat angling was tested by the regular crew at John Day Dam as a way to target concentrations of northern squawfish in the boat restricted zone (BRZ) outside the reach of land-based anglers (Table 2).

Field Procedures

In general, angling techniques used in 1992 were similar to those used in 1991 (see Beaty et al. 1991). Most of the changes in 1992 were made to reduce the impacts of the dam angling fishery on other species, particularly salmonids and white sturgeon (*Acipenser transmontanus*). Additional changes were made to increase catches of northern squawfish and increase overall efficiency.

Several measures were implemented to increase northern squawfish catch in 1992: (1) utilizing a mobile crew and volunteer anglers to supplement angling efforts at dams with high catch rates (Table 2); (2) utilizing boat angling in the BRZ at John Day Dam to target concentrations of fish inaccessible to anglers on the dam and shore (Table 2); (3) scheduling one crew to work two dams on alternate days to allow recruitment of northern squawfish into recently fished areas; and (4) continued testing and use of additional baits and lures (see Appendix Table A-1 for list of baits and lures used in 1992).

Table 2. Supplemental angling activities used in 1992.

Supplemental angling activity	Average crew size	Location (dam)	Dates worked
Mobile crew	4	Snake River ^a (Little Goose & Lower Granite dams)	May 3-June 4
Mobile crew	4	Columbia River ^b (Bonneville, The Dalles, & McNary dams)	June 8-July 31
Volunteer angling	4	Bonneville Dam ^c	June 28, July 31, Aug 16
Boat angling	4	John Day Dam ^d	June 22-25, July 1, July 7-9

^a The mobile crew was stationed in Pomeroy, WA, while working at Snake River dams.

^b The mobile crew was stationed in The Dalles, OR, while working at Columbia River dams.

^c Volunteer anglers generally fished the forebay of Powerhouse I at Bonneville Dam from 6 p.m. - 10 p.m. on these dates.

^d Boat angling was carried out by the resident crew in the boat restricted zone in the tailrace of John Day Dam.

Two measures were implemented to reduce the number of fish incidentally caught in 1992. First, fishing was restricted in areas where these fish were known to be abundant, such as near fishway entrances (also in 1991), in forebays when hold-over steelhead smolts were present, and near the river bottom. Second, once either one salmonid or three white sturgeon were caught at a particular site, that site was not fished by any angler for the remainder of the shift.

Barbless hooks were used to minimize injuries suffered by incidentally hooked fish. In most cases, barbless hooks allowed adult salmonids and white sturgeon to shake free when given slack line by the angler. Those adult salmonids and sturgeon unable to free themselves were released by cutting the line prior to landing the fish, to reduce some handling-caused stress and injury. Hooks used were bronze, rather than stainless steel, which facilitated the disintegration of hooks left in adult fish. Salmonids ≥ 0.50 m (approx. 1.5 ft) in length and sturgeon ≥ 0.75 m (approx. 2.5 ft) in length were considered adults. Smaller salmonids and

sturgeon, as well as all other fish incidentally caught, were reeled in, unhooked, and released.

As part of the predator control program, some northern squawfish caught at dams have been tagged and released by other agencies in previous years. However, in 1992 all northern squawfish caught at dams were sacrificed, and those bearing tags were kept in freezers for the agencies responsible for those fish. Any tagged catfish (*Ictalurus sp.*), bass (*Micropterus sp.*), or walleye (*Stizostedion vitreum*) caught at dams was released immediately after the tag number and location of capture were recorded.

Data Collection

With a few exceptions, data were collected using the same method used in the previous year (see Beaty et al. 1991). In 1992, adult salmonids and large sturgeon were not handled and were assigned the condition code "Lost" in the data. Detailed notes on the condition of each salmonid caught were taken by the angler when possible, including where the hook was imbedded in the fish, how much line was attached to the hook (if the line was broken or cut), whether the fish was bleeding, and the general behavior of the fish upon release. This information, along with catch and effort data, was provided in weekly summaries to the Oregon Department of Fish and Wildlife (ODFW), the contracting agency.

Early in the season, data were written on data forms and sent to Portland on a daily basis using facsimile machines. Midway through the 1992 field season we implemented an electronic data system that enabled field crews to enter data directly into a hand-held computer (CMT MC-V with custom software developed by Corvallis MicroTechnology, Inc.) and transfer the data daily to a host computer in our Portland office via modem. As a backup, each day's data file was printed out at each field location and mailed to Portland weekly. The electronic data system greatly reduced data-handling time and increased data accuracy.

Data Summary and Analysis

Preliminary data were summarized by dam and river for comparison with other results, particularly those from 1991. Sums of catch and effort were used to calculate average catch per angler hour (CPAH), which was the basis for comparing success within and between years, among dams, and among management alternatives.

Incidental catch data were summarized, and we compared the species composition (percent of total and incidental catch) among dams and between years. In addition, information regarding the disposition of incidentally caught fish at release was summarized.

To manage the mobile crew well, we had to assign it to the more productive river in the longer term and to the best dam(s) on that river in the shorter term. We evaluated the

mobile crew by comparing its CPAH to averages for the long- and short-term management alternatives. Specifically, we compared (1) the CPAH of the mobile crew to the average and maximum CPAH on the more productive river each month (long-term) and (2) the CPAH of the mobile crew to the average and maximum CPAH recorded at dams on the river that the mobile crew worked each week (short-term).

Our minimum standard was the average CPAH for all alternatives, which is equivalent to the result expected if we simply assigned the mobile crew randomly between rivers and among dams. The ideal standard was the maximum CPAH among alternatives, which would mean that we always chose the most productive alternative for the mobile crew. Even if the mobile crew was managed optimally, its productivity would not necessarily reach the ideal standard if resident crews in general were more effective, which seems to have been the case. Other factors, such as cost, must also be considered before we can fully evaluate whether the concept of the mobile crew and our management of it were successful.

The CPAH for volunteer and boat angling was calculated and compared with the average CPAH of the resident crew at the same dam during the same weeks. We did not consider factors other than CPAH (e.g., social considerations and cost) that would be necessary for a comprehensive evaluation of these supplemental methods.

RESULTS

Northern Squawfish Catch

From mid-April through mid-September, 27,868 northern squawfish were caught in 16,758.8 hours of angling at all dams, for a seasonal catch-per-angler-hour (CPAH) of 1.7. The total catch, effort, and CPAH for all dams combined in 1992 was below that of 1991 (Table 3), largely due to reduced catch rates at Snake River dams. In both years, effort, total numbers of fish caught, and catch rates were higher at Columbia River dams than Snake River dams (Table 3). Catch was distributed differently over time between the Columbia and Snake river dams in 1992 and 1991 (Figures C-2 and C-3).

Columbia River Dams

From early May through mid-September, 23,099 northern squawfish were caught in 9,575.3 hours of angling at Columbia River dams, for a seasonal CPAH of 2.4 (Table 3). The highest catches occurred in June and July (Figure C-2), and the highest CPAH was recorded in June (Figure C-3). The highest seasonal catch rates in 1992 were recorded at The Dalles Dam (3.0) and McNary Dam (2.9). In 1992, the total catch, effort, and seasonal catch rate were similar to 1991 (Table 3).

Bonneville Dam

From late May through early September, 4,814 northern squawfish were caught in 1,781.3 hours of angling at Bonneville Dam, for a seasonal CPAH of 2.7 (Table 3). The mobile crew supplemented the efforts of the resident crew from mid-June through late July (see ***RESULTS, Mobile Crew***). From early August through early September, the mobile crew replaced the resident crew at Bonneville Dam. Volunteer anglers were used at Bonneville Dam on three dates in June, July, and August to supplement the efforts of the resident crew (see ***RESULTS, Volunteer Angling***). In general, weekly catch rates increased from the beginning of the season and reached a distinct peak in early August, declining sharply over the next month (Appendix Table A-2). A similar peak in catch was observed in 1991, but it occurred a month earlier (Figure C-4). Forty percent fewer fish were caught at Bonneville Dam in 1992 than in 1991, although effort only declined approximately one-third from 1991 (Table 3). The seasonal CPAH fell slightly from 3.1 in 1991 to 2.7 in 1992.

The Dalles Dam

From mid-May through mid-September, 7,561 northern squawfish were caught in 2,496.2 hours of angling at The Dalles Dam, for a seasonal CPAH of 3.0 (Table 3). The mobile crew supplemented the efforts of the resident crew from early June through late July (see ***RESULTS, Mobile Crew***). The highest CPAH values of the season were observed in the first three weeks of angling, May 10 through May 30. Beginning in June, weekly catch rates declined gradually, with three distinct peaks of lesser value (Appendix Table A-3). A similar periodicity in catch rates occurred in 1991 (Figure C-4). In 1992, greater than twice the number of fish were caught than in 1991, with a little less than twice the effort. The seasonal catch rate in 1992 (3.0) was higher than in 1991 (2.8).

John Day Dam

From early May through mid-September, 3,427 northern squawfish were caught in 2774.7 hours of angling at John Day Dam, for a seasonal CPAH of 1.2 (Table 3). In June and July, boat angling was tested in the BRZ at John Day Dam (see ***RESULTS, Boat Angling***). Weekly catch rates in 1992 were highest from late June through mid-July (Appendix Table A-4). The highest catch rates in 1991 were recorded from early August through mid-September (Figure C-4). Thirty-two percent fewer fish were caught in 1992, compared to 1991, with virtually the same amount of effort (Table 3). Consequently, the seasonal catch rate in 1992 was lower than in 1991: 1.2 versus 1.8, respectively.

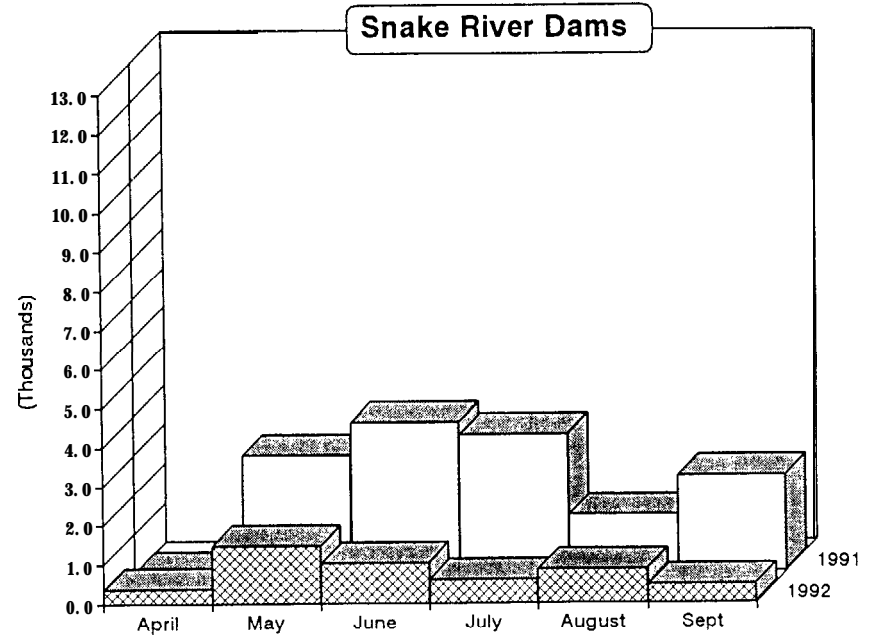
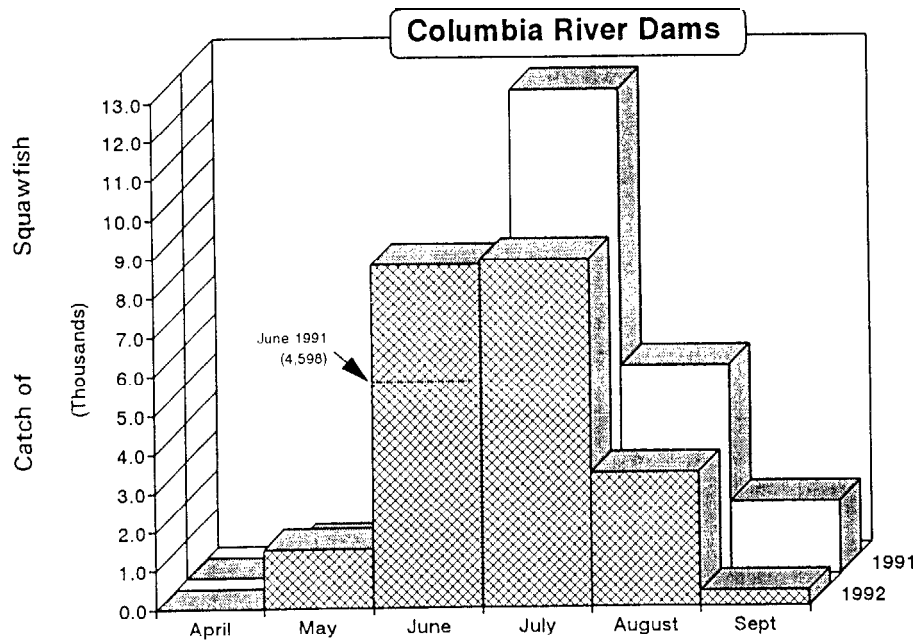


Figure C-2. Monthly catch of northern squawfish at Columbia and Snake river dams, 1991 and 1992.

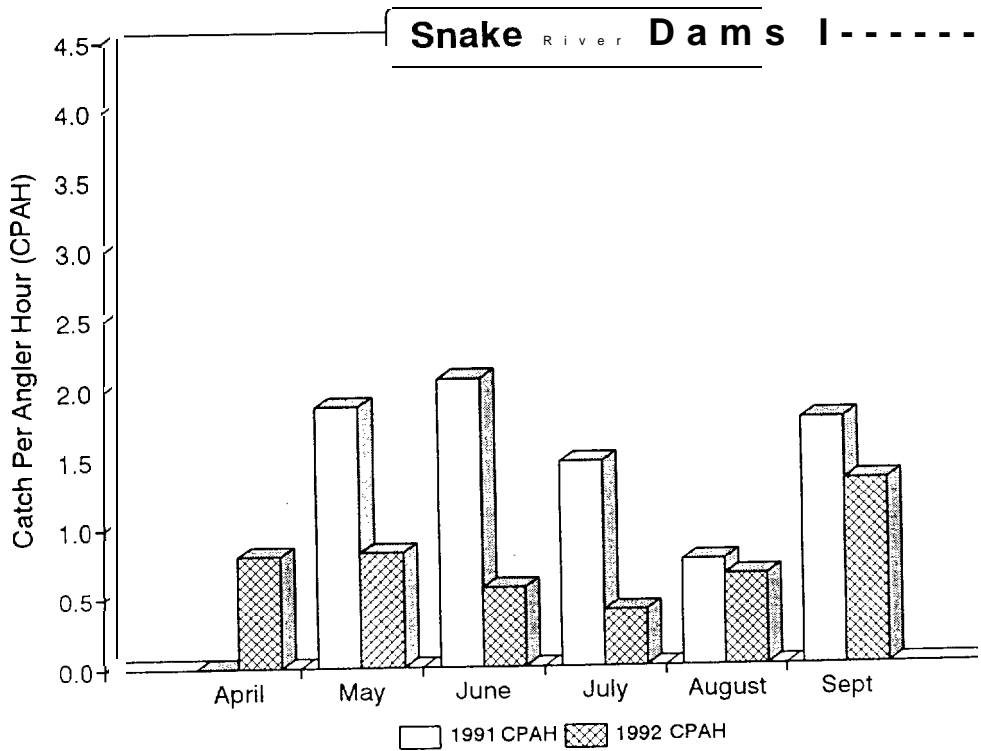
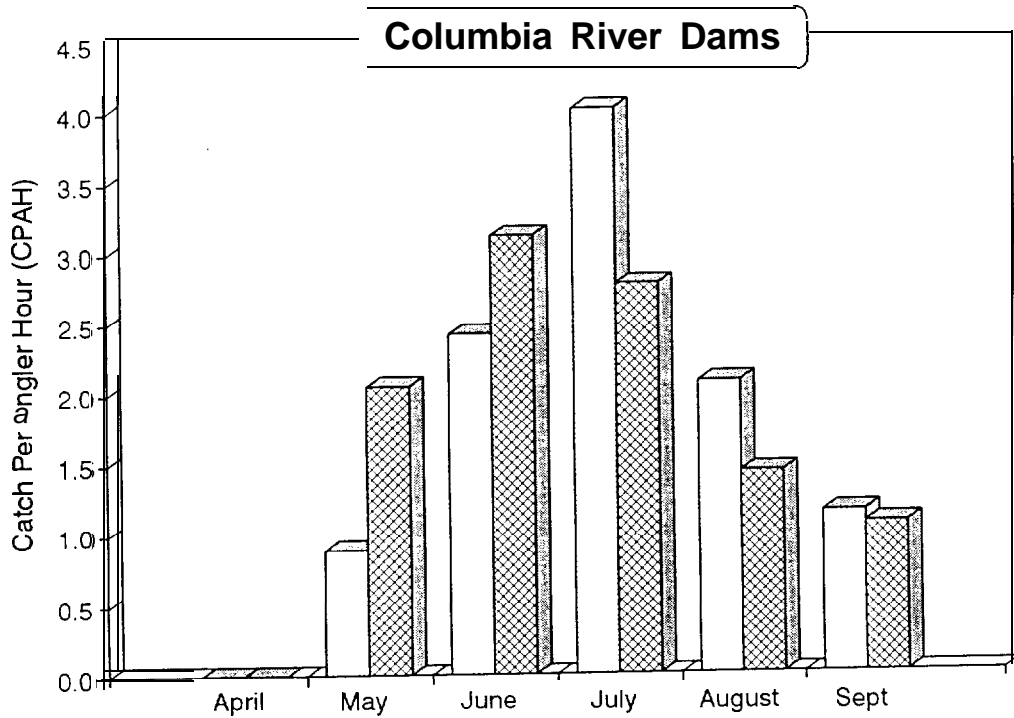


Figure C-3. Monthly catch per angler hour (CPAH) at Columbia and Snake river dams, 1991 and 1992.

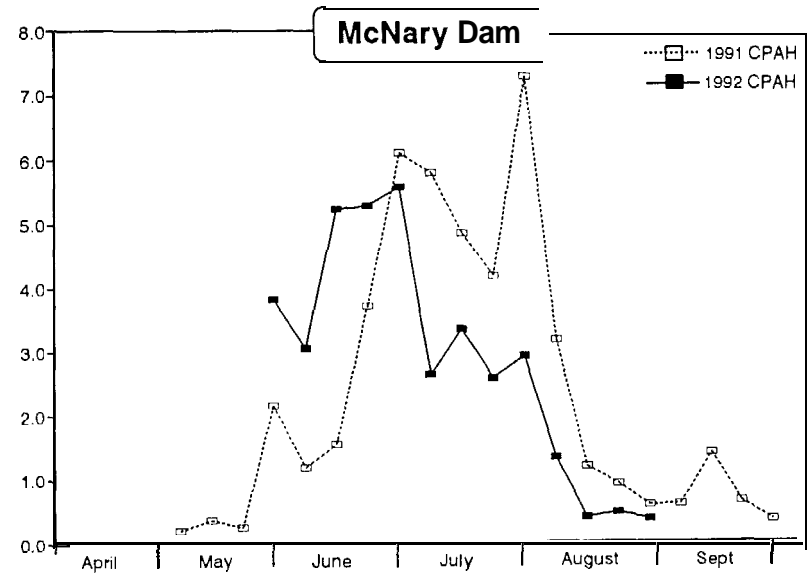
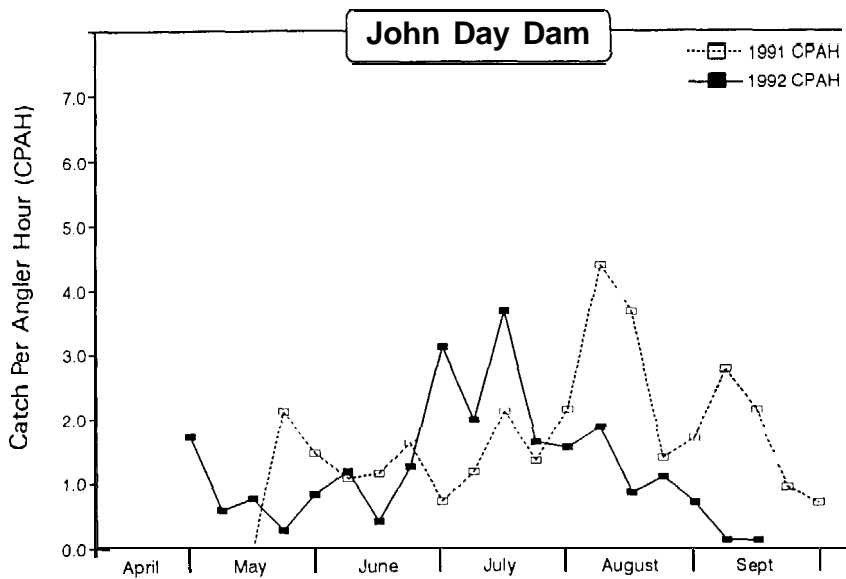
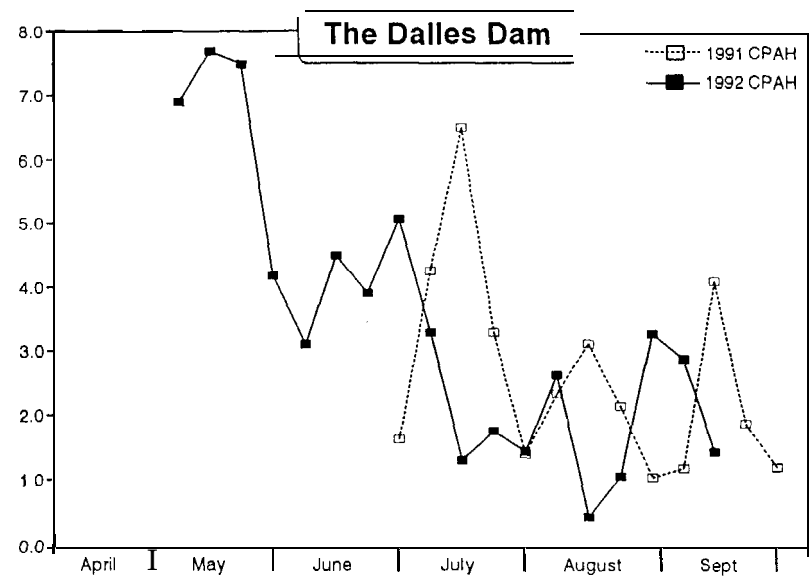
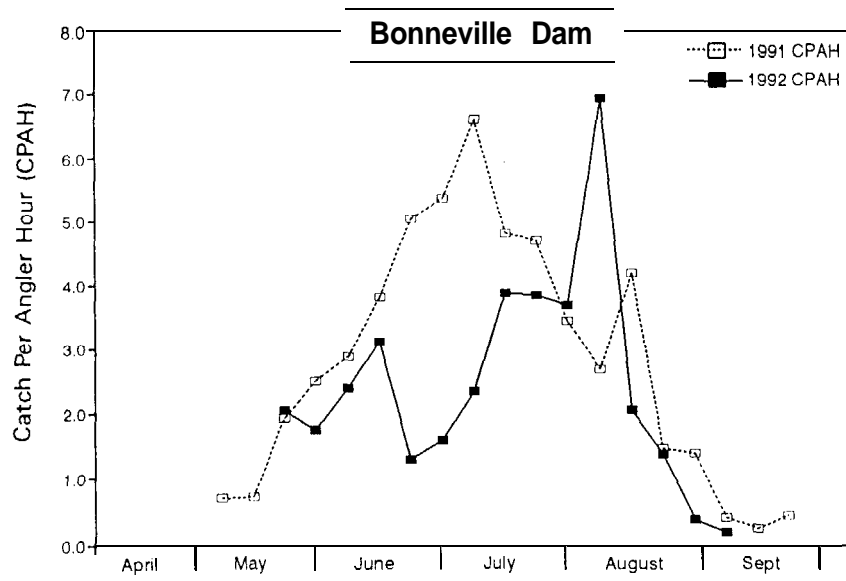


Figure C-4. Weekly average catch per angler hour (CPAH) at Columbia River dams, 1991 and 1992. Effort varied substantially within and between seasons.

Table 3. Angling effort and northern squawfish catch by dam, 1991 and 1992.

Dam	1991			1992				
	Seasonal totals			Seasonal totals			% of 1991 total	
	Hours fished	Northern squaw- fish	CPAH	Hours fished	Northern squaw- fish	CPAH	Hours fished	Northern squaw- fish
<u>Columbia River</u>								
Bonneville	2,621.3	8,131	3.1	1,781.3	4,814	2.7	68.0	59.2
The Dalles	1,333.0	3,674	2.8	2,496.2	7,561	3.0	187.7	205.8
John Day	2,816.3	5,004	1.8	2,774.7	3,427	1.2	98.5	68.5
McNary	3,415.9	8,348	2.4	2,523.1	7,297	2.9	73.9	87.4
Columbia Total	10,186.5	25,157	2.5	9,575.3	23,099	2.4	94.0	91.8
<u>Snake River</u>								
Ice Harbor	2,052.4	1,486	0.7	298.1	278	0.9	14.5	18.7
Lower Monumental	2,471.5	3,313	1.3	943.1	475	0.5	38.2	14.3
Little Goose	2,139.8	4,915	2.3	3,061.8	1,664	0.5	143.1	33.9
Lower Granite	2,448.1	4,480	1.8	2,880.5	2,352	0.8	117.7	52.5
Snake Total	9,111.8	14,194	1.6	7,183.5	4,769	0.7	78.8	33.6
GRAND TOTALS	19,298.3	39,351	2.0	16,758.8	27,868	1.7	86.8	70.8

McNary Dam

From early June through late August, 7,297 northern squawfish were caught in 2,523.1 hours of angling at McNary Dam, for a seasonal CPAH of 2.9 (Table 3). The mobile crew supplemented the efforts of the resident crew from late June through mid-July (*see RESULTS, Mobile Crew*). The highest catch rates at McNary Dam occurred from mid-June through early July. Weekly catch rates declined rapidly following this peak (Appendix Table A-5). A similar peak in weekly catch was observed in 1991, but it occurred later in the season, from early July through early August (Figure C-4). Thirteen percent fewer fish were caught at McNary Dam in 1992, although less effort was expended than in 1991 (Table 3). The seasonal CPAH was higher in 1992 than in 1991: 2.9 versus 2.4, respectively.

Snake River Dams

From mid-April through mid-September, 4,769 northern squawfish were caught in 7,183.5 hours of angling at Snake River dams, for a seasonal CPAH of 0.7 (Table 3). The highest combined catch for all dams was observed in May (Figure C-2), while the highest combined CPAH was observed in September (Figure C-3). Lower Granite Dam had the highest total catch (2,352 northern squawfish) -and Ice Harbor Dam had the highest seasonal CPAH (0.9) of all the Snake River dams. Sixty-six percent fewer northern squawfish were caught at Snake River dams in 1992 with 21% less effort than in 1991 (Table 3). The seasonal catch rate for Snake River dams in 1992 (0.7) was less than half of that recorded in 1991 (1.6; Table 3).

Ice Harbor Dam

From early June through late August, 278 northern squawfish were caught in 298.1 hours of angling at Ice Harbor Dam, for a seasonal CPAH of 0.9 (Table 3). In general, weekly CPAH values increased from the beginning of the season in late May to a peak in early July. The catch rate dropped dramatically the following week and rates remained low (< 1.0 fish/h) for the remainder of the season (Appendix Table A-6). Weekly CPAH values in 1992 were more variable than those in 1991 (Figure C-5). The total catch of northern squawfish in 1992 was only 19% of the 1991 catch; however, effort in 1992 was only 15% of the effort expended in 1991. The seasonal CPAH was greater in 1992 than in 1991: 0.9 versus 0.7, respectively (Table 3).

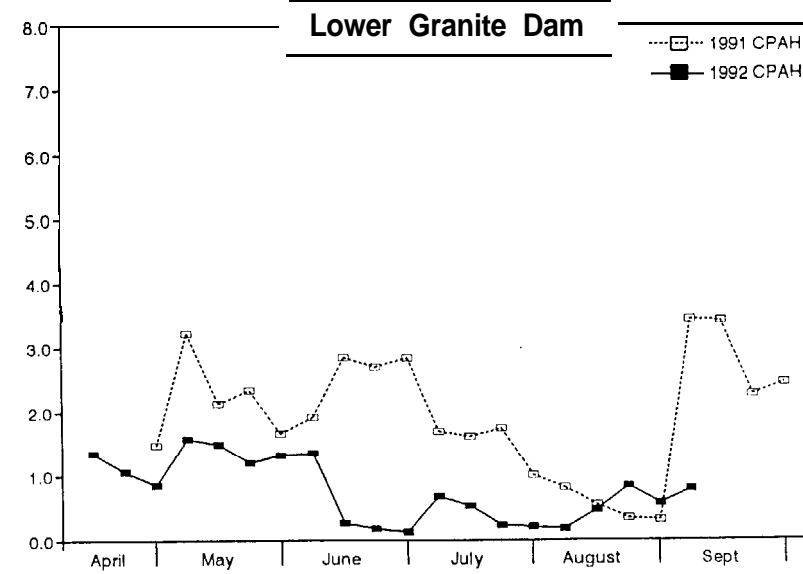
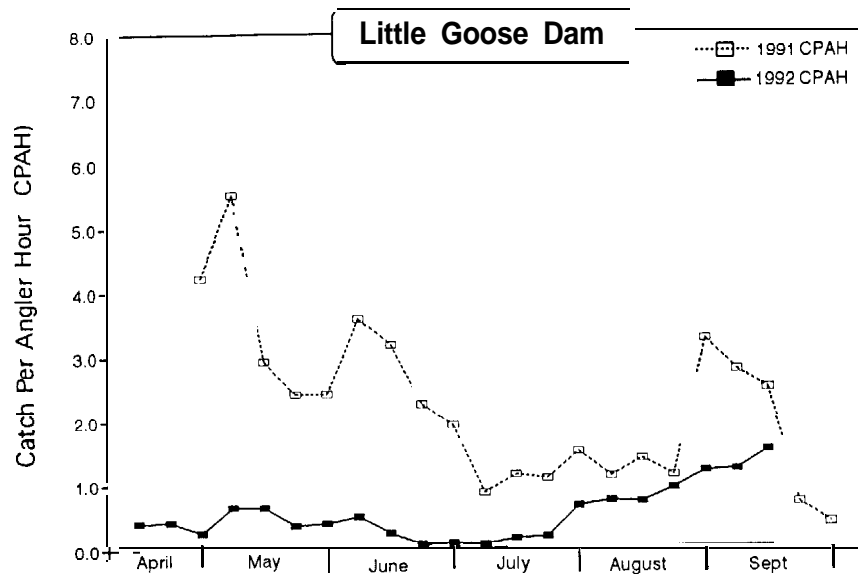
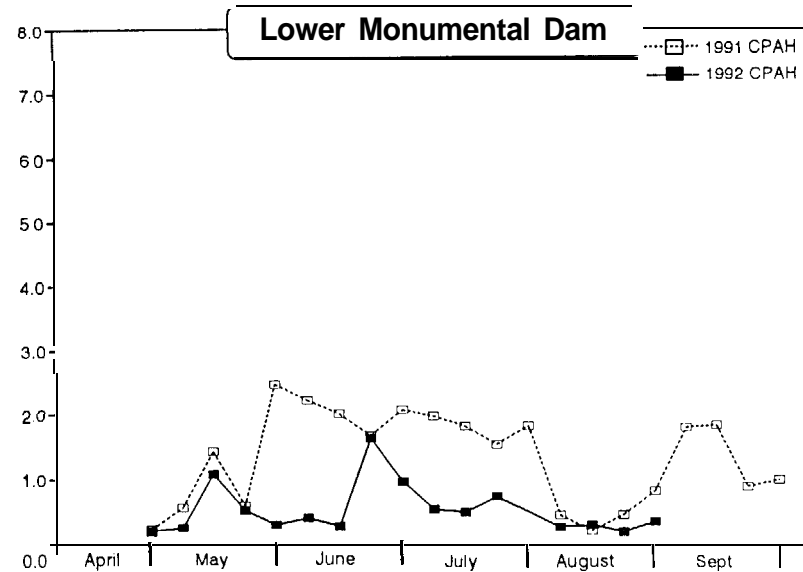
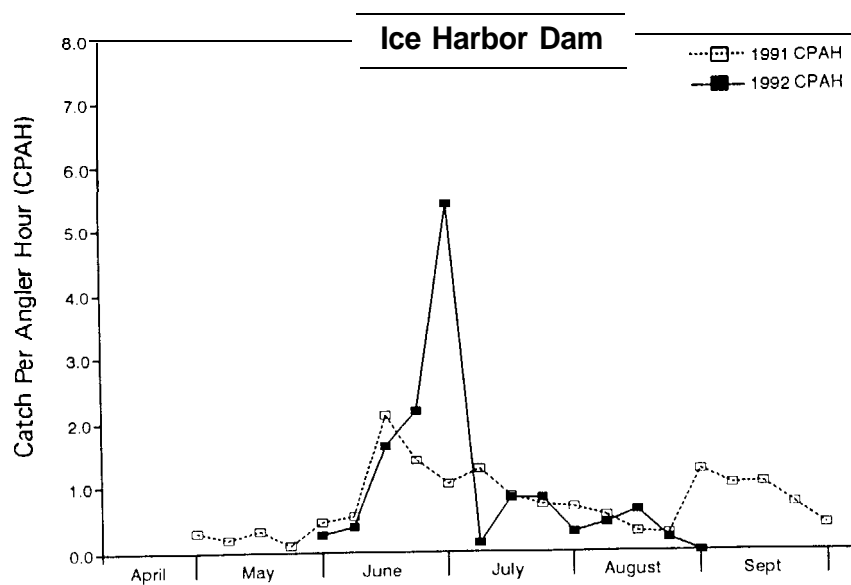


Figure C-5. Weekly average catch per angler hour (CPAH) at Snake River dams, 1991 and 1992. Effort varied substantially within and between seasons.

Lower Monumental Dam

From early May through late August, 475 northern squawfish were caught in 943.1 hours of angling at Lower Monumental Dam, for a seasonal CPAH of 0.5 (Table 3). In general, weekly CPAH fluctuated only slightly, with two small peaks in early to mid-May and in mid-June (Appendix Table A-7). In comparison to 1991, catch rates in 1992 were similar during the first few weeks of the season. However, from late May through the remainder of the season, catch rates in 1992 were substantially lower than in 1991 (Figure C-5). Total catch in 1992 was 14% of the catch in 1991, and the seasonal CPAH in 1992 (0.5) was less than in the previous year (1.3; Table 3).

Little Goose Dam

From mid-April through mid-September, 1,664 northern squawfish were caught in 3,061.8 hours of angling at Little Goose Dam, for a seasonal CPAH of 0.5 (Table 3). The mobile crew supplemented the efforts of the resident crew for the month of May (see **RESULTS, Mobile Crew**). Weekly catch rates were < 1 .0 fish/h until the last three weeks of the season (Appendix Table A-8). There was a modest upswing in catch rates toward the end of the 1992 season, compared with 1991 when peaks in catch occurred early and late in the season. Weekly catch rates in 1992 were much lower and less variable than in 1991 (Figure C-5). The catch of northern squawfish in 1992 was only one-third of the 1991 catch, despite a 43% increase in effort in 1992. Consequently, the seasonal catch rate in 1992 (0.5) was lower than that of the previous year (2.3; Table 3).

Lower Granite Dam

From mid-April through early September, 2,352 northern squawfish were caught in 2,880.5 hours of angling at Lower Granite Dam, for a seasonal CPAH of 0.8 (Table 3). The mobile crew supplemented the efforts of the resident crew from early May through early June (see **RESULTS, Mobile Crew**). Weekly catch rates were highest early in the season in 1992 (Appendix Table A-9) and were lower overall than in 1991. Catch rates increased toward the end of the season in both years; however, the increase in 1992 was much less than in the previous year (Figure C-5). Total catch in 1992 was only 52 % of that in 1991. The seasonal catch rate was much lower in 1992 (0.8) than in 1991 (1.8; Table 3).

Supplemental Angling Activities

Mobile Crew

In the long-term comparison (i.e., was the crew stationed on the better river each month?), the crew had mixed results (Table 4). In May, when the mobile crew was stationed on the Snake River, its CPAH (1.1) was less than the average CPAH for all dams combined (1.2). However, in June and July, while primarily on the Columbia River, its CPAH was intermediate between the average and the maximum (i.e., the better average for the two rivers) in both months. The overall results for the season (2.2) were also intermediate

between the average (0.7) and the maximum (2.6). In August and September, the mobile crew became the resident crew at Bonneville Dam, and those results have been presented above (**see RESULTS, Northern Squawfish Catch, Bonneville Dam**).

In the short-term comparison (i.e., did the crew work at the right dams while stationed on one or the other river?), the crew’s CPAH equalled the maximum while stationed on the Snake River (Table 5). However, its overall CPAH while on the Columbia River (2.8) was below the average (3.0).

Bout Angling

Angling for northern squawfish from a boat in the BRZ was conducted at John Day Dam by members of the resident crew during June (6/22-6/25) and July (7/1, 7/7-7/9). In June, boat anglers caught a total of 19 squawfish in 50.9 hours, for a CPAH of 0.4. In comparison, the CPAH of anglers fishing from the dam during the same week was 1.6. In July, boat anglers caught a total of 36 squawfish in 28.8 hours of fishing, with a CPAH of 1.2. In comparison, the CPAH of anglers fishing from the dam during these same weeks was 2.5.

Table C-4. Comparison of monthly CPAH values for the mobile crew with the maximum (of the combined average for either the Columbia or Snake river dams) average CPAH and the average CPAH (all resident crews combined on both the Snake and Columbia rivers).

Month	Mobile crew		Resident Crews	
	River	CPAH	Maximum CPAH ^a	Average CPAH
May	Snake	1.1	2.0	1.2
June	Snake/Columbia	2.9	3.1	2.0
July	Columbia	2.5	2.8	1.9
Average		2.2	2.6	1.7

^a The maximum CPAH for all three months was at all Columbia River dams combined.

Table 5. Comparisons of weekly CPAH values for the mobile crew with the maximum CPAH and the average CPAH for all resident crews at Snake and Columbia river dams separately.

SNAKE RIVER DAMS

Week ^a	Mobile Crew		Resident Crews	
	Dam ^b	CPAH	Maximum CPAH	Average CPAH
3	GO/GR	0.4	0.9 (at GR)	0.4
4	GO/GR	1.5	1.5 (at GR)	0.8
5	GO/GR	1.2	1.4 (at GR)	1.1
6	GO/GR	1.0	1.1 (at GR)	0.6
7	GR	1.6	1.1 (at GR)	0.5
Average		1.2	1.2	0.7

COLUMBIA RIVER DAMS

Week	Mobile Crew		Resident Crews	
	Dam ^b	CPAH	Maximum CPAH	Average CPAH
8	TD	3.3	3.0 (at MC)	2.4
9	BO	3.9	5.2 (at MC)	3.1
10	TD/MC	2.1	6.3 (at MC)	3.3
11	TD/MC	2.3	7.3 (at TD)	4.5
12	TD/MC	1.7	4.1 (at TD)	2.8
13	BO/TD	1.8	4.4 (at BO)	3.2
14	BO/TD	2.9	3.6 (at BO)	2.4
15	BO	4.4	2.9 (at MC)	2.1
Average		2.8	4.5	3.0

^a The mobile crew worked at Snake River dams from May 3-June 4 and at Columbia River dams from June 8-July 3 1.

^b BO=Bonneville Dam, TD=The Dalles Dam, MC=McNary Dam. GO=Little Goose Dam, GR=Lower Granite Dam.

Volunteer Angling

Volunteer anglers from The Dalles Rod and Gun Club supplemented effort at Bonneville Dam by fishing in the forebay of the first powerhouse during evening hours on June 28, July 31, and August 16. Volunteer anglers caught 100 northern squawfish in 22.8 hours of fishing, for a seasonal CPAH of 4.4.

To evaluate the effectiveness of volunteer angling, we compared the daily CPAH for the volunteer anglers to the corresponding weekly CPAH for the resident crew at Bonneville Dam. The CPAH for the volunteer anglers was greater than the resident crew CPAH in two of three comparisons (Table 6).

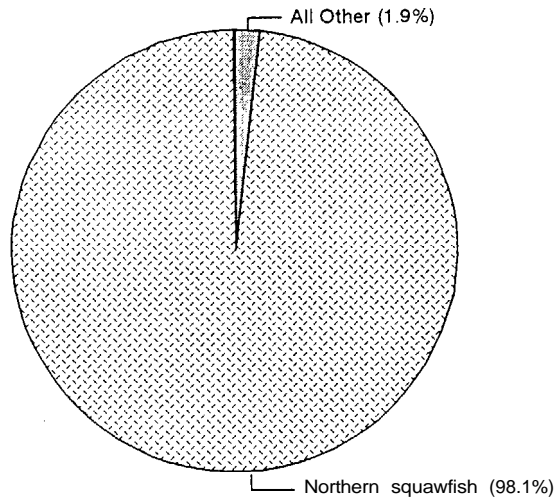
Incidental Catch

At all dams combined, 1,706 fish were incidentally caught, which was 5.77% of the total catch in 1992 (see Appendix Tables A-10 and A-11) and roughly half the number caught in 1991 (3,401). As in 1991, the majority of the incidental catch was catfish caught at Snake River dams (Figure C-6). Salmonids (4 adults and 20 juveniles) composed 1.41% of the incidental catch and 0.08% of the total catch in 1992, which was down from 1991 (Figure C-7). The catch of sturgeon (297) also declined in 1992 from the total in the previous year (384).

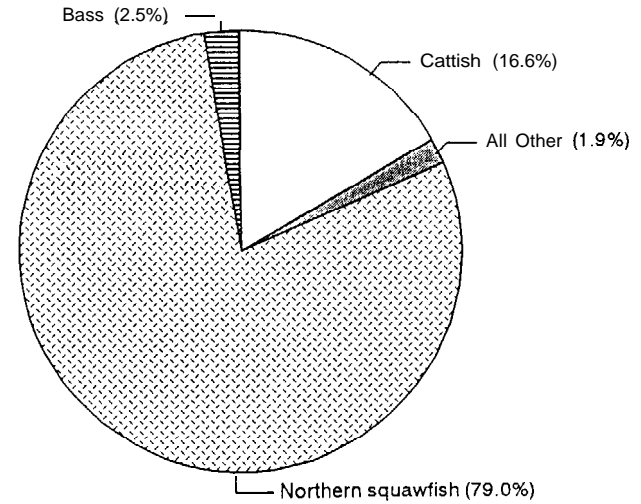
Table 6. Comparison of daily CPAH values for the volunteer anglers with the corresponding weekly CPAH for the resident crew at Bonneville Dam.

<u>Volunteer anglers</u>		<u>Resident crew</u>	
<u>Date</u>	<u>CPAH</u>	<u>Week</u>	<u>CPAH</u>
6/28	5.9	6/28-7/4	1.6
7/31	3.4	7/26-8/1	3.7
8/16	5.0	8/16-8/22	1.4

Columbia River Dams



Snake River Dams



All Dams Combined

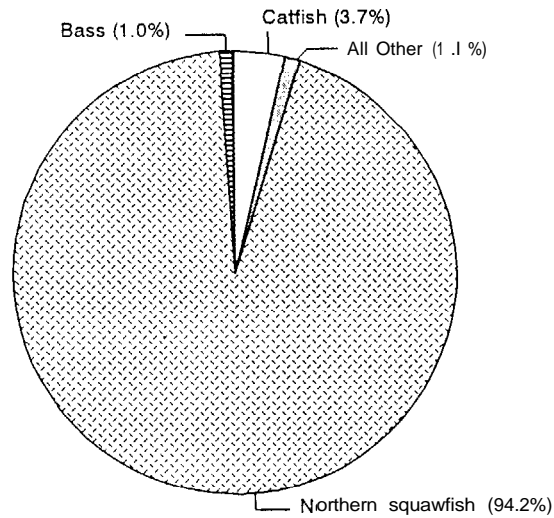


Figure C-6. Total catch percentages in 1992 at Columbia River dams, Snake River dams, and all dams combined. Individual species are displayed when they constitute 1 percent or more of the total catch; otherwise, they are combined with "All other."

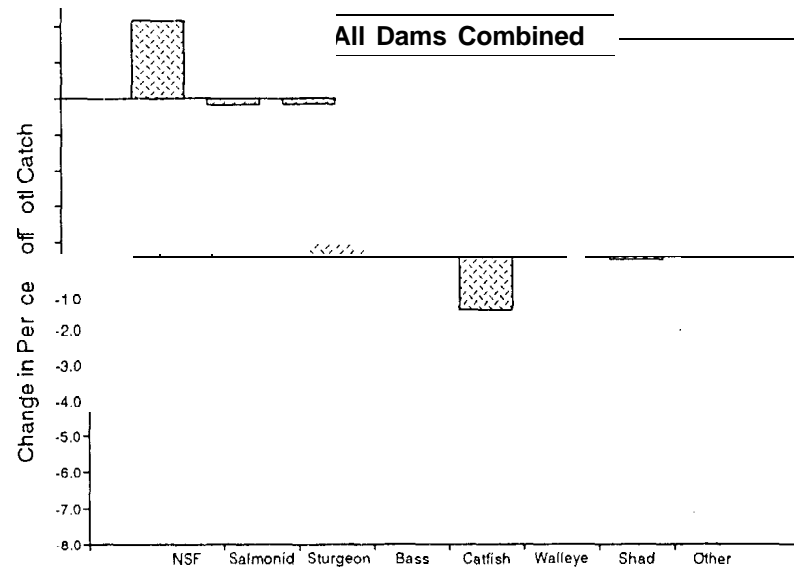
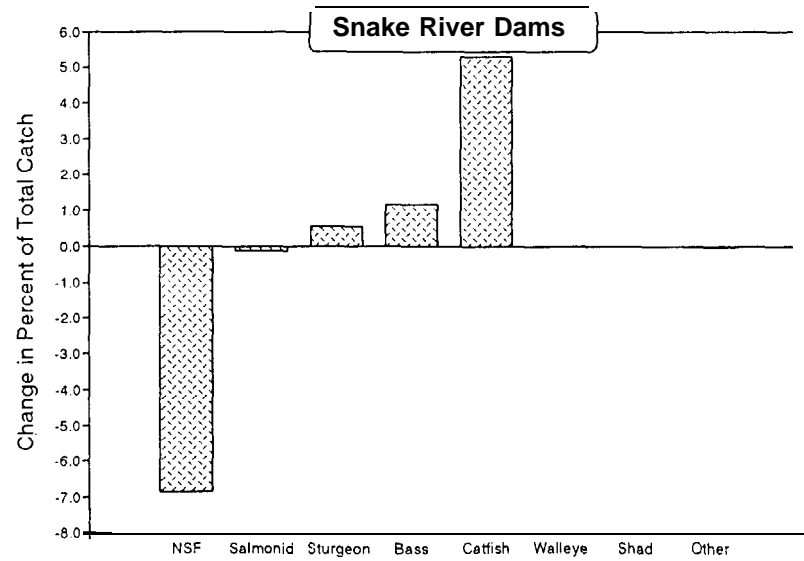
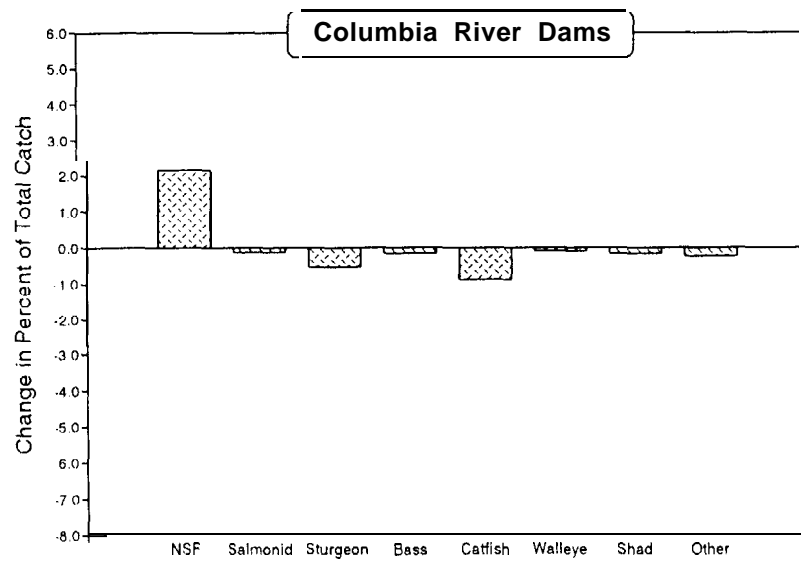


Figure C-7. Difference in percent of total catch of northern squawfish (NSF) and incidentally caught species between 1991 and 1992. Values were obtained by subtracting percent of total catch in 1991 from percent of total catch in 1992.

Columbia River Dams

At Columbia River dams, 439 fish were incidentally caught, which was 1.87% of the total catch in 1992 (see Appendix Tables A-10 and A-11). Fifty-eight percent fewer fish were incidentally caught in 1992 than in 1991 (1,055). Sturgeon and bass composed the highest proportions of the incidental catch in 1992, although each represented less than 1.0% of the total catch (Appendix Table A-11). Two juvenile and no adult salmonids (0.45% of incidental catch and 0.01% of total catch) were caught at dams on the Columbia River in 1992, down from 22 adult and 11 juvenile salmonids (3.13% of incidental catch and 0.12% of total catch) caught in 1991 (Figure C-7). Sturgeon composed 0.68% of the total catch at Columbia River dams in 1992, also down from 1991 (1.18%). All species caught incidentally constituted smaller proportions of the total catch in 1992 than in 1991 (Figure C-T).

Bonneville Dam

At Bonneville Dam, 13 fish (0.27% of total catch; Figure C-8) were incidentally caught in 1992 (Appendix Table A-12 and A-13), which was down from 58 fish (0.70% of total catch) the previous year. As in 1991, American shad (*Alosa sapidissima*) was the most commonly caught incidental species in 1992, composing 76.9% of the incidental catch and 0.21% of the total catch. The remaining incidental catch (three fish) consisted of one juvenile salmonid and two sturgeon, 0.02% and 0.04% of the total catch, respectively. All three fish were released in good condition. The incidental catch of salmonids and sturgeon in 1992 was down from 1991 (Figure C-9).

The Dalles Dam

At The Dalles Dam, 154 fish (2.00% of total catch) were incidentally caught in 1992 (Appendix Tables A-12 and A-13), which was down from 196 fish (5.04% of total catch) the previous year. Bass composed 73.4% of the incidental catch and 1.46% of the total catch in 1992 (Figure C-8), down from the previous year (Figure C-9). No salmonids were caught in 1992 at The Dalles Dam, compared to one juvenile salmonid caught in 1991. Compared to 1991, the total number of incidentally caught sturgeon increased slightly in 1992; however, the proportion of sturgeon in the total catch declined in 1992 (Figure C-9).

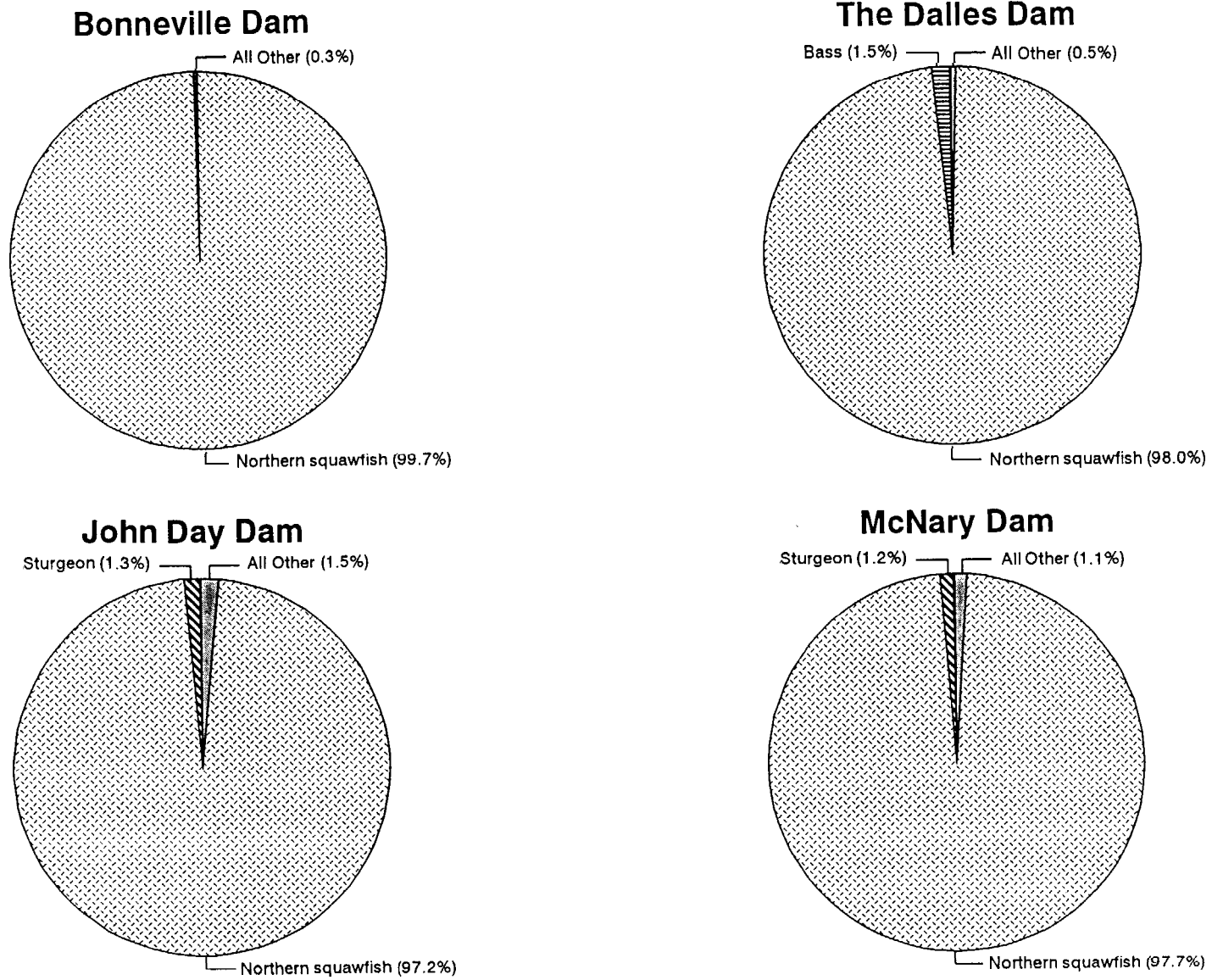


Figure C-8. Total catch percentages in 1992 for individual dams on the Columbia River. Individual species are displayed when they constitute 1 percent or more of the total catch; otherwise, they are combined with "All Other".

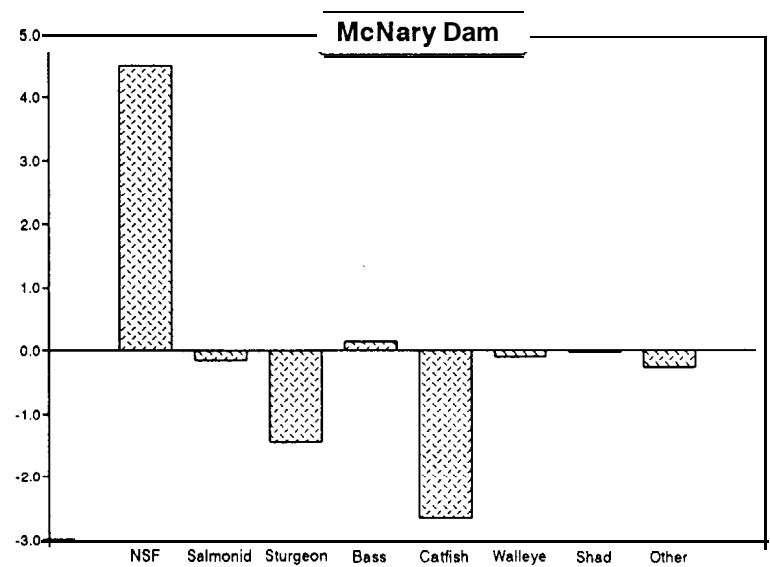
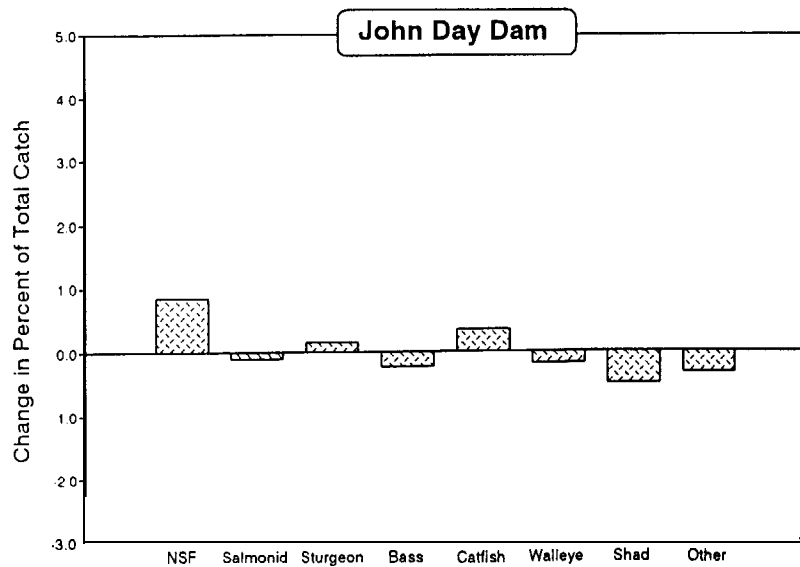
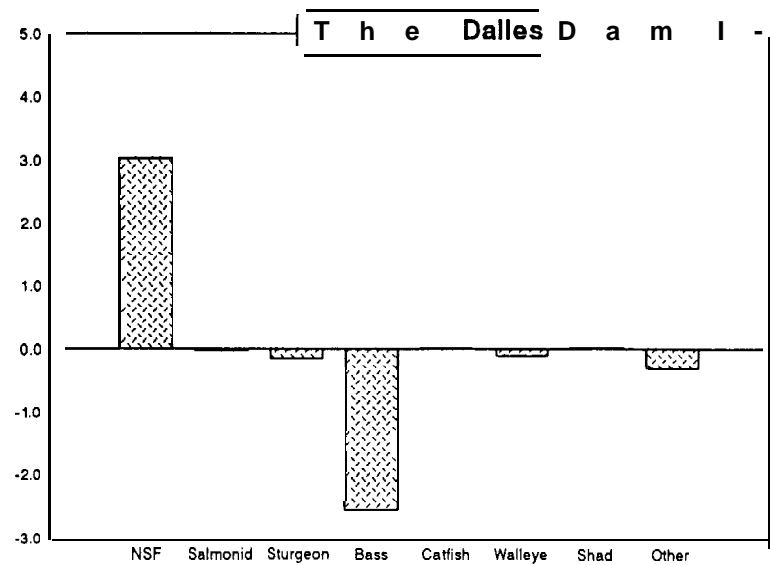
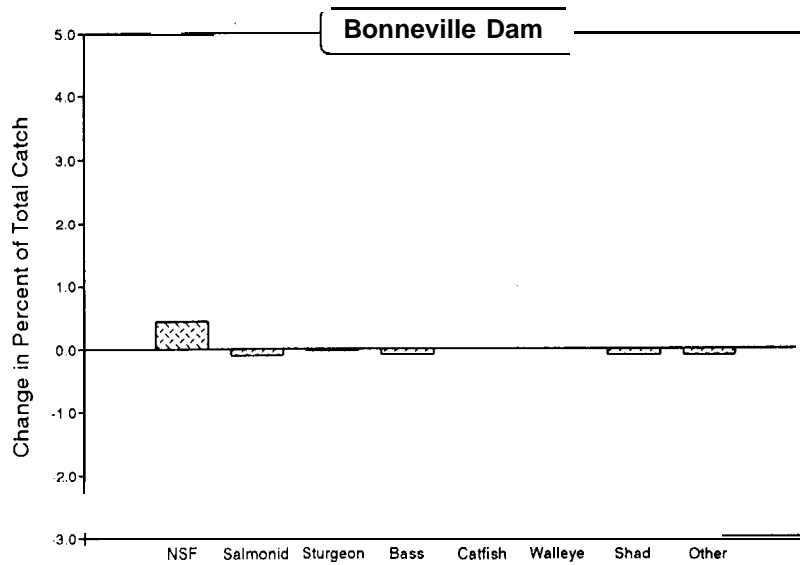


Figure C-9. Difference in percent of total catch of northern squawfish (NSF) and incidentally caught species between 1991 and 1992 at individual Columbia River dams. Values were obtained by subtracting percent of total catch in 1991 from percent of total catch in 1992.

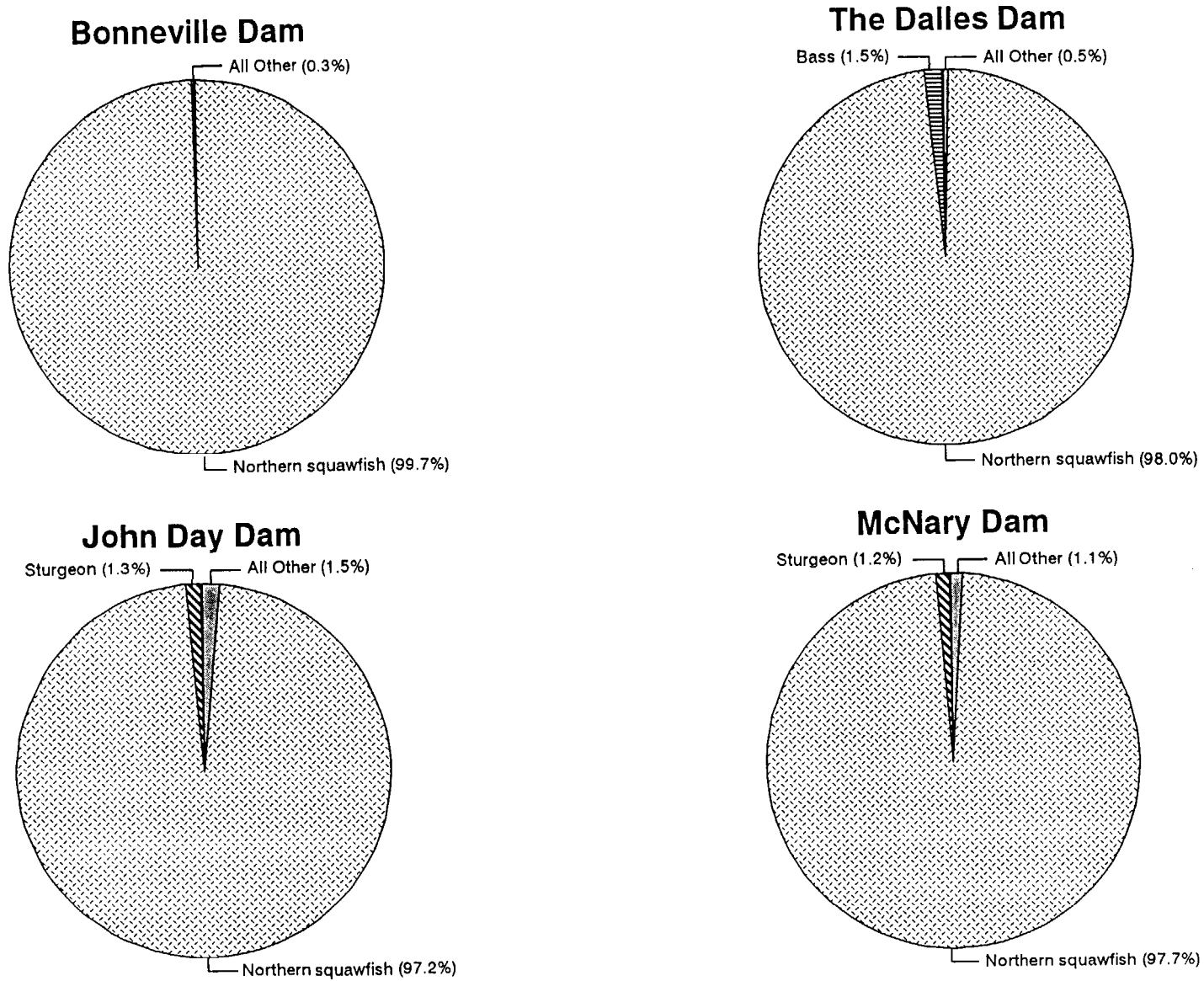


Figure C-8. Total catch percentages in 1992 for individual dams on the Columbia River. Individual species are displayed when they constitute 1 percent or more of the total catch; otherwise, they are combined with "All other."

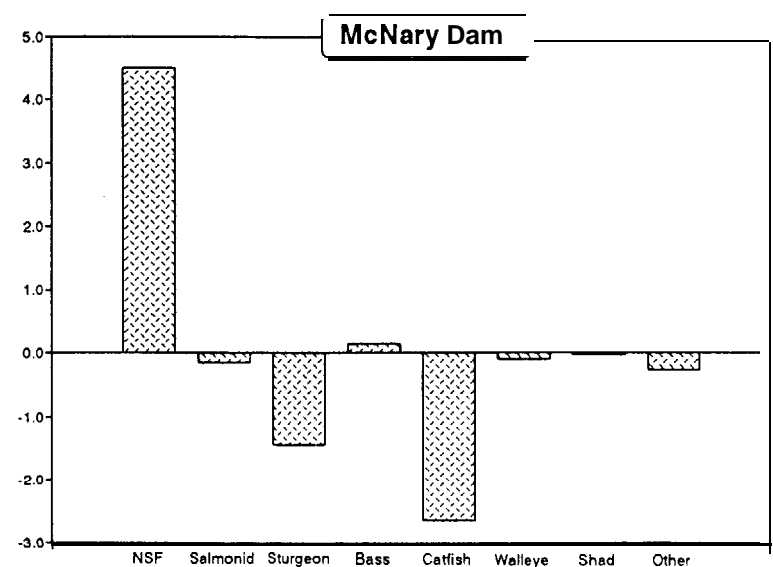
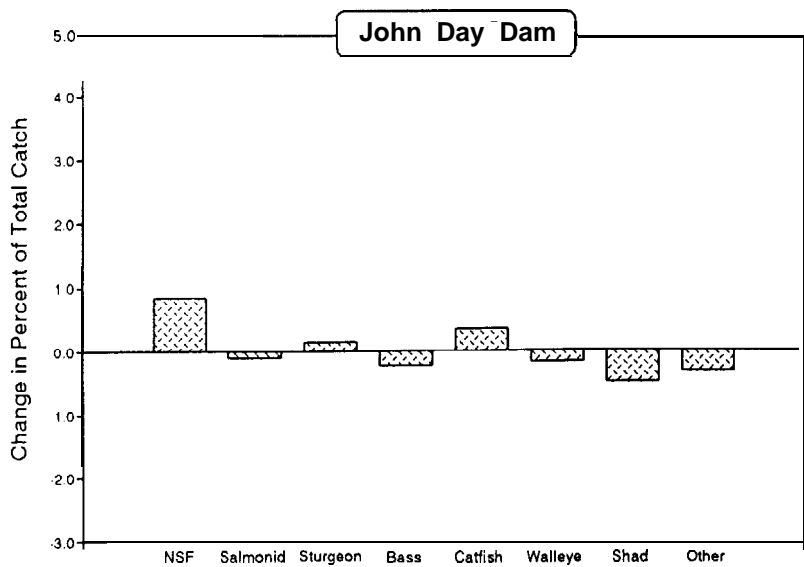
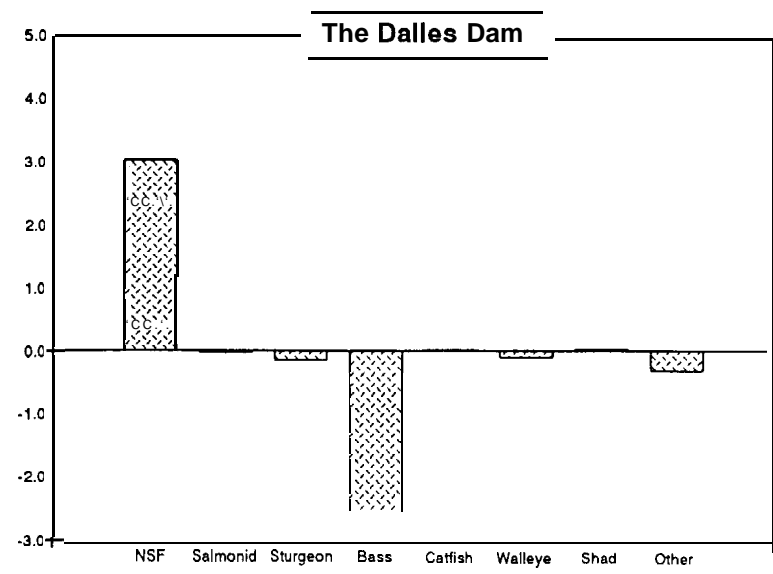
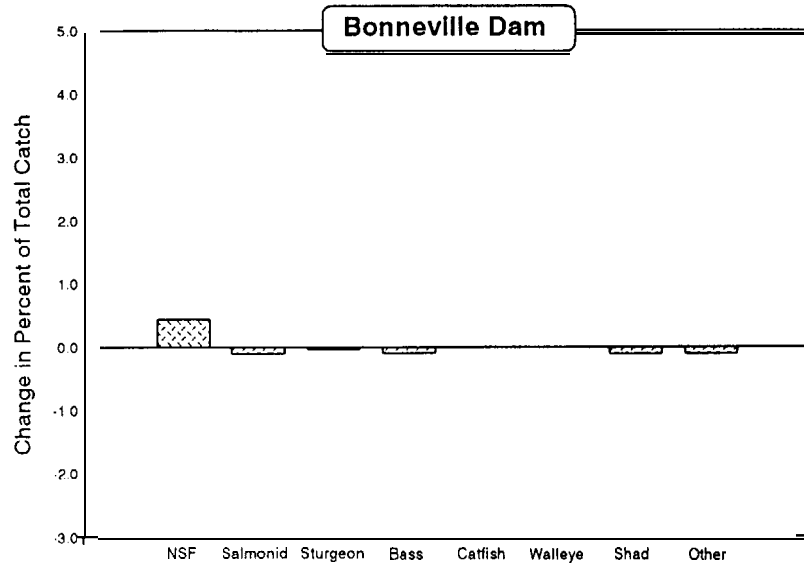


Figure C-9. Difference in percent of total catch of northern squawfish (NSF) and incidentally caught species between 1991 and 1992 at individual Columbia River dams, Values were obtained by subtracting percent of total catch in 1991 from percent of total catch in 1992.

John Day Dam

At John Day Dam, 99 fish (2.81% of total catch) were incidentally caught in 1992 (Appendix Tables A-12 and A-13), down from 190 fish (3.65 % of total catch) in 1991. Sturgeon accounted for the largest proportion of the incidental catch (45.4%) and composed 1.28% of total catch in 1992 (Figure C-8), up from the previous year (Figure C-9). A greater proportion of catfish was caught in 1992 (0.85% of total catch) than in 1991 (0.50% of total catch). One juvenile salmonid (0.03% of total catch) and no adults were caught at John Day Dam in 1992, compared to seven adults and no juveniles the previous year. Walleye, bass, shad, and “other” species constituted smaller proportions of the total catch in 1992 than in 1991 (Figure C-9).

McNary Dam

At McNary Dam, 173 fish (2.32% of total catch) were incidentally caught in 1992 (Appendix Tables A-12 and A-13), down from 611 fish (6.56% of total catch) in 1991. Sturgeon accounted for half of the incidental catch and composed 1.16% of the total catch in 1992 (Figure C-8), which was down from 1991 (Figure C-9). Fewer catfish were caught in 1992 (48) than in 1991 (295). No salmonids were caught in 1992 at McNary Dam, compared to 14 salmonids (five juveniles and nine adults) caught in 1991 (Figure C-9). A slightly larger proportion of bass was caught in 1992 than in 1991 (Figure C-9).

Snake River Dams

At Snake River dams, 1,267 fish were incidentally caught, which was 21.0% of the total catch in 1992 (Appendix Tables A-10 and A-11, which contain data presented in this paragraph). Forty-six percent fewer fish were incidentally caught in 1992 than in 1991 (2,346). Catfish (79.1%) and bass (11.9%) composed the highest proportions of the incidental catch. Salmonids (four adults and 18 juveniles) composed 0.36% of the total catch at Snake River dams in 1992, down from 17 adult and 62 juvenile salmonids (0.47% of total catch) in 1991. In 1992, a larger proportion of the total catch consisted of sturgeon, bass, and catfish than in 1991, due primarily to the decline in northern squawfish catch in 1992 (Figure C-7).

Ice Harbor Dam

At Ice Harbor Dam, 143 fish (34.0% of total catch) were incidentally caught in 1992 (Appendix Tables A-14 and A-15), down from 924 fish (38.3% of total catch) the previous year. Catfish accounted for the largest proportion of the incidental catch (94.4%) and 32.1% of the total catch in 1992 (Figure C-10), which was down from 1991 (Figure C-11). No salmonids were caught in 1992 at Ice Harbor Dam, compared to three salmonids (two adults and one juvenile) caught in 1991 (Figure C-11). All species caught incidentally constituted smaller proportions of the total catch in 1992 than in 1991 (Figure C-11).

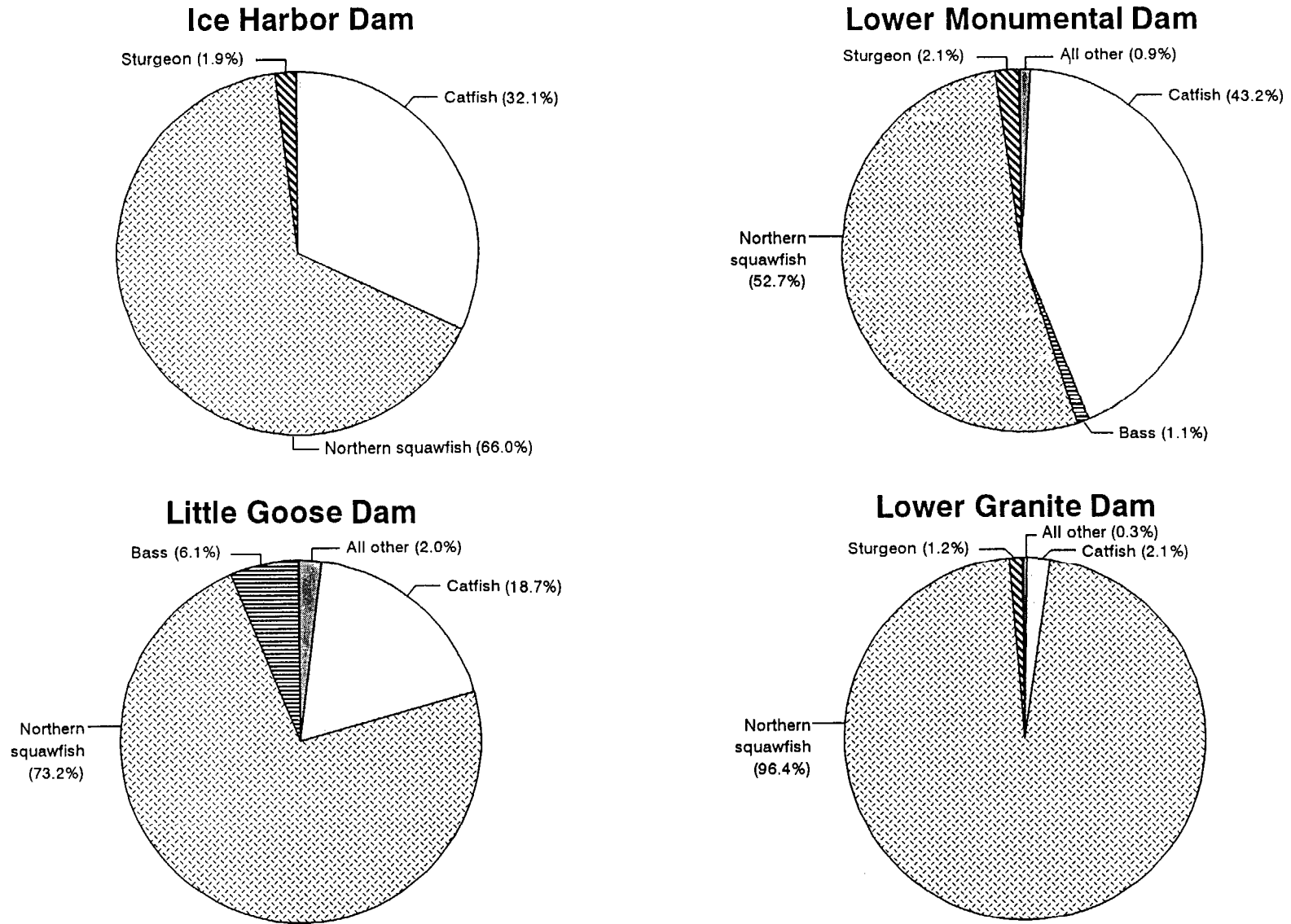


Figure C-10. Total catch percentages in 1992 for individual dams on the Snake River. Individual species are displayed when they constitute 1 percent or more of the total catch; otherwise, they are combined with "All other."

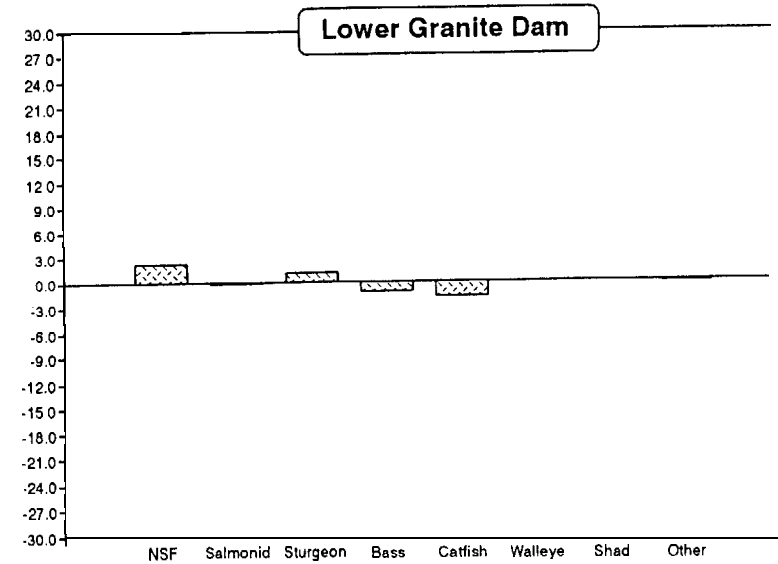
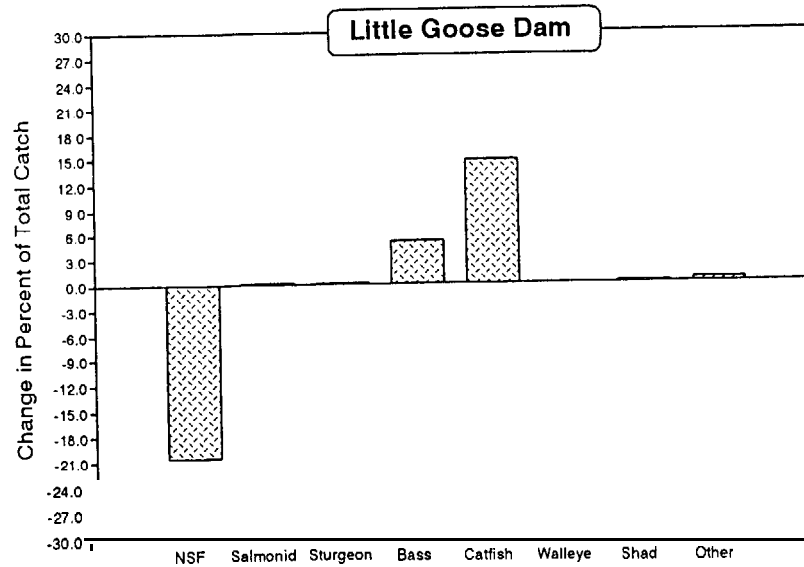
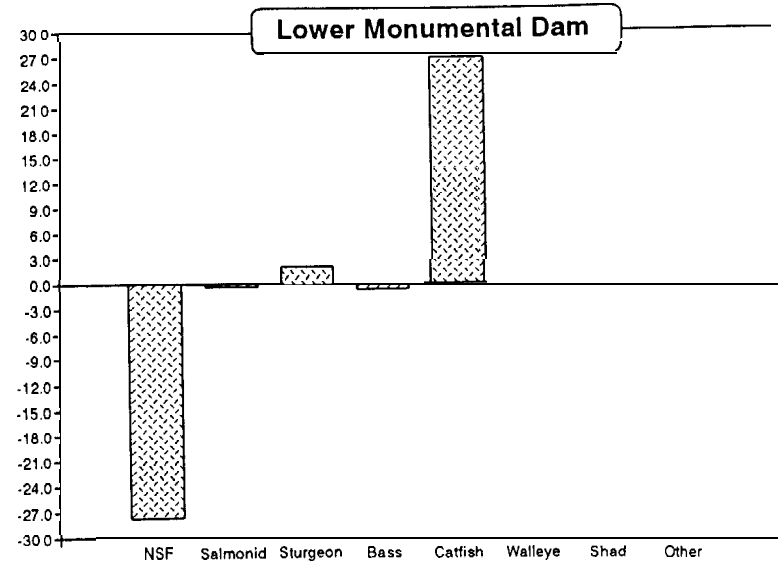
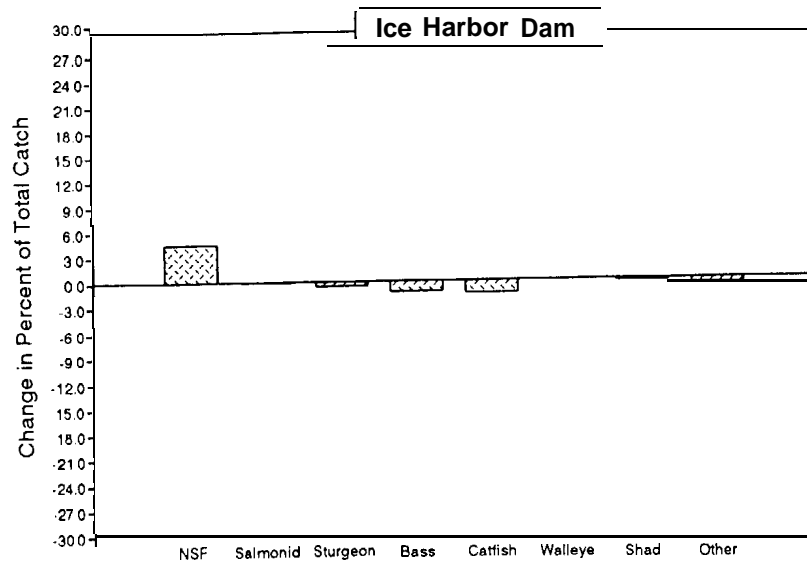


Figure C-11. Difference in percent of total catch of northern squawfish (NSF) and incidentally caught species between 1991 and 1992 at individual Snake River dams. Values were obtained by subtracting percent of total catch in 1991 from percent of total catch in 1992.

Lower Monumental Dam

At Lower Monumental Dam, 427 fish (47.3% of total catch) were incidentally caught in 1992 (Appendix Tables A-14 and A-15), down from 817 fish (19.7% of total catch) in 1991. Catfish were the largest component of the incidental catch, followed by sturgeon and bass (Figure C-10). Four salmonids (three adults and one juvenile) were caught at Lower Monumental Dam in 1992, compared to eight adult and 27 juvenile salmonids caught in 1991. Compared to 1991, proportions of catfish and sturgeon caught increased in 1992, while the proportions of salmonids and bass declined (Figure C-11).

Little Goose Dam

At Little Goose Dam, 610 fish (26.8% of total catch) were incidentally caught in 1992 (Appendix Tables A-14 and A-15), up from 329 fish (6.27% of total catch) in 1991. As in 1991, catfish and bass constituted the largest proportions of the incidental catch in 1992 (Figure C-10). One adult and 14 juvenile salmonids (0.66% of total catch) were caught at Little Goose Dam in 1992, down from five adult and 23 juvenile salmonids (0.54% of total catch) caught in 1991 (Figure C-11). Three sturgeon (0.13 % of total catch) were caught in 1992, compared to one the previous year.

Lower Granite Dam

At Lower Granite Dam, 87 fish (3.57% of total catch) were incidentally caught in 1992 (Appendix Tables A-14 and A-15), down from 276 fish (5.80 % of total catch) the previous year. Catfish and sturgeon composed the largest proportions of the incidental catch in 1992 (Figure C-10) and in 1991. Three juvenile salmonids (0.12% of total catch) were caught in 1992, down from two adult and 11 juvenile salmonids (0.27% of total catch) the previous year. In 1992, catches of bass, catfish, and "other" species also decreased relative to 1991 (Figure C-11). The catch of sturgeon increased slightly in 1992 (Figure C-11).

DISCUSSION

Northern Squawfish Catch

The changes in CPAH observed within and between years at Columbia and Snake river dams reflect changes in population size and/or catchability of fish near dams. This relationship is expressed symbolically as:

$$C/f = qN$$

where

C/f = (catch/effort) or catch per unit effort, in our case CPAH;
qN = (catchability coefficient * population size) or availability (for review see Ricker 1975).

There are many factors that might affect availability of fish and as a result cause differences in catch-rates among locations and over time.

Here we discuss some factors that potentially affect our catch rates at Columbia and Snake river dams. We recognize that other factors not addressed here -- expertise of anglers and weather conditions, for example -- may also be influential. Considerably more research would be required to fully explain the factors affecting northern squawfish abundance, their catchability, and, therefore, our catch rates. References to changes in catches and catch rates between 1991 and 1992 do not imply that those changes necessarily define a trend, particularly in the abundance of predaceous northern squawfish.

Columbia River Dams

The combined seasonal catch rate at Columbia River dams decreased slightly from 1991 to 1992, although seasonal catch rates at two of the four dams (The Dalles and McNary) increased (Table 3). Some factors that may have influenced changes in catch rates are described below.

Adjustments of Effort

Effort in 1992 was concentrated in months and at dams that were most productive in 1991. In 1992, a greater proportion of total effort was shifted to Columbia River dams and concentrated during mid-season, which successfully anticipated the high catch rates that recurred at those dams and times in 1992 (Table 3). Effort at Columbia River dams in 1992 was also augmented with supplemental angling activities (e.g., mobile crew, volunteer angling, boat angling). However, because of the relatively early and warm spring in 1992, we may have missed some productive weeks before the crews started working at Columbia River dams. Start dates that can be adjusted (by a couple weeks) depending on whether the spring is cool (as in 1991) or warm (as in 1992) could help us adapt to differences among years.

As we concentrate effort more in space and time, we expect that catch rates will decline. Rates of predator removal in the relatively small areas near the dams may exceed migration (or "recruitment") into those areas (see following section, ***Previous Removals***). Catch **rates** (e.g., CPAH) at Columbia River dams may have been higher in 1992 if effort had been lower, but **catches** would have been lower.

Previous Removals

In 1990 and 1991, roughly 175,000 northern squawfish were reportedly removed from the lower Columbia River (from the tailrace of McNary Dam to the tailrace of Bonneville Dam) by predator control program fisheries (Nigro 1990, Willis and Nigro 1991). In 1992, approximately 145,000 northern squawfish were reportedly removed from this same area (field activity reports 1992). Previous removals, however, will reduce population size within a given area only if recruitment is less than the exploitation rate (Ricker 1975).

“Recruitment” here applies both to growth of new individuals into the vulnerable population and immigration. Preliminary analysis of 1991 dam angling data has shown that catch rates at dams decrease over the days within each week that crews work (D. Neeley, unpublished data), suggesting that the rate of migration into areas near dams is not high in the short-term (i.e., day-to-day). However, an analogous decline across years has *not* been observed (Table 3), perhaps because recruitment (i.e., growth *and* immigration) has compensated for previous removals. Also, previous removals may not have been sufficient to cause a ***detectable*** reduction in our catch rates. Regardless, the collective efforts of the predator control program fisheries over the past three years have removed large numbers of predators from the lower Columbia River. Continued removals throughout this reach in coming years will probably decrease the number of fish available (in adjacent river areas) to migrate into areas near Columbia River dams. Not until this time are we likely to see appreciable and sustained decreases in both catch and catch rates at these dams.

Bird Wires

Recently installed bird wires used to protect out-migrating smolts from bird predation at John Day, The Dalles, and McNary dams have restricted angler access to good fishing areas and reduced the catchability of fish. The location of these wires in tailrace areas has caused crews to change angling techniques that were used successfully before the wires were installed. For example, at John Day Dam, anglers had great success letting baits drift across the face of the powerhouse and casting out far away from the dam. The location of wires across the front of the powerhouse deck prohibited the use of these techniques in 1992. Bird wires caused similar problems at McNary Dam. Because bird wires at The Dalles Dam were located above the heads of anglers, they did not significantly restrict anglers at that dam.

Snake River Dams

In 1992, catch rates decreased substantially at all Snake River dams from the previous year with the exception of Ice Harbor Dam (Table 3). At this point, we do not know the reason for the decline or whether it is the start of a trend. Several factors may have been responsible for the changes in catch rates at these dams.

Adjustments of Effort

On average, catch rates at Snake River dams were lower than catch rates at Columbia River dams in 1991. Therefore, in 1992, we decreased the average crew size at Snake River dams so that proportionately more effort could be spent at Columbia River dams (Table 3). In 1992, crews at Snake River dams started earlier than crews on the Columbia River to take advantage of high catches that were obtained at Snake River dams early in the 1991 season. For this same reason, the mobile crew was deployed to Snake River dams early in the season in 1992 (Table 2).

We had some success with these adjustments of effort at Snake River dams in 1992. Catch rates at Snake River dams were below rates recorded at Columbia River dams in 1992 (Table 3), substantiating our decision to concentrate proportionately more effort at Columbia River dams. Our decision to start resident crews and the mobile crew early on the Snake River did not prove to be productive compared to other alternatives. High catches at Snake River dams early in the 1991 season did not recur in 1992 (Figures C-2 and C-3). Therefore, a greater concentration of effort at Columbia versus Snake River dams early in the season would have yielded better results.

The exceptional (among Snake River dams) increase in CPAH at Ice Harbor Dam from 1991 to 1992 may reflect the large **decrease** (by 81% , Table 3) in effort there. This assumes, as described above, that catch **rate** is inversely related to the level of effort.

Previous Removals

Previous removals may have contributed to the decline in catch rates at Snake River dams in 1992 from 1991. In 1990 and 1991, roughly 45,000 northern squawfish were reportedly removed from the lower Snake River (from the confluence of the Clearwater River to the tailrace of Ice Harbor Dam) by predator control program fisheries (Nigro 1990, Willis and Nigro 1991). In 1992, approximately 40,000 squawfish were reportedly removed from this same area (field activity reports 1992). Based on predation indexing, northern squawfish are less abundant on the Snake River than on the Columbia River (Ward et al. 1991). Therefore, there may be fewer fish available in the reservoirs to migrate into areas around Snake River dams than there are in Columbia River reservoirs.

Reservoir Drawdown Activities

In March of 1992, the reservoirs behind Lower Granite and Little Goose dams were drawn down (36.5 ft and 12.5 ft below minimum operating pool, respectively) to test the physical effects of lowering reservoir levels to help juvenile salmonids in their downstream migration (U.S. Army Corps of Engineers 1992). Northern squawfish, like other fishes in these reservoirs, may have been entrained in the high flows passed through the turbines and over the spillway during drawdown. Several white sturgeon that had been marked and released in Lower Granite Reservoir prior to the drawdown were afterward recaptured in the tailrace of Lower Granite Dam (U.S. Army Corps of Engineers 1992). More data and

analyses are needed to determine to what extent entrainment and other results of drawdown affected changes in catch rates at Snake River dams in 1992.

Bird Wires

Bird wires posed similar problems to anglers at Snake River dams as they did at Columbia River dams. In 1992, bird wires were installed in tailrace areas at each of the Snake River dams. These wires obstructed anglers' ability to fish what were the most productive (measured by total catch) sites in 1991 at Ice Harbor, Little Goose, and Lower Granite dams. Anglers would often tangle their fishing line on these wires, thereby reducing angler effectiveness. The crew at Lower Monumental Dam also reported having difficulty fishing around bird wires.

Supplemental Angling Activities

For both the long-term and short-term comparisons for the mobile crew, our minimum performance standard was the *average* CPAH for alternatives, and the ideal standard was the ***maximum*** CPAH among alternatives, as reflected by the success of resident crews. In the long-term comparison, the mobile crew was below minimum standard in May while stationed on the Snake River, primarily because of the unexpectedly low catches at Little Goose and Lower Granite dams (Table 4). However, the mobile crew performed between minimum and ideal standards during June and July, when they were mostly on the Columbia River. Catch rates were better at Columbia River dams in all months, and the mobile crew could have removed more fish if we had deployed them to Columbia River dams for the entire season (Tables 3 and 4).

In the short-term comparison, the mobile crew did well while on the Snake River, with an overall CPAH that equalled the ideal standard (Table 5). However, the crew could have been used more effectively while on the Columbia River, where its overall CPAH did not meet the minimum standard. The crew's performance may have been better had we been more willing to incur the travel-related expenses of sending them from their station in The Dalles to McNary Dam (over 100 miles away), where catch rates were often high relative to other Columbia River dams.

Preliminary results (i.e., CPAH) suggest that volunteer angling may be effective in targeting productive times and locations, as might boat angling. For example, volunteers can easily fish short 2-4 hour periods in the evening when catch rates are exceptionally high (e.g., at Bonneville Dam's first powerhouse). Personnel management constraints make it more difficult for crews of technicians to work such short hours; those crews will usually have to fish some relatively less productive hours before and/or after the short periods when catches peak. Neither volunteer angling nor boat angling were thoroughly tested in 1992.

Incidental Catch

The incidental catch of other species at all dams combined was much less in 1992 than in 1991, both in absolute numbers (Beaty et al. 1991, Appendix Table A-10, Appendix Table A- 15) and proportion of total catch (Figure C-7). Measures implemented in 1992 to reduce incidental catch (**see METHODS, Field Procedures**) probably contributed to the decline. Also, the same unidentified factors that caused substantially lower catches of northern squawfish at Snake River dams in 1992 may have contributed to changes in incidental catch at those dams.

The incidental catch decreased relative to catches in 1991 at each dam except for Lower Monumental Dam (increase in proportion of total catch) and Little Goose Dam (increase in both proportion of total catch and absolute numbers; Appendix Tables A-12 through A-15, Beaty et al. 1991, Appendix Tables A-10 through A- 13). An increase in the catch of catfish accounts for most of the increase in incidental catch at both dams in 1992. Relatively low catch rates of northern squawfish at these dams may have prompted anglers to explore other angling methods (e.g., fishing closer to the river bottom) that led to greater catches of catfish. A reduction in catch rates for northern squawfish probably also contributed to the increase in the **proportions** of catfish and other incidental species at Lower Monumental and Little Goose dams in 1992 relative to 1991.

RECOMMENDATIONS

1. Continue controlled angling fisheries at all eight dams.
2. Continue to shape effort at the dams to be more effective and efficient:

<u>Dam</u>	<u>Anglers</u>	<u>Season & Notes</u>
Bonneville	5	May/June to August/September
The Dalles	6	May to September
John Day	5	May to September
McNary	8	May/June to August
Ice Harbor/ L. Monumental	3	May/June to August. Both dams will be staffed by a single crew that moves between them.
Little Goose/ Lower Granite	5	April/May to September. Both dams will be staffed by a single crew that moves between them.

3. Use a mobile crew to augment resident crew efforts. Crew will consist of five anglers and will work the entire season at Columbia River dams to take advantage of higher catch rates observed there. We will locate the crew to work the most productive dams on the Columbia River, taking into account travel-related costs.
4. Continue efforts to determine the feasibility of controlled boat angling in the boat-restricted zones at some dams (e.g., The Dalles, John Day, and McNary) where northern squawfish are known to be abundant and are inaccessible to dam-based anglers.
5. Increase the use of controlled volunteer angling at high catch dams, specifically Bonneville, The Dalles, and McNary. These efforts will be concentrated during weekends and at peak catch hours (dawn and dusk). All effort will be supervised by project staff and/or technicians and will be coordinated closely with the Corps of Engineers.
6. Work with Animal Damage Control and Corps biologists to relocate bird wires to increase angler access to good fishing sites, while at the same time protecting juvenile salmonids from bird predation.
7. Continue to seek more effective lures and baits for controlled angling fisheries.
8. Conduct limited biological sampling on the many *incidentally* caught channel catfish at McNary Dam and the four dams on the lower Snake River. Information gathered will help determine the extent to which catfish prey on salmonid smolts.
9. Develop and evaluate some alternative methods to capture northern squawfish where they concentrate in the mainstem, particularly near hatchery release points.
10. Identify concentrations of northern squawfish in the lower reaches of some Snake and Columbia river tributaries above Bonneville Dam, and determine the extent to which these concentrations comprise members of mainstem populations.
11. Continue analysis of data to better understand factors affecting catch.
12. Promote the development and implementation of effective and efficient squawfish control methods.

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APPENDIX A

**Lure and Bait Descriptions and
Tabular Data Regarding Angler Effectiveness
and Incidental Catches**

Appendix Table A-1. Lures and baits used by anglers at the Columbia and Snake River dams in 1992.

Category & type	Description	Color/condition ,
<u>HARD LURES</u>		
Kastmaster	metal spoon	chrome
Roostertail	metal spinner	black
Vibrax spinner	spinner	chrome
Zonar blade	metal blade	chrome
Steely	metal spoon	chrome
Rat-L-Trap	hard plastic plug, diving	blue, silver, black, scale, tiger perch; various combinations
Electric shad	hard plastic plug, diving	shad finish
<u>SOFT LURES</u>		
Grub	plastic; often augmented with scent	black, blue, brown, white, chartreuse, yellow, glo-in-the-dark, red, dark-green, purple, speckled (various color combinations);
Twin-tailed grub		
Tube tails		
Fish-like		
Slug		
<u>BAIT</u>		
Salmonid smolts	whole, cut	fresh, frozen
Salmonid eggs	whole	cured
Herring	whole, pieces	frozen, salted
Lamprey	whole, cut	fresh, frozen
Squawfish	belly skin	fresh
Nightcrawler, worms	whole or pieces	fresh
Crayfish	whole, pieces	fresh
Shad	juveniles	fresh
Grasshoppers	whole, pieces	fresh

Appendix Table A-Z. Weekly average CPAH at Bonneville Dam, 1992.

Week number ^a	Total hours fished	Number of northern squawfish	CPAH
6	24.0	49	2.0
7	93.0	161	1.7
8	102.3	243	2.4
9	238.1	740	3.1
10	131.6	169	1.3
11	127.4	201	1.6
12	116.6	273	2.3
13	153.0	592	3.9
14	196.4	753	3.8
15	179.5	661	3.7
16	86.5	598	6.9
17	100.1	204	2.0
18	95.7	130	1.4
19	82.7	30	0.4
20	54.4	10	0.2
Seasonal totals	1,781.3	4,814	2.7
Means	118.8	320.9	--

^a Fishing began at Bonneville Dam during Week 6 (5/24/92 - 5/30/92) and ended Week 20 (8/30/92 - 9/5/92) of the field season.

Appendix Table A-3. Weekly average CPAH at The Dalles Dam, 1992.

Week number ^a	Total hours fished	Number of northern squawfish	CPAH
4	33.6	232	6.9
5	45.8	352	7.7
6	65.8	493	7.5
7	133.2	557	4.2
8	240.9	752	3.1
9	145.2	653	4.5
10	161.9	632	3.9
11	165.7	841	5.1
12	205.7	677	3.3
13	185.9	240	1.3
14	169.5	297	1.8
15	165.1	236	1.4
16	221.8	582	2.6
17	125.7	55	0.4
18	116.4	121	1.0
19	125.6	412	3.3
20	111.2	319	2.9
21	77.2	110	1.4
Seasonal totals	2,496.2	7,561	3.0
Means	138.7	420.1	--

^a Fishing began at The Dalles Dam during Week 4 (5/10/92 - 5/16/92) and ended Week 21 (9/6/92 - 9/12/92) of the field season.

Appendix Table A-4. Weekly average CPAH at John Day Dam, 1992.

Week number ^a	Total hours fished	Number of northern squawfish	CPAH
3	71.4	123	1.7
4	178.7	105	0.6
5	143.1	108	0.8
6	175.6	48	0.3
7	122.3	100	0.8
8	96.7	113	1.2
9	186.9	75	0.4
10	194.5	242	1.2
11	135.8	420	3.1
12	205.0	402	2.0
13	126.3	463	3.7
14	136.9	221	1.6
15	147.3	226	1.5
16	206.1	380	1.8
17	183.8	152	0.8
18	149.1	160	1.1
19	100.6	69	0.7
20	137.4	13	0.1
21	77.2	7	0.1
Seasonal totals	2,774.7	3,427	1.2
Means	146.0	180.4	--

^a Fishing began at John Day Dam during Week 3 (5/3/92 - 5/9/92) and ended Week 21 (9/6/92 - 9/12/92) of the field season.

Appendix Table A-5. Weekly average CPAH at McNary Dam, 1992.

Week number ^a	Total hours fished	Number of northern squawfish	CPAH
7	110.7	422	3.8
8	175.4	534	3.0
9	192.1	1006	5.2
10	205.1	1086	5.3
11	221.1	1232	5.6
12	251.5	664	2.6
13	206.3	690	3.3
14	227.1	587	2.6
15	199.1	586	2.9
16	210.6	279	1.3
17	166.2	66	0.4
18	152.6	71	0.5
19	205.3	74	0.4
Seasonal totals	2,523.1	7,297	2.9
Means	194.1	561.3	--

^a Fishing began at McNary Dam during Week 7 (5/31/92 - 6/6/92) and ended Week 19 (8/23/92 - 8/29/92) of the field season.

Appendix Table A-6. Weekly average CPAH at Ice Harbor Dam, 1992.

Week number [']	Total hours fished	Number of northern squawfish	CPAH
7	19.2	5	0.3
8	13.2	5	0.4
9	24.6	40	1.6
10	22.2	48	2.2
11	16.0	86	5.4
12	14.0	2	0.1
13	35.5	29	0.8
14	25.6	21	0.8
15	50.9	15	0.3
16	11.5	5	0.4
17	27.3	17	0.6
18	26.1	5	0.2
19	12.0	0	0.0
Seasonal totals	298.1	278	0.9
Means	22.9	21.4	--

['] Fishing began at Ice Harbor Dam during Week 7 (5/31/92 - 6/6/92) and ended Week 19 (8/23/92 - 8/29/92) of the field season.

Appendix Table A-7. Weekly average CPAH at Lower Monumental Dam, 1992. During the last week of July (Week 15), this crew worked at Ice Harbor Dam.

Week number ^a	Total hours fished	Number of northern squawfish	CPAH
3	74.2	15	0.2
4	93.3	24	0.3
5	92.8	99	1.1
6	75.4	38	0.5
7	89.1	26	0.3
8	93.9	37	0.4
9	65.0	17	0.3
10	43.7	70	1.6
11	57.4	53	0.9
12	72.7	37	0.5
13	36.8	17	0.5
14	12.9	9	0.7
15	0.0	0	--
16	45.5	11	0.2
17	29.8	8	0.3
18	32.1	5	0.2
19	28.5	9	0.3
Seasonal totals	943.1	475	0.5
Means	58.9	29.7	--

^a Fishing began at Lower Monumental Dam during Week 3 (5/3/92 - 5/9/92) and ended Week 19 (8/23/92 - 8/29/92) of the field season.

Appendix Table A-8. Weekly average CPAH at Little Goose Dam, 1992.

Week number ^a	Total hours fished	Number of northern squawfish	CPAH
1	98.5	40	0.4
2	131.3	55	0.4
3	185.5	46	0.2
4	172.9	113	0.7
5	176.5	114	0.6
6	169.1	59	0.3
7	141.8	54	0.4
8	146.7	71	0.5
9	123.8	27	0.2
10	158.6	9	0.1
11	137.7	9	0.1
12	134.0	7	0.1
13	138.4	18	0.1
14	125.5	21	0.2
15	140.1	90	0.6
16	144.6	104	0.7
17	132.1	93	0.7
18	152.8	139	0.9
19	151.9	179	1.2
20	105.5	126	1.2
21	194.5	290	1.5
Seasonal totals	3,061.8	1,664	0.5
Means	145.8	79.2	--

^a Fishing began at Little Goose Dam during Week 1 (4/19/92 - 4/25/92) and ended Week 21 (9/6/92 - 9/12/92) of the field season.

Appendix Table A-9. Weekly average CPAH at Lower Granite Dam, 1992.

Week number ^a	Total hours fished	Number of northern squawfish	CPAH
1	102.9	139	1.4
2	136.0	143	1.1
3	143.7	123	0.9
4	203.1	321	1.6
5	179.5	267	1.5
6	197.7	237	1.2
7	228.7	300	1.3
8	144.2	193	1.3
9	145.9	39	0.3
10	171.8	30	0.2
11	120.8	15	0.1
12	115.3	77	0.7
13	150.8	80	0.5
14	137.4	30	0.2
15	114.4	24	0.2
16	108.1	20	0.2
17	131.2	61	0.5
18	140.0	115	0.8
19	118.7	67	0.6
20	90.3	71	0.8
Seasonal totals	2,880.5	2,352	0.8
Means	144.0	117.6	--

* Fishing began at Lower Granite Dam during Week 1 (4/19/92 - 4/25/92) and ended Week 20 (8/30/92 - 9/5/92) of the field season.

Appendix Table A-10. Monthly catch of incidental species by condition at release for Columbia and Snake river dams, 1992. Condition codes: (1) minimal injury, certain to survive; (2) moderate injury, may or may not survive; (3) dead, nearly dead, or certain to die; (L) line cut or broken, fish not removed from the water.

	Total catch (all species)	Total inci- dental catch	Salmonids				Sturgeon				Bass			Catfish			Walleye			Shad	Other
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3		
COLUMBIA R.																					
May	1,592	82	0	0	0	0	3	7	1	0	4	22	1	1	11	0	0	10	0	2	2
June	8,912	88	10	0	0	0	18	0	0	10	12	0	0	25	1	0	0	0	0	9	12
July	9,016	93	0	0	0	0	32	0	0	11	23	0	0	16	0	0	2	0	0	8	1
August	3,583	131	0	0	0	0	25	0	0	12	62	0	1	13	1	0	4	0	0	11	2
Sept	435	45	10	0	0	0	3	1	0	5	19	2	0	12	0	0	10	0	0	1	0
Season	23,538	439	2	0	0	0	115	2	0	42	138	3	2	77	2	0	5	0	0	31	17
SNAKE R.																					
April	434	57	3	0	0	1	2	0	0	3	0	0	0	42	1	1	0	0	0	0	4
May	1,675	219	2	0	0	3	4	0	0	11	26	0	1	158	6	1	0	0	0	1	6
June	1,265	254	0	0	0	0	5	0	0	14	19	0	0	206	6	0	0	0	0	0	4
July	978	378	0	0	0	0	3	0	0	6	39	0	4	304	4	5	0	0	0	2	11
August	1,188	317	13	0	0	0	0	0	0	10	49	0	0	234	5	1	0	0	0	0	5
Sept	496	42	0	0	0	0	0	0	0	0	13	0	0	28	0	0	0	0	0	0	1
Season	6,036	1,267	1a	0	0	4	14	0	0	44	146	0	5	972	22	8	-6	0	0	3	31
GRAND TOTAL																					
April	434	57	3	0	0	1	2	0	0	3	0	0	0	42	1	1	0	0	0	0	4
May	3,267	301	2	0	0	3	41	1	0	15	48	1	2	169	6	1	10	0	0	3	8
June	10,177	342	10	0	0	0	23	0	0	24	31	0	0	231	7	0	0	0	0	9	16
July	9,994	471	0	0	0	0	35	0	0	17	62	0	4	320	4	5	2	0	0	10	12
August	4,771	448	13	0	0	0	25	0	0	22	111	0	1	247	6	1	4	0	0	11	7
Sept	931	87	10	0	0	0	3	1	0	5	32	2	0	40	0	0	1	0	0	1	1
Season	29,574	1,706	20	0	0	4	129	2	0	86	284	3	7	1,049	24	8	8	0	0	34	48

Appendix Table A-11. Monthly species composition of dam angling catch for Columbia and Snake river dams, 1992.

Month	Percent northern squawfish in total catch	Percent incidental species in total catch	Percent of total catch (all species)						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
<u>COLUMBIA R.</u>									
May	94.85	5.15	0.00	2.64	1.51	0.69	0.06	0.13	0.13
June	99.01	0.99	0.01	0.31	0.13	0.29	0.00	0.10	0.13
July	98.97	1.03	0.00	0.48	0.25	0.18	0.02	0.09	0.01
August	96.34	3.66	0.00	1.03	1.76	0.39	0.11	0.31	0.06
Sept	89.66	10.34	0.23	2.07	4.83	2.76	0.23	0.23	0.00
Season	98.13	1.87	0.01	0.68	0.61	0.34	0.03	0.13	0.07
<u>SNAKE R.</u>									
April	86.87	13.13	0.92	1.15	0.00	10.14	0.00	0.00	0.92
May	86.93	13.07	0.30	0.89	1.61	9.85	0.00	0.06	0.36
June	79.92	20.08	0.00	1.50	1.50	16.76	0.00	0.00	0.32
July	61.35	38.65	0.00	0.92	4.40	32.00	0.00	0.20	1.12
August	73.32	26.68	1.09	0.84	4.12	20.20	0.00	0.00	0.42
Sept	91.53	8.47	0.00	0.00	2.62	5.65	0.00	0.00	0.20
Season	79.01	20.99	0.36	0.96	2.50	16.60	0.00	0.05	0.51
<u>GRAND TOTAL</u>									
April	86.87	13.13	0.92	1.15	0.00	10.14	0.00	0.00	0.92
May	90.79	9.21	0.15	1.74	1.56	5.39	0.03	0.09	0.24
June	96.64	3.36	0.01	0.46	0.30	2.34	0.00	0.09	0.16
July	95.29	4.71	0.00	0.52	0.66	3.29	0.02	0.10	0.12
August	90.61	9.39	0.27	0.99	2.35	5.32	0.08	0.23	0.15
Sept	90.66	9.34	0.11	0.97	3.65	4.30	0.11	0.11	0.11
Season	94.23	5.77	0.08	0.73	0.99	3.66	0.03	0.11	0.16

Appendix Table A-12. Monthly catch of incidental species by condition at release for Columbia River dams, 1992. Condition codes: (1) minimal injury, certain to survive; (2) moderate injury, may or may not survive; (3) dead, nearly dead, or certain to die; (L) line cut or broken, fish not removed from the water.

Month	Total catch (all species)	Total incidental catch	Salmonids				Sturgeon				Bass			Catfish			Walleye			Shad	Other
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3		
BONNEVILLE																					
May	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	1,384	2	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	2,419	8	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0
Aug	971	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Sept	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	4,827	13	10	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
THE DALLES																					
May	1,102	25	0	0	0	2	0	0	1	19	1	1	0	0	0	0	0	0	0	0	1
June	2,973	21	0	0	0	3	0	0	1	10	0	0	0	0	0	0	0	0	0	4	3
July	1,965	32	0	0	0	6	0	0	0	22	0	0	10	0	0	2	0	0	0	1	0
Aug	1,287	57	0	0	0	6	0	0	2	44	0	1	0	0	0	2	0	0	0	1	1
Sept	388	19	0	0	0	0	0	0	4	15	0	0	0	0	0	0	0	0	0	0	0
Total	7,715	154	0	0	0	17	0	0	8	110	1	2	10	0	0	4	0	0	0	6	5
JOHN DAY																					
May	441	57	0	0	0	3	5	1	0	3	3	0	0	11	0	0	10	0	2	1	
June	733	6	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	0	1
July	1,537	2	0	0	0	0	0	0	0	1	0	0	10	0	0	0	0	0	0	0	0
Aug	772	8	0	0	0	0	0	0	1	10	0	0	2	0	0	2	0	0	2	0	
Sept	43	26	10	0	0	3	1	0	1	4	2	0	12	0	0	10	0	0	1	0	
Total	3,526	99	10	0	0	38	2	0	5	10	2	0	30	0	0	4	0	0	5	2	
McNARY																					
June	3,822	59	0	0	0	14	0	0	9	10	0	0	21	1	0	0	0	0	5	8	
July	3,095	51	0	0	0	25	0	0	11	0	0	0	14	0	0	0	0	0	0	0	1
Aug	553	63	0	0	0	19	0	0	9	17	0	0	11	1	0	0	0	0	5	1	
Total	7,470	173	0	0	0	58	0	0	29	18	0	0	46	2	0	0	0	0	10	10	

Appendix Table A-13. Monthly species composition of dam angling catch for Columbia River dams, 1992.

Month	Percent northern squawfish in total catch	Percent incidental species in total catch	Percent of total catch (all species)						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
<u>BONNEVILLE</u>									
May	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June	99.86	0.14	0.07	0.07	0.00	0.00	0.00	0.00	0.00
July	99.67	0.33	0.00	0.04	0.00	0.00	0.00	0.29	0.00
Aug	99.69	0.31	0.00	0.00	0.00	0.00	0.00	0.31	0.00
Sept	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Season	99.73	0.27	0.02	0.04	0.00	0.00	0.00	0.21	0.00
<u>THE DALLES</u>									
May	97.73	2.27	0.00	0.27	1.91	0.00	0.00	0.00	0.09
June	99.29	0.71	0.00	0.13	0.34	0.00	0.00	0.13	0.10
July	98.37	1.63	0.00	0.31	1.12	0.05	0.10	0.05	0.00
Aug	95.57	4.43	0.00	0.62	3.50	0.00	0.15	0.08	0.08
Sept	95.10	4.90	0.00	1.03	3.87	0.00	0.00	0.00	0.00
Season	98.00	2.00	0.00	0.32	1.46	0.01	0.05	0.08	0.06
<u>JOHN DAY</u>									
May	87.07	12.93	0.00	8.84	0.68	2.49	0.23	0.45	0.23
June	99.18	0.82	0.00	0.00	0.14	0.54	0.00	0.00	0.14
July	99.87	0.13	0.00	0.00	0.06	0.07	0.00	0.00	0.00
Aug	98.96	1.04	0.00	0.13	0.13	0.26	0.26	0.26	0.00
Sept	39.53	60.47	2.32	11.63	13.95	27.91	2.33	2.33	0.00
Season	97.19	2.81	0.03	1.28	0.34	0.85	0.11	0.14	0.06
<u>MCNARY</u>									
June	98.46	1.54	0.00	0.60	0.03	0.57	0.00	0.13	0.21
July	98.35	1.65	0.00	1.16	0.00	0.45	0.00	0.00	0.03
Aug	88.61	11.39	0.00	5.06	3.07	2.17	0.00	0.90	0.18
Season	97.68	2.32	0.00	1.16	0.24	0.64	0.00	0.13	0.13

Appendix Table A-14. Monthly catch of incidental species by condition at release for Snake River dams, 1992. Condition codes: (1) minimal injury, certain to survive; (2) moderate injury, may or may not survive; (3) dead, nearly dead, or certain to die; (L) line cut or broken, fish not removed from the water.

Month	Total catch (all species)	Total incidental catch	Salmonids				Sturgeon				Bass			Catfish			Walleye			Shad	Other
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3		
<u>ICE HARBOR</u>																					
June	147	49	0	0	0	0	2	0	0	0	0	0	0	42	5	0	0	0	0	0	0
July	207	54	0	0	0	0	0	0	0	1	0	0	0	53	0	0	0	0	0	0	0
Aug	67	40	0	0	0	0	0	0	0	5	0	0	0	35	0	0	0	0	0	0	0
Total	421	143	0	0	0	0	2	0	0	6	0	0	0	130	5	0	0	0	0	0	0
<u>LOWER MONUMENTAL</u>																					
May	251	75	10	0	3	0	0	0	3	2	0	0	64	1	0	0	0	0	0	0	1
June	288	115	0	0	0	0	0	0	11	4	0	0	99	0	0	0	0	0	0	0	1
July	264	171	0	0	0	0	0	0	3	10	0	0	165	0	0	0	0	0	0	0	2
Aug	99	66	0	0	0	0	0	0	2	3	0	0	61	0	0	0	0	0	0	0	0
Total	902	427	10	0	3	0	0	0	19	10	0	0	389	1	0	0	0	0	0	0	a
<u>LITTLE GOOSE</u>																					
April	140	45	0	0	0	1	0	0	0	0	0	0	38	1	1	0	0	0	0	0	4
May	445	113	10	0	0	0	0	0	0	22	0	1	78	5	1	0	0	0	0	1	4
June	237	72	0	0	0	0	0	0	0	15	0	0	54	0	0	0	0	0	0	0	3
July	278	137	0	0	0	0	0	0	0	38	0	4	75	4	5	0	0	0	0	2	9
Aug	722	207	13	0	0	0	0	0	3	45	0	0	135	5	1	0	0	0	0	0	5
Sept	452	36	0	0	0	0	0	0	0	13	0	0	22	0	0	0	0	0	0	0	1
Total	2,214	610	14	0	0	1	0	0	3	133	0	5	402	15	8	0	0	0	0	3	26
<u>LOWER GRANITE</u>																					
April	294	12	3	0	0	0	2	0	0	3	0	0	4	0	0	0	0	0	0	0	0
May	979	31	0	0	0	0	4	0	0	a	2	0	16	0	0	0	0	0	0	0	1
June	593	1a	0	0	0	0	3	0	0	3	0	0	11	1	0	0	0	0	0	0	0
July	229	16	0	0	0	0	3	0	0	2	0	0	11	0	0	0	0	0	0	0	0
Aug	300	4	0	0	0	0	0	0	0	0	10	0	3	0	0	0	0	0	0	0	0
Sept	44	6	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
Total	2,439	87	3	0	0	0	12	0	0	16	3	0	51	1	0	0	0	0	0	0	1

Appendix Table A-15. Monthly species composition of dam angling catch for Snake River dams, 1992.

Month	Percent northern squawfish in total catch	Percent incidental species in total catch	Percent of total catch (all species)						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
<u>ICE HARBOR</u>									
June	66.67	33.33	0.00	1.36	0.00	31.97	0.00	0.00	0.00
July	73.91	26.09	0.00	0.48	0.00	25.60	0.00	0.00	0.00
Aug	40.30	59.70	0.00	7.46	0.00	52.24	0.00	0.00	0.00
Season	66.03	33.97	0.00	1.90	0.00	32.07	0.00	0.00	0.00
<u>LOWER MONUMENTAL</u>									
May	70.12	29.88	1.59	1.19	0.80	25.90	0.00	0.00	0.40
June	60.07	39.93	0.00	3.82	1.39	34.37	0.00	0.00	0.35
July	35.23	64.77	0.00	1.14	0.38	62.50	0.00	0.00	0.76
Aug	33.33	66.67	0.00	2.02	3.03	61.62	0.00	0.00	0.00
Season	52.66	47.34	0.44	2.11	1.11	43.24	0.00	0.00	0.44
<u>LITTLE GOOSE</u>									
April	67.86	32.14	0.71	0.00	0.00	28.57	0.00	0.00	2.86
May	74.61	25.39	0.22	0.00	5.17	18.88	0.00	0.22	0.90
June	69.62	30.38	0.00	0.00	6.33	22.78	0.00	0.00	1.27
July	50.72	49.28	0.00	0.00	15.11	30.21	0.00	0.72	3.24
Aug	71.33	28.67	1.80	0.42	6.23	19.53	0.00	0.00	0.69
Sept	92.04	7.96	0.00	0.00	2.88	4.87	0.00	0.00	0.22
Season	73.18	26.82	0.66	0.13	6.07	18.69	0.00	0.13	1.14
<u>LOWER GRANITE</u>									
April	95.92	4.08	1.02	1.70	0.00	1.36	0.00	0.00	0.00
May	96.83	3.17	0.00	1.22	0.20	1.63	0.00	0.00	0.10
June	96.96	3.04	0.00	1.01	0.00	2.02	0.00	0.00	0.00
July	93.01	6.99	0.00	2.18	0.00	4.80	0.00	0.00	0.00
Aug	98.67	1.33	0.00	0.00	0.33	1.00	0.00	0.00	0.00
Sept	86.36	13.64	0.00	0.00	0.00	13.64	0.00	0.00	0.00
Season	96.43	3.57	0.12	1.15	0.12	2.13	0.00	0.00	0.04

REPORT D

**Evaluation of Harvest Technology
for Squawfish Control in Columbia River Reservoirs**

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1992 Annual Report

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RESEARCH SUMMARY

During 1992, the University of Washington (UW) continued its efforts to develop large-scale removal methods for northern squawfish on the Columbia River. At the start of the fourth and possibly final year of harvest technology development and evaluation, the most promising methods for removal that remained untested were mobile floating trap nets and boat-based electrofishing.

Merwin trapping has proven to be successful at capturing squawfish without harming incidental fish species. However, Merwin traps as originally designed and tested are not mobile enough to be operated throughout the Columbia River system. During the past winter (1991-92), a mobile version of the Merwin trap was designed based on major modifications to the prototype mobile trap that was constructed and operated by UW in 1991. It was expected that this newly designed smaller mobile trap would be equally successful in capturing squawfish to the full size stationary Merwin trap; data are contained in this report to indicate this. An in-depth evaluation on the effectiveness of the Merwin trap as a squawfish control mechanism is provided in a Master of Science thesis authored by James Lynch at the University of Washington, April 1993 (Lynch 1993).

Additionally, fishing restrictions and regulations for a potential large-scale floating trap net fishery were also investigated. Such variables as what time of day to operate the traps to avoid incidental capture of salmonids, how to remove incidental salmonids from the trap in the least harmful way, and logistic requirements for operating the newly developed mobile trap were explored. A comprehensive mobile trap site survey was performed on the Columbia and Snake rivers during the winter of 1993 and has been provided to the Oregon Department of Fish and Wildlife (ODFW) under separate cover.

The second gear type to be evaluated in 1992 for large-scale removal of squawfish was boat-based electrofishing. This method has been traditionally used in the ODFW predator indexing efforts and has consistently produced a high rate of squawfish catch per unit of effort. If this gear were used for removal efforts instead of research, catch rates on squawfish could be substantial.

The most prohibitive factor in boat-based electrofishing is the potential harm to incidental species. UW has completed a comprehensive literature survey and synopsis of electrofishing procedures and has been presented in Appendix B (Mahoney et al. 1993).

It is known that squawfish congregate at the dams for feeding and apparently school up in midriver locations for spawning. Since electrofishing for squawfish was restricted at the dams due to incidental salmonid catch criteria, spawning congregations were sought away from the dams where large catches of squawfish might be achieved with very little effort. A portion of this study was dedicated to determining if these spawning concentrations can actually be found and easily removed.

The final task of this project was to present a report that comprehensively discussed all methods that have been investigated for squawfish removal. Each gear was evaluated as to squawfish catch rates, incidental catch rates, ease of deployment, and potential contribution to the overall squawfish removal program. This report was presented to ODFW as a “special issue paper” in October 1992 (Mathews et al. 1993).

MERWIN TRAPPING

Introduction

Merwin traps have been found to be an effective gear for capturing northern squawfish (*Ptychocheilus oregonensis*). In 1991, the University of Washington (UW) caught 4,206 squawfish in a Merwin trap operated in The Dalles Dam cul-de-sac from May through August (Mathews et al. 1991). Results from the 1991 study indicated that floating traps could capture significant numbers of squawfish, but the high degree of incidental catch raised questions as to their potential as a large-scale squawfish removal method. The two main areas of concern regarding this gear observed in 1991 were its high incidental catch of salmonids and its lack of mobility for operating in mid-river locations. In 1992, efforts were directed at resolving these concerns to prepare this gear for large-scale application.

The high incidental catch and potential delay of migrating salmonids was of particular concern to the Fish Passage Advisory Council (FPAC) prior to the 1992 field season. As a result of its concerns, restrictions were placed upon UW operations in 1992 to ensure limited delay and stress to migrating salmonids. Specific criteria (listed in the “Methods” section of this report) were placed on the maximum amount of time salmon could be held and the periods of the day fishing could occur during the course of the season. In addition, alternative methods of incidental catch removal were to be investigated to limit, if not avoid, the use of dipnets. Fishing operations were to be determined by squawfish to salmon catch ratios as well as overall salmon catch rates. These operating criteria created the need to determine the specific times of the day a trap could be fished to maximize squawfish catch while limiting salmonid catch.

Data regarding the physiology of squawfish were again collected in 1992 to relate the efficiency of this gear to the maturity of squawfish during the course of a season. Correlations among environmental conditions, squawfish maturity, and trap catches will provide insight as to what periods of the season trapping effort should be concentrated.

An objective of last season (1991) was to construct and deploy a “mobile” version of the Merwin trap to target mid-reservoir populations of squawfish. The mobile trap that was constructed in 1991 met with limited success. With experience acquired in 1991, it was possible to develop a workable model capable of fishing throughout the Columbia River in 1992.

Floating trap net research was carried out in 1992 with the objective of evaluating its use in a large-scale removal fishery for northern squawfish. This was achieved by improving the efficiency of the stationary Merwin trap and learning specific fish behavioral patterns in the cul-de-sac area around The Dalles Dam. Also, development of an efficient mobile version of the trap was continued. The results from these investigations can be used to determine potential fishing regulations for a large-scale removal fishery in the future.

Methods

Stationary Trap

With the bulk of design and logistical work done in 1991, it was possible to identify seasonal and diurnal periods of fishing that might reduce incidental salmon catch while maintaining a significant squawfish removal effort. As previously stated, determinations regarding fishing times were guided by operational criteria imposed by FPAC. These criteria included:

1. Fishing only in six-hour intervals until a 1:1 salmon to squawfish ratio was exceeded.
2. When a 1: 1 ratio was exceeded, fishing would only be performed at night (roughly 6 p.m. to 6 a.m.).
3. When salmon catch exceeded 40 individuals in a six-hour interval, fishing periods would be shortened to three-hour intervals.
4. When salmon catch exceeded 40 individuals in a three-hour interval, fishing was to be discontinued until ladder counts indicated that salmon catches would decline.
5. Efforts would be made to devise alternative methods for removing salmonids from the trap net other than the use of dipnets.

Based on these FPAC criteria and data collected in 1991 regarding diurnal trends in salmonid abundance, fishing periods were determined that would provide insight into species availability at different periods of the day. Results from 1991 studies indicated that the period from dusk until dawn yielded relatively high squawfish catch rates while minimizing incidental salmon catch. For this reason, fishing occurred during the hours of 6 p.m. to 6 a.m. in time intervals of three to six hours to identify peak squawfish and salmonid catches according to time of day. In addition to these periods, permission was granted by FPAC to carry out daytime fishing experiments to supplement 1991 daytime catch data.

One of our main objectives for the 1992 season was to develop the least harmful way to remove salmonids from the traps. Several methods were employed including zippered pockets in the webbing, lowering the cork line to facilitate release, installing a weir to separate salmon from squawfish and developing an efficient dipnet design and dipnetting

procedure that would limit handling stress on salmonids. Each of these modifications was tested and evaluated with the purpose of determining the least stressful method of removing incidentally encountered salmonids from the trap.

Specific physiological data collected regarding squawfish included lengths and sexes (when possible) of all squawfish. A gonadal somatic index (GSI) ratio of maturing squawfish was determined by comparing gonad weights to total body weights of squawfish. This ratio is an indication of squawfish maturity and can be used to predict the peak vulnerability of squawfish to this gear during the course of a season. In addition to these data, approximately 100 squawfish per week were tagged to estimate squawfish abundance near The Dalles Dam. Detailed information regarding these estimates can be found in Lynch 1993.

Mobile Traps

Development of the mobile trap design began prior to the 1992 field season. With knowledge obtained from operating a prototype mobile trap during the 1991 field season, it became evident that a lightweight, easily trailerable trap design was needed if this gear was to be effective. Plans for a mobile trap were developed prior to the 1992 season and the first mobile trap was completed by the first week of May.

Trap frames were designed to be assembled and disassembled with minimal effort (Appendix A). The mobile traps were composed of lightweight materials to limit the weight and bulk of individual components. Flotation was provided by two aluminum pontoons (24.5' long x 2' wide x 2' deep) that were connected by three aluminum walkways (11' long x 1.5' wide x 3" deep). These walkways were held in place by a series of poles that could be removed to allow collapsing and trailering of components (Appendix A). Netting consisted of 1.25-inch stretched, knotless mesh, identical to that used in the stationary trap.

After the first mobile trap was delivered for use on May 5, 1992, it became evident that the height of the pontoons caused instability in towing and assembly. The individual pontoons tended to roll onto their side making it difficult to connect the walkways. As a result of this observation, modifications in the design were made prior to the construction of the second mobile trap, which was delivered on June 1, 1992. This second trap had pontoons that were 24 feet long by 2 feet wide by 16 inches deep. These pontoons tended to float upright, easing the assembly process.

Experimental mobile traps were fished in a variety of locations in the Columbia and Snake rivers, both near dams and midriver. The main goal of the mobile trap research was to develop and operate this gear in a variety of environmental conditions (e.g., **substrate**, current strength, wind exposure) to see how such variables would affect squawfish catch rates. It was felt that this gear had been proven effective for capturing squawfish in previous seasons and that a better evaluation of its logistical and operable parameters was needed.

In addition to exploring this gear's limitations and capabilities from a mechanistic standpoint, efforts were made to compare the catch efficiency of the mobile trap to the already established, stationary trap fished at The Dalles Dam. Such a comparison would indicate whether a large-scale squawfish removal effort utilizing mobile gear would be practical,

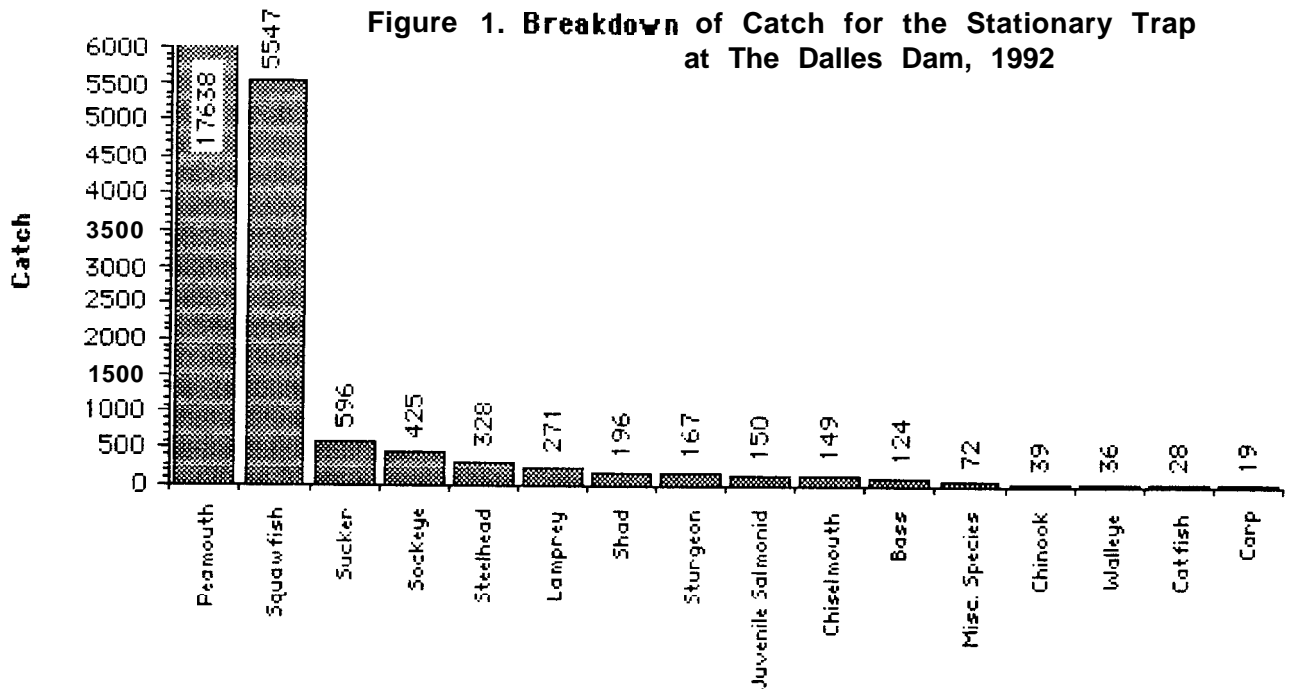
Results

Stationary Trap

Catches of the stationary trap in the cul-de-sac of The Dalles Dam indicate that this gear can be fished in such a manner that limits incidental salmonid catch and delay while maintaining a significant squawfish removal effort. Over 5,500 squawfish were captured during the 1992 season, accounting for 21.5% of the overall catch of all species in the stationary trap (Figures 1 and 2). Squawfish were exceeded only by peamouth (68.4%) in total catch with all species of salmonids comprising 3.63% of the total catch. The salmonid catch decreased by over 82.6% from 1991 levels while the total squawfish catch increased by 31.9% over 1991 levels (Table 1). Comparisons of trap catches with ladder counts in both years indicate that changes in trap operation were primarily responsible for the decreased catch of salmonids in 1992 (Lynch 1993).

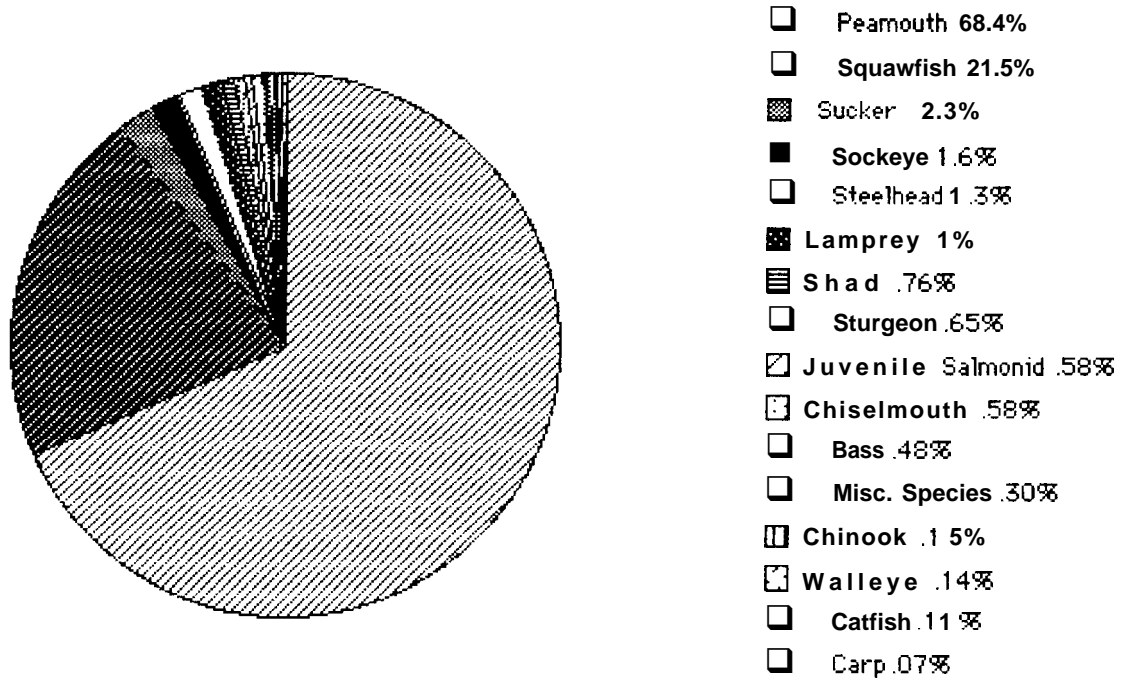
Squawfish catches peaked early in the summer (May 1) and then again late in the summer (August 17) with squawfish catch per hour (cph) peaking during August (Figure 3). The initial peak catch consisted of mature, migrating individuals, whereas the second peak consisted primarily of small, juvenile squawfish (< 250 mm in length). As Figure 4 indicates, catch rates increased in August as average length of squawfish decreased. If the smaller fish (< 250 mm) were excluded from the data in Figure 3, the distribution of catch per hour by week would be more similar to that observed in 1991 (Figure 5). The increased catch of juvenile squawfish in 1992 may indicate a spike in recruitment, a possibility which should be closely monitored.

The overall mean length of squawfish captured in the cul-de-sac declined from 314 mm (N= 1,011) in 1991 to 295 mm (N=2,478) (Figures 6 and 7). The decrease in overall mean length is a direct result of the increased number of juvenile squawfish encountered in 1992. Of the 4,206 squawfish caught in 1991, approximately 3% were less than 250 mm long. Of the 5,547 squawfish captured in 1992, approximately 49% were less than 250 mm in length. This 46% increase in catch of squawfish less than 250 mm resulted from the large number of juvenile squawfish encountered during the month of August.



Misc. species : crappie, sunfish, whitefish, sculpin

Figure 2. Breakdown of Catch for the UW Stationary Trap The Dalles Dam, 1992



**Table 1. Comparison of 1991 and 1992 Mervin Trap Catches
The Dalles Dam Cul-de-sac**

	199 1 Totals	1992 Totals	Percent Change 1991 to 1992
Squawfish	4206	5547	31.9
Salmonids	5427	942	-82.6
Sockeye	2643	425	-83.9
Steelhead	1685	328	-80.5
Chinook	366	39	-89.3
Coho	13	0	-100
Juvenile	720	150	-79.2
Sturgeon	261	167	-36
Walleye	69	36	-47.8
Bass	63	124	96.8
Catfish	25	28	12
Shad	4306	196	-95.4
Chiselmouth	2830	149	-94.7
Peanmouth	1625	17638	985.4
Lamprey	1257	271	-78.4
Sucker	2171	596	-72.5
Carp	22	19	-13.6
Total	22262	25713	15.5
Total Hours Fished	1588.55	1538	-3.2

Figure 3. Catch per Hour of Squavfish for the Stationary Trap at The Dalles Dam, 1992

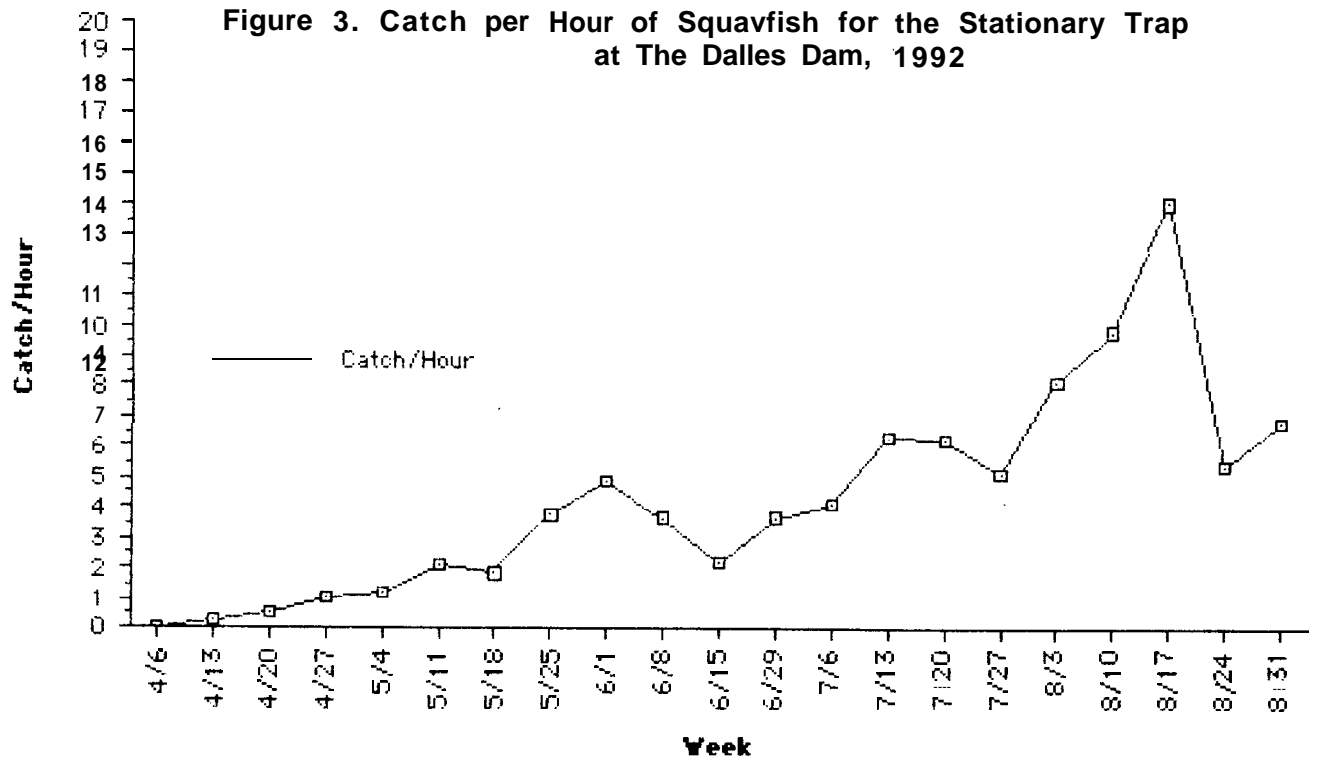


Figure 4. Average Length of Squavfish by Week at The Dalles Dam, 1992

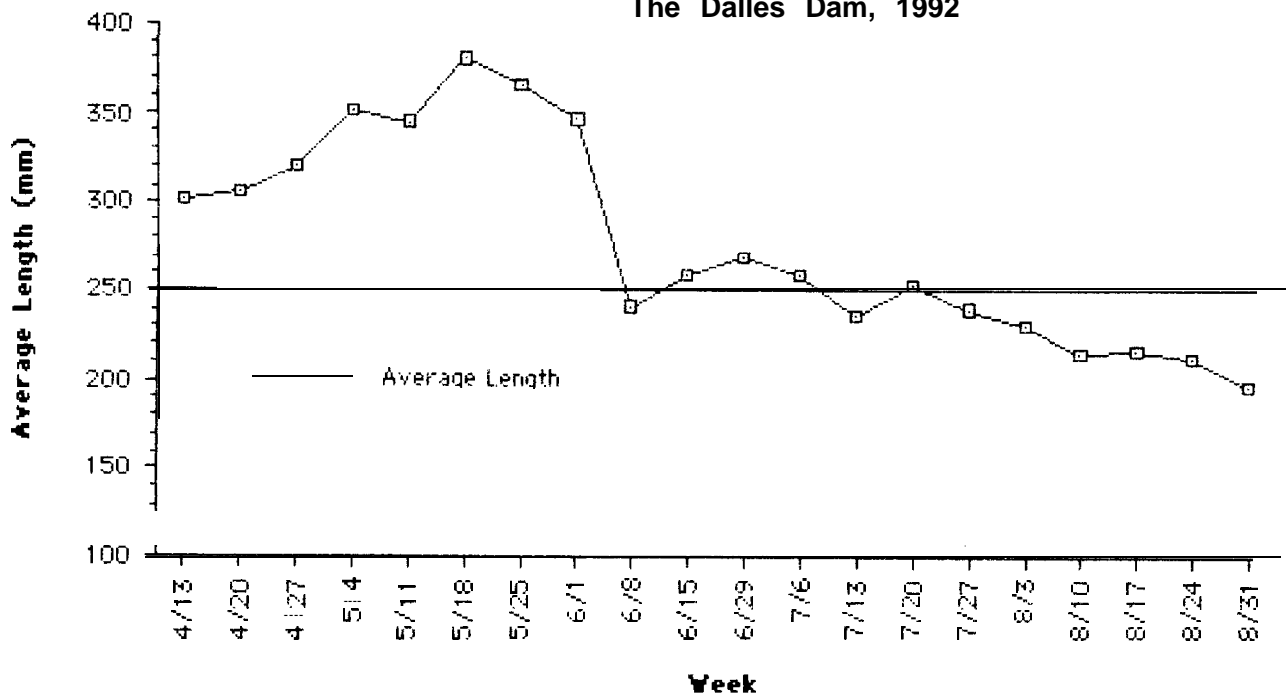
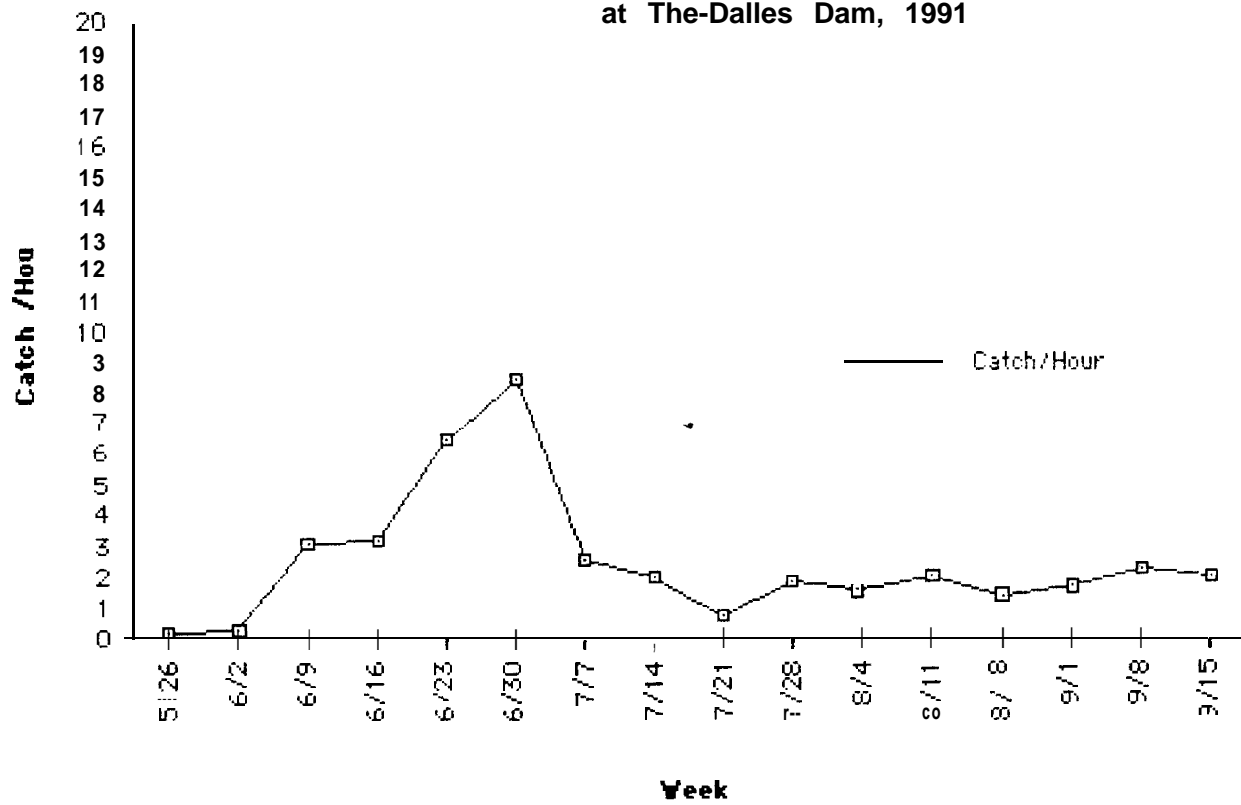
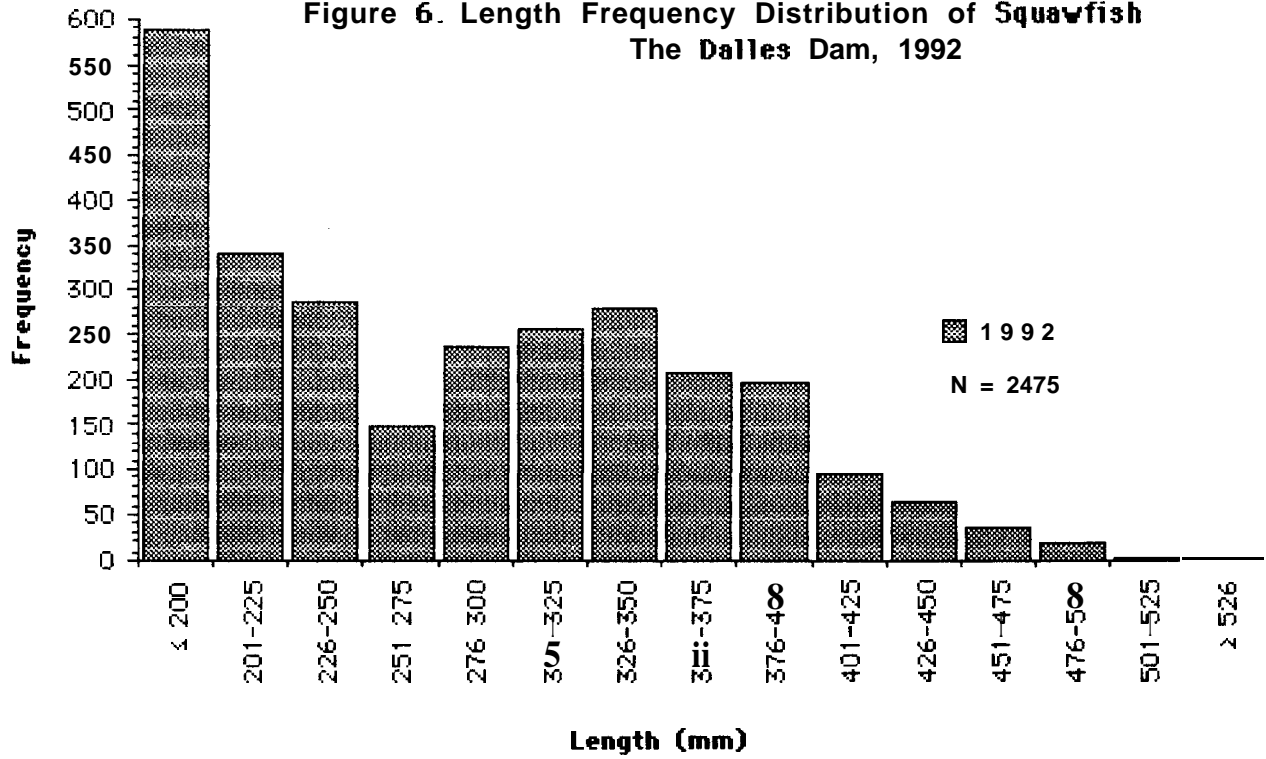


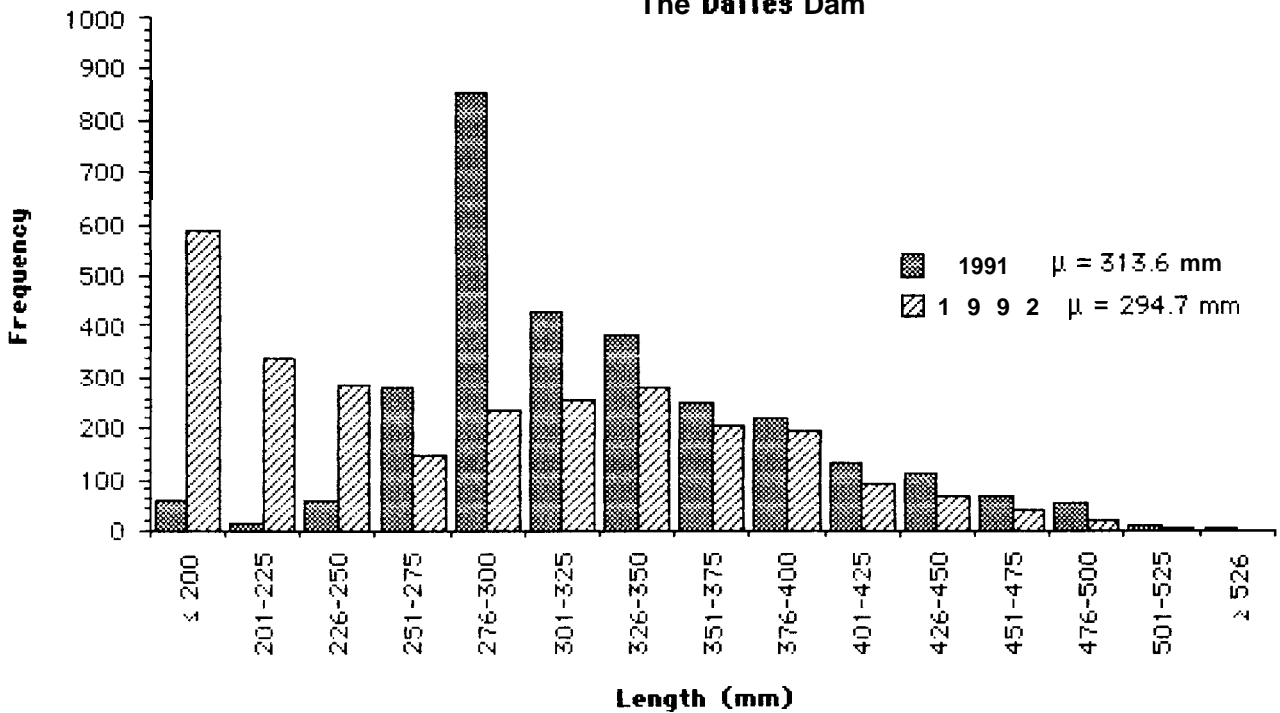
Figure 5. Catch per Hour of Squawfish for the Stationary Trap at The-Dalles Dam, 1991



**Figure 6. Length Frequency Distribution of Squawfish
The Dalles Dam, 1992**



**Figure 7. 1991 and 1992 Length Frequencies
The Dalles Dam**



Fishing in various time periods during the day and night indicate that salmonids tend to be most vulnerable to this gear during periods of peak daylight (6 a.m. to 6 p.m.) whereas squawfish tend to be most vulnerable to this gear during periods of peak darkness (6 p.m. to 6 a.m.; Table 2; Lynch 1993). Furthermore, during periods of peak sockeye migration, the highest incidentally encountered salmonid, squawfish catches tended to peak during the periods of 9 p.m. to 3 a.m. (Tables 2 and 3). The seasonal and diel vulnerabilities of squawfish and sockeye indicate that selective fishing of traps can significantly reduce incidental salmonid catches without significantly reducing squawfish catches (Lynch 1993).

Observations regarding trap catches and squawfish maturity indicate a strong correlation between trap catch, and squawfish maturity, which in turn is highly correlated with water temperature. In both 1991 and 1992, trap catches of predaceous-sized squawfish peaked when GSI ratios peaked (Figures 8-11). In addition, female squawfish maturity peaked in both seasons when water temperatures reached 63° F, approximately one month earlier in 1992 compared to 1991 (Figure 12). These data indicate that squawfish maturity is highly correlated with water temperature, a fact that should enable a trap fishery to be operated so as to maximize effort during periods of peak squawfish vulnerability (Lynch 1993).

Experimental results obtained with alternative salmonid removal techniques have lead us to conclude that dipnets are by far the most effective and least stressful means of removing salmonids from floating fish traps. Several alternative removal methods were attempted including zippered holes, which were installed in the spiller portion of the net. It was thought that these escape holes would enable salmonids to escape while detaining squawfish. However, this modification proved ineffective due to the fact that as the zipper was opened, all fish within the spiller tended to escape including squawfish. Attempts were made to guide salmonids through these escape holes, but the amount of stress to salmonids resulting from being guided greatly surpassed that of customary dipnetting techniques.

The zippered escape holes (2 feet in diameter) were installed in both the pot and spiller portions of the net, roughly 6 inches below water level. Based on observations during 1991 Merwin trapping operations, it was known that salmonids maintain a position near the surface while holding in the trap and squawfish tended to hold near the bottom of the trap. Due to this observation, the escape holes were left open for a period of time in the hopes that squawfish and salmonids would separate by depth and the salmonids, being nearer surface, would exit through these holes. Unfortunately, all fish including squawfish found and used the escape holes making this modification useless.

**Table 2. Incidental Catch of Mervin Trap Fished in Different Time Periods
The Dalles Dam, 1992**

Month	Time of Day Fished	Effort (Hours)	Squawfish Catch	Incidental Salmon Catch			Catch/Hour Salmonids	Catch/Hour Squawfish
				Sockeye	Chinook	Steelhead		
April	0600-1200	70.5	9	0	1	7	0.11	11.13
	1200-1800	53.75	5	0	2	4	0.1	0.08
	1800-2400	41.25	49	0	2	4	0.15	1.19
	2400-0600	43.5	46	0	1	3	0.04	1.06
	Total	215	109	0	6	18	0.11	0.51
May	0600-1200	117.5	165	0	5	16	0.18	1.4
	1200-1800	84.5	174	0	4	8	0.14	2.06
	1800-2400	65.25	158	0	2	6	0.12	2.42
	2400-0600	95	190	0	3	10	0.14	2
	Total	362.25	687	0	14	40	0.15	1.9
June	0600-1200	47.5	69	47	2	3	1.09	1.45
	1200-1800	37	82	58	1	5	1.73	2.22
	1800-2400	26.75	73	13	1	10	0.3	4.6
	2400-0600	21.25	69	6	1	0	0.33	2.96
	Total	132.5	337	124	5	18	1.11	2.54

Table 2. Continued

Month	Time of Day Fished	Effort (Hours)	Squawfish Catch	Incidental Salmon Catch			Catch/Hour Salmonids	Catch/Hour Squawfish	
				Sockeye	Chinook	Steelhead			
July	0600-1200	0	0	0	0	0			
	1200-1800	0	0	0	0	0			
	1800-2400	90.75	432	137	0	48	2.04	4.76	
	2400-0600	63.5	347	134	2	32	2.65	5.46	
	• 3 hour sets from 1800 to 0300								
	1800-2100	21.75	18	52	0	16	3.13	0.83	
	2100-2400	39	309	40	0	15	1.41	7.92	
	2400-0300	13	77	30	0	2	2.46	5.92	
	Total	154.25	779	271	2	80	2.29	5.05	
	August	0600-1200	11.5	3	0	2	9	0.96	0.26
1200-1800		0	0	0	0	0			
1800-2400		75	1253	7	0	31	0.51	16.71	
2400-0600		92.5	431	7	0	58	0.7	4.66	
Total		179	1687	14	2	98	0.64	9.42	
September	0600-1200	0	0	0	0	0			
	1200-1800	0	0	0	0	0			
	1800-2400	17.5	158	0	0	13	0.74	9.03	
	2400-0600	11.5	47	0	0	8	0.7	4.09	
	Total	29	205	0	0	21	0.72	7.07	

**Table 3. Salmon and Squawfish Catch by Month for the Mervin Trap
The Dalles Dam, 1992**

Time Period (Approx.)	Hours	Squawfish		Sockeye		Steelhead		Chinook	
		Catch	Catch/Hr	Catch	Catch/Hr	Catch	Catch/Hr	Catch	Catch/Hr
April	322	195	0.61	0	0	26	0.08	14	0.04
May	429.43	988	2.3	0	0	46	0.11	14	0.03
June	369.33	1421	3.85	120	0.32	41	0.11	6	0.02
July	167.67	857	5.11	294	1.75	93	0.55	2	0.01
August	190.91	1869	9.79	11	0.06	100	0.52	7	0.04
September	30	205	6.83	0	0	21	0.7	0	0

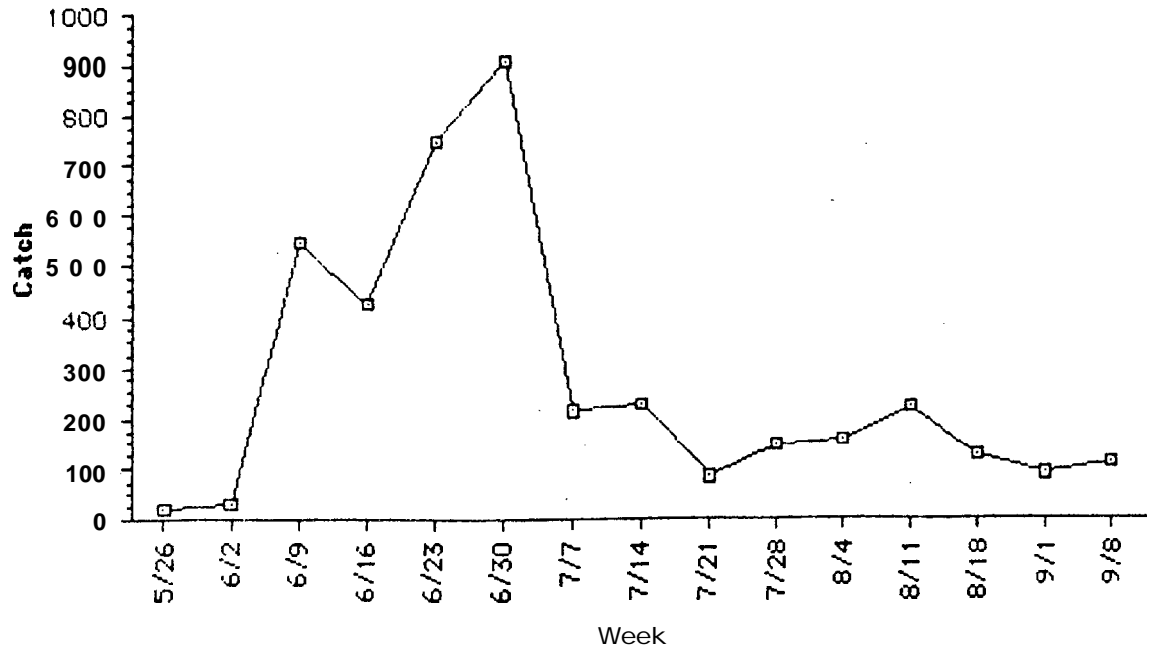


Figure 8. Weekly Squavfish Catch by the Mervin Trap The Dalles Dam, 1991

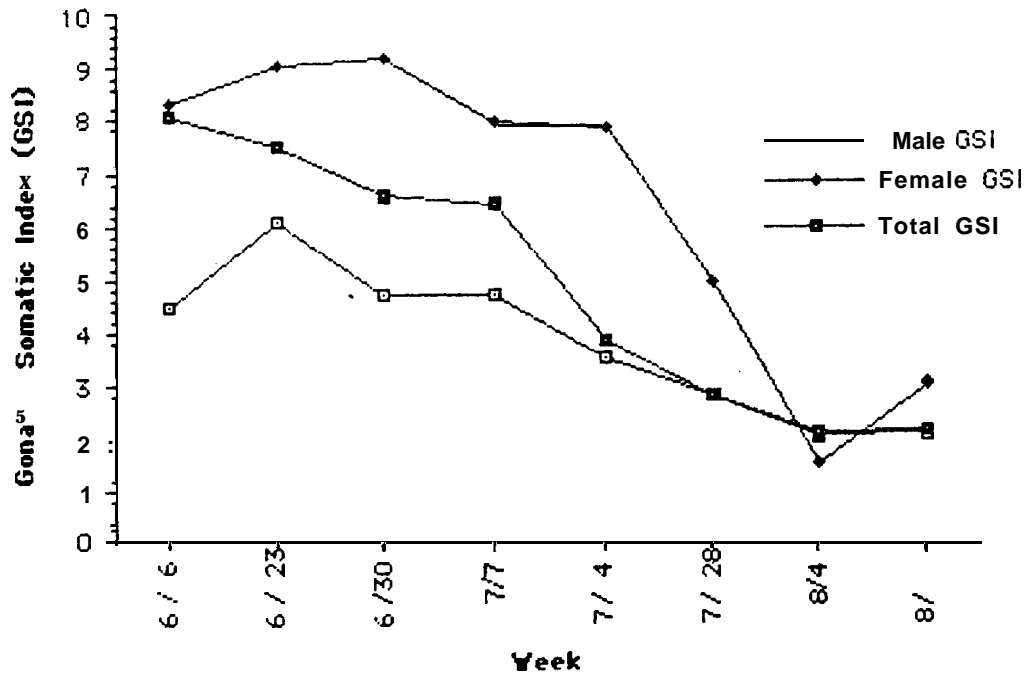


Figure 9. Average Weekly GSI Ratio of Squavfish at The Dalles Dam, 1991

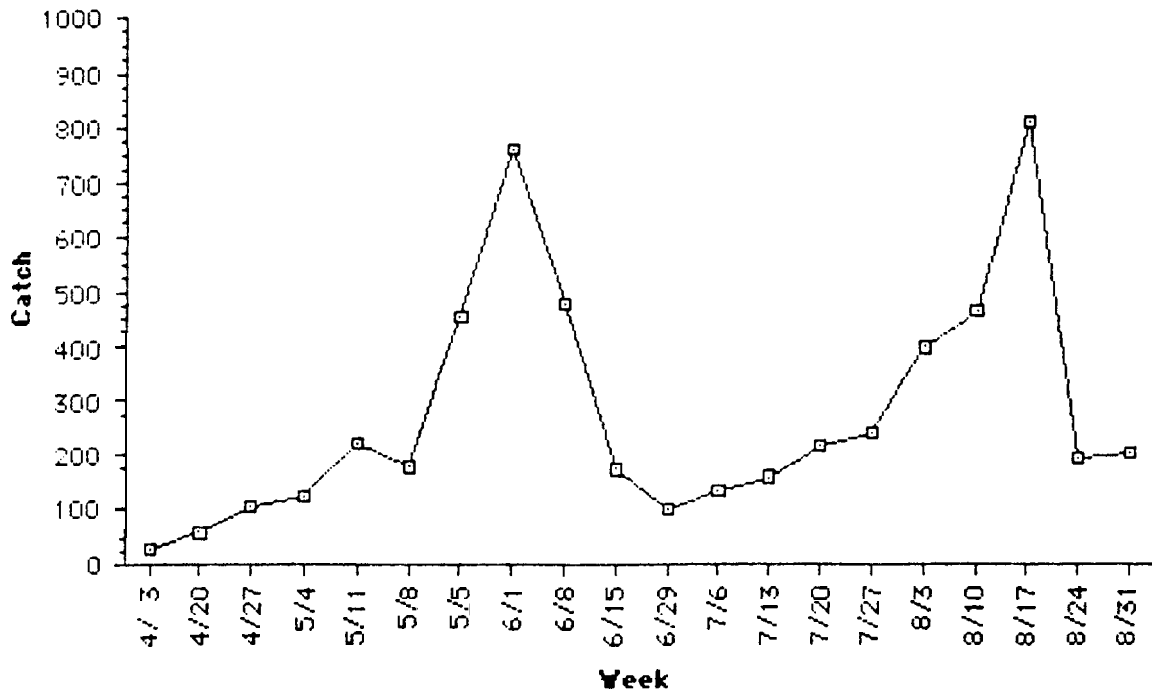


Figure 10. Weekly Squavfish Catch by the Mervin Trap
The Dalles Dam, 1992

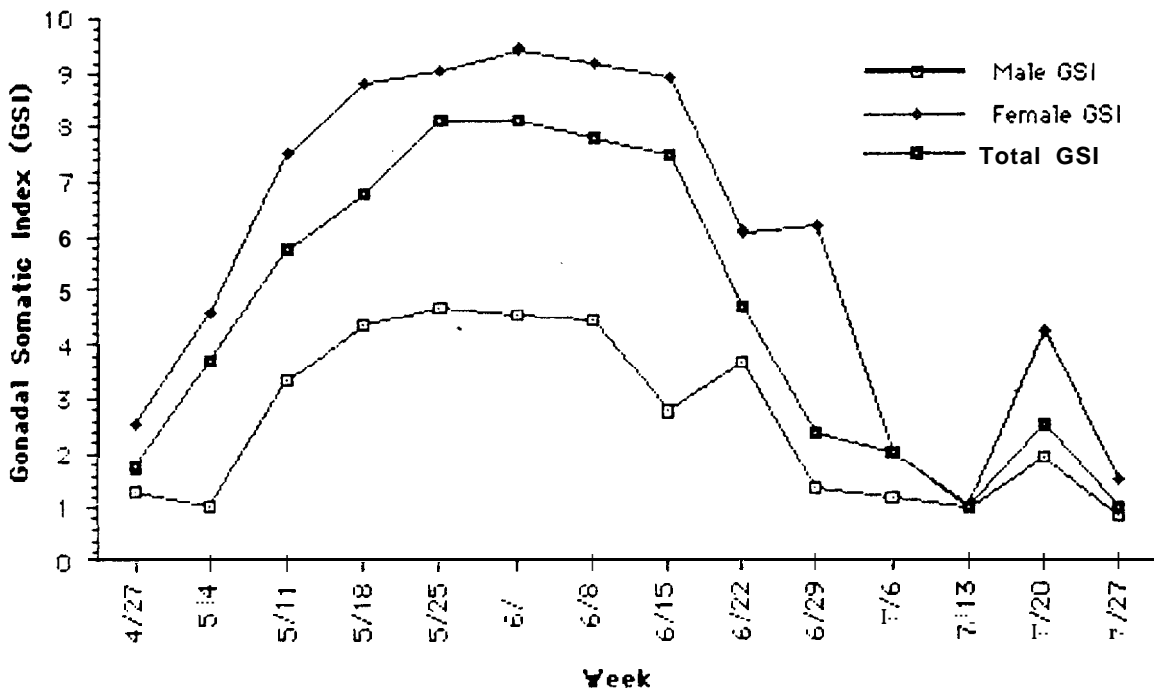


Figure 11. Average Weekly GSI Ratio of Squavfish at
The Dalles Dam, 1992

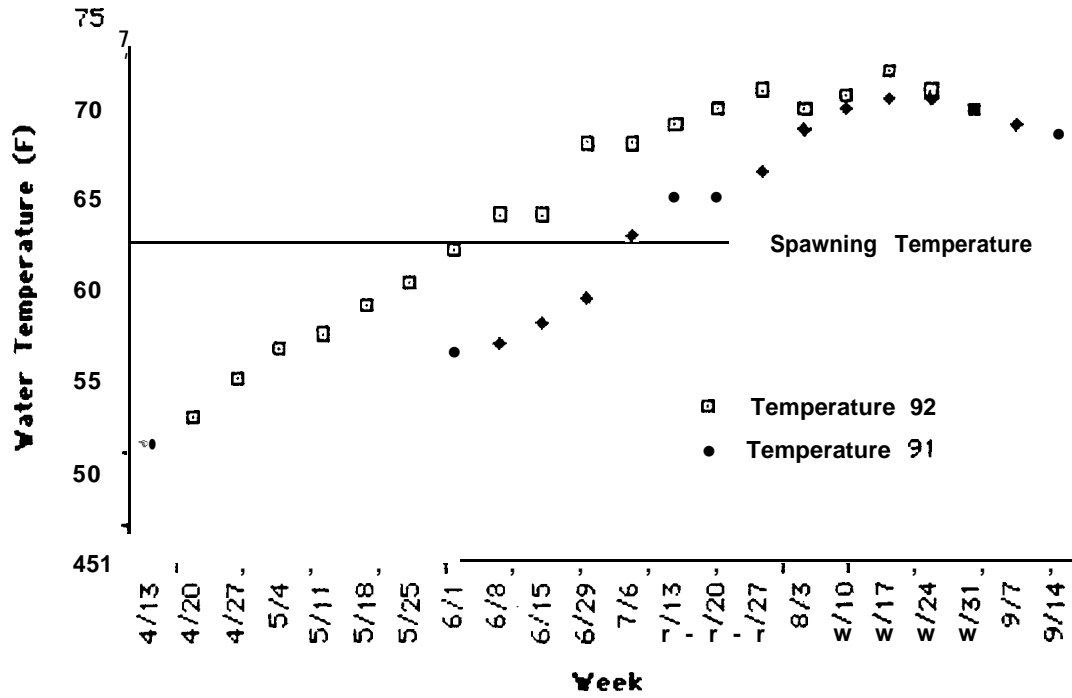


Figure 12. Average Weekly Water Temperature The Dalles Dam, 1991 and 1992

In addition to zippered escape holes, a picket weir was installed between the pot and spiller portions of the trap with the hope of separating larger salmonids from squawfish, leaving the large fish (primarily salmonids) in the pot while allowing the smaller fish (squawfish) to enter the spiller portion of the net (Figure 13). This weir, consisting of 1.25 inch, PVC pipes spaced five inches apart, served to separate larger salmonids from other species. However, sockeye were found to be of similar size and shape to squawfish, thereby limiting the overall effectiveness of this modification. Future applications of this gear may be able to devise similar, more effective strategies for separating squawfish and salmonids, given more time and resources.

Given the limited success of the structural modifications at reducing the handling of salmonids, efforts were made to develop a dipnetting procedure that inflicted the least possible amount of stress to salmonids. Although dipnetting might seem stressful in theory, it has proven to be the least stressful, most expedient method for removing salmonids from floating fish traps as well as other types of sampling gear. Large dipnets, 30 inches in diameter with very soft webbing material (1/2-inch stretch mesh) can be hung in such a way as to create a very shallow bag (6 inches in depth). This dipnet configuration enabled the removal of salmonids from the trap with least amount of stress.

Minor problems were encountered this season in the cul-de-sac area with various forms of predators (e.g., herons and/or otters). Several fish including two salmonids were found having fresh wounds resulting from predator attacks. Steps were taken to eliminate predator attacks with the installation of bird netting around holding areas. Due to the unwieldy nature of this material, an alternative was necessitated. It was determined that a plastic tarp could be mounted flush at the tops of holding areas, similar to a swimming pool cover. This barrier proved to be sufficient in stopping further predator attacks and proved to be more easily manageable than the bird netting.

Mobile Trapping

Crew and equipment requirements for the mobile traps consisted of three individuals, a small jet-powered outboard boat (16 feet long), a 20-foot trailer and two trucks equipped for towing. Three individuals were able to deploy and operate two mobile traps in most locations in an efficient manner. The mobile traps could be deployed in two to four hours depending on site accessibility and environmental conditions (current strength, wind speed, etc.). Both traps were transported via a 20-foot, flatbed trailer that held the trap frames and a 2-ton, flatbed truck that held the webbing for both nets.

Fishing occurred in a variety of locations throughout the Columbia River during the 1992 season. Mobile traps were fished a total of 79 days, capturing 1,108 squawfish (Table 4 and Figure 14). Squawfish comprised 21.2% of the total catch (Figure 15). Miscellaneous species such as peamouth, chiselmouth, sunfish and carp comprised 56.7% of the total catch. Salmonids accounted for 14.3% of the total catch with nearly 75% of these fish caught in two sets near McNary Dam during the peak of the sockeye run.

4' x 6', two by four frame
1.25" PVC tubing, 5" gap

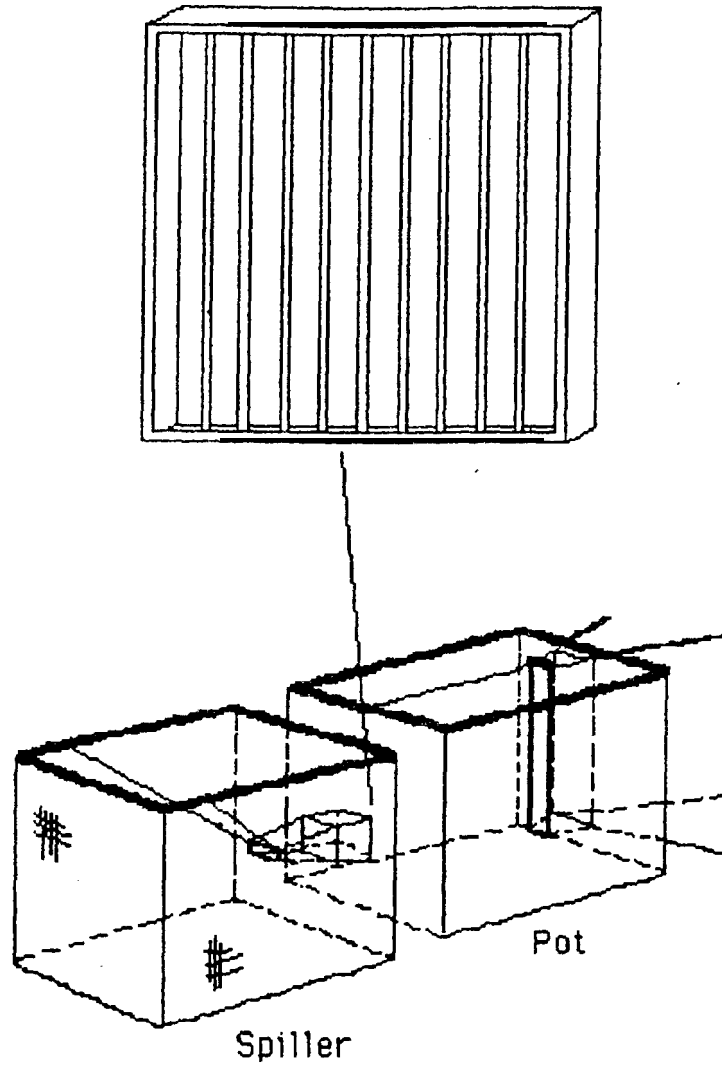


Figure 13. Experimental Fish Weir

(Note: 1 foot = 3.048 meters; 1 inch = 2.54 centimeters)

Table 4. location and Catch of Mobile Mervin traps, 1992.

Location	Dates Fished	Days Fished	Squawfish Catch	Squawfish Catch per Day	Adult Sal monid Catch	Adult Sal monid Catch per Day
Lyons Ferry area	5/11-5/14	3	10	3.33	0	0
Lower Granite Dam	5/19-5/29	6	75	12.5	1	0.17
The Dalles Dam cul-de-sac	6/1-6/30	22	259	11.77	147	6.68
McNary Dam area	7/1-7/10	8	64	8	141	17.63
Drano Lake	7/21-7/24	5	82	16.4	2	0.4
Horsethi ef Lake	7/22-7/24	3	2	0.67	0	0
CarrollsChannel	7/27-8/7	10	20	2	8	0.8
Elochoman Slough	8/3-8/14	10	142	14.2	0	0
Wallace Slough	8/10-8/19	8	26	3.25	1	0.13
The Dalles Dam cul-de-sac	8/26-9/1	4	428	107	9	2.25
	Total	79	1108	14.03	309	3.91

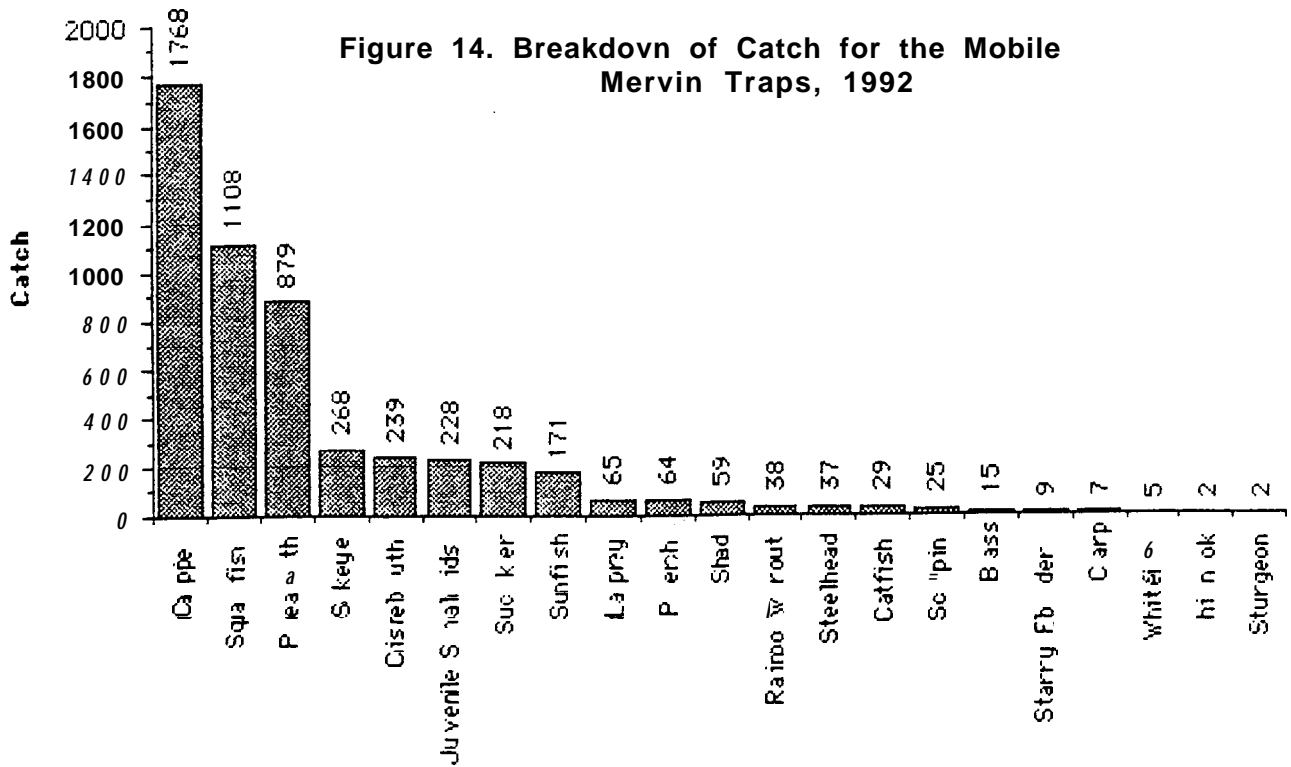
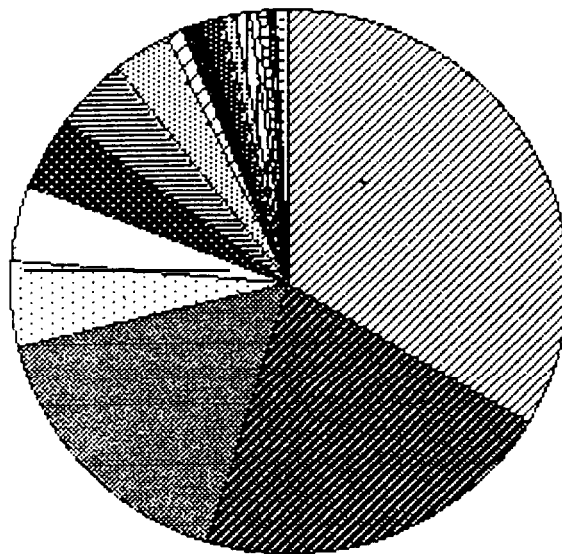


Figure 15. Breakdown of Catch for the Mobile Mervin Traps, 1992



Note : Chinook, Sturgeon, Whitefish > .1%

- Crappie 33.7%
- Squawfish 21.2%
- Peamouth 16.8%
- Sockeye 5.1%
- Chiselmouth 4.6%
- Juvenile Salmonids 4.4%
- Sucker 4.2%
- Sunfish 3.3%
- Lamprey 1.233%
- Perch 1.2%
- Shad 1.1%
- Rainbow Trout .7%
- Steelhead .6%
- Catfish .6%
- Sculpin .5%
- Bass .3%
- Starry Flounder .2%
- Carp .1%

The length frequency of squawfish captured with mobile traps outside of boat restricted areas closely resembles that of the larger trap operated in The Dalles Dam cul-de-sac (Figure 16). When squawfish catches occurring during late August (when juvenile squawfish were known to be present in large numbers from stationary trap catches) are removed from the length distribution, length classes in the range of 200 mm to 250 mm and 300 mm to 350 mm are represented in much the same manner as the stationary trap.

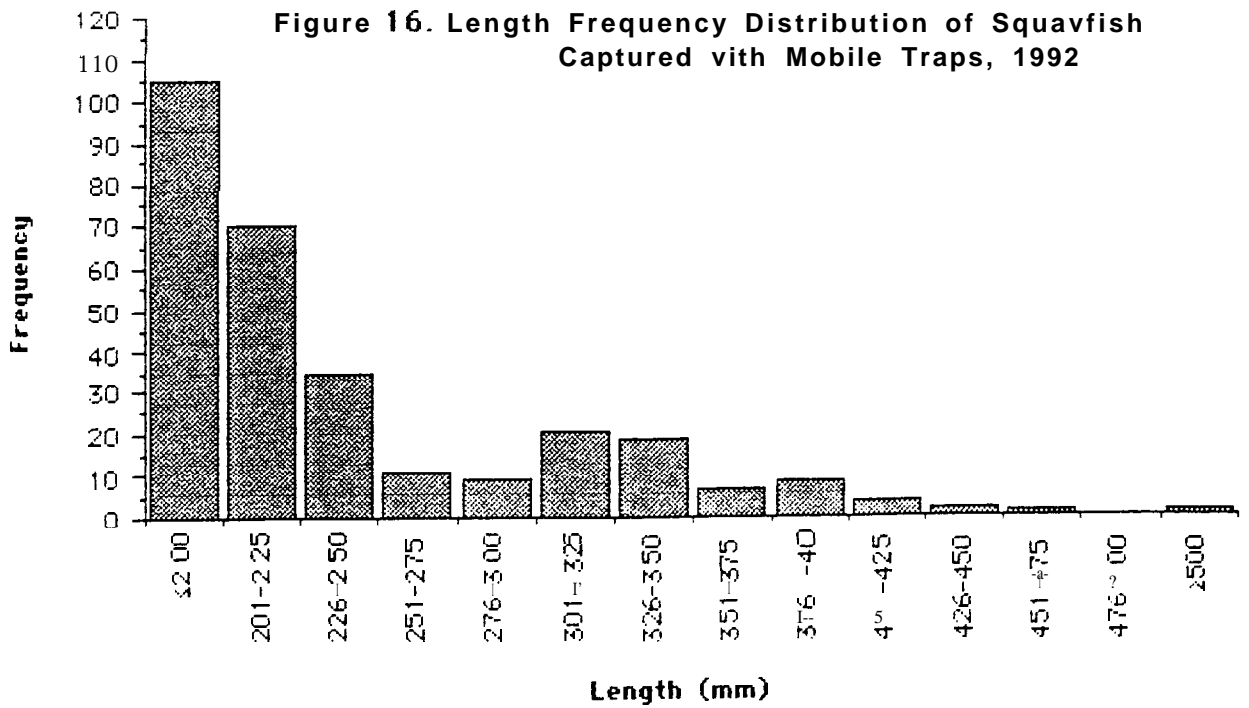
During the final two weeks of the 1992 season, comparisons of catch rates were made between the stationary and mobile traps in The Dalles Dam cul-de-sac. During the weeks of August 24 to August 28 and August 31 to September 3, the stationary trap and a mobile trap were fished alternately, two days per week, with the traps being checked every six hours. Squawfish catches during this period were very similar for both gears with the stationary trap catching 373 squawfish in 54 hours of fishing and the mobile trap catching 428 squawfish in 54 hours of fishing (Table 5). Results from this experiment indicate that both traps fish with similar effectiveness. However, these results may be biased due to the fact that 80% of the squawfish caught by both traps were less than 250 mm long.

The favorable environmental characteristics associated with efficient mobile trapping have been identified to include (1) moderate flow (< 1 foot per second), (2) relatively stable river level, (3) gentle sloping of submerged bank (the trap lead should maintain contact with the bottom while still presenting a uniform vertical barrier to the fish), and (4) adequate site accessibility via modern boat ramps (used as trap staging and launching areas).

A comprehensive riverwide survey was performed by UW during the winter of 1993. This survey was primarily concerned with the general physical characteristics of the river necessary for setting mobile trap nets. The survey evaluated 209 locations for accessibility, trap set potential, and estimated squawfish catch qualities. Trap sites targeted at tributary outflows, embayments and enhanced bank structures (e.g., bridge jetties, causeways, and artificial ponds) possessed good potential for success. Spring flows, current, incidental catch, and gear conflicts would limit trap net operations.

Conclusions

Research carried out in 1991 and 1992 with floating trap nets indicates that this gear could be an effective squawfish removal method on a larger scale. Incidental salmonid catches were greatly reduced in 1992 near dams while maintaining a significant squawfish removal effort. Delay of migrating salmonids and incidental mortality due to predators was also overcome with minor adjustments in operational procedures. Based on these results and the fact that salmonid concentrations away from dams would most likely be low, adverse impacts on incidental salmonids in a large-scale program are thought to be negligible.



Note: Fish captured in BRZ's not included

Table 5. Comparison of Catch Rates for the Stationary Met-win Trap and a Mobile Merwin Trap
The Dalles Dam, August 24 through September 3, 1992

Gear	Fish time (Hours)	Species	Catch	Catch per Hour
Stationary Trap	54	Squawfish	373	6.91
		Steel head	47	0.87
		Juvenile	0	0
		Bass	2	0.04
		Sturgeon	18	0.33
		Catfish	0	0
		Other	521	9.65
		Total	961	17.8
Mobile Trap	54	Squawfish	428	7.93
		Steel head	9	0.17
		Juvenile	2	0.04
		Bass	0	0
		Sturgeon	0	0
		Catfish	2	0.04
		Other	720	13.33
		Total	1161	21.5

Modifications made in mobile trap designs illustrate that this gear can be easily transported and deployed with limited effort. Comparisons carried out with mobile traps and the stationary trap indicate similar catch effectiveness, enabling the use of mobile versions while maintaining fishing power. Similar length frequency distributions of squawfish caught in both gears indicate that midreservoir locations could remove target species at a rate similar to locations within boat restricted zones near dams.

Mobile trapping was found to be effective to varying degrees based upon amount of current and tidal influence present in a given area. Areas fished below Bonneville Dam, near Longview and Cathlamet, Washington, possessed strong tidal fluctuations that would strand traps during low tide or place tremendous amounts of stress on components during changing tides. Squawfish catches in these areas were good when traps could be fished effectively, therefore, further modifications to trap net design should enable mobile traps to be fished in areas that have been shown to possess significant squawfish populations and extraordinarily high current.

Mobile trapping carried out in areas of relatively moderate current was found to be the most conducive to fishing. Sites in Drano Lake and Elochoman Slough provided ideal conditions for trapping due to their relatively moderate current. Fishing carried out in the cul-de-sac at The Dalles Dam was also quite productive. These sites possess similar characteristics in that current and water level were relatively stable over time, allowing for better trapping efficiency.

In addition to current and water level requirements, traps were most successful in areas of similar bottom topography. Using depth sounding equipment, bottom topography was categorized at all sites fished. Areas that sloped away from banks to a depth of 30 feet provided best conditions for trapping with a 25-foot deep lead. These conditions are logical due to the mode of operation of the trap (fish encounter an obstacle that leads them into the trapping portion). Shallower depths were not as productive, indicating that alterations in trap components may be necessary to fish in a variety of conditions.

ELECTROFISHING

Introduction

In 1992, the University of Washington operated an electrofishing boat in the Columbia and Snake rivers to evaluate the effectiveness of electrofishing as a squawfish removal method. Since 1983, the Oregon Department of Fish and Wildlife (ODFW) and U.S. Fish and Wildlife Service have used similar boat-based electrofishing gear in their ongoing studies of predation by resident fish on juvenile salmonids in the Columbia River (Poe and Rieman 1988). Electrofishing was chosen for these studies due to its historical effectiveness as a capture method.

For all electrofishing efforts on the Columbia River in 1990 through 1992, catch per unit effort (CPUE) averaged 24.77 squawfish per hour of on-time (Table 6). From 1984 to 1986, CPUE averaged 28.27 in the McNary Dam tailrace boat restricted zone (BRZ) and 1.89 throughout the rest of the John Day Reservoir (Table 7).

Electrofishing has been demonstrated to be an effective method for capturing squawfish. However, it is possible that past CPUE figures are conservative in assessing what an implemented control effort might yield. The ODFW predator indexing studies are research oriented and not direct attempts to maximize total squawfish catch. It is expected that if an electrofishing boat was assigned the sole task of squawfish removal, total catch could significantly contribute to the overall squawfish program exploitation rates.

Due to the extensive electrofishing operations planned for evaluating this gear as a removal method, the Fish Passage Advisory Council (FPAC) expressed concerns with the 1992 UW research. These concerns focused primarily on two issues: (1) potential incidental harm and delay to salmonids, specifically Snake River sockeye and salmonid concentrations in dam boat restricted zones (BRZs), and (2) addressing the existing levels of interagency (National Marine Fisheries Service, ODFW, University of Idaho) BRZ electrofishing. Restrictions were placed on the electrofishing operations during 1992 electrofishing research that addressed these concerns; these are listed in the “Methods” section of this report.

Methods

The first step in developing the UW electrofishing program was to complete an annotated bibliography and comprehensive synopsis of electrofishing (Appendix B, Mahoney et al. 1993). This report was intended to familiarize our crews with contemporary electrofishing theory, principles, and practices.

The electrofishing boat used for this study was equipped with a Smith Root Model 5.0 GPP electrofishing system. This unit has an output capacity of 5,000 watts, 0-750 RMS volts AC or 0-1,000 volts pulsed DC at frequencies of 7.5 up to 120 hertz (pulses per second). Electrical output was delivered into the water via two model UAA-6, dropper anode arrays. These boom anodes were bow-mounted at 20° and 90° off the starboard beam. The boat’s aluminum hull was used as one large cathode.

Table 6. Historical CPUE of northern squawfish by electrofishing on the Columbia and Snake rivers, 1990-92 (effort in on-time hours).

	Squawfish	On-Time Hours	CPUE
1990 ODFW Abundance Indexing (a)	1,014	102.25	9.92
1990 USFWS Consumption Indexing (a)	1,876	141.00	13.30
1991 ODFW/USFWS Predator Indexing (b)	1,732	221.50	7.82
1991 NMFS/USFWS/ODFW (c)	2,012	19.68	102.24
1992 ODFW Abundance Indexing (d)	4,924	133.75	36.81
1992 NMFS/USFWS/ODFW (e)	2,173	26.34	82.42
1992 NMFS Creek studies (f)	2,565	135.20	18.97
1992 UW Removal Efforts	4,076	43.16	94.44
1990-92 Electrofishing Totals	20,372	822.88	24.76

a - Vigg 1990.

b - Dave Ward, ODFW, Personal Communication.

c - Tom Poe, USFWS, Personal Communication.

d - 1992 ODFW Field Activity Reports.

e - Ledgerwood 1992.

f - 1992 NMFS Field Activity Reports.

Table 7. Comparison of electrofishing catch by ODFW predator indexing crews in the John Day Reservoir inside and outside of McNary Dam boat restricted zone, 1984-86. (Nigro et al. 1985a, Nigro et al. 1985b, Beamesderfer et al. 1987).

	1984	1985	1986	1984-86
John Day Reservoir				
Squawfish catch	874	799	511	2184
Effort (hours on time)	384	452	318	1154
CPUE	2.28	1.77	1.61	1.89
McNary boat restricted zone				
Squawfish catch	440	822	1367	2629
Effort (hours on time)	13	23	57	93
CPUE	33.85	35.74	23.98	28.27

The electrofishing system was installed on a 28-foot, shallow draft, aluminum boat powered by a 400 hp inboard engine with a jet drive. A crew of three (one driver and two dipnetters) was required for electrofishing operations. The increased size and horse power of this boat provided many advantages over the traditional 16- to 22-foot electrofishing boats: (1) a safe and stable work platform for up to three dipnetters, (2) an extended fishing range, typically 15 to 30 river miles round trip per night, (3) durability in rough weather and strong currents, (4) versatility for multi-purpose use (e.g., beach or purse seining, floating trap tender, survey vessel, and electrofisher), (5) large fish holds and long-term live-well capacity, (6) protection from the weather, and (7) a large cathode area (boat hull) that acted to efficiently distribute the electrical field, concentrating it toward the anodes.

The disadvantages to this increased boat size were: (1) limited manageability in strong winds due to the high wind-profile created by the boat's cabin and extended water line, (2) restrictive trailering (the boat's 10.5-foot beam required the use of special oversize permits and restrictive travel times -- daylight and weekdays only), (3) limited boat ramp access, and (4) prohibitive trailering and boat fuel costs (250 gallon capacity). It was strongly felt that the size of the vessel was by far an advantage in the overall removal operation.

The standard unit of effort for electrofishing is given as one hour of electrofishing unit on-time. Generally, a fishing run has a duration of 900 seconds (15 minutes of on-time). Two basic electrofishing techniques are used, steady on and power pulsing. The difference between these two methods is related to power unit on/off output time ratio. With steady on, electrical output remains on at all times. With power pulsing, generally a 1:3 time ratio is maintained. A power-pulsing, 900-second fishing run often takes up to an hour to complete. Power pulsing tends to catch more fish since it effectively reduces an electrofishing unit's applied perception zone, resulting in fewer fish being frightened out of an area before the electrofishing boat can get into an effective capture range.

During the day (9 a.m. - 3 p.m.) selected river reaches were surveyed for areas of desirable squawfish habitat (e.g., submerged rip-rap, moderate current, good visibility, steep slope, and associated prey holding areas); selected areas were then fished at night (9 p.m. - 3 a.m.). Standard practice was to use the power pulsing capture technique (900 seconds on-time per run) with three dipnetters selectively removing northern squawfish from the river and estimating the counts of all other species within the electric field. Two boom anodes were placed to one side of the boat (20" and 90° off the beam), which enabled the electric field to remain in constant contact with the shoreline.

Actual electrical parameters were maintained at the minimal levels required for satisfactory capture of squawfish. These parameters fluctuated by the physical constraints of the sampling area (e.g., water conductivity, temperature, flow, bottom substrate, turbidity). Commonly used output settings for squawfish in the Columbia River were 200 volts at 60 Hz pulsed DC on 40% duty cycle yielding a current of 3.5 amps to 5.0 amps.

Electrofishing operations were regulated by the following FPAC guidelines: (1) no fishing in any hydroelectric project boat restricted zone, (2) immediate stopping of fishing

whenever a smolt or adult salmon was encountered, (3) moving to a new fishing area upon encountering a second salmon, and (4) ceasing electrofishing for the night whenever a total of more than two adult salmon were encountered.

Results

From May 5 to July 30, 1992, UW spent 45 nights electrofishing on the Columbia and Snake rivers. A total of 4,076 squawfish were taken in 43.16 hours of unit on-time, yielding a CPUE of 94.44 squawfish/hour on time (Table 8). Electrofishing occurred on the Snake River from May 4 to May 29. During this four-week period, 448 squawfish were removed in 15.15 hours of electrofishing resulting in a CPUE of 29.57 squawfish/hour on-time (Table 8). The remaining eight weeks of the season, June 1 to July 31, were spent on the Columbia River where 3,628 squawfish were taken with 28.01 hours of effort for a CPUE of 129.53 squawfish/hour on-time (Table 8).

Roughly 80% of the squawfish caught during the 1992 UW efforts were 250 mm or smaller. The overall CPUE for squawfish greater than 250 mm was 18.9 squawfish/hour on-time. Factors that tended to skew length-frequency to the smaller size were (1) electrofishing away from project BRZs tends to yield smaller, resident fish, (2) effort occurred early in the season (most of the field season coincided with high CRITFC dam-angling catch rates of larger fish, indicating that the larger squawfish are probably concentrated in and around the hydroelectric projects, which, effectively removes them from the midreservoir fishing regions), and (3) inclement spring weather reduced boat handling and dip-netting efficiency, resulting in a reduction of CPUE. During the last two weeks, July 13-27, there was a significant increase in the number of squawfish greater than 250 mm in the nightly catch, suggesting a migration of larger fish away from the dams.

Conservative visual estimates were recorded by fishing run for incidental fish species affected by the electrofishing gear. The UW squawfish removal of 4,076 represents 13.72 % of the 29,719 observed fish (Table 9). Suckers comprised 50.44% of the affected fish, while peamouth and chiselmouth chubs combined for an additional 22.89%. In all, 25,273 incidentally affected fish were recorded; of these, 316 (1.06%) were salmonid smolts and 54 (0.19%) were adult salmonids (Table 9).

Midreservoir encounters with salmonids were isolated occurrences. Whenever a smolt or adult salmonid was observed, electrofishing was immediately stopped. Typically adult salmon were observed along the periphery of the electric field. Upon encountering the field, adult salmon exhibited a fright response, actively escaping any further contact with the electrical impulses. Salmonid smolts exhibited a wide range of responses (fright, taxis, tetanus) to the electric field. All species identification for salmonids were subjective visual estimates since fishing ceased upon the appearance of an individual in the electric field and fish quickly swam out of sight once the power was ceased. Some fish were only observed on the periphery of the electrical field, and therefore the counts in Table 8 may not be 100% accurate for salmonids.

Table 8. UW experimental electrofishing catch and effort, 1992.

Date	Area	Duration (On time Hours)	Squaw- fish	Salmonids Smolts	Adults	Total Fish	SQF/HR
5/4	Lyons Ferry	3.31	62	78	6	816	18.75
5/11	Lyons Ferry	5.61	111	59	0	1,925	19.77
5/18	Boyer Marina	4.09	164	91	2	2,172	40.13
5/25	Boyer Marina	2.15	111	21	1	1,329	51.75
Total	Snake River	15.15	448	249	9	6,242	29.57
6/1	Maryhill	4.24	188	38	1	2,920	44.38
6/8	Maryhill	5.38	287	6	2	1,169	53.34
6/15	Umatilla	2.78	357	10	11	4,300	128.55
6/22	The Dalles	1.63	629	3	9	1,369	386.55
6/29	The Dalles	3.69	557	4	12	1,638	150.79
7/6	Cascade Locks	2.68	611	0	2	1,711	227.99
7/13	Hood River	3.63	162	2	2	5,749	44.59
7/27	The Dalles	3.98	837	4	6	4,621	210.27
Total	Columbia River	28.01	3,628	67	45	23,477	129.53
Total	All Areas	43.16	4,076	316	54	29,719	94.44

Table 9. 1992 UW electrofishing, observed species composition.
 (These Figures represent visual **estimates**. While sampling, only
 squawfish were intentionally removed from the water.)

Species	Totals	Percentage of Catch
Suckers	14,989	50.44%
Squawfish	4,076	13.72%
Peamouth	3,606	12.13%
Chiselmouth	3,198	10.76%
Smallmouth Bass	1,820	6.12%
Shad	940	3.16%
Cottids	333	1.12%
Smolts	316	1.06%
Carp	174	0.59%
Yellow Perch	51	0.17%
Crappie	47	0.16%
Sunfish	44	0.15%
Sockeye	35	0.12%
Trout	33	0.11%
Steelhead	18	0.06%
Whitefish	16	0.05%
Sturgeon	12	0.04%
Channel Catfish	9	0.03%
Chinook	1	NA
Walleye	1	NA
Total	29,719	

A significant obstacle to midreservoir electrofishing was the seasonally unsettled weather of the Columbia River Gorge. Persistent strong winds and large waves resulted in inconsistent boat-handling and increased water turbidity. These environmental constraints caused significant numbers of stunned squawfish to be missed by dipnetters when fishing in waters deeper than 4 feet.

As a result of the 1992 evaluation, it was determined that certain environmental and diurnal characteristics tend to be associated with better squawfish electrofishing catch results:

SUBSTRATE TYPE	CPUE
Silt	7.81
Cobble	26.09
Large Cobble	36.96
Rip-Rap	42.69
Ledge	17.14

TIME OF DAY	CPUE
10 p.m. to 5 a.m.	56.63
5 a.m. to 10 p.m.	13.86

CPUE for squawfish was significantly higher at night, in areas of submerged rip-rap or large cobble with moderate current and low turbidity.

UW field operations were intended to be highly mobile and responsive. Generally, the crew was stationed directly on the river saving two to four hours of travel and preparation time each day. During the course of the season, areas were selectively sampled from above Lower Granite Dam on the Snake River to below Bonneville Dam on the Columbia River, encompassing a range of over 300 river miles.

A project goal was to identify and remove squawfish spawning concentrations. Gonadal somatic indexing (GSI), the ratio of gonad to body weight in female fish, and interagency weekly catch reports were used in this effort. GSI data along with visual inspections suggested that the majority of large squawfish (> 250 mm) taken by the electrofishing gear were spawned out individuals. UW midreservoir electrofishing was unable to positively identify large or persistent squawfish spawning congregations.

Initially, UW planned to beach seine potential squawfish spawning locations as indicated by the electrofishing catch results and habitat survey work. However, it was not possible to positively identify any squawfish spawning concentrations with our catch data. In addition, all of the productive squawfish habitat areas (moderate flow, submerged rip-rap,

steep slope, weedy prey fish holding areas) proved to be far too difficult to seine effectively and, therefore, this method had to be dropped from the removal procedures.

Conclusions

Historically, the most successful capture method for squawfish has been electrofishing in hydroelectric project tailrace and BRZ areas (Table 7). The UW CPUE for squawfish greater than 250 mm of 18.9 fish/hour of unit on-time compares favorably to the 1984-86 ODFW midreservoir CPUE of 1.9 squawfish/hour on-time. Of course this comparison is biased since ODFW efforts were research oriented and not direct attempts to maximize squawfish catch. However, results from UW research indicate that electrofishing efforts primarily focused on removal of squawfish can significantly increase CPUE and total catch when fishing in midreservoir locations (Table 8). Therefore, electrofishing has tremendous potential as a control method in the squawfish management program.

However, the amount of incidental catch by electrofishing is significant. Over 29,000 fish were affected by the 1992 UW efforts alone. Also, electric fields will have some effect on any fish that encounters them. A majority of the electrofishing induced injuries we observed resulted from fish coming in direct contact with the anodes. The standard (radio antenna or cable) anodes presently in use on the Columbia River create dangerously high voltage gradients close to the anode often burning or branding the fish. Increasing the anode diameter greatly decreases the voltage gradient in this area, reducing the amount of injury caused from direct contact with the anodes.

The short- and long-term effects of pulsed direct current electrofishing on fish from the Columbia River is not well-documented; of special concern are the effects on salmonids. Reports on electrofishing-induced harm are study-specific, yielding a tremendously wide range of results (Sharber and Carothers 1988; Holmes et. al. 1990; Roach 1992). Fredenberg (1992), through x-ray and autopsy, reported that 60 Hz pulsed DC current results in excessive injury rates to both rainbow (60-98% injury) and brown trout (44-62% injury) in Montana streams. These studies show that incidental harm research on the Columbia River is long overdue. Before electrofishing could be used as a control method, the potential incidental effects on salmonids and resident species should be investigated. According to our catch rates, current interagency electrofishing efforts could be potentially impacting over 30,000 resident and anadromous fish per boat each season.

When electrofishing in tailrace areas, some interaction with salmonids is unavoidable. Two issues that demand attention before any large-scale electrofishing operation can begin are (1) to what degree are resident fish being affected (e.g., short-term effects, mortality) and (2) how much incidental catch is acceptable. Presently there are no sufficient data that could be used to determine the expected rates of harm to these fish.

The number of places open to electrofishing are primarily limited by environmental (wind and current) and safety considerations. When winds approach the 15- to 25-knot

range, the combination of difficult boat handling, large waves, and turbidity makes dipnetting difficult, significantly reducing CPUE. Continued fishing under such conditions is counterproductive since many of the affected fish are missed by the netters and operators become quickly fatigued. There is evidence to suggest fish that are stunned, but not removed experience spatial displacement and may acquire a hyper-sensitivity to induced electric fields (Gatz et al. 1986, Gatz and Adams 1987, Mesa 1989). These fish may be temporarily lost to a sampling population. Generally a two- to three-week hiatus between repeated electrofishing efforts is recommended.

Although midreservoir electrofishing should be judged as a successful squawfish control tool, there exists room for improvement. Adjustments to operational procedure that improved UW CPUE were (1) fishing at night, (2) identifying and concentrating effort in squawfish holding areas, (3) employing the power-pulsing technique, and (4) increasing the number of dipnetters to three persons. Additional ways to increase the CPUE of large squawfish may include applying some portion of effort in the BRZ areas (e.g., one hour of on-time per week) and fishing later in the season (June 1 to September 30), thereby taking advantage of calmer, midsummer weather while intercepting larger squawfish as they disperse away from the dams.

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APPENDIX A

**University of Washington
1992 Mobile Trap Description and Specifications**

University of Washington Mobile Trap Net Bid Specifications

The following is a verbal description for bid specifications for two sizes of mobile floating fish traps that will be used for a squawfish removal program on the Columbia River in 1993. The 15' and 25' designations refer to the fishing depth of the trap lead and heart. The floating squawfish trap is a large, passive capture technique that has been developed specifically to be highly mobile and easily assembled. Because several of these traps are being constructed, it is important that each trap is built identical to the others in order for various parts to be interchangeable. These nets are supported by separate aluminum frames which provide a working platform and necessary buoyancy for accessing the fish holding areas of the trap. The aluminum frames will be interchangeable between either the 15' or 25' nets and are built under a separate bid request.

The trap net is constructed in three major parts: lead, heart, and pot/spiller (see attached drawings). Each of these parts is connected to each other using large Y.K.K. # 10 nylon separating zippers. This accelerates the assembly process in the field. The webbing used for all parts of these nets is 1¼" stretch mesh, #252 knotless nylon webbing. Framing lines and corklines are 3/8" braided polypropylene line. All leadlines are 4 pound per fathom except in the spiller tunnel where 2 pound per fathom leadline is used (Sampson Flexcore leadline or equivalent will be used). Floats on the heart and lead will be equivalent in size and buoyancy to Spongex K-4 expanded PVC floats. Upon completion, the entire net will be dipped in a green water-base latex netcoat (i.e. Flexdip Netcoat) in order to bind all fibers and prolong the life of these nets.

The Lead

The lead will be built in 2 or 3 sections depending on the size of the trap. Each section is 50 feet long with the shore-end section of the small trap and the mid-section of the large trap tapering to accommodate the bottom contour of the river. Y.K.K. #10 nylon separating zippers will be attached on both ends of the middle sections and only on the trap end of the shore sections. These vertical zippers should have their origin at the **corkline** and connect towards the bottom or leadline. The side of the zipper with the coupling piece attached (female) should be permanently attached on the shore end of the zipper and the trap end of the lead section; therefore, on each lead section a half zipper with the coupling piece permanently attached (female) should be on the trap end of the 50' section while a half zipper without the coupling piece (male) should be on the shore end. No zipper should be on the shore end of the shore section.

The Spongex K-4 (or equivalent) corks will be spaced on 9 inch centers over the 3/8" braided polypropylene corkline. A $\pm 2\frac{1}{2}$ inch (inner diameter) loop should be left on either end of the cork and lead lines for connecting lead sections by use of a snap shackle. The leadline should be 4 pound per fathom in weight (equivalent in durability to Sampson Flexcore). Webbing will be 1¼" stretch mesh, #252 knotless nylon webbing.

The Heart

The heart section of the trap is the most complicated. The heart works as a funnel to force fish to swim into the pot/spiller. The wings provide a wall that will redirect fish into the pot tunnel if they turn away before entering. There is an apron on the bottom of the heart to prevent fish from escaping by diving under the net. The heart entrance is split in two by a lead section. On this lead section there will be a half zipper attached on the shore end that does not have a coupling piece on it (male). In this way, all other lead sections will be able to attach to the heart. There will also be two zippers that attach the heart to the pot at the entrance to the pot tunnel. These zippers will start at the bottom middle of the pot tunnel entrance and follow the perimeter up each side of the pot tunnel entrance: out 3 feet and up 7% feet on the small trap and up 12 feet on the large trap. The zippers' origin should be at the bottom middle of the pot tunnel entrance and the zippers will close towards the surface or corkline. This allows the heart to be completely separated from the pot at the pot tunnel entrance.

Again, Spongex K-4 (or equivalent) corks will be spaced on 9 inch centers over the 3/8" braided polypropylene corkline throughout the heart, The leadline will be 4 pound per fathom in weight (equivalent in durability to Sampson Flexcore). Webbing will be 1¼" stretch mesh, #252 knotless nylon webbing. Loops should be left in the lead and cork lines wherever zippers are located. Also, loops should be left in all places where the spreader bars will attach: outer wings, terminus of inner wings, terminus of lead section, and the shore end of both the inner and outer wings.

There are two lines not shown in the accompanying drawings that should be added to each of the outer wings. These tie down lines should be 6' long and attach on the outer wing corkline, 4 feet from the front pot wall. When tied to the aluminum frame, this line will enable the wings to be used for anchoring the trap on shore without pulling the heart, pot and spiller out of shape.

The Pot/Spiller

The pot and spiller portions of the trap function as the holding area for captured fish. It is split in two sections by the mid panel. The length and width dimension for the

pot/spiller will be the same for both the large and small traps (10' wide X 8' 7½" pot length X 10' 1½" spiller length); however, the depth will be different due to fishing depth of the two traps. In this way, each aluminum mobile trap frame will be able to attach to either a large or small trap net.

The pot tunnel protrudes into the pot and is a continuation of the heart. Two zippers serve as the connection between the pot tunnel and heart (see Heart description). At the exit to the pot tunnel, inside the pot, a 1% foot spreader bar should be attached to the leadiine which will hold the pot tunnel open while fishing. Any material that sinks can be used for this purpose; for example, we have used ¾" galvanized water pipe. On the corkline of the pot tunnel, a ¼" polypropylene line should be provided that holds the tunnel open; a spreader bar is not necessary. The spreader line should simply be a bridle (Y) that ties at the center of the mid panel on the aluminum frame and branches in two, half way to the pot tunnel. Each branch of this bridle should tie to either side of the pot tunnel at the corklines.

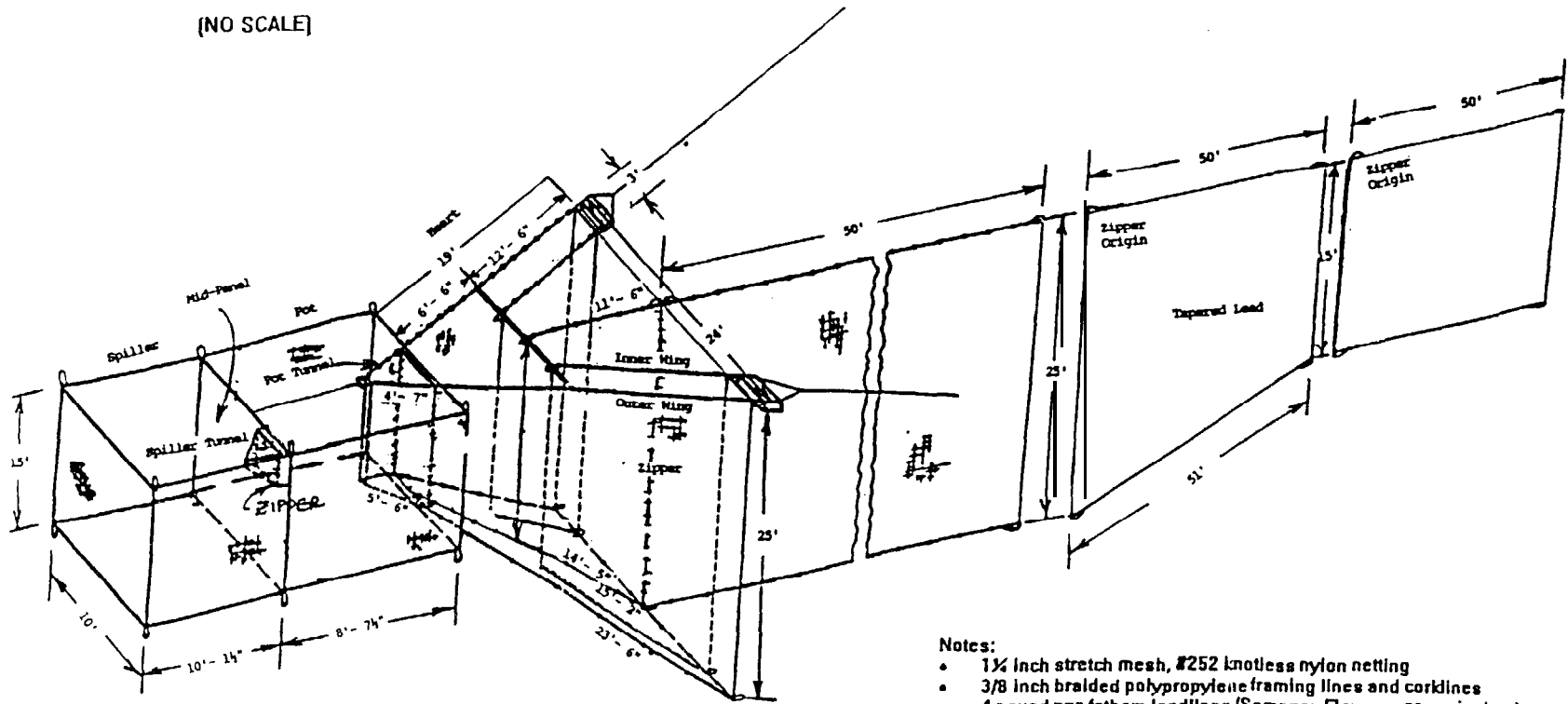
The spiller tunnel protrudes from the mid panel into the spiller portion of the net. This tunnel is removable from the mid panel. Two zippers are used that originate at the bottom, center of the tunnel entrance and follow the boundary with the mid panel out 1% feet, up the sides 3 feet, and close back towards the middle an additional 1½ feet. In this way, the tunnel can be removed while assembling the net. The spiller tunnel also needs a spreader support for the tunnel exit. This support should be a 1 foot square made out of a lightweight material (i.e. 3/8 inch round aluminum stock) and permanently attached to the tunnel exit. Two 9 foot lines (¼" braided polypropylene) should be attached to either side of this support. These lines will tie into the side of the aluminum floating frame and hold the spiller tunnel open.

No corks will be used in the pot/spiller section of the trap with the exception of the corklines on the pot tunnel. Leadiine will be used for the perimeter of the bottom of the pot/spiller section including the mid panel. Loops should be left on all four corners of the pot/spiller and on the two ends of the mid panel at the corkline and at the leadline. These loops will provide locations for the attachment of weights on the leadiine and improve ease of handling. The webbing, used in all parts of these nets, is 1% stretch mesh, #252 knotless nylon webbing. Framing lines and cork lines are 3/8" braided polypropylene line. All leadlines are 4 pound per fathom except in the spiller tunnel where 2 pound per fathom leadiine is used (Sampson Fiexcore leadiine or equivalent will be used).

Upon completion, the entire net will be dipped in a green water-base latex netcoat (i.e. Flexdip Netcoat) in order to bind ail fibers and prolong the life of these nets,

University of Washington Mobile Squawfish Trap

25' Net Layout
(NO SCALE)

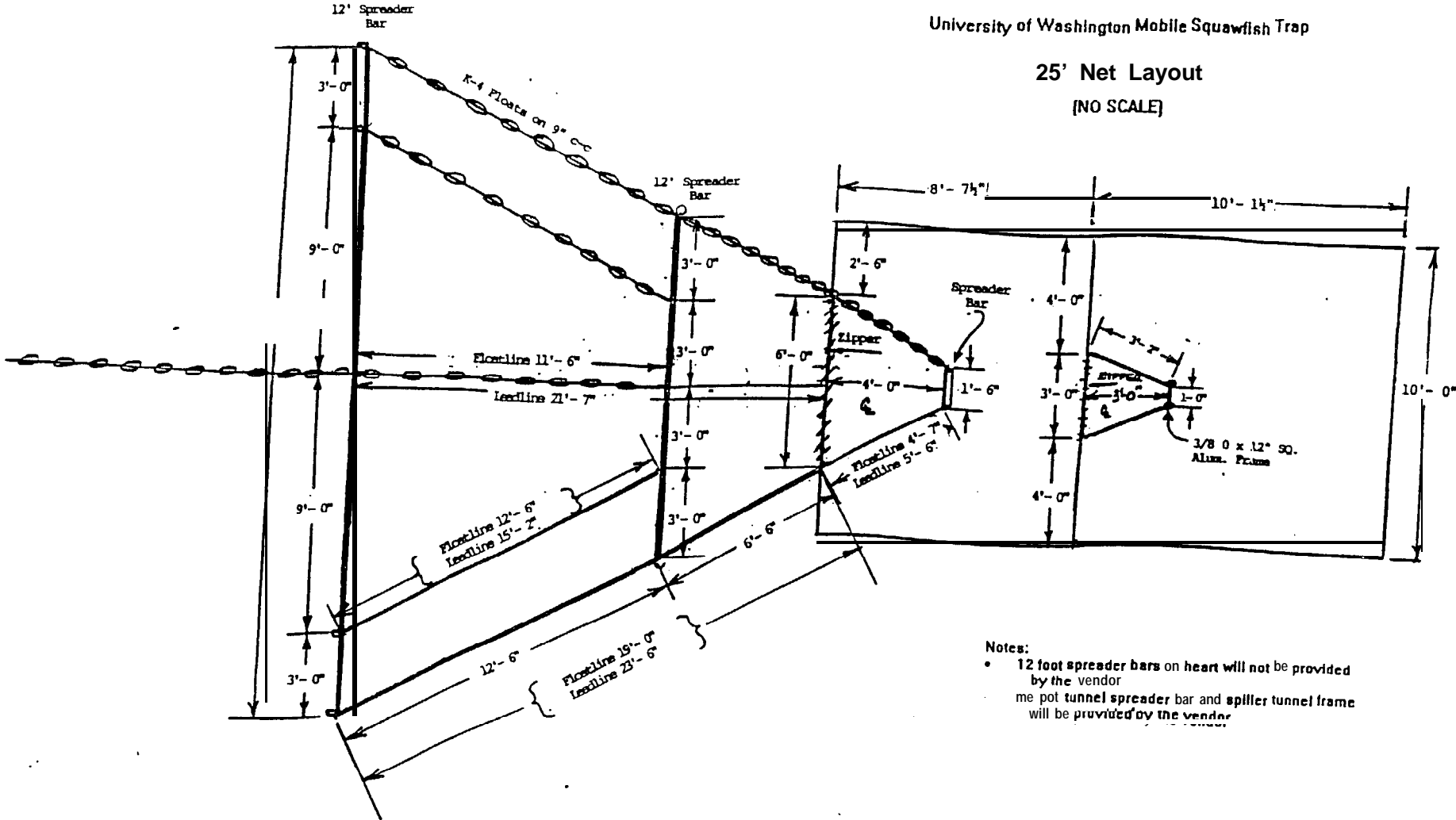


Notes:

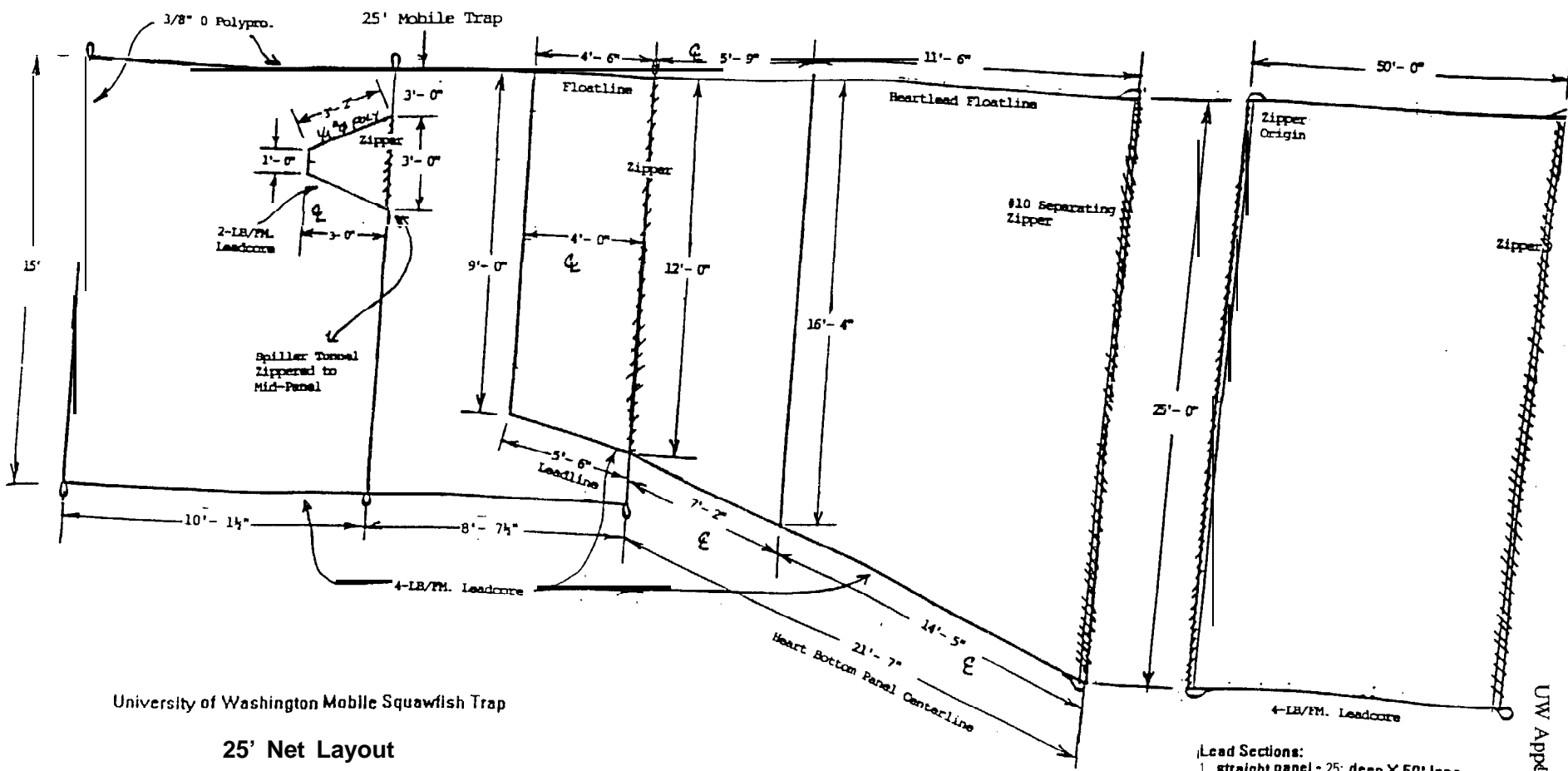
- 1 1/4 inch stretch mesh, #252 knotless nylon netting
- 3/8 inch braided polypropylene framing lines and cordlines
- 4 pound per fathom leadlines (Sampson Flexcore or equivalent)
- 2 pound per fathom leadlines in spillier tunnel only
- Y.K.K. #10 separating zippers
- Spongex K-4 expanded PVC floats or equivalent
- green water-base latex netcoat (Flexdip Netcoat or equivalent)
- see attached verbal description for further instructions

University of Washington Mobile Squawfish Trap

25' Net Layout
[NO SCALE]



- Notes:
- 12 foot spreader bars on heart will not be provided by the vendor
 - the pot tunnel spreader bar and splicer tunnel frame will be provided by the vendor



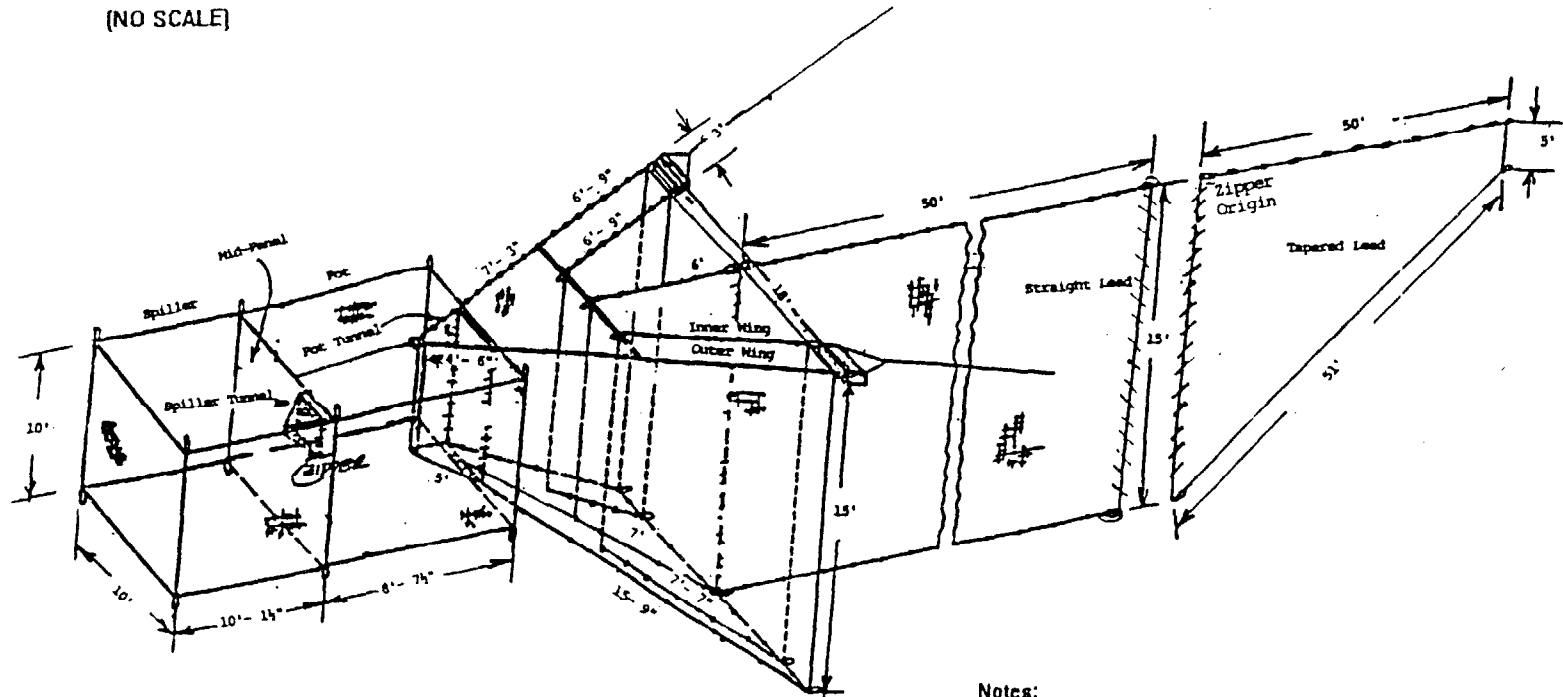
University of Washington Mobile Squawfish Trap

25' Net Layout
(NO SCALE)

- Lead Sections:
- 1 straight panel - 25' deep X 50' long
 - 1 tapered panel - 25' deep X 50' long X 15' deep
 - 1 straight panel - 15' deep X 50' long

University of Washington Mobile Squawfish Trap

15' Net Layout
(NO SCALE)

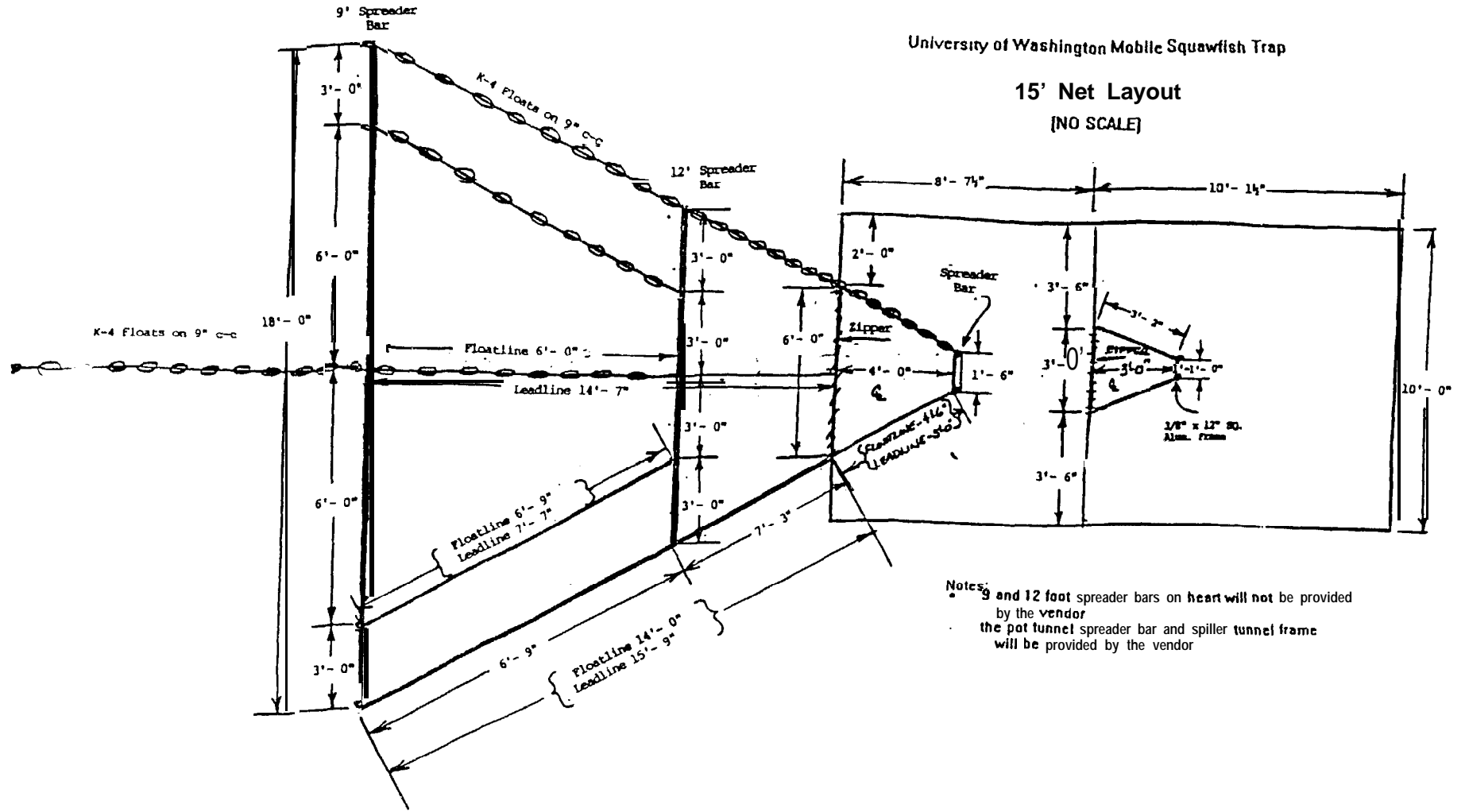


Notes:

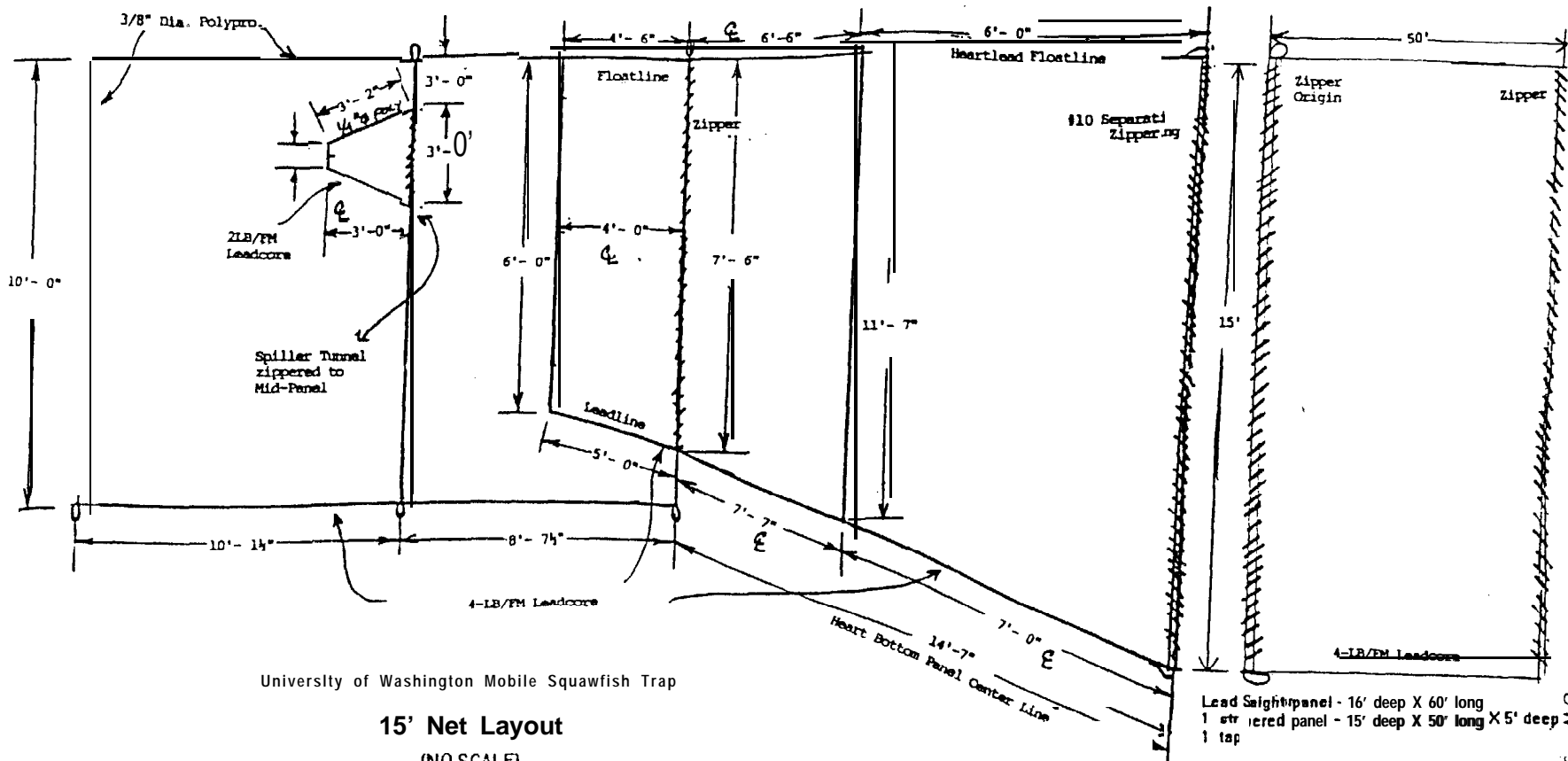
- 1 1/2 inch stretch mesh, #252 knotless nylon netting
- 3/8 inch braided polypropylene framing lines and corklines
- 4 pound per fathom leadlines (Sampson Flexcore or equivalent)
- 2 pound per fathom leadlines in spiller tunnel only
- Y.K.K. #10 separating zippers
- Spongex K-4 expanded PVC floats or equivalent
- green water-base latex netcoat (Flexdip Netcoat or equivalent)
- see attached verbal description for further instructions

University of Washington Mobile Squawfish Trap

15' Net Layout
[NO SCALE]



Notes:
 • 9 and 12 foot spreader bars on heart will not be provided by the vendor
 • the pot tunnel spreader bar and spiller tunnel frame will be provided by the vendor



University of Washington Mobile Squawfish Trap

15' Net Layout
(NO SCALE)

UW MOBILE TRAP FRAME SPECIFICATIONS

This trap is designed for fishing several remote locations on the Columbia and Snake rivers. For this reason it needs to be lightweight and transportable. This design emphasizes long term survivability, durability, and mobility. All of which are essential qualities for successful use throughout the Columbia and Snake river watersheds.

Specific design elements of the frame need to include the following: (1) reliability and ease of trailering over long distances and launching at remote field sites, (2) ease of on site assembly and break down, (3) in river stability and maneuverability while being towed behind a 17 foot trap tender boat to trapping locations at high speeds.

This prototype will be constructed as per the instructions below and the attached drawings. Vendor suggested modifications to the existing design and material specifications are encouraged.

Frame Construction

Pontoons:

The Merwin Trap is supported by two 24 foot 6 inch by 2 foot wide and 2 foot deep air tight aluminum pontoons. Each pontoon will have four deck mounted (outboard) 8 inch mooring cleats and two 4 inch diameter sailing winches(inboard) both fore and aft. Each pontoon will have three recessed 1 foot 6 inch by 2 foot wide and 3 inch deep walkway connection wells. These connection wells are centered (aft to forward) at 1 foot 9 inches, 12 feet 6 inches, and 23 feet 9 inches. Pontoons are to be decked with aluminum 'diamond plate'. Anchor wells 2 feet 6 inches long will be recessed and centered aft at 4 feet 3 inches in each. Net hooks are placed on 2 foot centers along both inboard sides 1 inch below the deck surface. These should be recessed if possible. The frame should be able to collapse in order to attach the pontoons together for towing and transporting.

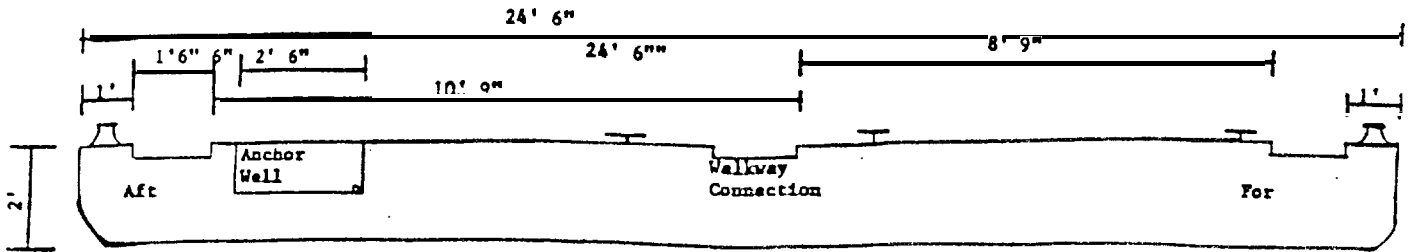
Walkways:

Three 11 feet by 1 foot 6 inch wide and 3 inch deep aluminum walkways will join the two pontoons. These walkways will be filled with styrofoam or other buoyant material. Walkways join the pontoons at the recessed connection wells presenting a flush deck surface. Connection to the pontoons is via an interlocking pin and flange system or an appropriate system suggested by vendor. Decks will be surfaced in 'diamond plate'. Net hooks will be placed on 2 foot centers 1 inch below deck surface along the forward edge of the aft and mid walkways, recessed if possible. Similar net hooks are placed along the aft edge of the forward walkway. This walkway has four additional net hooks placed 1 inch below the deck surface at each intersection point with the pot tunnel.

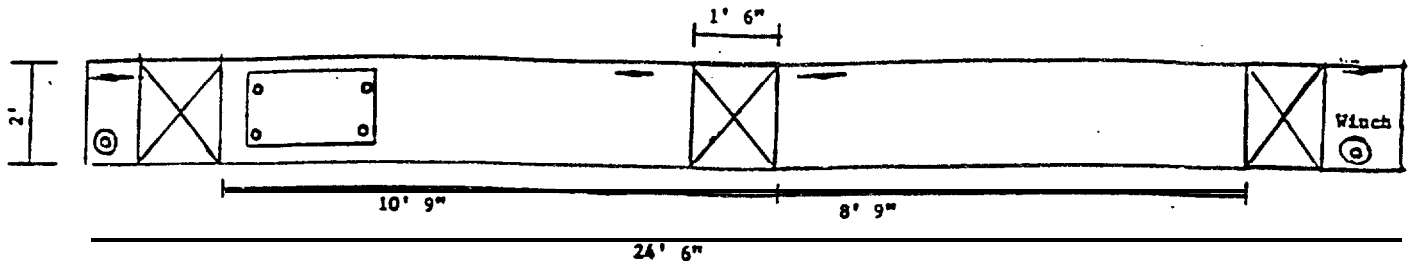
UW Mobile Trap Frame

Pontoons:

Side View

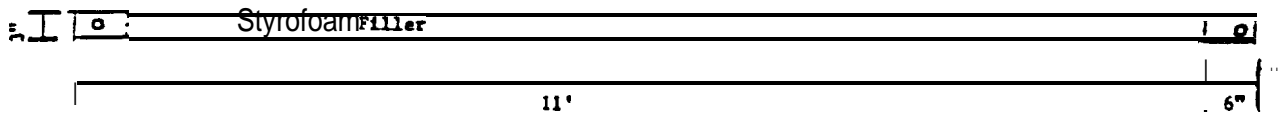


Top View

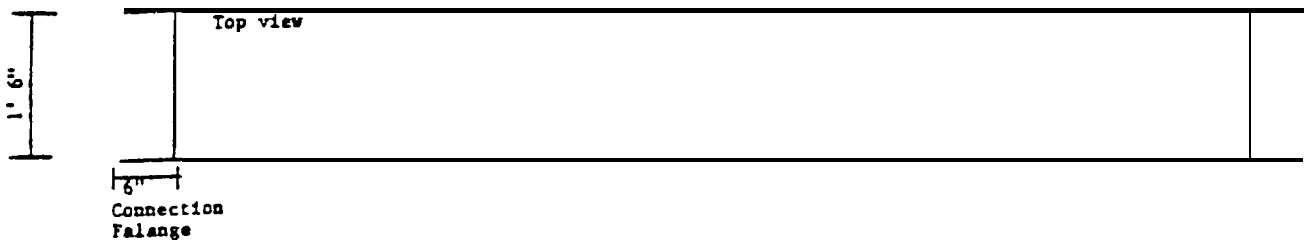


Walways:

Side View



Top View



APPENDIX B

**University of Washington
1992 Electrofishing Synopsis and Annotated Bibliography**

FRI-Uw-9306

April 1993

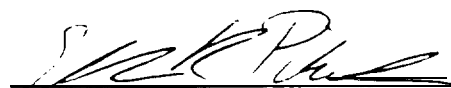
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**SYNOPSIS AND ANNOTATED BIBLIOGRAPHY ON
ELECTROFISHING WITH SPECIAL REFERENCE TO
COLUMBIA RIVER SQUAWFISH CONTROL**

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CENTER FOR QUANTITATIVE SCIENCE

Approved

Submitted 2 April 1993



Director

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We would especially like to thank Marcus Duke and Abby Simpson for their patience and efforts in editing this report and presenting a legible product.

KEY WORDS

electrofishing, injury, mortality, sampling methodology

INTRODUCTION

This report has two objectives: (1) to provide an introduction to electrofishing theory and practical application and (2) to review the existing electrofishing literature, emphasizing how the knowledge and experience of previous studies could be applied to squawfish removal efforts on the Columbia River. Some general principles and guidelines are provided for the understanding, construction, and application of safe, efficient, boat-based electric fishing equipment.

This review heavily relies on information from the following authors: Reynolds (1983) on principles of electrofishing, Koltz (1989) electricity and its application in electrofishing, Lazauski and Malvestuto (1990) on electrofishing and safety, Lamarque (1990) on fish response to electric shock and factors affecting electrofishing efficiency, Novotny and Priegel (1974) on electric fields and electrofishing equipment, Smith (1989) and D. Snyder (Colorado State Univ., Ft. Collins, pers. comm.) on the principles and techniques of electrofishing, and Zalewski and Cowx (1990) on factors affecting electrofishing efficiency.

HISTORY

Electric fishing is a well-established research and management tool for fisheries biologists. The history of electric fishing is surprisingly lengthy. The first patent for an electric fishing machine was granted in London, England, in 1863. The most important developments in the theory and application of boat based electric fishing occurred in the early 1970s.

At the University of Wisconsin, Novotny and Priegel (1973) developed a boat-mounted, multi-anode, boom-array electric fishing system, which was the forebearer of today's commercially available electrofishing units. In the past most electric fishing equipment was "home made" by biologists with limited electrical engineering backgrounds. For today's fisheries biologist, there exists a wide inventory of field-tested, dependable, commercially available electric-fishing equipment. The developments in today's electric-fishing gear have been directed towards reducing harm to fish, saving time and money, reducing the possibility of serious injury to fishery workers, and increasing catch-per-unit-effort.

BASIC ELECTRICITY

All matter consists of charged particles that attract or repel each other because of the positive or negative charges they bear. Electricity is the form of energy that results from this attraction or repelling of particles. Electricity can be defined as the force that moves electrons (Smith 1989). A circuit is a closed path along which an electric charge moves. The rate of flow or intensity that moves the charge is the current, which is measured in amperes. The electromotive force that moves the current is voltage and is measured in volts. Voltage may also be defined as the potential force available to move electrons through the circuit. The restriction of electron flow in the circuit

is resistance and it is measured in ohms. Electrical power is the rate at which electrical work is done and is measured in watts. One watt of power results when a current of one ampere flows through a resistance of one ohm under the force of one volt. The relationship between current, voltage, and resistance in a closed circuit is given by Ohm's Law:

$$\text{Current (amperes)} = \text{voltage (volts)} / \text{resistance (ohms)}$$

The current in a circuit is directly proportional to the applied voltage and inversely proportional to the circuit resistance. That is:

$$I = V/R$$

where I = current in amperes (amount of electron flow),
 v = voltage in volts (amount of charge causing electron flow), and
 R = resistance in ohms (restriction of electron flow).

The flow of current in a circuit is like the flow of water in a pipe. The pressure (voltage) drives the flow (current) through the pipe (circuit). The amount of flow the pipe can handle depends on its size and material (resistance). As the flow reaches the end of the pipe, it releases energy to do work at some rate (power).

Only two of the three Ohm's Law quantities are needed to calculate power:

$$\begin{aligned} w &= VI, \\ &= V^2/R, \text{ and} \\ &= I^2R. \end{aligned}$$

Wattage is simply the product of voltage and amperage.

When electrofishing, the Ohm's Law parameters are redefined in three-dimensional terms. In electrofishing, a closed circuit is created by passing electric current between two submerged electrodes through the water and fish. Current of sufficient densities will either frighten, lead, stun, or kill fish. As current flow leaves the electrodes, passing through the water, it spreads out in all directions forming a field pattern. Ohm's Law parameters for water now become voltage gradient, current density, and resistivity:

$$\text{Resistivity (ohms/cm}^3\text{)} = \text{voltage gradient (volts/cm)}/\text{current density (amps/cm}^*\text{)}.$$

Current density can be visualized as a measure of intensity of electron flow (current) at a given point in the water. The voltage gradient is the voltage between two closely spaced points causing the electron flow between the two points. Resistivity is the measure of the quality of the water as an electrical conductor. Resistivity is often referred to as conductivity and is the inverse of resistance (Smith 1989).

ELECTROPHYSIOLOGY

The basic principle of electric fishing is the transfer of electrical current into the water via electrodes and through the fish at high enough current densities to produce a desired effect (taxis, repulsion, or death). It is possible to stimulate or catch fish with any kind of electrical current (of a sufficiently strong field), but in order to maximize catch-per-unit-effort (CPUE), to avoid causing injury to the fish, or to fish under adverse physical conditions, the proper choice of electrical parameters and current is important. There are three types of current: alternating current (AC), pulsed direct current (PDC), and constant direct current (DC).

It is well established that AC can efficiently tetanize (immobilize) fish. A serious side effect of AC is the potential to kill a high percentage of affected fish. Unlike DC, current direction is changing every half cycle. In an AC field, the fish faces the cathode and anode successively as many times as the current alternates (Lamarque 1990). Above a certain field strength, this continuous reversing of current polarity quickly overwhelms the fish's nervous system. Constant DC has the desirable characteristic of producing anodic galvanotaxis (forced swimming toward the anode) with less harm to the fish. However, constant DC has a more limited effective range and generally large and inefficient power requirements.

At the same peak power, AC, DC, and PDC will have similar or equivalent fields in terms of size and intensity. However the response threshold levels of fish are higher for DC, thereby reducing the 'effective zone.' Also for DC, peak power = average power, whereas for PDC and AC average power, which determines the size of the generator, is much less (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.). The effects of pulsed DC are intermediate between that of AC and DC. Pulsed DC is most commonly used in boat-based electric fishing.

in choosing the appropriate electric parameters, we need to understand the behavior of fish in electric fields (electrophysiology). Unfortunately, fish electrophysiology is generally not well documented nor understood. Galvanotaxis is believed by some to be a result of direct stimulation of the central and autonomic nervous systems that control the fishes voluntary and involuntary reactions.

Many authors have classified fish reactions in electric fields, attempting to fully explain their causative mechanisms (Halsband 1967, Lamarque 1967, Vibert 1967, Sternin et al. 1972, Edwards and Higgins 1973). A general agreement of the results has proven difficult to achieve. The one matter that most scientists agree on is that AC is more harmful than DC. Pulsed DC can produce the desirable effects of both AC and DC while limiting the negative side effects (Lamarque 1990).

Fish may exhibit four general responses to induced electric fields (i.e., PDC at 60Hz), avoidance, taxis, narcosis, and tetany. These responses depend on the total duration and level of current density experienced. When electrofishing, it is necessary to establish an electric field of sufficient current density to achieve the desired response from fish. The field established is defined by three zones of increasing density: the perception zone, effective zone, and danger zone. If the perception zone is too large, fish are frightened and avoid capture. The desirable effect of taxis (forced swimming) occurs within the effective zone. If fish are not removed in a timely manner, narcosis (an induced relaxation of the body) occurs. Fish exposed to the danger zone will experience

seizure or tetany. Tetany is the rigid immobilization of all musculature. Fish become tetanized by the increased levels of current densities. Tetany most often causes death by asphyxiation. Ideally an electrofishing unit produces the smallest perception zones, largest effective zone and no danger zone.

A fish's first reaction to AC is to take up a transverse position to the electric field lines: oscillotaxis (Koltz and Reynolds 1989). The fish then repeatedly attempts to face the 'anode and cathode until the threshold current is reached, causing the fish to be tetanized on the spot. Some authors also describe movements toward, as well as away from the electrodes (Lamarque 1990). Little agreement on results was apparent in our literature review of electrophysiology.

In DC electrofishing, electric current flows continuously from the negative cathode to the positive anode. The actual mechanism for electron flow is electrolysis, that is the movement through water of ions that collect electrons at the cathode and release them at the anode (electron flow). The reaction of fish to DC is quite different than to AC. The first reaction observed in a DC field is a quivering of fish body muscles or fins; this occurs as the fish enters the perception zone. What happens after a fish enters the perception zone depends on a number of factors: the fish's orientation to the electric field (facing anode or cathode), species electrophysiological characteristics (resistance, fatigue), and current density. Assuming the fish does not flee (the perception zone), it then moves into the effective zone. As the fish moves through the effective zone it experiences increasing current densities, causing inhibited swimming followed by galvanotaxis. If the fish is not removed from the increasing field densities, it will continue its forced swimming toward the anode until relaxation of all its muscles is induced (**galvanonarcosis**). With prolonged exposure to DC, a second forced swimming occurs, which sends the fish into the area of highest current densities, the danger zone. Here tetany occurs, often followed by death (Lamarque 1990). If a fish is removed from the danger zone in time and allowed to recover under optimal conditions, death from tetany may be averted (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.).

Strong anodictaxis is possible with pulsed direct current. Lamarque (1990) suggests that the mechanisms of taxis are quite different for DC and PDC. PDC is produced by interrupting a steady DC current flow with an electronically controlled switch. The switch gives the number of ON-OFF pulses per second (frequency). Research has shown a species-specific reaction to frequency and pulse width. In general, pulse shapes with a fast rise and slow decay enhance anodictaxis. With PDC, no narcosis or second swimming towards the anode occurs. In the effective zone, fish are drawn more directly from a greater distance than DC toward the anode, generally becoming immobilized before reaching the danger zone.

The establishment of the perception, effective, and danger zones in AC, DC, and PDC depends on field strength, water conductivity, and electrode size. In review, DC produces galvanotaxis, inducing tetanus only near the electrode and after prolonged exposure, and is the least harmful to fish. However it has the most limited effective range and highest power requirements. PDC produces strong galvanotaxis, and has a large effective zone and greatly reduced power requirements. PDC does tend to immobilize a large portion of the catch farther away from the anode than DC. AC has the greatest effective range but little or no taxis, with the potential for tetanizing fish, resulting in the death and loss of capture.

INJURIES TO FISH

At its worst, electric fishing can kill or produce strong muscle fatigue. Normally a head to tail voltage gradient from 0.1 to 1 volts/cm of fish is required to safely collect fish with an electric current (Halsband 1967). The degree of injury depends on voltage gradient experienced across the fish's body (Stewart 1962), exposure time (Chmielewski et al. 1973, Whaley et al. 1978), current form (Lamarque 1967), and species and size of fish (Stewart 1962, Chmielewski et al. 1973).

The most common damage caused by electric fishing involves vertebral malformations, recovery from which is long term if not impossible. The rate of mortality following electric fishing capture has a wide range depending on the particular study. For trout mortality, rates ranged from <5% to 90% (Hauck 1949, Pratt 1954, McCrimmon and Bidgood 1965, Hudy 1985, Holmes et al. 1990, Fredenberg 1992, Newman 1992, Reynolds et al. 1992), and warm-water species ranged from 0% to 28% (Spencer 1967, Holmes et al. 1990, Newman 1992). Hauck (1949) also reported internal damage and bleeding from gill filaments in electrofished trout. Mortalities from electrofishing may be broken into two broad groups, those caused by injuries and those due to asphyxiation.

Electric fishing induces the typical changes in blood lactate levels normally observed when fish are stressed. Schreck et al. (1976) observed changes in lactate levels in the blood of rainbow trout (*Oncorhynchus mykiss*) after shocking (DC current). The lactic acid levels in the blood doubled immediately after the fish were shocked, remained high for 1 hr, and recovered to pre-shock levels after approximately 3 hr (Schreck et al. 1976).

In general AC, DC and PDC can produce mortality. The worst currents are condenser or burst form charges: AC at 50-60 Hz and 1/2 wave rectified AC at 50-60 Hz (Lamarque 1990). Currents that tend to draw fish towards the anode are least harmful. Mortality results from physical injury or asphyxiation brought on by physiological stress. The most common injuries are broken or ruptured vertebrae resulting from electrically induced, violent muscle contractions. The frequency and severity of vertebral injury is increased in spawning fish owing to decalcification (Stewart 1962). Other observed injuries include damage to internal organs and burst blood vessels in the gills and brain.

With salmonids, one can determine if vertebrae are damaged by examining the skin. Dark spots or bands will appear in proximity to the damaged vertebrae. While such marks typically represent vertebrae injury, they are not always present when spinal injury has occurred (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.). This discoloration is thought to be caused by the excitation of skin chromatophores when the sympathetic nerve fibers are damaged (Lamarque 1990). Also such discoloration could be caused by hemorrhages of damaged tissue near the skin surface; if a fish actually touches an electrode it will be burned (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.). The degree of vertebrae dislocation largely depends on the current type, water conductivity, operator ability, and exposure time. AC tends to cause breaks while DC results in compressions or misalignment of the vertebrae (Stewart 1962). Presently, numerous authors (Holmes et al. 1990, Fredenberg 1992, Reynolds et al. 1992) are closely examining the electrofishing-induced harm caused by PDC.

Physiological stress occurs when the fish has been overexposed to a tetanizing current. Death usually results from respiratory failure brought on by radical increases in fish blood lactate levels, critically reducing the oxygen carrying capacity (Black 1958, Schreck et al. 1976, Emery 1984). Once the lactic acid reaches a certain level, a fish will not fully recover. Such a fish may appear fine at release; however, it will eventually die, usually within 1-3 days. The complex physiological processes experienced by fish have been investigated by (Black 1958, Black et al. 1960, Sternin et al. 1972, Schreck et al. 1976, Wood et al. 1983, Holeton and Heister 1953, Emery 1984). Emery (1984) succinctly explains these physiological processes.

In a successful electric fishing operation, an electrostatic current is desirable, i.e., a current that attracts a fish to the anode but does not tetanize it. Some commonly used electrostatic currents are as follows: constant DC, 3-phase fully rectified AC at 30 Hz, and PDC square wave currents at 30-60 Hz and 10-50% duty cycles, rectangular pulsed DC at 400 Hz on 10% duty cycle and Complex Pulse System (CPS™). The key to a successful electric fishing removal operation (e.g., squawfish control on the Columbia River) is flexibility in current form (AC, PDC, DC) and shape (square, sine, smooth, CPS™), and minimal harm caused to fish. An electric fishing unit must have the ability to adapt to the variable physical conditions (conductivity, water temperature, and water velocity) of a selected sampling site. Fortunately, modern commercially available electric fishing units offer such a range of electrical current parameters.

SYSTEM COMPONENTS

Basically the function of an electric fishing system is to produce an appropriate electrical stimulus in fish near the electrodes to permit easy capture by netting or to cause fish to stay in areas where nets, trawls, or traps can be readily used (Novotny 1990). Any electric fishing system requires some minimum effective value of current density produced from the electrodes. The minimum value will vary with water conductivity, temperature, and target fish. This current level establishes the perception, effective, and danger zones in the electric field surrounding the anode.

The components of an electric fishing system can be classified into six subsystems according to function. These are (1) power supply to provide the electrical energy to the system, (2) power conditioner to condition (or modify) the raw electric energy to meet the requirements of the specific application, (3) instrumentation to provide knowledge of the electrical performance of the system, (4) interconnection systems to safely carry the conditioned power to the electrodes, (5) electrodes to properly couple the conditioned electrical power to the water, and (6) auxiliary equipment to provide the peripheral functions necessary for successful electric fishing (nets, lights, pumps, aerators, rubber gear, etc.) (Novotny 1990).

When electrofishing, it is advantageous to produce a galvanotaxic current (PDC or DC). DC generators, however, are prohibitively large for boat-based operations. A three-phase AC generator is generally preferred for most boat-based electric fishing applications because it is smaller and lighter (for the same power rating) and better suited as a supply source for most power conditioners (Novotny 1990). AC generators are more flexible in their output parameters than DC

generators and, therefore, more adaptable to a wider range of fishing conditions and water conductivities.

Raw, AC-generated electric power is modified via power conditioners. The function of the power conditioner is to provide the appropriate voltage level and wave form (DC, AC, PDC, CPS™, etc.) to suit the specific electric fishing application. A major advantage of modern power conditioners (i.e., Coffelt VVP-15, Mark 22, or Smith-Root GPP 7.5) is the flexibility they afford in terms of wave form, voltage level, pulse rate, and duty cycle. This flexibility enables a single electric fishing system to be used in a wide range of applications. Modern electric fishing systems may employ a combination of transformers, rectifiers, filters, and choppers in their power conditioners.

The individual components of the electric fishing system must be electrically interconnected in order to form the complete system. The interconnection system provides the following functions: (1) the main disconnection switch between the power supply and the rest of the system, (2) circuit protection devices, preferably circuit breakers, (3) suitable meters and instrumentation, (4) appropriate safety (dead man) switches and, most importantly, (5) proper electrical bonding of the cases of all the components to each other and to any metallic parts of the supporting structures. The bonding ensures that no two external metallic parts of the entire system (including the boat or other support structures) can ever have a potential voltage between them (Novotny 1990). The interconnection system should be carefully checked by qualified personnel in order to avoid a potentially dangerous situation.

The requirements of an effective electrode system include (1) establishment of a large effective zone while minimizing the perception and danger zones, (2) flexibility to meet variable water conductivities, (3) ability to negotiate weeds, obstructions and current while producing as little physical disturbance as possible, (4) ease of safe assembly (Novotny 1990). Commonly used electrode configurations that incorporate these principles are Coffelt's Wisconsin Ring, Smith-Roots UAA-6, and various sphere anode arrays.

The two basic electrode shapes are spherical and cylindrical. Spherical electrodes have generally superior electrical properties but have many mechanical disadvantages. The most effective electrode arrays combine the positive aspects of both electrode shapes. Cylindrical electrodes, arranged into a circular shape, achieves this. The best example of such a design is the commercially available Wisconsin Ring array. This design utilizes the desirable properties of spherical shapes (limited perception zone, no danger zone, large effective zone), while maintaining the advantageous mechanical properties of the cylindrical electrodes (ease of negotiating obstacles, little physical disturbance, and larger overall effective range).

Two guiding principles with electrodes are (1) always use the largest electrodes possible within the limitations imposed by the physical constraints and electrical limits imposed by the generator and electrical control system (Novotny and Priegel 1974); and (2) if possible, mechanically shield the anodes so fish can not come in direct contact with them (Holmes et al. 1990).

FACTORS AFFECTING EFFICIENCY

The parameters that regulate electric fishing efficiency are numerous: choice of current (AC, DC, PDC), electrical output, electrode shape and size, turbidity, water conductivity, temperature, depth, habitat, operator ability, fish species, behavior, and size. The most important parameter under the control of the electric unit operator is choice of current. To succeed at electrofishing, one must understand the actual electrical output characteristics (voltage, current, pulse rate, etc.) expected in the field. Operators also must understand the widely varying sampling conditions and be able to control current, voltage, and pulse shape to properly manipulate the electric fishing equipment, thereby maximizing catch-per-unit-effort.

The knowledge of electrical parameters and the components of an electric fishing system must be integrated with the understanding of all the biotic and abiotic external factors affecting catch rate. The most important factors are detailed below (adopted from Lamarque 1990).

Water conductivities in fresh water are divided into three groups. Low conductivity waters, 5-30 microsiemens per cm ($\mu\text{S}/\text{cm}$), are represented by mountain streams and lakes or areas associated with high rain runoff. Medium conductivity waters range from 30-500 $\mu\text{S}/\text{cm}$; the Columbia River is of medium conductivity ranging from 80-250 $\mu\text{S}/\text{cm}$. High conductivity waters have values greater than 500 $\mu\text{S}/\text{cm}$; these are mainly estuaries, brackish lagoons, and the sea.

Different fishing strategies must be adopted for each conductivity range. Fishing low conductivity waters is difficult, but good results may be achieved by using very large electrodes (anode diameter >60 cm) and high peak voltages (800- 1,650 volts). Best results in medium conductivity waters are achieved with a combination of large anodes and galvanotaxic current. In high conductivity water, PDC (rectangular waves of either 400 Hz or 100 Hz at 10% duty cycle) and smaller electrodes are needed to reduce energy requirements (Lamarque 1990).

Fish behavior in electric fields (electrophysiology) has a measurable effect on CPUE. The physical characteristics of the sampling habitat also play an important role in determining fishing success.

Predator fish (e.g., Salmonidae, Percidae, Centrarchidae) are more easily caught than prey species. Spawning or territorial fish are less likely to be frightened out of an area, thus allowing the boat to come in close. Bottomfish and poor swimmers are relatively difficult to catch. Thick-scaled fish like carp seem to be more electrically resistant than thin-scaled fish such as trout. Many fish build up a tolerance to subsequent electric fishings. Schooling species are easily frightened out of a fisher's effective zone by physical disturbances in the water. Smaller fish have less body size for a voltage difference to develop across, making them harder to catch than larger fish. Vegetation and cover can hide stunned fish from capture.

Fishing over a gravel substrate produces the best results. Electrode contact with muddy bottoms can short-circuit the field, causing a decrease in resistance, which can lead to overloading of the generator. In strong current, tetanized fish often are not visible and, therefore, are washed away from the netters. Turbid water allows a close approach towards fish but reduces catching efficiency through poor visual contact. In general, electrofishing efficiency decreases in moderately fast waters deeper than 10 ft.

The following table summarizes the factors affecting the efficiency of electric fishing.

ENVIRONMENTAL	BIOLOGICAL	TECHNICAL
1. Abiotic <ul style="list-style-type: none"> a. Conductivity b. Water quality c. Water clarity 	1. Community structure <ul style="list-style-type: none"> a. Species diversity b. Species composition 	1. Personnel <ul style="list-style-type: none"> a. Size of crew b. Experience c. Motivation
2. Habitat <ul style="list-style-type: none"> a. Habitat structure b. Habitat dimensions c. Substrate d. Water velocity 	2. Population structure <ul style="list-style-type: none"> a. Density b. Size distribution c. Age structure 	2. Equipment <ul style="list-style-type: none"> a. Design b. Maintenance
3. Seasonality <ul style="list-style-type: none"> a. Temperature b. Weather 	3. Species specific <ul style="list-style-type: none"> a. Behavior b. Physiology c. Morphology 	3. Organization <ul style="list-style-type: none"> a. Site selection b. Standard effort

(Adapted from Zalewski and Cowx 1990.)

SAFETY

Safety should be a primary consideration in all electric fishing operations. All personnel involved in electrofishing operations should be instructed as to the fundamentals of electricity, and understand and observe the safety requirements associated with electrofishing. The single most important factor in both electrofishing efficiency and safety is the training and experience of the crew. Regardless of the safety precautions given, the capability of the crew in adhering to those guidelines and good common sense in handling unforeseen circumstances, is of cardinal importance (Smith 1989). It is recommended that crew leaders attend the U.S. Fish and Wildlife Services' Fisheries Academy Course, "Principals and Techniques of Electrofishing." For further information on this course, contact Alan J. Temple, Chief Fisheries Management Training, Fish and Wildlife Service Office of Technical Fisheries Training, Route 3, Box 49, Kearneysville, WV 25430; telephone number (304) 725-8461, ext. 370.

A standard set of safety practices are listed below along with two daily field check lists concerning boat and electric fishing equipment. Safety practices should include the following (adapted from Lazauski H.G. and Malvestuto, 1990)

1. All United States Coast Guard safety equipment for the operation of a 28 ft. boat should be used.
2. Red Cross first aid and CPR training should be provided for all members of the electric fishing boat crew.
3. All members of the crew should be familiar with the electrical system of the boat.

4. All dip netters should wear rubber gloves, rubber boots, life vests and noise arresters if needed.
5. Boat operators should wear life vests, rubber boots and noise arresters if needed.
6. Electric fishing runs should be kept under 1 hr to avoid netter fatigue.
7. A strict check, via checklists, should be made of all electrical systems before each day's work in the field.
8. All fishing should cease at the first sign of lightning, rain, high winds, or dip netter fatigue.
9. Alcohol should never be allowed on an electric fishing boat.
10. Never touch the water or an electrode while the current is on.
11. Refuel the generator after engine has sufficiently cooled.
12. The boat driver should not make sudden turns or changes in boat speed.
13. No unauthorized passengers should ever be allowed on an electric fishing operation.
14. Know the range of your electric field. Avoid public recreation areas. Do not electrofish near people or animals.
15. Avoid all unprofessional conduct (horse play).
16. Carry appropriate spare equipment for the particular boat.
17. Carry a first aid kit.

Check lists should be developed for all phases of electric fishing operations. These should include items that are used daily, such as boat launching and electrical connections. An example of an electric fishing boat unit inspection sheet is given in Table 1.

A detailed instruction guide or manual should accompany each electric fishing apparatus to assist the operator. The operator should be familiar with both the unit and manual before fishing begins. A log book should also be available to record dates and times of use, maintenance, problems, and repairs.

An important emergency procedure is to have a pre-determined plan in the event of an accident. A documented route to medical facilities and procedures to follow is essential.

These safety procedures should be adhered to by all project personnel at all times. The safety check list and log book should be filled out every day. Also, all operational parameters (control box settings and meter readings) should be recorded with field data and any observations of abnormal appearance, behavior, or mortality. This data will help refine parameters for future trips, avoid undesirable effects, and add to the data base on such effects (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.). All members of the fishing crew should be familiar with the checklist material and compliance procedures.

Table 1. Daily check sheet for electric fishing boat safety inspection (adapted from Goodchild 1990).

Boat # _____ Date _____

Crew leader _____ Time _____

Crew members _____

Location _____

Log Book up to date Y/N

Manual present Y/N

BOAT

<ul style="list-style-type: none"> <input type="checkbox"/> Hull integrity <input type="checkbox"/> Safety railings intact and sturdy <input type="checkbox"/> Decks clean, free of excess water/bilges dry <input type="checkbox"/> Adequate mechanical protection of wiring <input type="checkbox"/> Adequate connectors and interlocking (integral with hull; <input type="checkbox"/> All metal equipment in boat electrically bonded to hull (check with volt/ohm meter) <input type="checkbox"/> Batteries fully charged-properly enclosed and vented <input type="checkbox"/> Communication gear working (where applicable) <input type="checkbox"/> Boat clean-equipment neatly stored 	<ul style="list-style-type: none"> <input type="checkbox"/> Auxiliary motor present and working (where applicable) <input type="checkbox"/> Oars/paddles present <input type="checkbox"/> Anchors/bailers present <input type="checkbox"/> Controls and gauges operational <input type="checkbox"/> hv output checks done <input type="checkbox"/> Adequate mechanical protection of wiring <input type="checkbox"/> Audible tone generator working <input type="checkbox"/> hv flashing light working <input type="checkbox"/> All foot switches working <input type="checkbox"/> KILL SWITCH' working <input type="checkbox"/> Operators safety switch working
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GENERATOR/ALTERNATOR

<ul style="list-style-type: none"> <input type="checkbox"/> Unit electrically bonded/connected to hull <input type="checkbox"/> Exhaust directed away from operator <input type="checkbox"/> All electrical connections secure and protected 	<ul style="list-style-type: none"> <input type="checkbox"/> Oil level O.K. <input type="checkbox"/> Gas topped off
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BOATMOTOR

<p><i>Inboard</i></p> <ul style="list-style-type: none"> <input type="checkbox"/> Oil level O.K. <input type="checkbox"/> Components secure <input type="checkbox"/> Belts O.K. <input type="checkbox"/> Visual inspection O.K. <input type="checkbox"/> Proper venting of exhaust <input type="checkbox"/> No gas leaks 	<ul style="list-style-type: none"> <input type="checkbox"/> Auxiliary motor working <input type="checkbox"/> Bilge blower working <p><i>Outboard</i></p> <ul style="list-style-type: none"> <input type="checkbox"/> Fastened securely-safety chain <input type="checkbox"/> Adequate gas supply
--	--

ANCILLARY EQUIPMENT

<ul style="list-style-type: none"> <input type="checkbox"/> Fire extinguisher present-fully charged <input type="checkbox"/> First aid kit and flash light present 	<ul style="list-style-type: none"> <input type="checkbox"/> Communication gear working <input type="checkbox"/> Lights working
--	--

PERSONNEL/CREW MEMBERS

<ul style="list-style-type: none"> <input type="checkbox"/> Each crew member briefed on boat operations <input type="checkbox"/> Minimum number of crew trained in CPR and basic electronics <input type="checkbox"/> Crew wearing PFD's <input type="checkbox"/> Crew wearing rubber gloves (long arm) <input type="checkbox"/> Crew wearing rubber boots 	<ul style="list-style-type: none"> <input type="checkbox"/> Crew wearing protective hearing gear <input type="checkbox"/> Each crew member has a dead man switch <input type="checkbox"/> Safety procedures covered <input type="checkbox"/> Local arrangements covered, i.e., police, etc <input type="checkbox"/> Hospital route outlined
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ELECTROFISHING GLOSSARY*

GENERAL

Alternating current: cyclic current, the mean value of which is nil during a total period. An alternating current is characterized by a sequence of positive and negative waves that are equal, usually sinusoidal, and follow each other alternatively at regular time intervals.

Anode: the positive electrode, usually hung from a boom extending away from the electrofishing vessel.

Aperiodic impulses: impulses following each other at varying time intervals.

Bonding: the permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity, with the capacity to safely conduct current.

Branch circuit: the circuit conductors between the final overcurrent device protecting the circuit and the electrical load(s).

Cathode: the negative electrode, usually located on the hull of the electrofishing vessel.

Circuit breakers: a device designed to open and close a circuit by a non-automatic means, and to open the circuit automatically on the predetermined overcurrent without damage to itself when properly applied within its rating.

Complex pulse system (CPS™): a complex pulse train or burst form of pulsed direct current by Coffelt Manufacturing, Inc., developed in response to recently detected high mortality rates caused by commercially available PDC wave forms.

Condenser discharges: current composed of a steady sequence of exponential discharges

Conductivity: the ratio of the density of the unvarying current in a conductor to the voltage gradient that produces it; the common unit of measurement is the $\mu\text{siemen/cm} = \mu\text{mhos/cm}$.

Conductance: the measure of the ability of a component to conduct electricity, the reciprocal of resistance: the unit of measurement is the siemen (mho).

Current: the rate of electrical charge flow in a circuit; the practical unit is the ampere (amps), which is one coulomb per second.

Current shape: the geometric shape of the current during one cycle; usually this refers to the rate of growth and decay of an impulse.

Cycle: one full revolution of a periodic phenomenon.

Deadman switch: a switch that requires constant pressure to supply electrical current to the circuit.

Direct current (continuous, galvanic): unidirectional constant current.

* Adapted from Cowx, I G, and P. Lamarque. 1990. **Fishing with Electricity. Applications** in Freshwater Fisheries Management; and Koltz, A K 1989 **A Power Transfer Theory for Electrofishing**

Effective fish conductivity: the apparent conductivity of live fish as determined by statistically fitting electroshock response data to the theoretical curve developed for the concept of constant power.

Electrical charge: a fundamental property of matter that can be classified as a fundamental physical quantity; the practical unit is the coulomb. The electron, the smallest charge identified in nature, has a magnitude of 1.6×10^{-19} coulomb.

Electrofishing: the use of electricity to provide a sufficient electrical stimulus in fish to permit easy capture by netting.

Frequency: total number of cycles per time unit measured in hertz; 1 Hz equals one cycle per second.

Ground: a conducting connection between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

Half-wave rectified current: current composed of a sequence of half sine waves in the same direction, separated by pauses of equal duration. This is obtained by passing an alternating current through a rectifier.

Impulse: electric phenomenon of short duration compared with the period.

Interrupted direct current: unidirectional current interrupted by periodic pauses. See pulsed direct current.

Isolation transformer: a transformer inserted into a system to separate one section of the system from undesired influences with other sections.

Mismatch ratio: the ratio of either the two resistance values or two conductivity values determined for adjoining media. For electrofishing, this is the ratio of conductivity of the water to the effective conductivity of the fish.

Multiphase current: the number of phases, the whole of n being alternating currents originating from the same source and out of phase with each other by $1/n$ of a period ($1/3$ of a period with three phase current).

Netter: the individual who nets the captured fish during electrofishing operations.

Pause duration: interval between two electric phenomena.

Period: time interval between two identical stages in an electric sequence.

Power: the rate of doing work or the energy-per-unit-of-time; the practical unit is the watt (W), which is one joule per second.

Applied power: incidental power at an electrical interface separating two mediae.

Constant transferred power: the constant value of transferred power desired under all conditions of mismatch.

Maximum output power: the maximum available power delivered to an external load from a power source having an internal resistance equal to that of the external load.

Reflected power: the portion of applied power that is not transferred to the second medium

Transferred power: the portion of applied power transferred from the first medium to the second medium.

Power control circuit: the circuit that interconnects and adjusts the power from the pulsator or generator to the electrodes.

Power density: the power or energy-per-unit-of-time dissipated in a given volume of material. The unit measurement is watts per cubic centimeter (W/cm^3).

Applied power density: power density available for transfer to a fish at a particular location in the water.

Power density in fish: the desired constant value of power density to be transferred to a fish. Also, the threshold of in vivo power density required to produce a specific electroshock response at a specific conductivity.

Pulse duration (pulse length): duration of an impulse.

Pulsed current (pulsating AC or DC): unidirectional current composed of a sequence of cyclic impulses.

Quarter-sine wave current: a special kind of current electronically obtained from alternating current, usually from V-max to zero.

Rectified alternating current: current composed of an uninterrupted sequence of half sine waves in the same direction, and obtained from an alternating current by means of a four-way bridge rectifier. Also called, full-wave rectified current.

Resistance: the ability to react to the flow of AC or DC with an opposition to the flow of current. Also, the ratio of the applied voltage to the induced current that it produces; the unit of measurement is the ohm.

Resistivity: the reciprocal of conductivity; the common unit of measurement is the ohm-cm.

Smooth rectified current: direct current derived from alternating current by using rectifiers and a suitable capacitance inductance filter. When insufficiently filtered, the current shows weak sinusoidal variations and is called 'partly smoothed rectified current,' or ripple current, or undulating current.

Square wave (syn. rectangular pulses): cyclic waveform with steep rise and fall time, with flat top and bottom.

Variable voltage pulsator electroshocker: the device used to deliver the pulsed electric current.

Volts or Voltage: the energy-per-unit-of-electrical-charge; the volt (V) is the unit of measure where one volt is one Joule per coulomb.

Voltage gradient: the rate of change of voltage with distance. Also, the force-per-unit-of-electrical-charge; the common unit of measurement is volts per centimeter (V/cm).

ELECTRIC FIELD CHARACTERISTICS

Anode (or cathode) field: in electric fishing, field around the electrode beyond which the values of potential gradient are unimportant.

Conductivity (of water): conductance of 1 cm^3 of water. Conductivity is the inverse of resistivity.

Critical zone of current density: in electric fishing, current density area around the electrode in which a fish is shocked.

Current lines (flow lines, equiflux): imaginary lines that represent direction of current flow perpendicular to equipotential surfaces.

Density (of current): current intensity passing through one unit of cross-sectional area perpendicular to the current lines of an electric field.

Equipotential surface: a surface on which all points are at the same electrical potential. Equipotential surfaces are perpendicular to the direction of the current flow.

External resistance: electrical resistance between electrodes.

Heterogeneous field: field in which current density and potential gradient decrease as a function of the distance from electrodes.

Horizontal field: see vertical field.

Isolines: lines of equal potential gradient.

Moving field (syn. movable field): field in which surfaces of equal relative potential (related to the supply voltage) are displaced as a function of time (rotating field, intersecting field, etc.).

Potential gradient: potential difference in an electric field-per-unit-length on the direction perpendicular to the equipotential surfaces; this gradient is measured in volts per centimeter (V/cm).

Resistivity (of water): resistance of 1 cm^3 . Resistivity is the inverse of conductivity.

Stationary field: field in which surfaces of equal potential (related to the supply voltage) are steady.

Vertical field: field in which the potential gradient is lower on a ground plane than on a vertical plane, so that a fish swimming horizontally into the field will be subject to a body voltage much lower than if the field were horizontal itself at the same distance from the electrode.

BEHAVIOR AND PHYSIOLOGY

Anelectrotonus: decrease of nerve excitability on the anode side.

Anodic (cathodic) curvature: curving of the fish body towards the anode (cathode) under the influence of a unidirectional current, when the fish is perpendicular to the current lines.

- Ascending current:** according to conventional direction of current (from + towards -), electric current ascending into the system from the periphery towards the fish nervous centers, occurring when the fish is facing the cathode.
- Autorhythm:** excitability of nerve and muscle provoked and sustained by a constant continuous current.
- Body voltage:** measured potential difference between head and tail of a fish in an electric field.
- Catelectrotonus:** increase of nerve excitability on the cathode side of a shocked fish.
- Closing of the circuit reaction:** nerve or muscle excitation produced by closing the circuit
- Descending current:** electric current going down into the system from nervous centers towards the periphery (see ascending current), as in the case of fish facing the anode.
- Electrotaxis:** fish swimming induced by any kind of electric current
- Fixation:** state of immobility of fish resulting from tetanus under the action of electric current, distinct from galvanonarcosis.
- Forced swimming (first swimming towards the anode):** a very fast swimming motion towards the anode, induced by a constant current.
- Frightening effect:** fish escape from an electrode under the action of current.
- Galvanonarcosis:** state of immobility of fish resulting from muscular slackening, under pulsating direct current.
- Inhibition of swimming:** slowing down of swimming movements; produced by a low and constant continuous current when a fish faces the anode.
- Narcosis:** state of immobility resulting from muscular slackening.
- Opening of the circuit reaction:** nerve or muscle excitation produced by opening the circuit.
- Oscillotaxis:** swimming artificially induced by an alternating current.
- Pseudo-forced swimming (second swimming towards the anode):** out of balance swimming produced by a strong and constant continuous current. Occurs when a fish faces the anode.
- Rheobase:** minimal intensity of current indefinitely maintained to release the excitation of nerve of muscle.
- Spatial summation:** cumulative effect produced on a neuron by means of several simultaneous stimuli.
- Taxis:** artificial swimming induced by a stimulating agent.
- Temporal summation:** cumulative effect produced on a neuron by a series of stimuli.
- Tetanus:** state of muscular rigidity.
- Threshold:** minimal value of current parameter inducing a determined reaction
- Useful time:** minimal time during which an electric current of a given value must be maintained to produce an excitation.

ANNOTATED BIBLIOGRAPHY

The following paper provides a review of current literature in electrofishing. Seventy five entries are indexed into four broad categories: (1) effects of electric fields on fish response and electrofishing efficiency (effects(E)), (2) gear design, construction and operations (techniques(T)), (3) applications, sampling design and analysis (applications(A)), and (4) safety, regulations and guidelines (safety(S)). A paper listed in one category often covers material that overlaps into another. This bibliography was prepared for a review of the existing electrofishing literature as it might pertain to our ensuing northern squawfish control efforts on the Columbia River. This work is intended to serve only as a quick reference and/or review, and not as a replacement to any of the cited literature.

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Adams, W.J., D.J. Behmer and W.O. Weingarten. 1972. Recovery of shocked common shiner, *Notropis conutus*, related to electric energy. Trans. Am. Fish. Soc. 101(3):553-555.

Common shiner (*Notropis conutus*), physiology, electrical parameters, pulsed direct current, electric fishing.

The time necessary for electroshocked fish to recover swimming equilibrium (recovery time) was evaluated for the common shiner under the controlled conditions of the laboratory. Halsband (1967) and Lamarque (1967) both established that it is the 'head to tail' potential voltage drop that determines just how much applied electric energy an electroshocked fish is actually exposed to. Larger fish experience more current through their bodies. Electric fishing is size selective and has a more pronounced effect on larger fish.

Adams et al. showed that after treatment with pulsed direct current (15 seconds duration), longer fish (total length) experienced a longer recovery time and greater mortality than similarly exposed shorter fish. Recovery time for all fish increased with an increase in exposure time to the current. Twenty-four hours was the suggested time necessary for a full physiological recovery in the laboratory. In the field it is suggested that retained electroshocked fish be held out of the applied electric field for minimum time needed to regain their swimming equilibrium, before release.

An attempt was made to establish which variable (voltage drop, current, duration, or power density) could be used to best define an expected electrical stimulus in fish. It was suggested that power density,

$$\text{Power Density} = E^2 / R \times (\text{Volume of a Fish})$$

E = Voltage and R = Resistance,

may be a more meaningful measure of experienced electrical stimulus than potential voltage drop.

The physiological effects to incidentals (salmon, walleye, and sturgeon) of electrofishing for squawfish in the Columbia River should be evaluated. The recommended observation period is from 24 to 72 hours. As long as practicality allows, non-game incidentals (sculpins, peamouth, suckers, etc.) should be held in electrically isolated holding tanks, at least until swimming equilibrium has been re-established, so as to reduce the loss of lethargic fish to predators. Unfortunately, the limitations of holding space and sampling time may greatly restrict this activity.

Amiro, P.G. 1990. Variation in juvenile Atlantic salmon population densities between consecutive 'enclosed sections of streams. Pages 96- 101 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), Nova Scotia, electric fishing, hand-held electrode, Coffelt VVP-2C, barrier nets, modeling.

The homogeneity of juvenile Atlantic salmon densities was tested for consecutive sections of wadeable streams. Densities were generally heterogeneous between sections for all size or age classes. This paper suggests that larger sampling areas and consolidating effort to suitable locations within an area (habitat pro-rating) may be required for meaningful comparisons of inter-site or inter-river fish densities.

Although the target species and sampling habitat detailed within are unique, the sampling procedures suggested here may also be employed in the removal of Columbia River squawfish.

Armstrong, M.C. and J.H. Mundie. 1983. Floating fish shocker. *Prog. Fish Cult.* 45(4):236-237.

Coho salmon (*Oncorhynchus kisutch*), Nanaimo, British Columbia, electric fishing, fish culture, habitat improvement.

This short paper describes construction and operational specifications for a floating fish shocker proven suitable for removing fish from channels and raceways. The shocker consists of a hand-held switch, 12 aluminum dropper electrodes suspended from an aluminum pipe made buoyant by six Styrofoam net floats, and a flexible ground electrode of four lengths of copper pipe, each one meter long.

This equipment could prove to be useful as an auxiliary piece of collection gear. The floating shocker could be used in areas inaccessible to an electric-fishing boat. It could also be used in collecting juvenile lampreys for squawfish longline bait.

Balayave, L.A. 1981. The behavior of ecologically different fish in electric fields. II. Threshold of anode reactions and tetanus. *J. Ichthy.* 21: 134- 143.

Baltic Sea, Black Sea, behavior, anodic reactions of various ocean fishes.

The behavior of 18 Black Sea and 4 Baltic species of fish in an electric field of rectified current was investigated. The fish were divided into three behavioral groups, strong anodic reaction (galvanotaxis), intermediate galvanotaxis, and no galvanotaxis. Galvanotaxis was characteristic of active swimming fishes. Sessile or bottom fish responded to the applied electric current by trying to hide or burrow into the bottom. The behavioral responses of the intermediate group, which consisted of active, migrating, and bottom species, were more difficult to label.

This paper concludes: (1) the presence or absence of galvanotaxis depends on the ecological stereotype of behavior; (2) irrespective of the presence or absence of galvanotaxis, all species can distinguish the anode from the cathode, preferring the anode; (3) narcosis or tetanus does not depend on the orientation of the fish in the electric field, but rather on field intensity.

This paper provides useful insight into the behavior of fish within a field of rectified current. Electrofishing for squawfish will employ various forms of rectified electric current. Squawfish may be classified as an active species. It is expected that squawfish will show strong galvanotaxis to an appropriately applied field, greatly increasing our catch potential,

Bird, D. and I.G. Cowx. 1990. The response of fish muscle to various electric fields. Pages 23-33 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Rainbow trout (*Oncorhynchus mykiss*), roach (*Rutilus rutilus*), European eel (*Anguilla anguilla*), physiology, electric stimuli, muscle stimulation, fatigue, inter-specific and intra-specific variability.

Electric fishing is a well-established technique for sampling fish populations in freshwater. Recently, the applications of methods to improve the efficiency and accuracy of the technique have received considerable attention. These developments, however, have been hindered by an incomplete understanding of the precise effects of electric fields on fish (electrophysiology).

In this study, the response of fish musculature to direct electrical stimulation was investigated. Individual variability in contractile performance was high in muscle preparation for each of the species tested. **Neg**a linear relationships were found between fatigue resistance and pulse frequency for the three species examined. Therefore, the longer a fish is exposed to high-frequency current, the greater the chances are of that fish becoming tetanized, permanently damaged, and lost to a collection effort.

Bowles, F.J., A.A. Frake and R.H.K. Mann. 1990. A comparison of efficiency between two electric fishing techniques on a section of the River Avon, Hampshire. Pages 229-235 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Roach (*Rutilus rutilus*), coarse fish populations, Hampshire, United Kingdom, electric fishing, hand-held electrodes, boom-boat, stop nets, modeling, efficiency and cost comparisons.

A pilot survey was carried out to assess the most suitable electric fishing technique for a fish population study of the Hampshire Avon in the United Kingdom.

The initial technique was to adapt the traditional electric fishing boat technique by using three boats fishing in tandem downstream with two hand-held anodes on each, and to conduct a four-catch depletion survey. This method produced very low catches of fish. Catch efficiency was assessed by introducing a known marked population into an isolated section of stream and then fishing them.

This paper compares the catch rate and population estimates produced by the 'three boat' method on a known population of roach, with a second trial on the same section using boom-mounted equipment. The labor and equipment costs of each are compared.

The 'three boat' technique recaptured 11% of the 570 introduced roach after four catches. The boom boat caught a greater percentage of the stocked fish, 36% after three runs. Both methods of capture underestimated population size. The mean percentage caught was 3% for the 'three boat' and 13% for the boom boat. The boom boat was later chosen for the main survey since it caught a larger proportion of the introduced fish, gave a more accurate population estimate, and was more cost effective.

The squawfish removal effort on the Columbia River will employ boom-mounted electric fishing boats. The multi-anode arrays described in this paper differ in that the anodes are arranged in a straight line equidistant along the boom. For our effort, two Wisconsin Ring arrays, or Smith Root UAA-6 dropper arrays, will be used.

Cave, J. 1990. Trapping salmon with the electro-net. Pages 65-69 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Sport Fishing News, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), electric gear, electric fences, electric fishing, fish culture, habitat improvement, comparison of catch methods.

An electric trammel net was developed to catch Atlantic salmon (*Salmo salar*) of Tyne River origin for stripping and rearing at a hatchery. The resultant progeny were restocked to replace the anticipated juvenile losses caused by a hydrodam. With constant modification, the catch-per-unit-effort (CPUE) of the equipment increased sixteen times in four years. Rod catches per season improved five times in the same period. An increase of salmon on the spawning fjords was related to improvements in the estuaries' water quality.

This paper shows that the addition of electricity to some existing fishing gear increases those gears' efficiency. In future investigations on the Columbia, the CPUE of purse seining and Merwin Traps for squawfish could possibly be increased if so modified.

Cowx, I.G., A. Wheatly and P. Hickley. 1988. Development of boom electric fishing equipment for use in large rivers and canals in the United Kingdom. *Aquacult. Fish. Manage.* 19: 205-712.

Fishing gear research, fishery surveys, canals, rivers, British Isles, electric fishing.

The construction of a multiple-electrode fishing boom is described. The efficiency of the equipment was compared with more conventional hand-held electric fishing equipment and seine netting in a series of field trials.

The boom electric fishing equipment with a direct current output produced more consistent catches and is considered to be a good cost-effective method for sampling large slow-moving bodies of water. Hand-held electrodes are limited in their horizontal and vertical effective range. Seines were of limited use because of excessive current ($>1 \text{ m/s}$), underwater obstacles, and large manpower requirements.

Multi-electrode boom arrays have been developed to overcome the problems associated with sampling large rivers and canals. Boom fishing is common practice in the United States. The results from this investigation show that the boom-mounted, pulsed direct current equipment caught 48.4% of a known population, compared with 24.6% for hand-held gear. Three advantages of boom fishing were low cost, increased maneuverability, and greater CPUE. This gear, however, still underestimated the known population size by 25.6%.

Cowx, LG., G.A. Wheatly, P. Hickley and A.S. Starkie. 1990. Evaluation of electric fishing equipment for stock assessment in large rivers and canals in the United Kingdom. Pages 34-40 in I.G. Cowx. ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publication Ltd.

Roach (*Rutilus rutilus*), electric fishing, multiple-electrode fishing boom, hand-held electrodes, assessment of efficiency of equipment under varied conditions.

In order to efficiently sample large rivers, canals and lakes in the United Kingdom, a cost-effective approach to boat-based electric fishing, similar to that used in the United States by Novotny, was developed. The Cowx boom differs from Novotny's Wisconsin Ring in that it is composed of ten pendant anodes spaced equidistant along a nine-meter boom made of reinforced polyester hydroglass tubing.

To overcome the excessive power demands required to fish high conductivity waters ($>800 \text{ mhos}$), a pulsating direct current (PDC) control box was developed. It fires up to ten electrodes, energizing one at a time, beginning outward and progressing inward. This sequential firing system presents the electrode array as a single elongated anode with a field of more than nine meters. This system can successfully fish waters with conductivities of more than 4000 mhos. There may be some inadequacies to this system when it is used in very fast, deep, and wide rivers.

The squawfish removal effort will use commercially available equipment from either Smith-Root Inc. or Coffelt Manufacturing. This gear owes much to Novotny's original work.

Cowx, I.G. 1990. Developments in electric fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Physiology, fishing gear, CPUE, sampling, modeling, electric screens, safety, electric fishing

A symposium 'Fishing With Electricity' was hosted by the Humberside International Fisheries Institute in Hull, England, 12-16 April 1988. The objective of this symposium was to advance the scientific basis of electric fishing and provide a medium for the dissemination and exchange of ideas. The main symposium was attended by 128 delegates from 23 countries. Fifty-five papers were organized into seven sessions. The presentations demonstrated that electric fishing has advanced considerably in equipment technology, safety, and sampling design; however, it has remained static in our understanding of electrophysiology. the response of fish to electric currents and factors affecting the efficiency of electric fishing.

This text contains forty-two selected papers from the symposium, and, along with its complement, Developments in Electric Fishing, should be considered a primary reference source and required reading for any electric fishing project.

Cowx I.G. and P. Lamarque. 1990. Fishing with electricity; applications in freshwater fisheries management. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Physiology, fishing gear, electric parameters, modeling, electric gear, electric screens, electric fishing, safety, text on the theory and applications of electric fishing.

In April 1988 the European Inland Fisheries Advisory Commission (ELFAC) held a symposium to analyze and evaluate the many improvements and applications of contemporary electric fishing in Europe and the United States. The results of this symposium are available in the form of two new books, Fishing With Electricity and Developments in Electric Fishing. Both texts should be required reading for any electrofishing personnel.

Fishing With Electricity details the following: Electrophysiology of fish in electric fields. electric fishing apparatus and electric fields, factors affecting the efficiency of electric fishing, electric fishing for sampling and stock assessment, electric screens and guides, electric fishing and safety, electric fishing in practice, and the future of electric fishing.

Cross, D.G. and B. Stott. 1975. The effect of electric fishing on subsequent captures of fish. *Journal of Fish Biology* 7:349-357.

Roach (*Rutilus rutilus*), gudgeon (*Gobio gobio L.*), Great Britain, modeling, bias in electrofishing population estimates.

This paper addresses the question of decreased catchability experienced during a series of replicated electric fishing passes and the resulting negative bias in various catch depletion population estimates. The experiments conducted clearly showed electrofishing can cause a decrease in catchability so that second and subsequent catches are made from reduced populations. This fact violates the equal catchability assumption associated with catch depletion methods, resulting in seriously low population estimates. The authors provide a method for adjusting population estimates for this factor of decreased catchability.

Dwyer, W.P. and D.A. Erdahl. 1992. Effects of electroshock voltage, wave form, and frequency on trout egg mortality [Abstract]. Page 13 in Western Division of The American Fisheries

Society, July 13- 16, 1992, Colorado State University, Program abstracts [Annual meeting]. American Fisheries Society, Western Division, Fort Collins, Colorado.

Rainbow trout (*Oncorhynchus mykiss*), eggs, injury, mortality, electrofishing, Montana, DC, PDC, Coffelt Pulsed System (CPS).

This study raises the question of how much incidental harm is being done to salmonid eggs while in the redd if an electrofishing operation passes over them. Tests with trout eggs have shown that electrofishing may be having more detrimental effects than previously thought. When shocking over redds, it was shown that eggs in the laboratory can be killed during the sensitive period by electroshock. Tests in the field yield similar results. This paper reports the results of testing and defining the effects of continuous DC, PDC and CPS, at different voltages. Electrofishing should be avoided in spawning areas of any species of fish. The levels of incidental harm to eggs, larval and weakened adult fish, are too significant.

Edwards, J.L. and J.D. Higgins. 1973. The effects of electric currents on fish. Final Technical Report. Projects B-397, B-400 and E 200-301. Game and Fish Division, Department of Natural Resources. Atlanta, Georgia. 75 p.

Channel catfish (*Ictalurus punctatus*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), bowfin (*Amia calva*), behavior, electric field, teleostean, controlled conditions.

To improve the effectiveness of electrofishing techniques, an investigation into the physiological mechanisms responsible for the reaction of fish to electric currents of various types was performed. It is clear that the responses often involve the sensory and motor nerve system, but the mechanisms are complex and not completely understood.

Pulsed direct current at low current densities produces agitation or fright. At higher current densities, the fish move involuntary toward the anode. At still higher densities the fish are immobilized. If alternating current is used, there is no tendency to swim toward either electrode, and fish tend to take up a transverse orientation between the electrodes. At sufficiently high current levels the fish are immobilized.

This study had two goals: to investigate the possibility of selectively affecting a particular species or size of fish by choosing the appropriate wave form and other electrical parameters, and to investigate the possibility of reducing average power requirements through the use of pulsed shapes and frequencies to which fish exhibit a particular sensitivity.

Pulsed direct currents were the most effective at inducing temporary immobilization of fish. Rectangular and exponential pulse shapes were tested at frequencies up to 200 pulses per second (burst form). Various wave forms were compared at the value of peak field strength required to immobilize 75% of a similar group of fish. Twelve different wave forms were tested on six groups representing four species. No species variation could be discerned. The data showed that larger fish are generally more susceptible to electric shocks than small, because larger fish intercept more current.

Three techniques were demonstrated to be effective in reducing the required average power: reduction of duty cycle, use of exponentially decaying pulses, and periodic interruption of the pulse trains. Power reductions of 92% to 99% as compared with those required when using continuous DC were demonstrated.

Eloranta, A. 1990. Electric fishing in the stony littoral zone of lakes. Pages 91-95 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Bullhead (*Cottus gabis*), burbot (*Lota lota*), oligotrophic lakes, Finland, sampling, electric fishing.

The fish populations of stony littoral areas have been poorly known until recently. Although this habitat is quite open and easy to approach, the small size, night activity and benthic behavior of fish found there have made it difficult to use conventional capture methods. This paper deals with fishing strategy, effects of different catching conditions and results achieved from DC electric fishing in the Finnish Lake District.

Direct-current electric fishing worked well for catching night-active bottom-feeders from the stony littoral zone. Ideal conditions were when the weather was calm and light with few shadows or reflections on the water, shallow depth (< 1 M), good water clarity, a homogeneous gravel bottom, gently sloping shore and the lack of vegetation. Stop nets were used, but shown to be unnecessary; on average, less than 3% of the total catch migrated in or out of the sampling area.

Direct current worked well in low conductivities (30 to 50 μ hos). Temperature ranged from 4 to 14 degrees Celsius. Moderate winds (5 to 7 m/s) disturbed fishing, especially on deep and exposed shores, and high waves made fishing impossible. Fishing was abandoned during rain.

This paper details procedural aspects that would be important to any electric fishing operation.

Eloranta, A., E. Jutila, and S. Kanno. 1990. Electric fishing and its safety requirements in Finland. Pages 340-343 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Safety, fishery research, electric fishing, fishery technology, Finland.

Finnish tradition in electric fishing is short. The method was not established in Finnish fisheries until the 1970s. This paper presents a review of the shortcomings observed in the electric fishing method and suggests some improvements.

In 1987, there were over forty electric fishing units operational in Finland. The majority were DC units powered by 0.5 - 2.0 KVA generators. All systems were made in Nordic countries, most less than ten years old. Most electrofishing was in small streams and rivers with backpack units.

Legal requirements of electric fishing are detailed along with a list of suggestions for improving fishing methods, with regard to electrical and other equipment and operating procedures. This list should be reviewed and used with the similar safety guidelines from Hickley (1990), McLean (1990) and Lazauski (1990) in order to produce a set of standard operating procedures for fishing with electricity.

Frankenberger, L. 1960. Applications of a boat-rigged direct-current shocker on lakes and streams in west central Wisconsin. *Prog. Fish Cult.* 22: 124- 128.

Walleye (*Stizostedion vitreum*), Wisconsin, aquaculture, fishing gear, electric fishing, applications of experimental gear.

Many of the problems associated with AC electric fishing (stunning of fish out of sight, physical harm or death, high power requirements) may be overcome by using PDC to achieve electrostatic effects on fish. The boat-

rigged direct-current shocker described in this paper was effective because the fish are attracted to the grid suspended just below the water. This unit was developed primarily for use as a sampling and cropping device in walleye rearing ponds.

Detailed construction and operational specifications are given for an experimental pulsed DC boom-boat shocker. Much of this information is still applicable to a present-day electric fishing operation.

Fredenberg, W. 1992. Evaluation of electrofishing-induced spinal injuries resulting from field electrofishing surveys in Montana. Montana Dept. Fish, Wildl. Parks.

Electrofishing, PDC, rainbow trout (*Oncorhynchus mykiss*), injury mortality, Montana.

This paper, along with Holmes (1990), addresses the issues of potential electrofishing-induced injury that were raised by Sharber and Carothers' (1988) work. About nine hundred fish were examined during this research. Sampling was designed to evaluate the differences in injury rates due to various factors, including variability in electrical wave forms and electrofishing methods, as well as species and size of fish. The two primary wave forms compared were 60 Hz square PDC and smooth DC (Coffelt VVP15). Substantial evidence demonstrated that 60 Hz PDC results in excessive injury rates to both rainbow trout (60-98% injury) and brown trout (44-62% injury), regardless of wave form (rectified sine-wave), water conductivity (33-900 mhos/cm), and equipment design variables. Limited sampling of Arctic grayling, sauger, and shovelnose sturgeon did not reveal spinal injury problems with these species. A discussion of electrofishing efficiency and proposed guidelines for minimizing spinal injury are included.

Because of the unacceptable high injury rates to salmonids, all electrofishing with PDC 60Hz square wave has been halted in Montana. This same method of electrofishing has been used extensively in the Columbia River for population indexing, and the removal of northern squawfish. The results reported by Sharber and Carothers (1988), Holmes (1990), and Reynolds (1992) will need to be evaluated and applied to the ongoing northern squawfish electrofishing work on the Columbia River. In 1993, the University of Washington will propose to evaluate electrofishing-induced harm on resident fish.

Gatz, A.J., Jr and S.M. Adams. 1987. Effects of repeated electroshocking on growth of bluegill x green sunfish hybrids. N. Am. J. Fish. Manage. 7:448-450.

Hybrid sunfish, bluegill (*Lepomis macrochirus*) x green sunfish (*Lepomis cyanellus*), physiology, laboratory, electrofishing, DC backpack electrofisher.

Gatz et al. (1986) reported that 2 to 7 exposures to electroshocking within a 12-month period significantly reduced the growth rate of wild rainbow trout. This follow-up paper showed that similar results could be obtained with hybrid sunfish (bluegill x green sunfish) that were electroshocked in the laboratory over a three-month period.

Hybrid sunfish that were shocked once a week for three months experienced a reduction in average growth rate as compared with less frequently shocked fish and unshocked fish. The reduced growth in the frequently shocked fish was attributed to fish having to expend a greater portion of their total energy reserves for tissue repair and respiration. Gatz et al. (1986) reported that the reduction in growth of wild rainbow trout was due to behavioral interactions between shocked and unshocked trout. Unshocked fish were able to dislodge shocked fish from prime feeding areas. Shocked fish tended to seek cover and show no interest in feeding following electroshock.

Repeated exposure to the voltages necessary to capture fish in the field will induce some negative behavioral and physiological response, the severity of which depends on the quality and amount of a particular electrofishing

effort, habitat quality, food availability, and species of fish in question. Gatz suggests that repeated electrofishing at intervals of less than three months may be harmful to some species of fish.

Gatz, A.J., Jr., J.M. Loar, and G.F. Cada 1986. Effects of repeated electroshocking on instantaneous growth of trout. *N. Am. J. Fish. Manage.* 6: 176- 182.

Rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), North Carolina, Tennessee, small streams, population estimates, growth, backpack electrofishing, PDC.

Electroshocking is a commonly used method for collecting fish in streams. Many fisheries management studies employ techniques that require multiple captures of fish. This paper explored the non-lethal side effects of repeated exposure to electroshocking and the possibility of any bias in population estimates that may result.

Instantaneous growth rates were calculated for age I+, 2+, and 3+ wild rainbow and brown trout. The growth rates of individual trout that had been electroshocked 2 to 7 times within a 12-month period were shown to be lower than the average growth rate of similar age class unshocked fish. The reduced growth rates were attributed to fish expending energy reserves to repair damaged tissue, physiological and behavioral responses to handling stress, and especially, fish experiencing a loss of stamina (Horak and Kline 1967) resulting in shocked individuals being pushed out of prime feeding habitat by competing unshocked similar-sized trout. Decrease in growth rate happened more often and to a greater extent in age I+ and 2+ trout than those 3 and older, and more frequently among trout that had been electroshocked within the last two and a half months than among trout that had three or more months to recover from their last electroshock.

The results reported here are of practical significance to fisheries studies that estimate growth of production in streams from a series of collections obtained by electrofishing. Researchers should be aware that their results could be negatively biased if more than a small fraction (e.g., >20%) of the total population is shocked repeatedly. Bias will be greatest on younger age classes. To avoid bias it is recommended that repeated electrofishing occur at intervals of greater than three months.

Hauck, F.R. 1949. Some harmful effects of the electroshocker on large rainbow trout. *Trans. Am. Fish. Soc.* 77:61-64.

Rainbow trout (*Oncorhynchus mykiss*), morphology, physiology, fish dissection, fisheries management, electric fishing.

The use of the electric shocker in the salvage of rainbow trout from an irrigation canal is described. An account is given also of physiological effects observed during shocking and the morphological effects determined by dissection.

Dissection of some specimens disclosed fractured vertebrae, ruptured arteries and veins, hemorrhaging, death of tissues, curvature of the spine, and extreme dilation of blood vessels in various parts of the body, including the brain.

Power was supplied via a portable gas-powered generator of 110 volt 60 cycle alternating current with a maximum output of 495 watts. Captured trout were transferred to a local hatchery and observed for 2 to 5 days. An output of 80 to 90 volts was sufficient to stun fish momentarily. The effective range was a radius of ten feet and to a depth of five feet. The water was alkaline, pH 7.5, and temperature was 58 to 70 degrees Fahrenheit.

Ten rainbow trout that exhibited representative symptoms of injury were selected for dissection. The total mortality of fish due to shocking was only 2% of the entire test group. Low mortality may have been attributable to low voltages applied, short observation time and the controlled conditions in the hatchery.

Hickley, P. 1985. Aspects of fishing electrode design. *Aquaculture and Fisheries Management* 1: 297-298.

Electric fishing, design, electrodes.

Two important aspects of equipment design are commonly ignored by manufacturers. Connectors are placed on the end of the anode pole so it can be quickly detached from the power cable. The cable from the electrode must be continuous from within the hollow electrode handle as far as to its terminal plugs used for connection to the control box. The mixing of high and low power tension in the same connector is not safe.

The fixing of separate high tension and low tension plugs onto the same piece of three-core anode cable is schematically detailed.

Hickley, P. and A. Starkie. 1985. Cost-effective sampling of fish populations in large bodies of water. *J. Fish. Biol.* 27(Supplement A):151-161.

Sampling, economics, lakes, fishery surveys, stock assessment, fishery management, British Isles, methodology.

The problems of estimating fish populations in large bodies of water are addressed. Case histories are presented showing how a range of large habitat types have been surveyed. The survey methods are discussed in terms of relative success and cost. (1) The status of the River Severn fish population was monitored by postal questionnaires addressed to contest fishermen, cost effectively collecting valuable data. (2) A predator cull and population estimate for a 35-hectare lake was made by sequential netting of sections. The population estimates arrived at were questionable and the results in general were poor. This sampling method proved to be very labor intensive and costly. (3) A boat-based electric fishing technique was used in estimating fish populations in large canals. The boat-based electric fishing unit and sampling methods used are described by Cowx. The perpendicular, ten pendant, bow mounted anode array gave the most consistent catch-per-unit-effort, while operating at a cost-effective level.

This paper details alternative effective electric-fishing techniques for streams and rivers.

Hickley, P. and B. Millwood. 1990. The United Kingdom safety guidelines for electric fishing: its relevance and application. Pages 311-323 in LG. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Electric fishing, electric gear, construction, health and safety, fishery survey.

The United Kingdom, unlike the United States, has adopted legislation that strictly regulates the applications and procedures of electric fishing. This paper reviews recommendations for all aspects of working with electricity, from daily working procedure to equipment design. Established national safety guidelines are discussed in the context of their relevance, necessity, and suitability for application in the field.

All components of the electrical equipment must be suitable for exposure in a wet, outdoor environment, and particular attention should be given to standards of enclosure, robustness, construction, mounting of components, termination, plugs, and sockets--in short, a durable solid-state system is required.

In electrofishing operations, power supplies are restricted to those from portable generators or spill-proof batteries. Power must always be fed via a control box, the primary reason for this being operator protection when a high-tension generator is used. Generators must be modified so that they are not grounded internally and must be clearly labeled to this effect. The generator must be housed in an insulated, ventilated enclosure so as to prevent bodily contact with any person while the generator is running.

This paper provides a comprehensive review of safety requirements, along with a safety checklist of gear specifications for prospective purchasers. This information should be incorporated into any electric fishing operation.

Hollender, B. 1992. Injury of wild brook trout by backpack electrofishing [Abstract]. Page 13 in Western Division American Fisheries Society, July 13-16, Colorado State University Program Abstracts [Annual meeting]. Am. Fish. Soc. Western Div., Ft. Collins, Colorado.

Brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), alternating current (AC), PDC, backpack electrofishing, injury, mortality, Pennsylvania.

The objective of this study was to assess internal injuries of wild brook trout that were captured with AC and PDC backpack **electrofishing** units in four small infertile streams. X-ray and autopsy were used to assess injury rate of 579 brook trout captured by electrofishing and 89 captured by angling. Injuries consisted of internal hemorrhages, and spinal-misalignment and fracture, or both. There were 74 hemorrhages and 91 spinal injuries. Injury rates were not significantly different between current types: 26% for AC and 22% for DC. It was concluded that even for relatively small trout in infertile waters, the incidence of electrofishing-induced injury can be significant.

A review of this and other papers contained in this synopsis makes it clear that the harmful effects of any type of electrofishing need to be evaluated (with standard evaluation protocols) on an individual project basis.

Holmes, R., D. McBride, T. Vivant and J.B. Reynolds 1990. Electrofishing mortality and injury to rainbow trout, Arctic grayling, humpback whitefish, least cisco, and northern pike. Fishery Manuscript 90-3. Alaska Dept. Fish Game, Anchorage. 95 p.

Electrofishing, PDC, rainbow trout (*Oncorhynchus mykiss*), Arctic grayling (*Thymallus arcticus*), northern pike (*Esox lucius*), humpback whitefish, (*Coregonus pidschian*), least cisco (*Coregonus sardinella*), injury, mortality, Kenai River, Alaska, Coffelt VVP- 15.

The publication of Sharber and Carothers' (1988) work on the possible deleterious effects of PDC electrofishing on large rainbow trout in the Colorado River has stimulated ongoing debate and agency-wide re-evaluation of The Standard Principles and Field Practices of electrofishing.

Before their work, it was generally believed that PDC electrofishing presented limited incidental harm to fish. Sharber and Carothers reported a range of 44% to 67% spinal injury to large rainbow trout exposed to standard PDC. Holmes et al. took this information and set out to test the applicability of these results to Alaska's electrofishing efforts.

This paper examined the effects of PDC electrofishing on all species for which electrofishing was being used as a sampling method by the Alaska Department of Fish and Game. The huge injury and mortality rates for large rainbow trout were confirmed. Large rainbow trout are unique in their hypersensitivity to electric current. The paper addresses this by examining five different species of fish and evaluating the observed short-term mortality, and injury caused by electrofishing. Rainbow trout sustained the highest rate of mortality (13.9%) and injury (40.9%). Northern pike sustained zero mortality and an injury rate of 12.5%. Two species of whitefish had a short-term (7 days) mortality of 5.4% and 0% electrofishing-caused injury. The injury rates for Arctic grayling varied from 0% to 18.3%.

With this information in hand, the study then addresses the issue of establishing species-specific threshold power levels, and detailed methods for mechanically shielding the anodes, as ways to reduce harm from electrofishing. In order to make comparisons between different species and study sites, the capture methods, sampling protocols and sample test must be as uniform as possible. For this reason, this paper, along with Fredenberg's (1992), Reynolds' (1992), and Sharber Carothers' (1988), will establish the sampling program and research focus for the University of Washington's 1993 proposal to evaluate electrofishing-induced mortality and injury to fish species in the Columbia River.

Horak, D.L. and W.D. Klien. 1967. Influence of capture methods on fishing success, stamina, and mortality of rainbow trout in Colorado. *Trans. Am. Fish. Soc.* 96:220-222.

Rainbow trout (*Oncorhynchus mykiss*), Parvin Lake, Colorado, physiology, morphology, aquaculture, methodology, electric fishing, fly fishing.

Delayed mortality caused by various capture methods is of concern to fishery managers. Bouck and Ball (1966) encountered 87% delayed mortality within ten days after collecting hatchery rainbow trout with artificial lures. This paper evaluates effective capture techniques and their effects on 'put and take' fish populations.

The criteria used to evaluate the effect of capture methods were: (1) return to the creel of stocked trout before and after special fishing size limit regulations were imposed, (2) stamina evaluation of collection by electrofishing and fly fishing, and (3) mortality after collection by electrofishing and fly fishing.

Under the special fishery regulations (slot limits), fishermen harvested 37.7% of a known population of marked rainbow with subsequent returns of individual plantings ranging from 28.2% to 49.9%.

Two groups of hatchery trout were tested for stamina. one group collected by fly fishing, the second with a PDC electrofisher. Both capture methods resulted in reductions in individuals' swimming stamina (performance index). The higher an individual's performance index (P.I.), the greater its stamina. The control group performance index was 60 minutes, fly fishing P.I. was 54.7 minutes, and electrofishing P.I. was 35.2 minutes. The low conductivity of the hatchery water may have introduced a negative bias on the electrofished group: 39% of shocked fish were visibly burned, indicating that excessive power may have been applied to the water.

Mortalities in the three groups were recorded over a five--week period. The control group had five delayed mortalities; fly fishing had five initial hooking mortalities and three delayed mortalities; and electrofishing suffered only two delayed mortalities over 35 days.

Hudy, M. 1985. Rainbow trout and brook trout mortality from high voltage AC electrofishing in a controlled environment. *N. Am. J. Fish. Manage.* 5:475-479.

Rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), physiology, morphology, alternating current, sampling, electrofishing.

Delayed mortality could: (1) bias population estimates (Pratt 1954), (2) limit spawning success (Maxfield et al. 1971), or (3) cause misinterpreted change in population level or structure. In moderate to high conductivity waters where low AC or DC current voltages are effective for stunning fish (Vibert 1976), mortality from electrofishing is negligible (Godfrey 1954, Horak and Kline 1967, Maxfield 1971). This paper presents data on immediate mortality, delayed mortality and vertebral injuries in hatchery rainbow and brook trout following electrofishing with high AC voltages.

The immediate, delayed, and total mortalities were low with no significant differences (analysis of variance, $p > 0.05$, $N = 12$) among treatment means for both rainbow and brook trout, or for the combined data from both species. Only 28 of 3,000 fish in the experiment died, 7 immediately and 21 delayed over a 15-day period. Rainbow trout represented 79% total mortality, while the brook trout accounted for the remaining 21% of the mortality. The combined total mortality was 0.0% for the control group (unshocked), 1.8% at 350 volts, 1.3% at 700 volts, and 0.5% at 760 volts.

The number of survivors with visible abnormalities (bums, erratic swimming) was low, 0.0% for the control group, 1.6% at 360 V, 2.4% at 700 V, and 0.8% at 760 V. Radiographs showed that only 21% (6 of 28) of the dead trout had fractured or dislocated vertebrae; 77% (27 of 36) of the abnormal surviving fish had fractured or dislocated vertebrae, the injury usually occurring between the 15th and 25th abdominal vertebrae.

Hudy, M. 1986. Comments: Mortality from high voltage AC electrofishing. *N. Am. J. Fish. Manage.* 6: 134.

Rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), morphology, electric fishing, electrodes.

Hudy responds to Norman G. Sharber's criticism of his 1985 results, defending his conclusion that "high voltage AC electrofishing probably is acceptable for most management uses in low conductivity waters."

Jesien, R. and R. Hocutt. 1990. Method for evaluating fish response to electric fields. Pages 10-18 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Channel catfish (*Ictalurus punctatus*), controlled environment, physiology, electric gear, electric parameters, electric fishing.

Experimental apparatus designed to investigate fish response to electric fields induced by commercially available electric fishing units is described. The objective of the study was to determine threshold power densities to tetanize channel catfish over a range of conductivities, pulsed AC and 30 Hz and 120 Hz PDC were used. Fish were exposed to the field for one second. The threshold power densities increased with increasing conductivity. Peak power densities required to tetanize fish at 100 $\mu\text{S}/\text{cm}$ ranged from 4.8 to 13.5 $\mu\text{W}/\text{cm}^3$ and at 10,000 $\mu\text{S}/\text{cm}$ ranged from 8.1 to 51.5 $\mu\text{W}/\text{cm}^3$. Average power density to tetanus ranged from 0.5 to 2.4 $\mu\text{W}/\text{cm}^3$ at 100 $\mu\text{S}/\text{cm}$ and from 8.7 to 53.0 $\mu\text{W}/\text{cm}^3$.

Fish were more sensitive to DC when facing the cathode and sensitivity became more apparent as conductivity increased.

Understanding electric parameters and fish electrophysiology will greatly increase the CPUE of the Columbia River predator control fishery.

Johnson, I.K., W.R.C. Beaumont and J.S. Welton. 1990. The use of electric fish screens in the Hampshire Test, Itchen, England. Pages 256-265 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), Hampshire, England, experimental gear, electric screens, fish passage.

Electric fish screens provide an alternative method to mechanical devices for blocking upstream fish passage. Electric fish screens were used in conjunction with resistivity fish counters in an investigation of upstream migration of salmonids in the Hampshire test. Three sites of differing configurations are presently being used. The experimental design and the preliminary results from using the screens are discussed.

Electric screens may prove to be an effective method to frighten squawfish away from areas of high smolt concentration, such as the tailrace areas of dams.

Koltz, A.L. and J.B. Reynolds. 1990. A power threshold method for the estimation of fish conductivity. Pages 5-9 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Gold fish (*Carassius auratus*), physiology, controlled environment, electric fishing, electrical parameters.

Electric fishing is primarily a problem of transferring electrical power from water to fish. If a sufficient amount of power is transferred, a particular response, such as taxis or narcosis, can be achieved. The major deterrent to power transfer is the difference between the conductivities of water and fish.

Goldfish were exposed to various voltage gradients in a tank containing water of 10 to 10,000 mhos conductivity. The resultant power densities applied to the water in order to achieve various responses (twitch, galvanotaxis or narcosis), when plotted as a function of water conductivity, conformed to the theory of maximum power transfer, i.e., when conductivities of fish and water were equal, the applied power needed was at a minimum. The resultant estimates of fish conductivity proved to be 5 to 10 times lower than reported elsewhere.

Lamarque, P. 1990. Twenty years of electric fishing expeditions throughout the world. Pages 344-351 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Electric fishing, electric gear, electric parameters, sampling.

The parameters that regulate electric fishing efficiency are numerous: water conductivity, temperature, depth, current velocity, turbidity, vegetation, operator ability, electrode suitability, fishing methods, and fish species and size. Electric fishing conditions from site to site are rarely similar. Comparisons of like fishing techniques are scarce. There is no general agreement among users as to the single best method. There is only a quasi-general agreement: direct current is the most efficient method if conductivities permit its use.

This paper outlines the characteristics of successful electric fishing operations. In a successful electrofishing operation it is highly desirable to produce an electrostatic current (i.e., a current which attracts fish to the anode but does not tetanize them). The most commonly used electrostatic currents are constant DC, 3-phase fully rectified AC, single phase fully rectified AC at 30 Hz, and rectangular pulsed DC at 400 Hz on 10% duty cycle. The key to a successful electric fishing operation is flexibility in current form and shape.

Water conductivities are divided into three groups: Low conductivity waters (5 to 30 $\mu\text{S}/\text{cm}$), such as mountain streams and lakes, or areas associated with high rain runoff; medium conductivity waters (30 to 500 $\mu\text{S}/\text{cm}$), such as the Columbia River, which ranges from 80 to 200 $\mu\text{S}/\text{cm}$; and high conductivity waters (values greater than 500 $\mu\text{S}/\text{cm}$), mainly estuaries, brackish lagoons, and the sea.

Different fishing strategies must be adopted for each conductivity range. Fishing low-conductivity waters is difficult, but good results may be achieved by using very large electrodes (anode diameter >60 cm) and high peak voltages (800 to 1650 volts). Best results in medium waters are achieved with the combination of large anodes and electrostatic current. In high-conductivity water, pulsed DC (rectangular waves of either 400 Hz or 100 Hz at 10% duty cycle) and smaller electrodes need to be used in order to reduce energy requirements.

In general, all pulsed current can produce some mortality. The worst currents are condenser charges, AC at 50 to 60 Hz and 1/2 wave rectified AC at 50 to 60 Hz. Currents with electrostatic characteristics are least harmful. Mortality is species dependent, being the result of synaptic exhaustion (violent shock) or dislocation of vertebrae, particularly if the fish is decalcified because of spawning or poor nutrition.

Predator fish (e.g., salmonids, Percidae, Centrarchidae, *Esocidae*) are more easily caught than prey species. Bottom fish and poor swimmers are also difficult to catch. Carp and tilapia seem to build up a tolerance to subsequent electric fishing. Many species are frightened out of a fisher's effective zone by physical disturbances in the water. Smaller fish tend to be more resistant than larger fish. Vegetation and cover can hide stunned fish from capture. Electrode contact with muddy bottoms causes a diminution effect in the field; this may cause an increase in resistance and lead to overloading of the generator. In strong current, tetanized fish often are washed away from the catchers. Turbidity allows a close approach towards fish but reduces catching efficiency through poor visual contact.

The experiences gained from Lamarque's twenty years of work in electric fishing should be applied to the removal effort for squawfish.

Latta, W.L. and G.F. Myers. 1961. Night use of a direct current electric shocker to collect trout in lakes. *Trans. Am. Fish. Soc.* 90:81-83.

Brook trout (*Salvelinus fontinalis*), lakes, Michigan, traps, electric fishing gear, electric fishing, gear efficiency.

Fishing was done at night from a small electrofishing boat. A Homelite DC generator (230 volts, 9.3 amperes) provided power both for underwater illumination and for the electrical field. The specifications on wiring and boat layout were detailed.

Eight hours of electrofishing at night in 1959 in a small lake produced 514 fish from a known population of 700 fish. Night shocking resulted in the capture of as many trout per hour as did 36 trap days (one trap day being equivalent to one submerged wire trap set for 24 hours). Similarly in Ford lake, night shocking yielded as many trout per hour as did 30 trap days.

The CPUE for squawfish collected by electrofishing during the day and night should be compared as are day and night Merwin trap catches. Such comparisons would establish the best times for catching squawfish.

Malvestuto, S.P. and H.G. Cowx. 1990. Electric fishing: results of a survey on boat construction configuration and safety in the United States. Pages 327-339 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd

Electric fishing, electric gear, methods, survey, United States.

The intention of this survey was to gather information pertaining to: (1) boat types and uses, (2) anode and cathode design, (3) boat construction, (4) formation of standards for electric fishing boat configuration, construction, and safety. The comprehensive standards detailed for boat construction, configuration and safety should be reviewed and adopted by any electrofishing operation.

The survey results showed that a combination of techniques (current types) was preferred over any one technique. Most agencies use both backpack and boat shocking. Population estimation, tagging, and specimen collection were the most common reasons that agencies electrofished. The majority of electric fishing is done in the 100 to 200 $\mu\text{S}/\text{cm}$ conductivity range. Only a minority of agencies indicated that they had ever actually assessed the efficiency of their equipment. The most common electrode design closely followed that of Novotny and Priegel (1974), using their circular Wisconsin ring array. Many agencies used homemade electric boats (271 units). All commercial units were purchased from either Smith Root Inc. or Coffelt Electronics.

Loeb, H.A. 1958. Comparison of estimates of fish populations in lakes. *New York Fish and Game* 5:66-76.

Carp (*Cyprinus carpio*), New York, population estimates, fishing gear, traps, electric fishing, electric seine, rotenone.

Population studies involving a number of fish, primarily carp, were carried out in three lakes ranging from 30 to 800 acres in size. Different sampling techniques were used and the data analyzed by both the Schnabel method and direct proportion. Loeb showed clearly that electrofishing for some species was more effective at night than during the daylight hours. Often the increase in effectiveness of this tool when used at night is ignored.

CPUE data for electrofishing on squawfish during the day vs. nighttime needs to be assessed and incorporated into our sampling schedule.

Lui Q., W. Darning, X. Ronngong and L. Jiefu. 1990. A method of improving fishing efficiency in lakes by using a seine net with pulsed current. Pages 41-45 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Common carp (*Cyprinus carpio*), crucian carp (*Carassius auratus*), China, aquaculture, electric seine, electric fishing, fisheries management, efficiency comparison.

In ponds with uneven, heavily silted bottoms, it is difficult to harvest the bottom-living common carp and crucian carp. Capture efficiency using the traditional seine netting method was as low as 5%. Carp exhibit diving behavior once enclosed in a seine, often escaping capture. In order to improve catch efficiency, an electric seine net equipped with pulsed current was developed. The foot rope of a 1200-m drag seine-net was bound to an electric wire with 20% of its insulation stripped off to act as an anode. The power output was three phase, 220 V, half wave rectified AC irregularly pulsed at a frequency of 10 Hz. This current can be controlled to drive, concentrate and seine the escaping fish. Capture efficiency increased, ranging from 20% to 30%. Because squawfish also exhibit diving behavior in a net, future seining efforts may test electric seining.

Lui, Q. 1990. Development of the model SC-3 alternating current scan fish driving device. Pages 46-50 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications. Ltd.

Silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), aquaculture, electric gear, electric parameters, electric fishing, gillnets, physiology.

The response of silver and bighead carp to alternating current was studied. It was reported that frequencies of the order of 80 Hz appear to have the greatest long-term residual effects on fish. but above and below this value the effect is less traumatic. The threshold electric field intensity for the different responses decreased with elevated conductivity. Significant differences were also found in the threshold field intensity between continuous and intermittent alternating currents.

The SC-3 Alternating Current Scan Fish Driving Device was developed to catch silver and bighead carp in reservoirs. With use of this gear, the catching efficiency was of the order of 62%, increasing to a maximum of 92%.

The concepts explored here may prove useful to a future capture technique that could combine the congregating effects of electricity on fish with a purse OF large beach seine.

Mann, R.H.K. and T. Penczak. 1984. The efficiency of a new electrofishing technique in determining fish numbers in a large river in Central Poland. *J. Fish. Biol.* 24: 173- 185.

Pilica River, Poland, fisheries management, sampling, electric gear, AC electric barrier, electric fishing.

A new method for determining fish populations in large rivers, which entailed electrofishing from boats downstream to an AC electric barrier, produced capture efficiencies ranging from 28% to 82%.

This study had two objectives: (1) to test a new electrofishing technique for estimating the numbers of fish in a large river, (2) to compare these catch results with those made before changes occurred in the management of the river.

A section of river to be sampled was divided into three subareas (A, B, C). A 220 V AC barrier was set across A, B, and C at the end of the fishing site. The subareas were fished simultaneously, each with boat-mounted pulsed DC equipment (3 Kw, 220 V, 50 Hz). Energy was delivered to the water via two hand-held anodes. The boats were steered downstream towards the AC barrier. Any fish not picked up by the boats were driven into the AC barrier and killed by the current. Most fish were recovered 25 m downstream of the AC barrier.

This sampling technique yielded good catch results. However, many of the captured fish were killed by the AC barrier. Therefore, this sampling technique would not be applicable in a project where incidental mortality is of concern.

Malvestuto, S.P. and B.J. Sonski. 1990. Catch rate and stock structure: a comparison of daytime versus nighttime electric fishing on West Point Reservoir, Georgia. Pages 210-218 in LG. Cowx. ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), West Point Reservoir, Georgia, CPUE, nighttime, daytime, size distribution, electric fishing.

A boom mounted electric fishing boat was used to sample shoreline areas of West Point Lake. A three phase, 120 to 240 V, 3.5 Kw, AC generator was used to supply pulsed DC via Coffelt model VVP-2C variable voltage pulsator. Catch rate (number of stock-sized fish caught per 45 minutes electric fishing sample) and stock structure (proportional stock density, PSD) were compared for daytime versus nighttime samples of largemouth bass >20 cm in total length and for bluegill >8 cm total length.

Six paired (day, night) samples were taken during fall, spring, and summer. Statistical analysis showed a significant difference ($p = 0.05$) between catch rate of bass captured during the day vs. night for the summer season only, with an increase of nine bass for sample at night. Bluegill catch rates were significantly greater during the night for all seasons.

Electrofishing at night is generally thought to be more effective than electrofishing during the day. This paper showed the importance of incorporating the seasonal and diel movements of the target species when establishing a sampling regime.

Maxfield, G.H., G.E. Monan and H.L. Garrett. 1969. Electrical installation for the control of the northern squawfish. U.S. Fish Wildl. Serv. Spec. Sci. Rep. No. 583. 14 p.

Squawfish (*Ptychocheilus oregonensis*), Cascade Reservoir, Idaho, electricity, trap, experiment to trap squawfish for the purpose of control.

Electricity was tested in Cascade Reservoir, Idaho, as a means to attract squawfish into traps during their spawning migration. Significantly more squawfish entered the traps when power (140 to 180 volts, AC) was on (354 fish) than off (110 fish). A variety of voltages, pulse durations and frequencies were tested. Other fish species were also captured in the traps.

This study demonstrated that electricity could be used to enhance catches of squawfish. However, electricity may not be useful for controlling squawfish throughout the Columbia River because of safety restrictions and the need for electrical generators when fishing away from a dam.

Maxfield, G.H., R. H. Lander and C.D. Volts. 1970. Laboratory tests of an electric barrier for controlling predation by northern squawfish. U.S. Fish Wildl. Serv. Spec. Sci. Rep. No. 611. 8 p.

Squawfish (*Ptychocheilus oregonensis*), salmon, Drano Lake, Columbia River, electricity, control of movements and predation of squawfish below hatcheries.

Preliminary laboratory results suggest that squawfish will avoid electrical fields, which could be used to reduce predation during releases of hatchery smolts. Although results may vary with water temperature and resistivity, these data suggest that electrodes placed 61 cm apart were most effective. Approximately 85%, 93% and 96% of

the swimming squawfish were blocked by voltage gradients of 0.75, 1.00, and 1.25 volts, respectively. Electricity appears to have potential for blocking squawfish movements, although field testing is needed.

Maxfield, G.H., R.H. Lander and K.L. Liscom. 1971. Survival, growth, and fecundity of hatchery-reared rainbow trout after exposure to pulsating direct current. *Trans. Am. Fish. Soc.* 3:546-552.

Rainbow trout (*Oncorhynchus mykiss*), morphology, physiology, controlled environment, electric fishing.

Unshocked control and shocked test rainbow trout were held through spawning to determine the effects of electrical shock on the survival, growth, and fecundity of two year classes--young-of-the-year 1953 and yearlings of the 1952 year class--and on the survival of the eggs and fry of the exposed fish. The test fish were exposed for 30 seconds to one of two sets of electrical conditions. Exposure was longer than that usually encountered by fish during either electrical guiding or collection with a pulsating direct current shocker.

The survival, growth, and fecundity of the fish apparently were not affected by the electric shock, nor were the survival and development of their offspring. For the 1952 year class, cumulative survival percentages were 92.9 for the test fish and 89.6 for the controls. For the 1953 year class, the respective percentages were 90.1 and 84.0.

McCrimmon, H.R. and B. Bidgood. 1965. Abnormal vertebrae in the rainbow trout with particular reference to electrofishing. *Trans. Am. Fish. Soc.* 94:84-88.

Rainbow trout (*Oncorhynchus mykiss*), Great Lakes, laboratory experiments, morphology, gear comparisons, electric parameters, electric fishing, x-ray.

Rainbow trout collected by AC and DC electrofishing from four distinct Great Lakes watersheds were found, when x-rayed for taxonomic purposes, to include fish with abnormal vertebrae. Damage caused by electrofishing shock was compared with naturally occurring abnormal vertebrae in immature and mature fish.

Of 291 trout taken by electrofishing, 7.6% showed abnormal vertebrae. An examination of the vertebral columns of 80 hatchery-reared trout prior to shocking showed 3.8% abnormal vertebrae. A reexamination of the vertebral columns of the hatchery-reared fish following electrofishing showed no change in the incidence of abnormal vertebrae.

A total of 371 hatchery trout were shocked and examined by x-ray. The 371 trout examined had an average of 62.4 vertebrae. In 23 of the 25 fish with damaged vertebrae, the damage was between the 17th and 44th vertebrae, the abdominal region between the dorsal and pelvic fins. There was an average of 6.2 damaged vertebrae. Dissection of the trout with abnormal vertebrae showed these vertebrae to be immovably and permanently fused together (25%-40% thicker than adjacent normal vertebrae). This fusion precludes any possibility that this condition was caused by electrofishing shock.

The prevalence of abnormal vertebrae among fish is well established (Gabriel 1944). Hauck (1947) reported on several types of injuries found in rainbow trout subjected to 80 to 90 volts AC, including damaged vertebrae. Unless fish are x-rayed prior to shocking, as done in this study, the extent of damage to the vertebral column actually caused by shocking may be difficult to assess.

The incidental damage to non-target species, salmonids especially, needs to be monitored. This paper presents useful information as to the type and frequency of naturally occurring vertebral damage.

McLean, I.A. 1990. Safety in electric fishing: a United Kingdom view. Pages 324-326 *in* I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Electric fishing, safety survey, United Kingdom.

In 1986, the Health and Safety Executive Board carried out a survey within the United Kingdom to examine present electric-fishing practices. The aim of the survey was twofold: (1) to examine the safety aspects of electric fishing equipment actually being used, (2) to examine safety procedures followed in electric fishing and compare those with existing national guidelines.

Safety in electrofishing should be a project's number one concern. All information regarding this topic should be given special consideration.

Mesa, M.G., and C.B. Schreck. 1989. Electrofishing mark-recapture and depletion methodologies evoke behavioral and physiological changes in cutthroat trout. *Trans. Am. Fish. Soc.* 118:644-658.

Cutthroat trout (*Oncorhynchus clarki*), Yamhill River, Oregon, hatchery, streams, behavior, physiology, electrofishing.

This paper evaluated electrofishing for use in population estimation studies. The effects of capture, handling, marking and multiple electro-shocks on normal behavior and physiology of cutthroat trout were described. Electrofishing and the procedures involved in estimating fish population size (capture, handling, marking) elicit a general stress response in fish. In a natural stream, cutthroat trout released after capture by electrofishing and marking showed distinct behavioral changes: fish immediately sought cover, remained inactive, did not feed, and were easily approachable by a diver. A 3-4 hour recovery time was required for 50% of the fish. In an artificial stream, hatchery-reared and wild trout decreased their rate of feeding and aggression. Hatchery fish appeared to return to normal after 2-3 hours, wild fish recovering in 24 hours. Hierarchical rank was affected only among the wild trout: socially dominant fish recovered faster than intermediate and subordinate fish. Physiologically, multiple electroshocks elicited the most severe stress response by elevating blood levels of lactate and cortisol. Plasma concentrations of cortisol and lactate returned to control levels by 6 hours after electroshock treatment.

The behavioral and physiological responses of fish to electrofishing affect the accuracy of catch depletion population estimates by violating key assumptions of the methods, especially the assumption of equal catchability of fish.

Newman, L.E. 1992. Spinal injury of walleye caused by PDC electrofishing [Abstract] Page 14 in *Western Division of the American Fisheries Society, Program Abstracts [Annual meeting]*. American Fisheries Society, July 13-16 1992, Western Division, Bethesda, Maryland.

Walleye (*Stizostedion vitreum*), electrofishing, PDC, injury, mortality, Wisconsin.

Walleye were taken by PDC electrofishing and analyzed by x-ray and autopsy for spinal injuries. Of the 30 fish examined 9 (28%) had spinal injuries involving fractured vertebrae, and ruptured dorsal arteries. There was no difference in injury rate between 30 Hz and 120 Hz. Future work will include tests using larger sample sizes, controls and egg viability.

Nigro, A. et al. 1985. Abundance and distribution of walleye, northern squawfish and smallmouth bass in John Day Reservoir. Annual progress report, 1985. Oregon Dept. Fish. Wildl. 162 p.

Squawfish (*Ptychocheilus oregonensis*), walleye (*Stizostedion vitreum*), smallmouth bass (*Micropterus dolomieu*), Columbia River, gillnets, trapnets, boat electrofishing, hook and line, radio tracking, angler survey, characteristics of salmon predator populations.

A variety of gear types were used to determine the distribution, abundance, and rates of growth and mortality of squawfish, walleye, and smallmouth bass in the John Day Reservoir. Radio tagging indicated that squawfish and walleye moved throughout the reservoir, although they tended to be close to the shore during periods of high water velocity. Squawfish were captured in greatest quantities during May to July. Abundance of squawfish (>250 mm), walleye (250 mm), and smallmouth bass was approximately 95,000, 16,000, and 11,000 fish, respectively.

Detailed records of catch data are given in an appendix and may be used for comparison in the squawfish control study. Greatest catch rates of squawfish were made by electrofishing (3 to 4 fish per hour) and the small-mesh bottom gillnet (1.34 fish per hour).

Novotny D.W. and G.R. Priegel. 1974. Electrofishing boats. Improved designs and operational guidelines to increase the effectiveness of boom shockers. Technical Bulletin No. 73. Department of Natural Resources. Madison Wisconsin 49 p.

Electric gear, electric parameters, boat configurations, construction, safety, electric fishing.

The first segment of this report presents basic concepts and design guidelines for electrofishing boats, including a summary of problem areas, descriptions of the basic aspects of electricity, safety, and general design and operating guidelines.

Experimental and operational PDC, DC, and AC electrofishing boats designed during the project are described in detail in the second segment. Electrofishing performance and operating guidelines based on actual field operation as well as design information on power supplies, controls and electrode systems are presented. Supporting information on electrofishing safety, calculations of electrode resistance, wiring diagrams and lists of components used in newly designed electrofishing boats are included in the appendices.

This paper should be considered required reading for any persons working with electrofishing equipment. The material presented here has served as the baseline standard from which present-day commercially available electric fishing gear has evolved.

Paragamian, V.L. 1989. A comparison of day and night electrofishing: size structure and catch-per-unit-effort for smallmouth bass. N. Am. J. Fish. Manage. 9:500-503.

Smallmouth bass (*Micropterus dolomieu*), catch-per-unit-effort, modeling, Maquoketa River, Iowa, electrofishing, day vs. night fishing comparisons.

Catch-per-unit-effort and proportional stock density (PSD) of smallmouth bass were compared between day and night electrofishing samples. The data were collected from the Maquoketa River, Iowa, during the spring of 1978. CPUE for all size ranges of smallmouth bass was significantly higher for night fishing than for daytime. Smallmouth bass were captured with the aid of a boat-mounted, 230-V, AC, 3,000-W, 7.5-A

electrofishing unit and two experienced dipnetters. The PSD from daytime catches was 27, whereas it was 33 for night, a 22% increase. Night electrofishing in rivers is recommended for this species to improve gear efficiency, reduce the time necessary to make population estimates, and increase sample size for determining length frequency distributions and age structures.

Squawfish are active nocturnal feeders. An electrofishing evaluation for potential removal programs should have a strong night fishing component to it.

Penczack, T., and H. Jakubowski. 1990. Drawbacks of electric fishing in rivers. Pages 115-122 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Large rivers, Poland, modeling, site characteristic vs. fishing efficiency, behavior, electric fishing.

In order to obtain an accurate picture of the fish community and population structure in large rivers, it is necessary to have not only an adequate sampling technique but also a knowledge of the biology of the fish species (Hunt and Jones 1974).

The number of a species caught is related to the importance of each species in the community structure and their migratory habits. Increased fishing effort (number of successive runs) on each sampling occasion can determine the importance of a species in a community, while repetition of electric fishing during each year is required to fully assess the contribution of migratory species. The relationship between site characteristics and catching efficiency for some species is well pronounced.

Squawfish exhibit a spawning migration and then form feeding aggregations. To be most effective, a removal effort should be aligned with these seasonal and behavioral patterns.

Pierce, R.B., D.W. Coble and S.D. Corley. 1985. Influence of river stage on shoreline electrofishing catches in the upper Mississippi River. *Trans. Am. Fish. Soc.* 114:857-860.

Bluegill (*Lepomis macrochirus*), drum (*Aplodinotus grunniens*), modeling, catch-per-unit-effort, upper Mississippi River, Illinois, boom electrofishing boats, electric fishing.

The numbers of fish and the species caught per unit of effort along main channel shorelines in pool areas of the upper Mississippi River were inversely related to river water level.

Fish were stunned with AC electrofishing gear. A boom shocker, described by Novotny and Priegel (1974), was initially operated at 9 to 11 amps with 320 V, and later at 7 to 9 amps with 230 V because of bleeding observed on shocked fish. A second catcher boat was used to pick up fish missed by the netting crew. A total of 5,652 fish of 50 species was caught. Sampling occurred in June, August and October in 1978 and 1979, and in June and August in 1980.

Lower catch-per-unit-effort at higher river stages could be caused by reduced fish abundance along shorelines, reduced electrofishing efficiency, or both. In general, electrofishing catches are inversely related to water level, but it varies for individual species--strong for some, no relation for others.

Squawfish catch rates may be low during the high flows of spring. Increased catch-per-unit-effort should be experienced after the Snake and Columbia River Dams cease spilling.

Pratt, S.V. 1954. Fish mortality caused by electrical shockers. *Trans. Am. Fish. Soc.* 84:93-96.

Brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), controlled environment, morphology, electric parameters, AC current verses DC current, electric fishing.

Under experimental conditions, legal-sized brook, brown, and rainbow trout were exposed to 110 volt AC and 230 volt DC. The average mortality was 6.4%. Immediate mortality was 4.3% and delayed mortality accounted for 2.1%. Of the trout exposed to AC, 11.1% died, whereas only 2.0% treated with DC were killed. Mortality appeared unrelated to species or size.

Hauck (1949). using 495 watt, 110 volt AC with hand-held electrodes, reported a 26% mortality in the rescue of large rainbow trout (average weight, 3.7 pounds) from an irrigation canal. Shelter (1947), using similar equipment on smaller trout in Michigan streams had a mortality rate of generally less than 1.0%. In Pratt's work, all of the fish that were killed immediately had been accidentally left in the electric field longer than the prescribed period (one foot away from an electrode for 15 seconds).

Incidental harm and delayed mortality to salmonids from electrofishing for squawfish need to be evaluated and kept at a minimum.

Pugh, J.R., G.E. Monan and J.R. Smith. 1970. Effects of water velocity on the fish-guiding efficiency of an electrical guiding system. *U.S. Fish Wildl. Serv., Fish. Bull.* 68(2):307-324.

Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), rainbow trout (*O. mykiss*), Yakima River, Prosser, Washington, fish passage, electrical screens, inclined screen trap, gear efficiency.

This study was performed in 1962 in a diversion of the Yakima River near Prosser, Washington. Massive structures for regulating the water velocity, producing the desired electrical field, and collecting the guided fish were installed. The fish tested were wild downstream migrating fingerlings of chinook salmon, coho salmon, and rainbow trout.

Fish guiding efficiency tended to decrease with increasing water velocity. The guiding efficiencies of the electrical system at water velocities of 0.2, 0.5, and 0.8 m/s were, respectively, 84.2, 54.2 and 50.2% for chinook; 82.4, 47.8, and 42.8% for coho; and 69.9, 40.2, and 44.8% for rainbow. The use of electricity to guide juvenile migrating salmon may be feasible in certain environments where water velocity does not exceed 0.3 m/s.

If future squawfish removal efforts were to include electric traps, weirs, or nets, the effects of water velocity on the efficiency need to be addressed

Randall, R.G. 1990. Effect of water temperature, depth, conductivity and survey area on the catchability of juvenile Atlantic salmon by fishing in New Brunswick streams. Pages 79-80 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), small streams, New Brunswick, Canada, modeling, environmental factors, gear efficiency, electric fishing.

During the electric fishing surveys in the Miramichi and Restigouche rivers, New Brunswick, probabilities of capture of juvenile Atlantic salmon varied significantly, both spatially and temporally. Average capture probabilities were significantly greater for parr (0.5) than fry (0.4). The hypothesis that environmental factors at the time of sampling (water temperature, conductivity, depth, discharge, and survey area) significantly affected capture probabilities could not be rejected. However, correlations between environmental factors and catchability were poor and inconsistent. Environmental conditions that would maximize capture probabilities could not be identified. Therefore, at least four electric fishing sweeps are necessary to estimate in-stream juvenile salmon populations.

Although the habitat and objectives detailed here are unique, the basic principles of factors affecting electrofishing success are applicable to squawfish removal.

Reynolds, J.B., S.M. Roach, and T.T. Taube. 1992. Injury and survival of northern pike and rainbow trout captured by electrofishing [Abstract] Page 15 in Western Division of the American Fisheries Society, Program Abstracts [Annual Meeting]. Am. Fish. Soc., July 1- 16 1992 Western Division, Bethesda, Maryland.

Northern pike (*Esox lucius*), rainbow trout (*Oncorhynchus mykiss*), PDC, Coffelt Pulsed System (CPS), injury, mortality, Alaska.

The 1990 and 1991 studies were conducted to determine the effects of various electrical wave forms on large northern pike and rainbow trout. The results were quite different for the two species. PDC (30-60 Hz, 100-400V) produced spinal injury rates among northern pike of only 5-12%, with an increase to 29% when a 120Hz wave form was applied at 300-600V. Survival and growth of injured and control groups of pike held for nearly one year were not significantly different. All types of conventional PDC (20-60Hz) produced spinal injury rates of 40-60% in hatchery rainbow trout. Only continuous DC and CPS™ produced injury rate under 18% in the hatchery. In the field, CPS™ produced the lowest injury rates. It was concluded that 60Hz PDC could be used to capture northern pike with minimal injury problems and the DC and CPS™ should be further evaluated for electrofishing rainbow trout. Electrofishing-induced injuries vary among species and studies. More species need to be studied.

Saltveit, S.J. 1990. Studies on juvenile fish in large rivers. Pages 109-114 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), Norwegian rivers, population parameters, hydroelectric power, habitat surveys, electric fishing.

Norway is the largest user of hydroelectric power per capita in the world. In order to evaluate the effect of regulating large rivers and to identify the necessary mitigation measures (in-stream flows, stocking, fish passage), power companies have organized studies both before and after regulation. Electric fishing is a

commonly used tool in these studies. Electric fishing has been used together with other sampling techniques to study the habitat preference of juvenile Atlantic salmon and brown trout in some Norwegian rivers.

This paper details alternative uses and parameters of electric fishing.

Schreck, C.B., R.A. Whaley, M.L. Bass, O.E. Maughan and M. Solazzi. 1976. Physiological responses of rainbow trout (*Salmo gairdneri*) to electroshock. J. Fish. Res. Board Can. :76-84.

Rainbow trout (*Oncorhynchus mykiss*), physiology, lactate, pulsed direct current, controlled environment, electric fishing.

This paper investigated the physiological consequences of electroshock-induced paralysis in rainbow trout as part of an investigation into the efficiency of electroshocking as a tool for population estimation. The assumption tested was that once a fish is shocked and swims away, it rapidly returns to a normal physiological condition, or whether there are lasting residual effects (stress, avoidance or mortality) that would reduce an individual's chance for recapture. A total of 48 15-month-old hatchery-reared rainbow trout (average weight, 169 +/- 5.4 g) was held outside in concrete raceways. A Coffelt backpack shocker (230 V, 2.3 A DC) was used to simulate electrofishing in a stream.

The results showed that electroshocking elicited an immediate increase in plasma corticoid and lactate concentrations. Plasma lactic acid levels doubled immediately after shocking and remained high for one hour and returned to near normal within three hours. Plasma protein, calcium, magnesium, and androgen levels were not measurably affected. A violent 'coughing' response was noted. Normal breathing resumed after 60 seconds. The circulatory efficiency of these fish was impaired by raised blood lactate levels.

Schreck postulates that electrofishing elicits a general stress response lasting several hours. This stress closely parallels that induced by hypoxia (oxygen debt) or severe muscular activity, the degree of stress being directly related to the severity and duration of applied electric field.

Death of fish collected by electrofishing may be the result of both acute and chronic factors. Immediate death is due to direct trauma, i.e., respiratory failure, hemorrhaging, or fractured vertebrae. Delayed mortality results from the combined effects of trauma, factors associated with the repayment of oxygen debt, and stress-induced exhaustion.

If electrofishing is to be used as the capture technique in a mark-recapture population study for squawfish in the Columbia River, the sampling bias of the electrofishing unit used in such a regime should be carefully assessed.

Sharber, N.G. and S.W. Carothers. 1987. Submerged, electrically shielded live tank for electrofishing boats. N. Am. J. Fish. Manage. 7:453-455.

Humpback chub (*Gila cypha*), Colorado River, physiology, electric gear, Faraday's law, electric fishing.

Fish caught by electrofishing are usually held in live tanks until data are recorded. If water in these holding tanks is not circulated, changes in temperature and oxygen concentration may be harmful to the fish.

This paper details the design specifications for a successfully used live tank which is submerged through the hull of a catamaran type white water raft. The tank is placed in the water being electrofished so that power free, continuous water circulation is maintained. Fish in the tank are protected from the electrofishing field by the

design of the tank, which uses to advantage a phenomenon known as Faraday shielding (an electrostatic shield created with conductor, ground, and a series of parallel wires). This tank is easy and inexpensive to construct and safe to use on many styles of boat.

Sharber, N.G. and S.W. Carothers. 1990. Influence of electric fishing pulse shape on spinal injuries in adult rainbow trout. Pages 19-26 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Rainbow trout (*Oncorhynchus mykiss*), Colorado River, morphology, x-ray, autopsy, electric parameters, electric fishing.

Adult rainbow trout captured from the Colorado River by electric fishing were analyzed for spinal injury by x-ray and autopsy techniques. During electric fishing, three pulse shapes were used and compared. The analysis of 209 x-rays showed that 50.2% of the fish suffered spinal injuries involving an average of eight vertebrae (dislocated and/or splintered vertebrae). The number of fish injured was significantly different between the exponential pulse (44.4%) and the 1/4 sine wave pulse (67.3%) and between the square wave (43.6%) and the 1/4 sine wave (67.3%). The severity of the injuries in the spinal column changed as a function of pulse shape. The average number of vertebrae displaced or broken was significantly greater with the 1/4 sine wave (9.5) than for the exponential pulse (6.6). Of the three commonly used pulsed wave shapes, the exponential pulse is the most effective and least traumatic.

In this study, electric fishing was performed at night using a boat-mounted Honda 6.5 KVA. gas-powered single-phase (60 Hz), 240 volt generator. Electrodes were two stainless steel balls 30 cm in diameter. Captured fish were placed in a Faraday shielded live well (Sharber and Carothers 1987). A Coffelt WP-15 (variable volt pulsator) generated the square wave and 1/4 sine waves. The exponential pulse was generated through a pulsator of the authors' design (Vector Max 101). Water temperature ranged from 9 to 11 degrees Celsius, conductivity ranged from 600 to 800 $\mu\text{S}/\text{cm}$, and water depth ranged from 1 to 3 meters. The trout had a mean total length of 360 mm.

During x-ray analysis and autopsy, it was possible to distinguish between the abnormalities caused by electric fishing and those occurring naturally. Natural abnormalities were indicated by more dense and fused section of the vertebral column. Electric-induced injuries are usually separations of the vertebrae showing visible misalignment. All injuries noted were associated with internal bleeding and/or splintered bones due to compression fractures caused by tetanus in the muscle tissue along the spinal column. Fish that possessed natural abnormalities (compacted vertebrae) displayed no hematoma or splintered bone.

The incidence of injury (43.6% - 67.3%) reported here represents the highest level of electric fishing induced damage to fish vertebrae and nearby soft tissue yet reported. Hauck (1949) recorded 26% mortality with large rainbow trout, Pratt (1954) reported 6.4% mortality on rainbow. Hudy (1985) recorded >5% on brook and rainbow trout, McCrimmon and Bidgood (1965) reported 7.6% in rainbow trout, and Spencer (1967) had mortalities on bluegill which ranged from 1.5% to 12.2%.

It has been Sharber and Carothers' ground-breaking work on electrofishing-induced injuries that has established the need for extensive re-evaluation of accepted electrofishing principles and practices.

Simpson, D.E. and J.B. Reynolds. 1977. Use of boat-mounted electrofishing gear by fishery biologists in the United States. *Prog. Fish Cult.* 3(2):88-89.

Mail survey, United States, fishery biologists, electric gear, electric fishing.

A 1976 mail survey of fishery biologists in the continental United States indicated that boat-mounted electrofishing gear was used on lakes more often than streams (71%), and for management rather than research (54%, 231 respondents). Alternating current was used by 62%, and about two thirds had at least one device for modifying electrical current (e.g., variable voltage pulsator). PDC was used more often in research than in management, in streams than in lakes, and in the West than in other regions of the country.

A boat-mounted Smith-Root 7.5 GPP or Coffelt VVP-15 electrofishing system would prove effective at removing squawfish from the Columbia River.

Snyder, D.E. and S. A. Johnson 1991. Draft index bibliography of electrofishing literature. Prepared for USDI Bureau of Reclamation and Glen Canyon Environmental Studies Team. Larval Fish Laboratory, Colorado State Univ., Ft. Collins, CO 8052 1.

Electrofishing, indexed bibliography.

This topically indexed bibliography of 854 references was prepared for a review of fish injuries and mortality caused by electrofishing and the various factors associated with these impacts. This bibliography is extensive and should be considered a primary reference source for any electrofishing project. The topic headings covered are: effects of electric fields on fish, factors affecting fish response and electrofishing efficiency, comparisons of effects of factors with non-electric gear as technical gear design, construction and operation, application, sampling design and analysis, safety regulations and guidelines. The required research involved in establishing and maintaining an electrofishing operation would be greatly facilitated by use of this bibliography,

Spencer, S.L. 1967. Internal injuries of largemouth bass and bluegill caused by electricity. *Prog. Fish Cult.* 29: 168-169.

Largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), controlled conditions, Alabama, harm caused by AC, DC electrofishing.

This paper reported on the incidence and severity of injury on three warm-water species of fish (bluegill, largemouth bass and channel catfish) after being exposed to several common types of AC and DC electrofishing current.

Fish were subjected to the selected voltage and exposure period, frozen, and then later dissected. In bluegill, dislocated vertebrae and ruptured dorsal arteries were easily seen with the unaided eye. Most ruptures were accompanied by a local blood clot. In every test with bluegill 230 volts AC gave the highest incidence (12.2%) of injury, 115 volts AC gave 4.6% injury, and 115 volts DC gave 1.5% injury. Additional tests on bluegill showed that there is no apparent relationship between exposure time and incidence of injured vertebrae. Vertebral injury appears to occur immediately upon exposure to the electrical stimulus.

When electrofishing for squawfish, potentially harmful effects on incidentals such as bluegill may be abated by operating the electrofishing equipment at less harmful current and waveforms (i.e., pulsating 115 volt DC over AC).

Steinmets, B. 1990. Electric fishing: some remarks on its use. Pages 1-4 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Mail survey, European Inland Fisheries Advisory Commission (EIFAC), fishery biologists, electric gear, electric fishing.

A questionnaire to identify the present use of electric fishing was sent to 25 EIFAC national correspondents. Replies from 30 agencies in 10 European countries were received. Classical wading and classical boat fishing (two hand-held anodes) on large water bodies are the main electric fishing activities in Europe. In the United States, boat fishing with boom-mounted arrays is most common (Lazauski and Malvestuto 1984).

Sternin, V.G., I.V. Nikonorov and Y.K. Bumeister. 1972. *Electric fishing, theory and practice*. Translated from Russian by Israel Program for Scientific Translations. Jerusalem, 1976.

Electric parameters, behavior, physiology, morphology, fishing gear, electric gear, electric fishing.

This textbook presents detailed material on electric theory, electrical conductivities in water, electrode function and design. electrical fields in water, conductivities of fish, fish behavior in electric fields, the effects of electricity on fish, and electric fishing gear and its operation.

This book should be considered a complementary text to I.G. Cowx's *Fishing with Electricity*

Stewart, P.A.M. 1990. Electrified barriers for marine fish. Pages 243-255 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), marine aquaculture, Aberdeen, Scotland, controlled environment, behavior, physiology. electric parameters, electric barriers, behavior of fish to electric barriers.

This study was concerned with low-powered electrified fish barriers. Useful basic information on the form of electric stimulus needed to operate a barrier by defining the pulse shapes which induce significant muscular contractions in fish is detailed. These contractions are an irritant. which do not themselves produce a particular behavioral reaction, but can induce fish to leave an electrified zone.

It was found in both aquarium and sea-cage experiments that the electrified zone has to be clearly visible to the fish before it acts as a barrier. The electric field appears to reinforce the visual impact of a barrier. Observations on the effects of an electrified barrier in a sea cage found that flat fish, but not round fish, could be confined. A bubble curtain tested under the same conditions confined round fish, but not flat fish.

It is feasible that present Merwin Traps could be upgraded to include electric barriers.

Taylor, G.N., L.S. Cole and W.F. Sigler. 1957. Galvanotaxic response of fish to pulsating direct current. *J. Wildl. Manage.* 21(2):201-213.

Rainbow trout (*Oncorhynchus mykiss*), physiology, electrical parameters, continuous direct current, pulsating direct current, alternating current.

The galvanotaxic response of fish to PDC and DC was investigated. Both PDC (96 pulses per second) and DC using duty cycles of 0.33, 0.47, and 0.88 yielded good galvanotaxic responses in rainbow trout. Pulsed DC reduced the necessary power requirements by 45% as compared with continuous DC. Tests using 0.47 and 0.88 duty cycles indicate that they were less efficient at producing galvanotaxis than the 0.33 duty cycle.

There were no mortalities on the 91 fish treated with continuous DC, 0.3% mortality occurred in the 1,641 PDC-treated fish, and 42% mortality occurred in the 46 fish treated with alternating current. In general, this study suggests that PDC (triangular pulse shapes) run at lower duty cycles with a fast pulse rate (96 Hz) is an effective and efficient method of electrofishing. This information could be directly applied to the squawfish electrofishing removal effort.

Vibert, R. 1963. Neurophysiology of electric fishing. *Trans. Am. Fish. Soc.* 92(3):265-275.

European eel (*Anguilla anguilla*), brown trout, (*Salmo trutta fario*), rainbow trout (*Oncorhynchus mykiss*), neurophysiology, laboratory experiment, direct current, galvanotaxis, electric fishing.

The basis for contemporary understanding of the causative mechanisms involved with fish neurophysiology in electrofishing has been established primarily by the work of R. Vibert and fellow Frenchman P. Lamarque.

This paper summarized Vibert's 100-page study that comprehensively identified the main reactions fish demonstrate in a continuous direct current electric field. The mechanisms of the observed behavior were investigated and explained in terms of the fish nervous system.

Vibert described the following reactions of fish to a direct-current field of increasing strength: (1) primary reactions without galvanotaxis, fins and muscular twitching, (2) inhibition of normal swimming, (3) galvanotaxis, induced forced swimming (4) narcosis, relaxation of musculature, (5) pseudo-forced swimming, tetanus, second stage of forced swimming period, (6) tetanus hypertonic stiffness, seizure of musculature being induced at high voltages, often followed by death.

The material presented by Vibert is one of the definitive works on fish neurophysiology in electric fields. This material is still directly applicable to today's electrofishing operations.

Weisser, J.W. and G.T. Klar. 1990. Electric fishing for sea lampreys (*Petromyzon marinus*) in the Great Lakes. Pages 59-64 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Sea lamprey (*Petromyzon marinus*), Great Lakes, fishery management, fishing gear, traps, poison, electric weirs, electric fishing.

By the mid 1940s, it was apparent that the parasitic-phase sea lamprey were rapidly depleting valuable fish stocks in the Great Lakes (Smith et al. 1974). This paper summarizes electric fishing gear developed to collect adult and larval sea lampreys in the tributaries and offshore areas of the Great lakes.

Electric fishing for lampreys in the Great Lakes began with stream surveys in the 1940s. The first control effort began in 1952 with the development of in-stream electric weirs. More than 750,000 adult sea lampreys were trapped and destroyed from 1953 to 1969 (Smith 1971). Juvenile lampreys were collected with various backpack shocking units, the most modern and effective being the Abp-2 backpack electrofishing unit. Electric trawls were also used, but with limited success, being later replaced by an effective bottom toxicant.

Future agency-operated squawfish removal methods could include electric weirs or electrified Merwin Traps. The present longline commercial fishery could utilize the backpack units in the collection of juvenile lampreys for bait purposes.

Welton, J.S., W.R.C. Beaumont and R.H.K. Mann. 1990. The use of boom-mounted multi-anode electric fishing equipment for a survey of the fish stocks of the Hampshire Avon. Pages 236-242 in I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications. Ltd.

River Avon, Hampshire, United Kingdom, collection methods, site selection, modeling, electric gear, electric fishing, comparison of capture techniques.

Two methods were compared: (1) three wooden punts deployed across a width of river, each containing a fishing team with a generator and two hand-held anodes, and (2) a boom-mounted, multi-anode electric fishing system on a single boat. After a series of trials, the boom-mounted multi-anode system was chosen to be used in the main survey of the river.

The boom electric fishing boat was modeled after the system designed by the Severn-Trent Water Authority (Cowx et al. 1988). It was a 4.3 meter long cathedral hulled boat, propelled by a Honda 100 (9.9 HP) outboard, with a 10 m boom pivoted in the center and mounted on the bow. Ten 800 mm tubular copper anodes (30 mm diameter) were suspended at equally spaced intervals along the boom. Two inflatable rubber boats were rowed behind the main boat to act as additional catchers. Electrical power was from a 7.5 KVA Allan generator to a Millstream LR (FB8A) electric fishing box. This produced an output of 230 V, 18 A at 100 pulses per second.

Fishing down stream, four successive fishing runs were carried out at each site. The boom was kept at right angles to the bank. Speed was maintained at slightly faster than the current.

In this study, 14 species of fish were caught, totaling 2,807 individuals ranging in size from 3 to 1,100 mm. Catch efficiency ranged from 33% (grayling) to 52% (barbell). The efficiency per fishing run for all species combined at each site ranged from 33% to 50%, with an average of 42%.

In an attempt to increase catch efficiency, stop nets were set around electrofishing sites. Difficulties were encountered in setting stop nets in the river. If placed where water velocity was high, a large bag developed, making it impossible to extract weed or fish from the net. Accumulation of weed in the net disrupted sampling (lead line lifted). There was no evidence of fish being driven in front of the boat. If no stop nets were used, larger sections of the river could be fished in the time available. The net setting and retrieval took two to three hours per day.

The electric fishing gear detailed here represents a successful alternative to Novotny's Wisconsin ring. Regardless of which anode is used, the sampling procedure outlined for the multi-anode boom boat, would be successful in the Columbia River.

Whaley, R.A., O.E. Maughan and P.H. Whiley. 1978. Lethality of electroshock to two freshwater fishes. *Prog. Fish Cult.* 40(4):161-163.

Fantail darter (*Etheostoma flabellare*), bluegill (*Lepomis macrochirus*), electrophysiology, electric fishing.

The lethality of electroshock to bluegill and fan-tailed darters subjected to commonly employed ranges of pulsating direct current was examined. The knowledge of lethality of electric shock to targeted fish is of primary concern to fisheries biologists in the field. If electroshock is employed as a capture tool of a **catch-depletion**-based population estimate, fish not captured during the first electrofishing attempt must remain available for capture during later attempts.

Whaley et al. showed that even electrotoxic currents (pulsed DC) produce some amount of mortality. Duration of exposure time appeared to be the factor most responsible for the death of fish. Mortalities were low when exposure time was kept under fifteen seconds. With experience and by understanding the electro-physiological responses in fish, researchers can adjust electrofishing units to operate efficiently with minimal harm to fish.

Willemstad, J. 1990. The electrified trawl as an alternative type of fishing gear to eel traps. Pages 70-78 **in** I.G. Cowx, ed., *Developments in Electric Fishing*. Oxford: Fishing News Books, Blackwell Scientific Publications. Ltd.

European eel (*Anguilla anguilla*), perch (*Perca fluviatilis*), Lake Ijssel, Netherlands, commercial fishing, fishing gear, beam trawl, electric beam trawl, electric fishing.

This study investigates whether an electrified beam trawl would be a **good** alternative to the commercial eel trap, a gear which causes high incidental mortality among the young of other commercially important species. The electrified trawl proved to be effective for catching eel. Catch rates were 7 to 20 times greater in nets with electric current than without. Incidental catches of perch, bream, and roach were reduced by a factor of two to three.

Future squawfish removal efforts may want to upgrade existing trap or purse seine equipment by adding electricity to their design.

Willis, C.F. et al. 1985. Abundance and distribution of northern squawfish and walleye in the John Day Reservoir and Tailrace, 1982. Annual Progress Report, 1982. Oregon Dept. Fish Wildl.. 33 p.

Squawfish (*Ptychocheilus oregonensis*), **walleye** (*Stizostedion vitreum*), Columbia River, drift and stationary **gillnets**, trap nets, boat electrofishing, hook and line, radio tag, abundance and distribution of salmon predator populations.

A variety of gear types were used to assess the abundance and distribution of squawfish and walleye in the John Day Reservoir. Squawfish abundance in the boat restricted zones of John Day and **McNary** Dams was approximately 4,600 and 8,500 fish, respectively. Walleye abundance could not be estimated because they were not recaptured.

Angling appeared to be the most effective method in capturing squawfish near the dams (2,100 fish. 4 fish per hour), compared with other gear types (670 fish, <1 fish per hour). Beach seines (20 sets) were ineffective at catching either species. **Electrofishing** tended to capture smaller fish, whereas angling captured squawfish >300 mm. Squawfish moved into the **tailrace** area after spilling stopped.

Witt, A.J. and R.S. Cambell. 1959. Refinements of equipment and procedures in electrofishing. Trans. Am. Fish. Soc. 88:33-35.

Centrarchids, Missouri, seine nets, electric fishing gear, electric fishing, efficiency comparison.

A boat-mounted electric seine is described. This, boom seine was three times more efficient at night than during the day. The catch of the boom seine in a Missouri impoundment is compared with the catch from nets. This gear was found to be selective for centrarchids (except white crappie) in waters where nets were selective toward white crappie, gizzard shad, white bass and freshwater drum. Selectivity was related to the behavior of fishes and the habitat where fishing was done. Average catch for diurnal electrofishing in June was 98 fish per hour and for nocturnal electrofishing on the same day was 346 per hour.

The results of electrofishing for any one species is dependent on its diel movements. Having an understanding of squawfish behavior will greatly increase capture rates.

Yundt, S. 1983. Changes in catchability related to multiple electroshock. Proceedings of the Annual Conference, Western Association of Fish and Wildlife Agencies 63: 116-123.

Rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta fario*), Bighorn River, Wyoming, population estimates, electrofishing, throwing electrode.

The purpose of this study was to determine whether the length of time between electrofishing mark-and-recapture runs affected population estimates, and if so, to determine which population model assumptions had been violated.

Electrofishing mark/recapture population estimates were shown to be affected by the length of time between fishing runs. The assumption that all fish have the same probability of being recaptured is violated if subsequent electrofishing runs occur too close together. Electroshocked fish develop avoidance behavior and experience spatial drift, making them less available to subsequent sampling efforts.

Squawfish population indexing efforts in the Columbia River have accounted for the potential sampling bias of electrofishing by allowing for sufficient recovery time between re-sampling of designated areas. Our efforts in the Columbia will concentrate on simple squawfish removal, not population estimates. Therefore, the induced bias of unequal catchability will have only a limited effect on our efforts.

REPORT E

Effectiveness of Predator Removal for Protecting Juvenile Fall Chinook Salmon Released from Bonneville Hatchery

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INTRODUCTION

Despite the almost universal belief that removal of northern squawfish (*Ptychocheilus oregonensis*) will increase survival of juvenile salmonids (*Oncorhynchus* spp.) in the Columbia River Basin (Figure 1), there has yet to be a direct demonstration of the benefit of predator removal. Heretofore, research has focused on estimating abundance of northern squawfish in selected locations (e.g., tailraces and forebays of dams, particular reservoir reaches and near-hatchery release sites) and assessing northern squawfish predation on smolts (Thompson 1959, Uremovich et al. 1980, Poe et al. 1991, Vigg et al. 1991, Nigro 1990).

In 1987, survival of subyearling chinook salmon (*O. tshawytscha*) released at the shoreline downstream from Bonneville Dam was poor compared to that of fish released at midstream and was thought to be related to increased predation by northern squawfish (Ledgerwood et al. 1990). Northern squawfish are known to inhabit protected shoreline areas; a large population of northern squawfish exists in the tailrace area of Bonneville Dam adjacent to Tanner Creek (Vigg et al. 1990, Petersen et al. 1990). Poor survival of smolts released at the shoreline prompted the National Marine Fisheries Service (NMFS), in cooperation with Oregon Department of Fish and Wildlife (ODFW), to begin a release-site survival study at Bonneville Hatchery to evaluate the advantage of midstream Columbia River release.

Bonneville Hatchery is located about 1 km downstream from Bonneville Dam. Fish are normally released into Tanner Creek, which enters the Columbia River about 400 m downstream from the hatchery. Subyearling fall chinook salmon were marked, then simultaneously released into Tanner Creek and into the midstream Columbia River, lateral to its confluence with Tanner Creek (Figure 2). Differences among seine recoveries of juvenile salmon in the estuary indicated that survival following the 157-km migration was dramatically better for midstream Columbia-River-release groups than for Tanner Creek-release groups. In 1989 and 1990, the differences were about 65% and 40%, respectively. These differences were also thought to be related to greater predation by northern squawfish on fish released into Tanner Creek than on fish released into the deep-water/high-current area of the midstream Columbia River.

In 1991, a second cooperative study was begun by NMFS, ODFW, and the U.S. Fish and Wildlife Service (USFWS) to demonstrate the effectiveness of removing northern squawfish from the migration route of juvenile salmon released at Bonneville Hatchery (Ledgerwood et al., in prep.). About 400,000 juvenile fall chinook salmon (upriver bright stock) were marked with both coded wire tags (CWT) and freeze brands at Bonneville Hatchery for the study. Two paired groups of 100,000 fish were released into the midstream Columbia River and into Tanner Creek four days apart. On intervening nights, northern squawfish in the vicinity of the hatchery release site were removed by electrofishing. Stomach contents of captured northern squawfish were examined for the presence of CWTs from study fish. As in previous years, subyearling chinook salmon released into the midstream Columbia River had significantly higher survival rates than fish released into

Tanner Creek. It also was apparent from CWT recoveries in the stomachs of northern squawfish that Tanner Creek-released juveniles were more vulnerable to predation than juveniles released in midstream. However, the electrofishing efforts did not significantly reduce the survival difference between midstream Columbia River and Tanner Creek release groups, although the survival difference of about 21% in 1991 was considerably less than the previous years and appeared to be inversely related to the movement rate of the Tanner Creek release groups to the estuary. We speculate that the higher river flow in 1991 dispersed test fish more rapidly, reduced their exposure time to predation, and resulted in higher survival rates for the Tanner Creek releases. Additional data, with different river conditions, were needed to better understand the effectiveness of localized predator removal on survival rates of juvenile salmon.

This report summarizes the results of a third cooperative study conducted in 1992, with objectives similar to 1991 research: (1) to assess survival differences for juvenile salmon after the removal of northern squawfish from Tanner Creek and adjacent shoreline areas of the Columbia River; (2) to assess effectiveness of electrofishing to remove northern squawfish from the migration route of juvenile salmon in the vicinity of the hatchery release site; (3) to assess prey consumption by northern squawfish before and after large-scale predator removal efforts to determine the effects of predator size and density on the rate at which juvenile salmonids are consumed; and (4) to provide samples of study fish collected in the estuary to determine the degree of smoltification (ATPase activity, reflectance, and morphometrics)¹, feeding behavior (stomach fullness and diet), and diel migratory behavior of study fish.

METHODS

Experimental Design

Prior to northern squawfish removal efforts, one uniquely marked group of 100,000 juvenile fall chinook salmon was released into Tanner Creek and another into the midstream Columbia River, lateral to the confluence of Tanner Creek. During the following four nights, extensive electrofishing efforts were made to remove northern squawfish from Tanner Creek and from the adjacent shoreline areas of the Columbia River extending 1 km upstream and 6 km downstream from the release sites. Catch per unit effort (CPUE), size of fish removed, numbers of salmon ingested, and overall food consumption by northern squawfish were assessed to evaluate changes in the local northern squawfish population and their impacts on released salmon. Following the northern squawfish removal efforts, a second pair of uniquely marked 100,000-fish groups was released at the two study sites. The second

¹ Smoltification work was conducted by the USFWS (Alec Maule and Phil Haner) under a separate contract to Bonneville Power Administration and will be reported independently.

pair of releases was followed by another two nights of extensive electrofishing for northern squawfish to evaluate their possible response to the reintroduction of juvenile salmon.

Purse and beach seining were conducted near the upper boundary of the Columbia River estuary at Jones Beach, River Kilometer (RK) 75, to recover marked fish. Recovery percentages were used for evaluating short-term survival differences between fish groups released at the two study sites before and after northern squawfish removal efforts. Similar comparisons of the relative contribution of marked fish recovered in ocean and river fisheries and returning to the hatchery will provide a long-term evaluation for all release groups.

Test Fish

Test fish were the progeny of fall chinook salmon (upriver bright stock) collected by ODFW personnel at Bonneville Hatchery. About 400,000 of these fish were reared at the hatchery for this study. At release, the mean size of these subyearling-age fish was 6.0 g (76 fish/lb), which was similar to that of fish used in the 1989 ($\bar{x} = 7.0$ g), 1990 ($\bar{x} = 6.3$ g), and 1991 ($\bar{x} = 7.4$ g) studies.

Marking Procedures

Test fish were marked from May to June 3, Monday through Friday, by two eight-person crews marking fish eight hours per day; about 40,000 fish were marked each day. Each marked group had unique CWTs (Bergman et al. 1968). Cold brands (Mighell 1969) were applied to allow visual identification of fish from different treatment groups in samples seined from the estuary.

Logistics for marking fish were similar to those described by Ledgerwood et al. (1990). Two measures were taken to ensure that marked groups did not differ in fish size, fish condition, rearing history, or mark quality: (1) the four groups were marked simultaneously; and (2) differences in mark quality among groups were minimized by rotating fish markers and mark codes among fish marking stations every two hours so that each marker and each station contributed equivalent numbers of marked fish to each treatment group. To assess and maintain quality control in the tagging process, samples of 30 to 100 fish from each treatment were collected intermittently from outfall pipes at the marking trailer and checked for CWTs (Appendix Table A-1). Similarly, samples of about six fish from each treatment were diverted into net pens eight times each day and held for a minimum of 29 days to determine tag loss. Samples from each treatment were held in separate net pens. Estimates of tag loss ranged from 3.5% to 7.3% ($\bar{x} = 5.2$, $n = 1,610$; Appendix Table A-2). Release numbers for each CWT release group were adjusted for estimated tag loss based on tag loss for the marked fish held a minimum of 29 days.

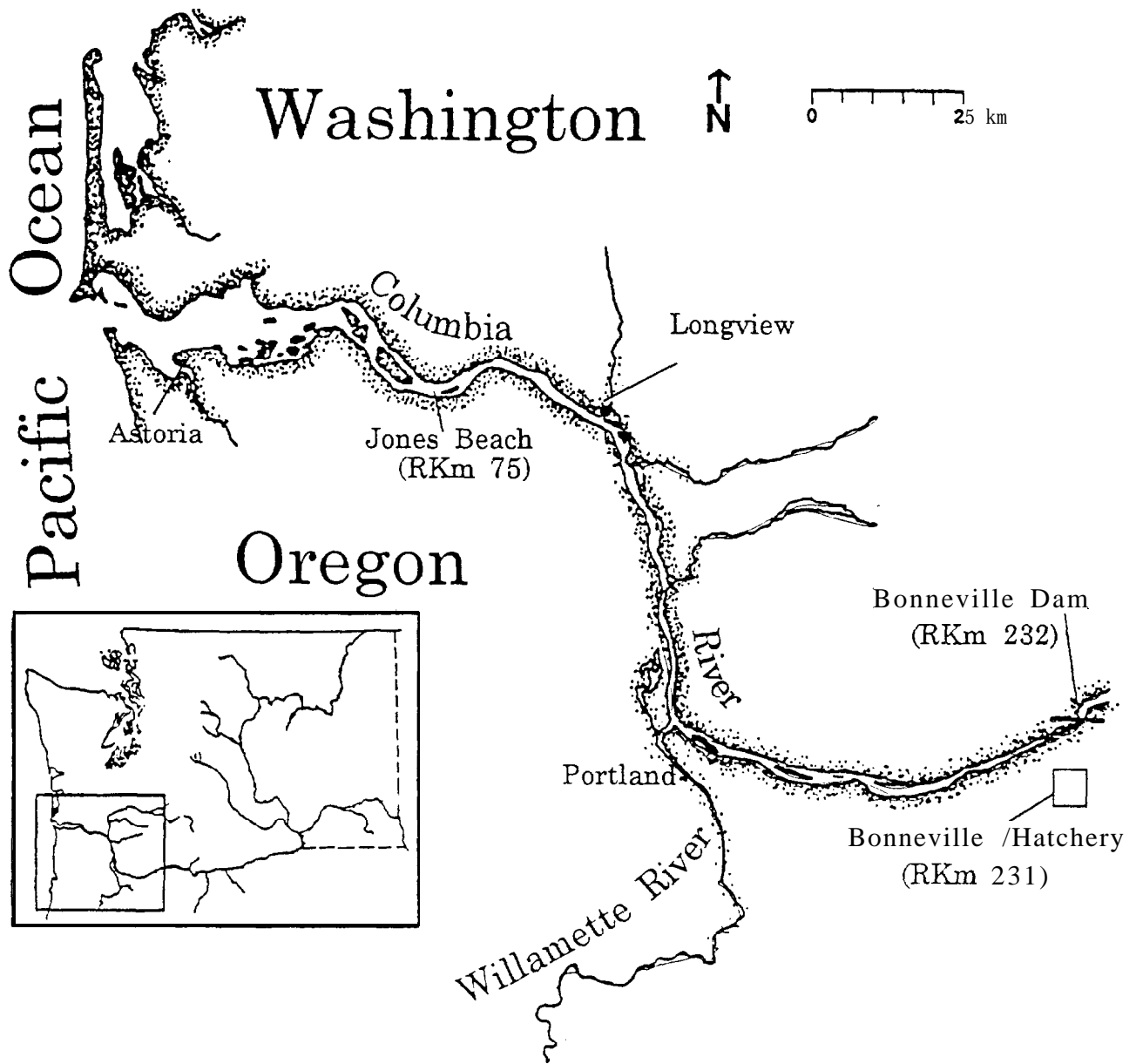


Figure 1.--Columbia River Basin showing the study area.

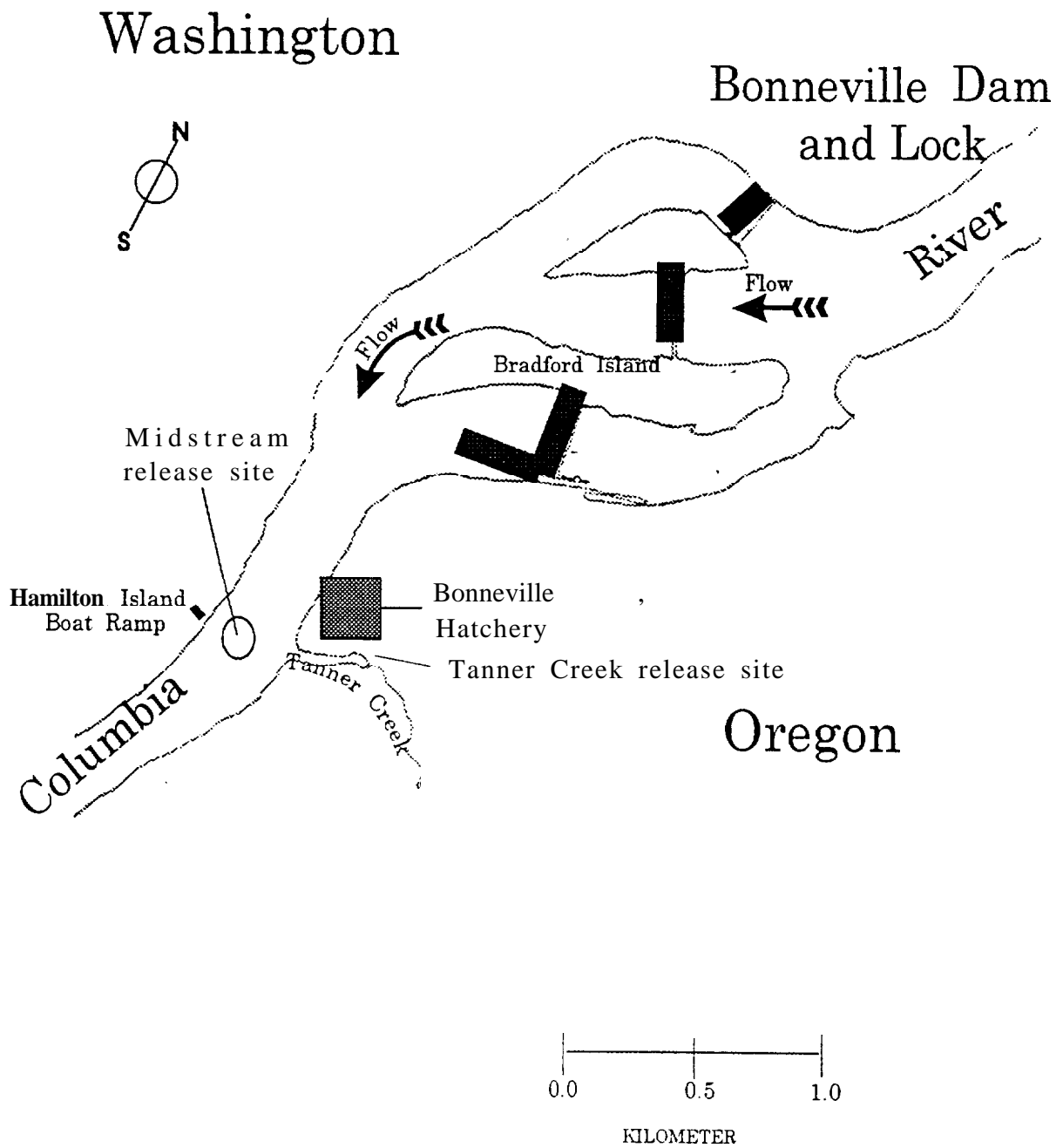


Figure 2.-Release locations for subyearling chinook salmon, 1991-1992.

Release Locations and Procedures

Groups of marked fish were released into Tanner Creek (the normal hatchery release site) and into the midstream Columbia River, lateral to the confluence of Tanner Creek (Figure 2). The specific release locations and procedures were as follows.

1. Tanner Creek: Test fish were released using the normal hatchery procedure of drawing down the water in the rearing pond and crowding fish into an underground flume. The flume carried fish about 650 m to Tanner Creek, where they were free to migrate to its confluence with the Columbia River, about 400 m downstream. At the confluence, fish were lateral to and about 150 m from the midstream Columbia River release site. Tanner Creek releases began at 8:30 p.m., about an hour prior to midstream releases, to provide extra time for fish traveling to the Columbia River.
2. Midstream Columbia River: Test fish were pumped through a hose with a diameter of 15 cm into 4,000-L tanker trucks; three trucks were used on each release night. Each truck was loaded with about 34,000 fish to maintain transport densities of about 60 g fish/L water (0.5 lb/gal). The trucks were loaded aboard a barge at the boat launch on Hamilton Island with one truck per barge trip. At midstream, the fish were released into the river through a 3-m-long hose with a diameter of 15 cm. Releases occurred between 9:30 p.m. and 11 p.m. at about RK 232.

Electrofishing Northern Squawfish

Two 5.5-m electrofishing boats (Smith-Root brand, model SR-18E)² were used to capture northern squawfish. The bow platform of each boat was equipped with a pair of adjustable booms fitted with umbrella anode arrays. These arrays consisted of six stainless steel cables, which were lowered into the water when fishing. All electrofishing was pulsed direct current using 60 pulses/sec, 400-500 volts, and 4-5 amperes.

Electrofishing activities began at 3 a.m. on June 16, about six hours following the first pair of releases (Appendix Table B-1). On subsequent nights through June 19, electrofishing was conducted from 9 p.m. to 9 a.m. Electrofishing was delayed the first night to allow test fish to disperse following release. Nine areas between RK 232 and RK 225 were electrofished, one in lower Tanner Creek and eight others in nearshore areas in the Columbia River (Figure 3). Each area was electrofished at least twice for about 30 minutes during each electrofishing period. Though transects on both the Oregon and Washington sides of the Columbia River were electrofished, removal efforts were more concentrated in transect areas closest to the release locations.

² Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

Northern squawfish stunned from electrofishing generally came to the water surface and were collected with a dipnet; some stunned fish were lost in the swift currents. Netted fish were placed in a lethal solution of tricaine methane sulfonate (MS-222) and within about 40 minutes of capture, taken to a processing station on shore where weight (g), fork length (mm), sex, and state of sexual maturity were recorded for each fish. The digestive tract (esophagus to anus) was removed from each fish, placed in a plastic bag, and frozen for later analysis.

In the laboratory, frozen digestive tracts were thawed and prepared for analysis using a digestive enzyme solution (pancreatin) to dissolve flesh, but leave diagnostic bones and CWTs from ingested fish intact (Petersen et al. 1990). The 2% (by weight) pancreatin solution, prepared using lukewarm tap water, also contained 1% sodium sulfide. This solution was added to the plastic bags containing the digestive tracts and the bags were placed in a 40° C desiccating oven for 24 hours. The stainless steel CWTs, having a greater density than bone, sank to the bottom after agitation of the digested samples, and were removed. In addition, these samples were checked for missed CWTs using an electronic tag detector. CWTs were decoded using a compound microscope (Appendix Table B-2). The solid contents of the bags were then rinsed through a 425 μ m sieve using tap water. A compound microscope and forceps were used to remove diagnostic bones (primarily cleithra, dentaries, and opercles) from the samples (Hansel et al. 1988). Diagnostic bones were identified and paired to enumerate salmonids and other prey consumed.

Sampling at Jones Beach

Short-term survival differences among release groups were assessed from comparisons of tagged fish recovered near the upper boundary of the Columbia River estuary at Jones Beach (RK 75). In addition to determining recovery differences, captured fish were observed for differences in descaling, injuries, size, feeding, and migration behavior. Dawley et al. (1985, 1988) described the sampling site and the fishing gear.

Sampling was conducted by two or three crews working seven days per week for eight to 12 hours per day, beginning at sunrise (Appendix Table C-1). Both purse seines (midstream) and beach seines (Oregon shore) were used to determine whether study fish were more abundant in midstream or near shore (Figure 4) and to maximize effort using the gear type that captured the greatest numbers of study fish.

All captured fish were processed aboard the purse seine vessels. The catch from each set was anesthetized in a 50-mg/L solution of ethyl p-aminobenzoate (benzocaine) and enumerated by species. Numbers of dead, injured, or descaled salmonids were recorded. Subyearling chinook salmon were examined for excised adipose fins and brands (possible study fish) and separated for mark processing. Non-study fish were returned to the river immediately after counting, evaluation, and recovery from anesthesia. Descaling was judged rapidly while counting and separating study fish from non-study fish. Fish were classified as descaled when 25% or more of their scales on one side were missing.

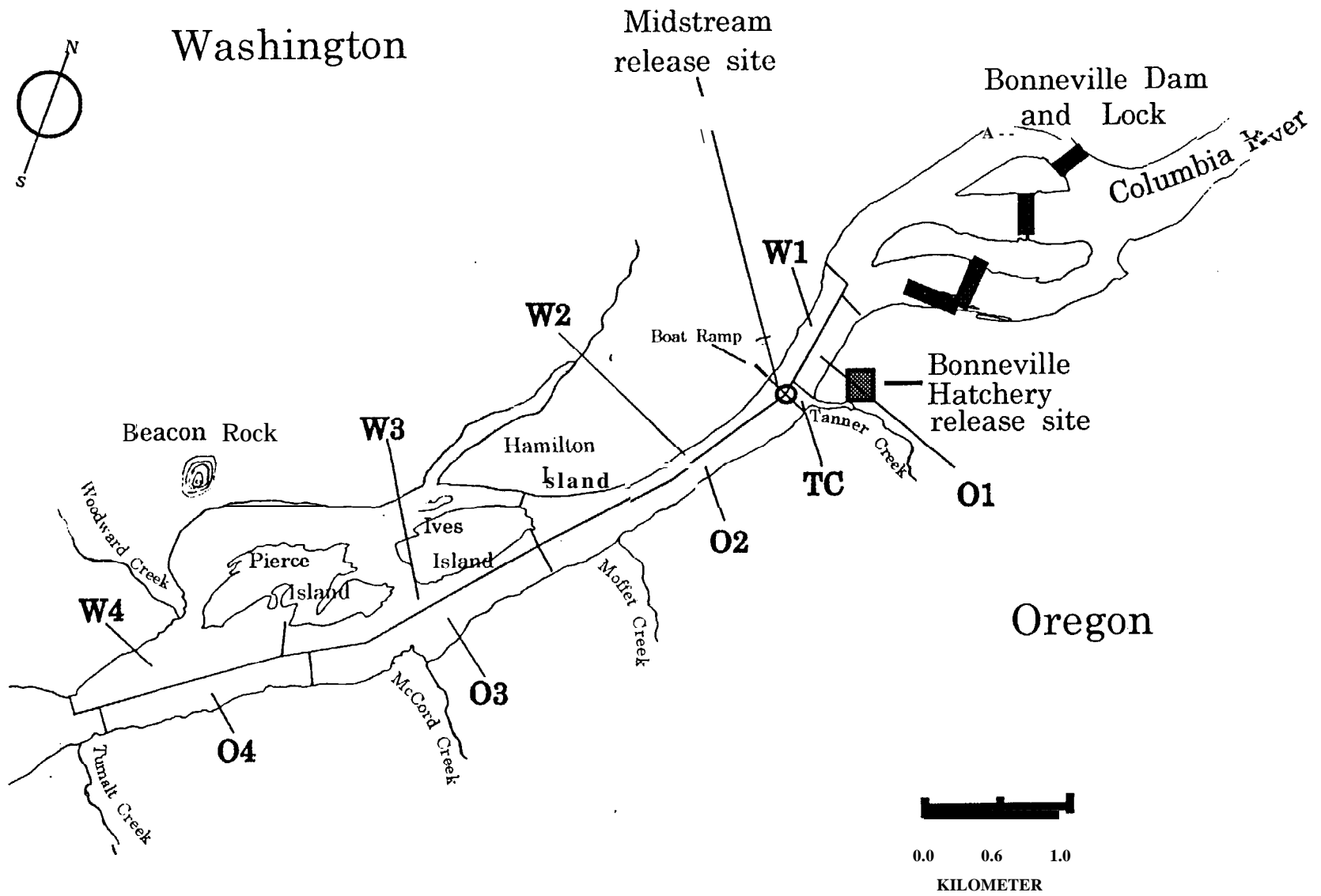


Figure 3.--Electrofishing areas in Tanner Creek and adjacent shoreline areas of the Columbia River, 1991-1992.

Freeze brands were used to identify study fish for collecting CWTs, obtain biological samples, compare fish size among treatment groups, and adjust the daily sampling effort to attain the desired minimum sample size of 0.5% of the number of fish released. Brand information, biological and associated sampling data (e.g., date, vessel code, gear code, set number, time of examination, fork length, and descaling) were immediately entered into a computer data base and printed. Fork lengths of marked fish were recorded to the nearest mm. All branded fish (including those with illegible brands) were sacrificed to obtain CWTs, which identified treatment group and day of release.

The heads of branded fish were processed in lots, and segregated by recovery day and site of capture. A 40% aqueous solution of potassium hydroxide was used to dissolve the heads and obtain CWTs. All CWTs were decoded and later verified; additional details of tag processing are presented in Appendix D by Ledgerwood et al. (1990).

Purse seine data, obtained from June 19 to July 22, were standardized to a 10-set-per-day effort; beach seine catch data from the same period were standardized to a 5-set-per-day effort. The following formula was used for standardizing each marked group.

$$A_i = N_i (S \div P_i)$$

where

A_i = Standardized purse or beach seine catch on day i ,

N_i = Actual purse or beach seine catch on day i ,

S = Constant (weighted daily average number of purse seine sets (10) or beach seine sets (5) during the sampling period), and

P_i = Actual number of purse or beach seine sets on day i .

On the day when there was no sampling effort for a particular gear type (beach seine, June 25), the standardized catch was derived by averaging standardized catches for one day prior to and one day after the missed day. Dates of median fish recovery for each marked group were determined using the combined standardized data from purse- and beach-seine catches. Movement rates for each CWT group were calculated as the distance from the midstream Columbia River release site (RK 232) to Jones Beach (RK 75) divided by the travel time (in days) from release date to the date of the median fish recovery.

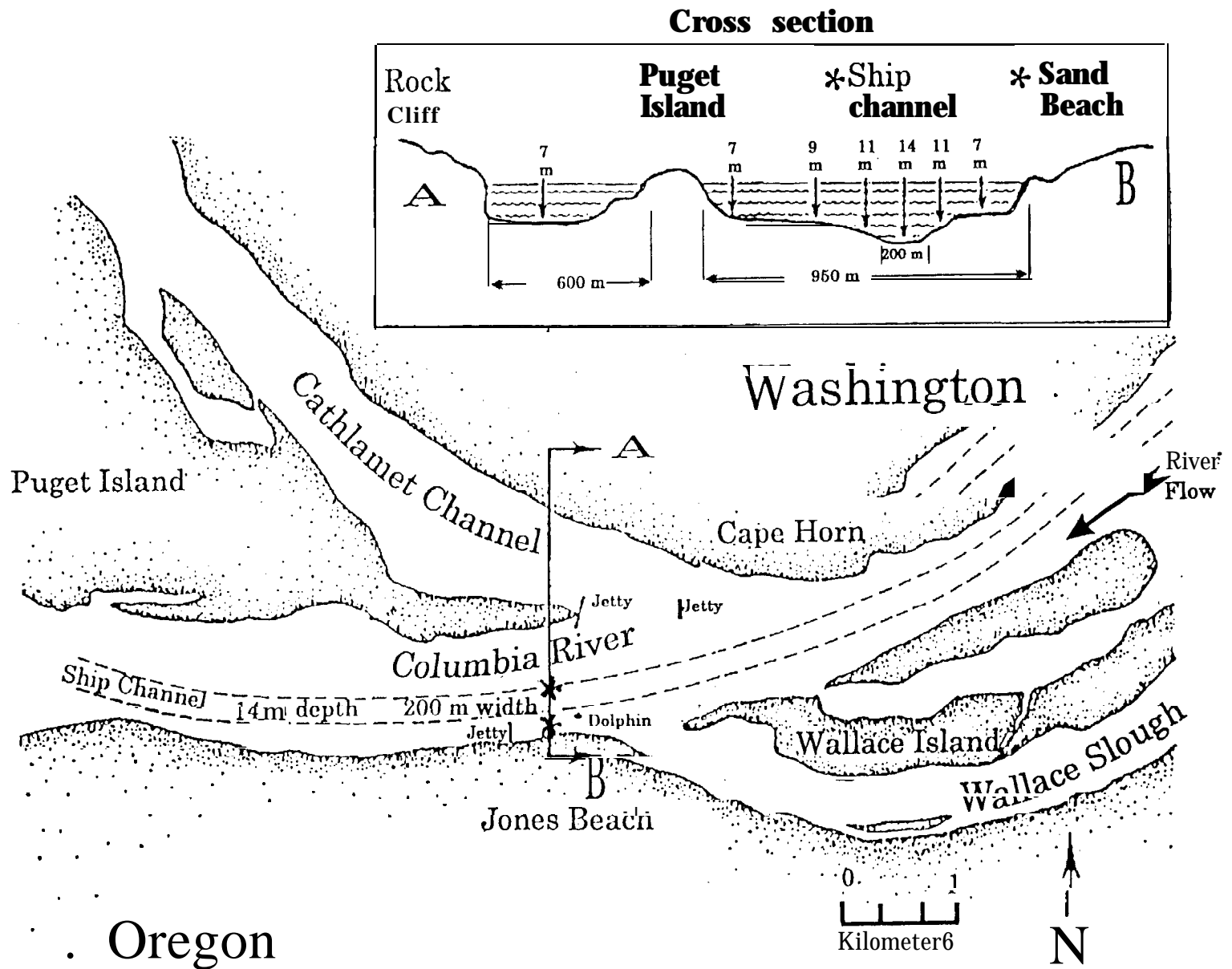


Fig-we 4.--Jones Beach, Columbia River, sampling sites. The beach and purse seining area8 are denoted by asterisks.

Diel, Physiological, and Biological Sampling at Jones Beach

On June 26-27, beach and purse seine sampling was extended through the nighttime hours to determine diel migratory behavior and to assess possible differences among targeted upriver bright and tule stocks³. Physiological samples, used for determining degree of smoltification, and stomachs, were taken from selected CWT fish captured during the diel sampling period. Methodology and results for physiological samples will be described in a separate report. Stomachs were excised (esophagus to pyloric caeca), and cleaned of external fat. A stomach fullness value, based on the proportion of the total stomach length containing food, was estimated. A scale of 1 to 7 was used to quantify the fullness as follows:

1 = empty, 2 = trace of food, 3 = one-quarter full, 4 = half full, 5 = three-quarters full, 6 = full, and 7 = distended full (Terry 1977). All stomachs appearing empty were opened for examination, and a value of 2 was assigned if traces of food were observed. Subsamples of stomachs were preserved in 10% buffered formaldehyde solution for weight determination and content analysis (to be reported separately). Holding time prior to fullness observations was about 35 minutes.

Statistical Analyses

The hypothesis that recovery ratios at Jones Beach were equal for fish released into Tanner Creek and the midstream Columbia River was tested using a paired difference z-test. The hypothesis that different marked groups, released the same day, had equal probability of capture through time was tested using chi-square goodness of fit (Zar 1974).

RESULTS

We marked 398,735 fish with freeze brands, CWTs, and excision of the adipose fin before release (Table 1). Between the two release dates, 1,793 northern squawfish were captured and removed from the study area (Table 2). An additional 380 northern squawfish were removed from the study area following the second release. We recovered 1,988 study fish in the estuary (about 0.5% of fish released); 84% of these were captured with purse seines in midstream (Appendix Table C-2). Handling mortality for all subyearling chinook salmon captured at Jones Beach was about 0.2 %; descaling averaged 0.6%, however, no study fish were descaled.

³ Two stocks of branded/CWT subyearling chinook salmon were present in the estuary and targeted during the diel sampling period; upriver bright stock used in this study and tule stock used for a concurrent study being conducted at Bonneville Dam (Earl Dawley, NMFS, Hammond, OR, pers. commun.). The goal was to compare behavioral and biological characteristics of the two stocks in the hatcheries prior to release and after migration to the estuary. Detailed results of this sampling will be reported separately.

Electrofishing Northern Squawfish

We captured and removed 2,173 northern squawfish from the nine transect areas during about 26 hours (94,930 seconds) of electrofishing (Table 2). Sixty-six percent (1,438) of those removed were caught in Tanner Creek or adjacent transect areas along the Oregon shore (O1, O2, and O3), similar to 1991 (Figure 5). During the June 16-19 electrofishing periods (following the June 15 release), catch rates of northern squawfish were higher than during the June 20-22 electrofishing periods (following the June 19 release) and there was little indication that northern squawfish recolonized the Tanner Creek or adjacent transect areas (Table 3).

The mean fork length (303.0 mm) and weight (234 g) of northern squawfish were fairly consistent throughout the removal periods and considerably smaller than northern squawfish captured during the study in 1991 (means 343.8 mm and 605.9 g; Figure 6). The number of CWTs recovered in the digestive tracts of northern squawfish (representing ingested juvenile salmon) diminished over time. Of the 238 CWTs recovered from the digestive tracts of northern squawfish (Appendix Table B-2), 98% were from study fish and all except one were from study fish released June 15 into Tanner Creek; the exception was a June 15 midstream Columbia River released fish recovered in Transect Area O3⁴. The CPUE was highest in Transect Area O4, along the Oregon shoreline, but no CWTs from study fish were recovered from those northern squawfish (Table 3).

Migration Behavior and Condition of Study Fish

There was no evidence to suggest non-homogeneity between treatment recovery distributions of study fish groups released on the same day ($\alpha = 0.05$; Appendix D); thus the recovery data were standardized to a constant daily effort to determine the date of median fish recovery and to calculate movement rates (Appendix Table C-2). Temporal catch distributions of each release group are presented in Figure 7.

Movement rates of study fish to Jones Beach ranged from 17.4 to 19.6 km/day, intermediate to movement rates in 1991, but faster than movement rates in 1989 or 1990 (Table 4). Movement rates of fish from the second release groups were about 13% higher than those of the first release groups, probably in part because of increased river flow at the time of the second release (Figure 8).

⁴ Northern squawfish captured following the June 19 release were neither weighed nor examined for the presence of CWTs.

Table 1. Summary of releases of marked subyearling chinook salmon, Tanner Creek vs. midstream Columbia River, 1992.

Marking dates	Release date	Brand ^a	Number released			Wire tag code (AG D1 D2) ^e
			Total ^b	Untagged ^c	Tagged ^d	
Tanner Creek releases						
20 May-3 June	15 June	RD Z2	99,718	4,901	94,817	23 30 07
20 May-3 June	19 June	LD Z2	99,579	3,484	96,095	23 30 08
Midstream Columbia River releases						
20 May-3 June	15 June	RD Z1	99,550	7,310	92,240	23 30 09
20 May-3 June	19 June	LD Z1	<u>99,888</u>	<u>5,054</u>	<u>94,834</u>	23 30 10
		Total	398,735	20,749	377,986	

^a Brand codes: 1st and 2nd characters, RD = right dorsal position; 3rd character is the brand symbol; 4th character is brand rotation where 1 = symbol in the upright position and 2 = symbol rotated clockwise 90° from upright position.

^b Total fish marked, branded, tagged, and adipose fin clipped (less observed pre-release mortality and fish retained for tag loss evaluation).

^c Estimated number of fish released without coded-wire tags (Appendix Table A-2).

^d Estimated number of fish released with coded-wire tags.

^e CWT code key: AD D1 D2 = Agency code, Data 1 code, Data 2 code.

Table 2. Number of northern squawfish removed by day (all electrofishing sites) and number of coded wire tags recovered in digestive tracts of northern squawfish, 1992.

Electrofishing period	Northern sauawfish removed				CWTs recovered ^a		
	Time shocker on (sec)	Total catch	CPUE ^b	Mean length (mm)	Mean weight (g)	Release site	
						Tanner' Creek	Mid-stream ^d
Data pertinent to first paired release							
16 June(0300-0900)	9,242	159	62	335	529	156	0
16-17 June(2100-0900)	16,415	753	165	279	380	63	1
17-18 June(2100-0900)	17,097	321	68	296	426	12	0
18-19 June(2100-0900)	25,239	560	80	301	385	3	0
Subtotal ^e	67,993	1,793	93.75	302.8	430.0	234	1
Data pertinent to second paired release							
20-21 June(2100-0900)	12,829	134	38	337	-- ^f		
20-22 June(2100-0900)	14,108	246	63	270	--	--	--
Subtotal	26,937	380	50.5	303.5	--		
Total	94,930	2,173	79.3	303.0	430.0	234	1

^a CWT = coded wire tag (Agency code/Data 1 code/Data 2 code). Number of CWTs recovered in the digestive tracts of northern squawfish represent a minimum number of juvenile salmon ingested.

^b CPUE = catch per unit effort, number of fish caught per hour.

^c CWT code = 23/30/07, released June 15.

^d CWT code = 23/30/09, released June 15.

^e Means weighted by day.

^f Dashes indicated date not available.

Table 3. Electrofishing effort, number of northern squawfish removed, and number of coded wire tags recovered from the digestive tracts of northern squawfish for each electrofishing transect. 1992.

Location	Mean effort ^b (sec)	Northern sauawfish removed				CWTs recovered ^a	
		Total number	CPUE ^d	Mean length (mm)	Mean weight (g)	Release site	
						Tanner Creek	Mid-stream ^e
01	14,739	348	29.0	332	598	22	0
02	23,155	678	67.8	275	346	199	0
03	12,964	348	58.0	292	374	6	1
04	6,795	229	45.8	254	262	0	0
W1	10,343	254	31.8	321	496	0	0
w 2	9,213	131	26.2	267	442	0	0
w 3	3,797	22	11.0	337	512	0	0
w 4	10,613	99	19.8	308	439	0	0
TC	3,311	65	7.2	349	630	7	0
Total	94,930	2,174	--	--	--	234	1
mean	10,547.8	241.4	33.0	303.9	455.4	--	

^a CWT = coded wire tag (Agency code/Data 1 code/Data 2 code). Number of CWTs recovered in the digestive tracts of northern squawfish represent ingested juvenile salmon.

^b Mean effort per sampling period for each location; total effort (at bottom) is the total time, in seconds, that the shockers were on for all dates and all locations (see Appendix Table B1).

^c Location codes (2 characters): TC = Tanner Creek transect area; other Columbia River transect areas, where, 1st character, 0 = Oregon shoreline, and W = Washington shoreline; 2nd character, 1-4, transect areas (refer to Figure 3 for precise locations).

^d CPUE = catch per unit effort, number of fish caught per hour (Appendix Table B-1).

^e CWT code = 23/30/07, released June 15.

^f CWT code = 23/30/09 released June 15.

Table 4. Movement rates to Jones Beach for marked groups of subyearling chinook salmon released in Tanner Creek and in midstream Columbia River, 1989, 1990, 1991, and 1992.

Release date	Movement rate (km/day) ^a		Mean FL (mm) ^b	Flow (k•ft ³ /sec)	
	Midstream Columbia	Tanner Creek		At release ^c	At median ^d
29 June 1989	10.4	9.8	101	142	113
1 July 1990	12.1	12.1	91	247	190
24 June 1991	15.7	17.4	92	215	262
28 June 1991	22.4	22.4	92	272	258
15 June 1992	17.4	17.4	95	191	198
19 June 1992	19.6	19.6	94	207	186

^a Movement rate = distance from the midstream Columbia River release site (RK 232) to recovery site (RK 75) divided by the time in days from release to median fish recovery. Median fish recovery based on purse seine recoveries standardized to a 10 set per day effort plus beach seine recoveries standardized to a 5 set per day effort (Appendix Table C-2).

^b Mean fork length of fish recovered at Jones Beach.

^c Average flow through Bonneville Dam on the day that fish were released.

^d Average flow through Bonneville Dam within 4 days of the date that the median fish was captured; by convention, English units were used for river flow volumes (k . ft³/sec = 1,000 ft³/sec = 28.3 m³/sec).

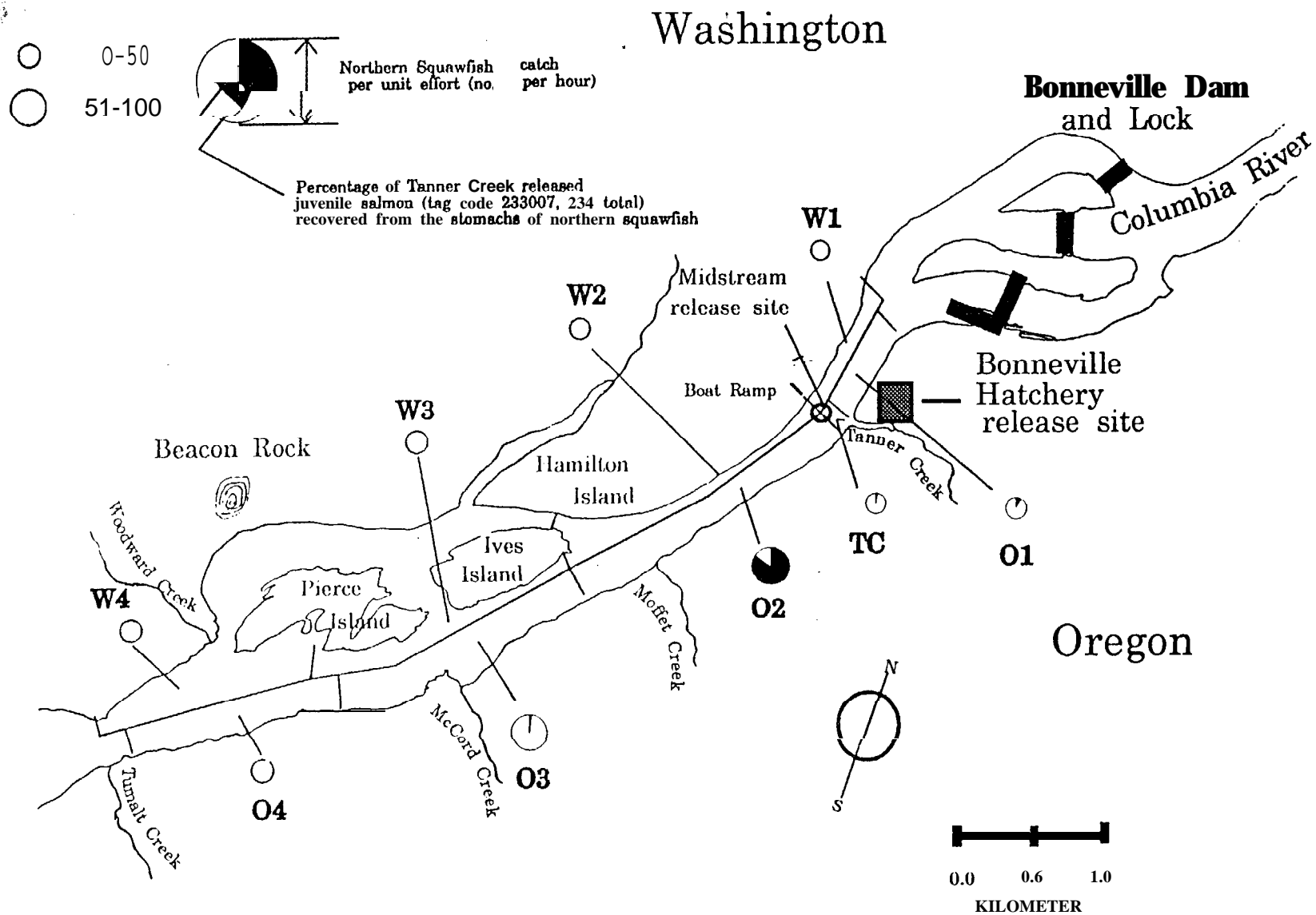


Figure 5.--The study area showing the northern squawfish catch per unit effort at each electrofishing transect area and proportion of tags (representing ingested juvenile salmon) from the 15 June Tanner Creek release group recovered in those northern squawfish, 1992.

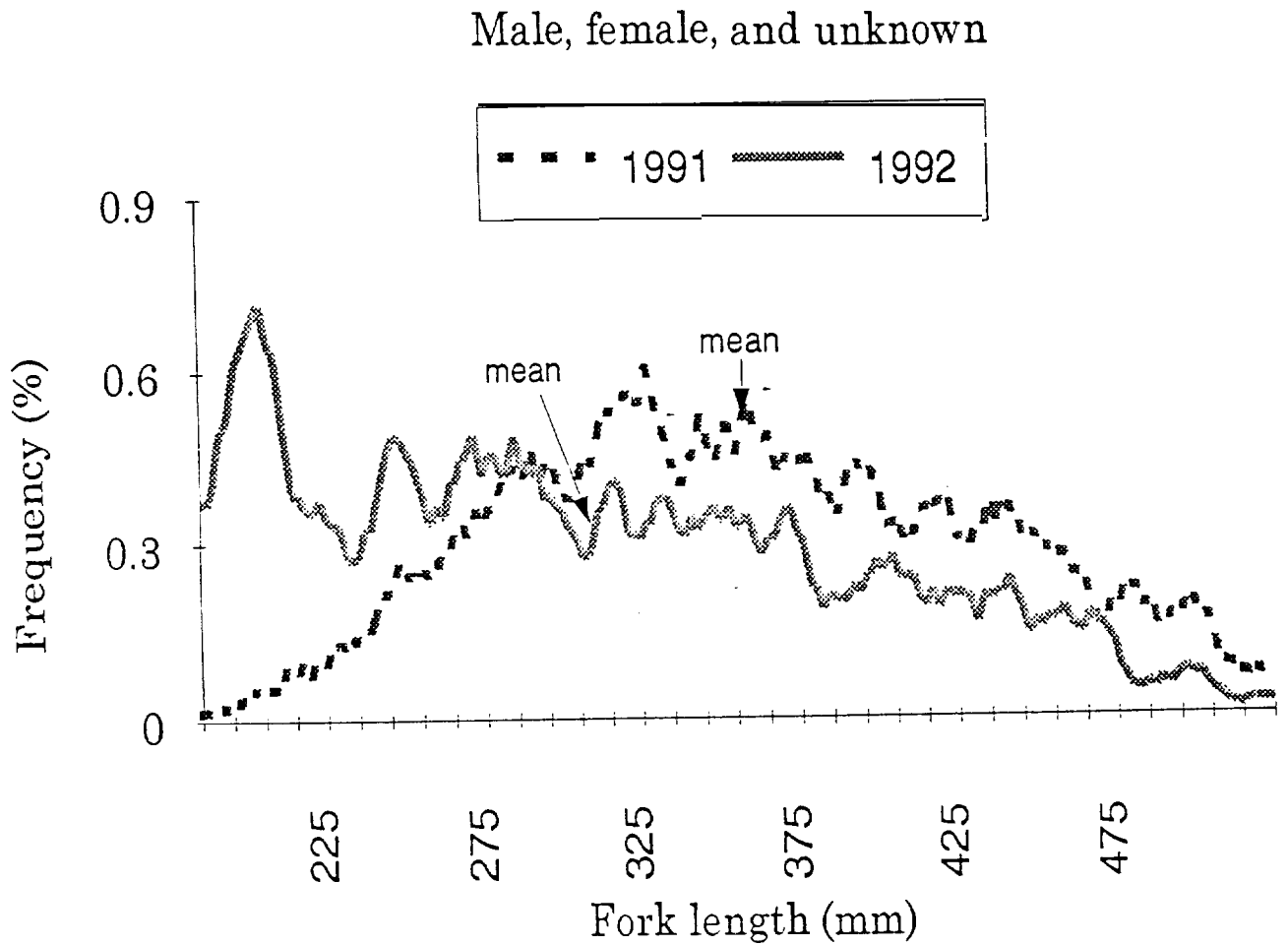


Figure G.--Fork length distributions of northern squawfish removed from the study area by electrofishing, 1991 and 1992.

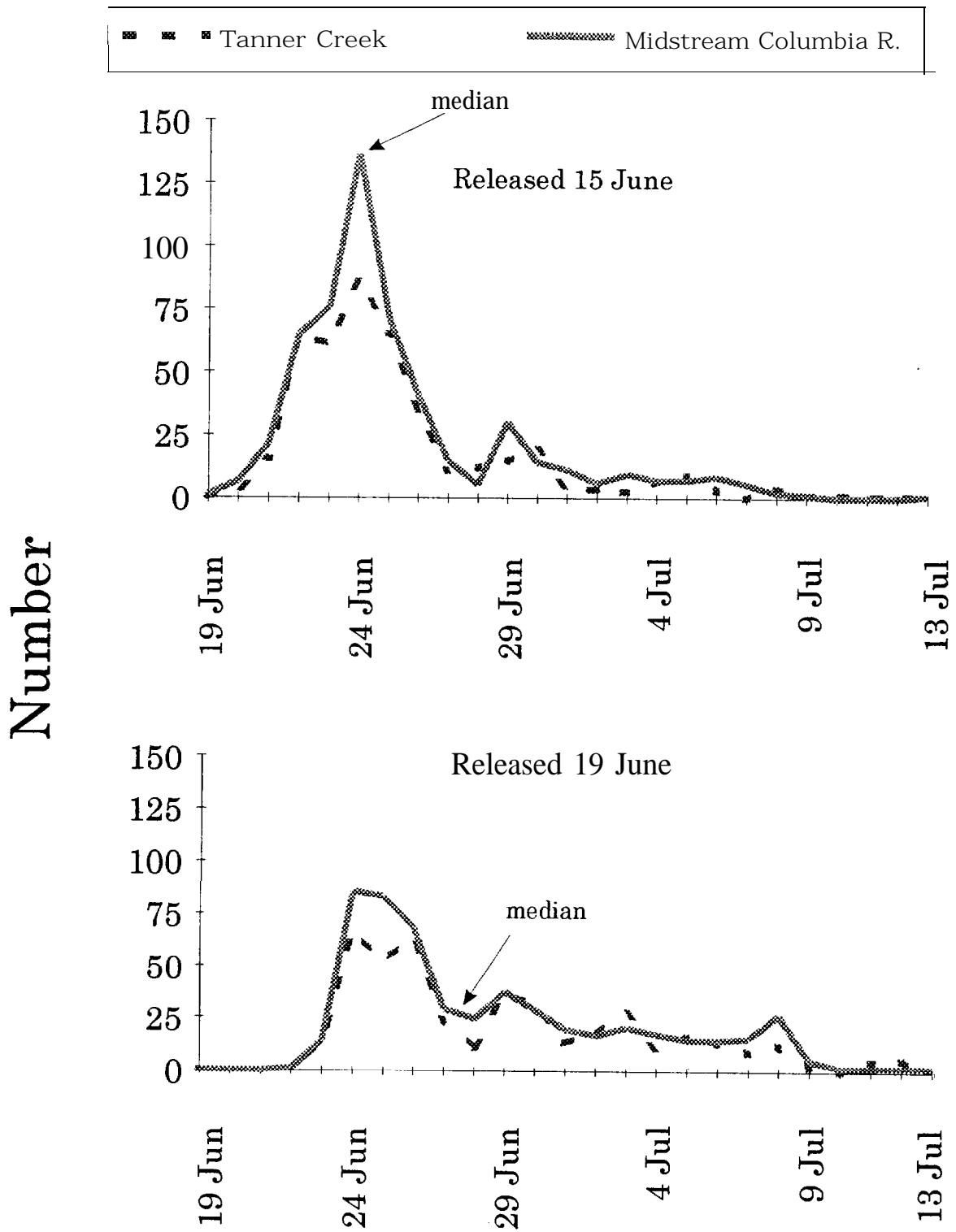


Figure 7.-- Daily recoveries of test fish at Jones Beach (standardized for effort) comparing midstream Columbia River to Tanner Creek release-groups, 1992.

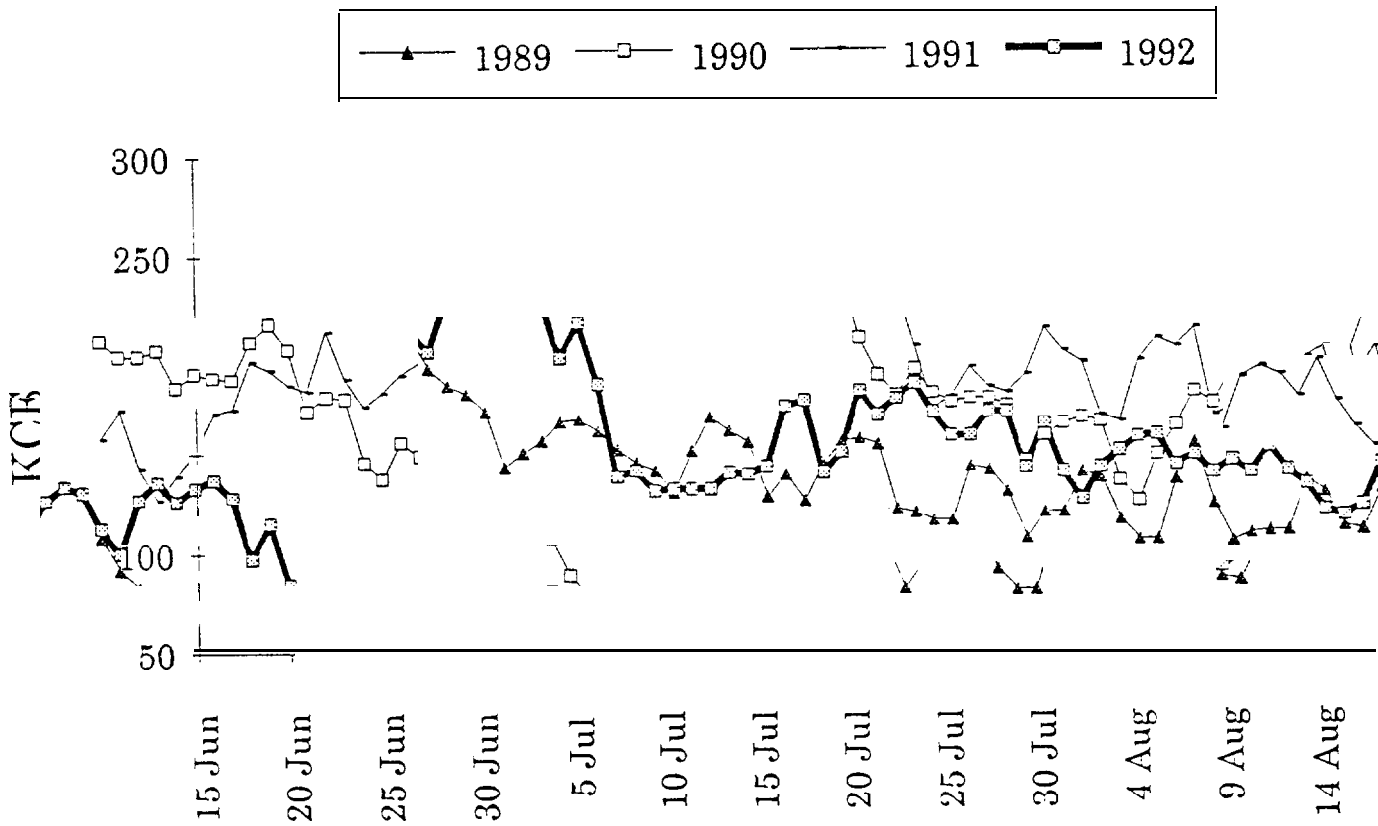


Figure 8.--Daily mean flows of the Columbia River at Bonneville Dam during the estuarine sampling periods, 1989, 1990, 1991, and 1992; flow measurements provided by the U. S. Army Corps of Engineers, Portland, Oregon.

Generally, fish from both pairs of releases showed a decreasing mean length during the first four to six days of the recovery period, followed by increasing mean lengths during the remainder of the recovery period (Figure 9). This suggests that the larger individuals of the released populations traveled faster to Jones Beach and that slower moving individuals grew during the migration period. There were no apparent differences among treatment groups in daily mean lengths at recovery. Comparisons of fork length distributions of study fish at release to those captured at Jones Beach also suggest that all groups grew during the migration period (Figures 10 and 11). The frequency distributions were similar for most groups allowing for a growth rate of about 1 mm per day. The exception may be the June 15 release at Tanner Creek (Figure 10) where the smallest individuals released were not as prevalent in the sample recovered at Jones Beach.

Diel Recovery Patterns

During the diel sampling period, about 12,000 and 10,000 subyearling chinook salmon (primarily non-study fish) were captured in the beach seine and in purse seines, respectively (Appendix Table C-3). In the purse seines, catches were highest at sunrise, generally decreased during the afternoon, increased again at dusk, and were lowest at night (Figure 12). In the beach seine, catches peaked about three hours after sunrise, declined during the afternoon, increased again in late afternoon, and were lowest at night. The pattern of very low catches during darkness for both gear types is similar to patterns observed in previous years at Jones Beach (Ledgerwood et al. 1991a, 1991b). Details comparing recoveries of tule and upriver bright stocks will be reported separately.

Stomach Fullness and Smoltification

Based on examination of stomach fullness of selected marked fish, study fish were feeding by the time they arrived at Jones Beach. Stomachs were generally about half full in fish collected during daylight hours. Upriver bright stock used during this study had slightly higher fullness values than tule stock sampled concurrently (means 4.0 and 4.5, respectively; Figure 12). Detailed analyses of diet content, diel feeding patterns, and results of other samples related to the degree of smoltification will be reported separately.

Juvenile Recovery Differences

Analysis of CWT-fish recoveries at Jones Beach (Appendix D) indicated that the recovery percentages for fish released from the midstream Columbia River were significantly higher than for fish released into Tanner Creek for both the first (0.57% versus 0.42%; $P < 0.01$) and the second pair of release groups (0.60% versus 0.51%; $P < 0.01$). After the removal of northern squawfish, the difference in recovery percentages between the two release sites was reduced from 35.7% to 17.6% (Table 5, Figure 13); this 50.7% reduction in recovery percentage differences $(35.7 - 17.6) \div 35.7 * 100$ was insignificant ($P = 0.19$).

Although the recovery percentages of the second pair of groups were higher than those for the first release-group pair, they are not directly comparable because releases made on different dates were subject to different river conditions and sampling effort.

To further assess data consistency, we analyzed purse seine recoveries separate from total recoveries (Appendix Table C-2, Appendix D). Conclusions regarding differences among recovery ratios derived from the purse seine data were the same as those reached with the total catch data; recoveries of study fish released from the midstream Columbia River were significantly higher ($P < 0.01$) than those for fish released into Tanner Creek and no significant change ($P = 0.42$) was observed between recovery percentages following removal of northern squawfish. Beach-seine recoveries separate from total recoveries were too few as a data subset for meaningful analysis (less than 0.1%).

Table 5. Recovery percentages of tagged subyearling chinook salmon at Jones Beach, Tanner Creek release vs. midstream Columbia River release, 1989, 1990, 1991, and 1992.

Release date	Midstream Columbia River ^b	Bonneville Hatchery at Tanner Creek	Benefit ^c for midstream release (%)
29 June 1989	0.43	0.26	65.4 ^d
1 July 1990	0.42	0.30	40.0'
24 June 1991	0.37	0.30	23.3'
28 June 1991	0.39	0.33	18.2'
15 June 1992	0.57	0.42	35.7*
19 June 1992	0.60	0.51	17.6*

^a The percent benefit for midstream Columbia River release (MC) over Tanner Creek release (TC) is calculated as: $\{(MC\% \text{ recover} - TC\% \text{ recover}) \div TC\% \text{ recover}\} \times 100$.

^b Fish transported by truck and barged to the middle of the Columbia River adjacent to the confluence with Tanner Creek.

^c Normal hatchery release site.

^d * = significant difference in recovery percentages for fish released in midstream Columbia River or Tanner Creek ($P \leq 0.05$).

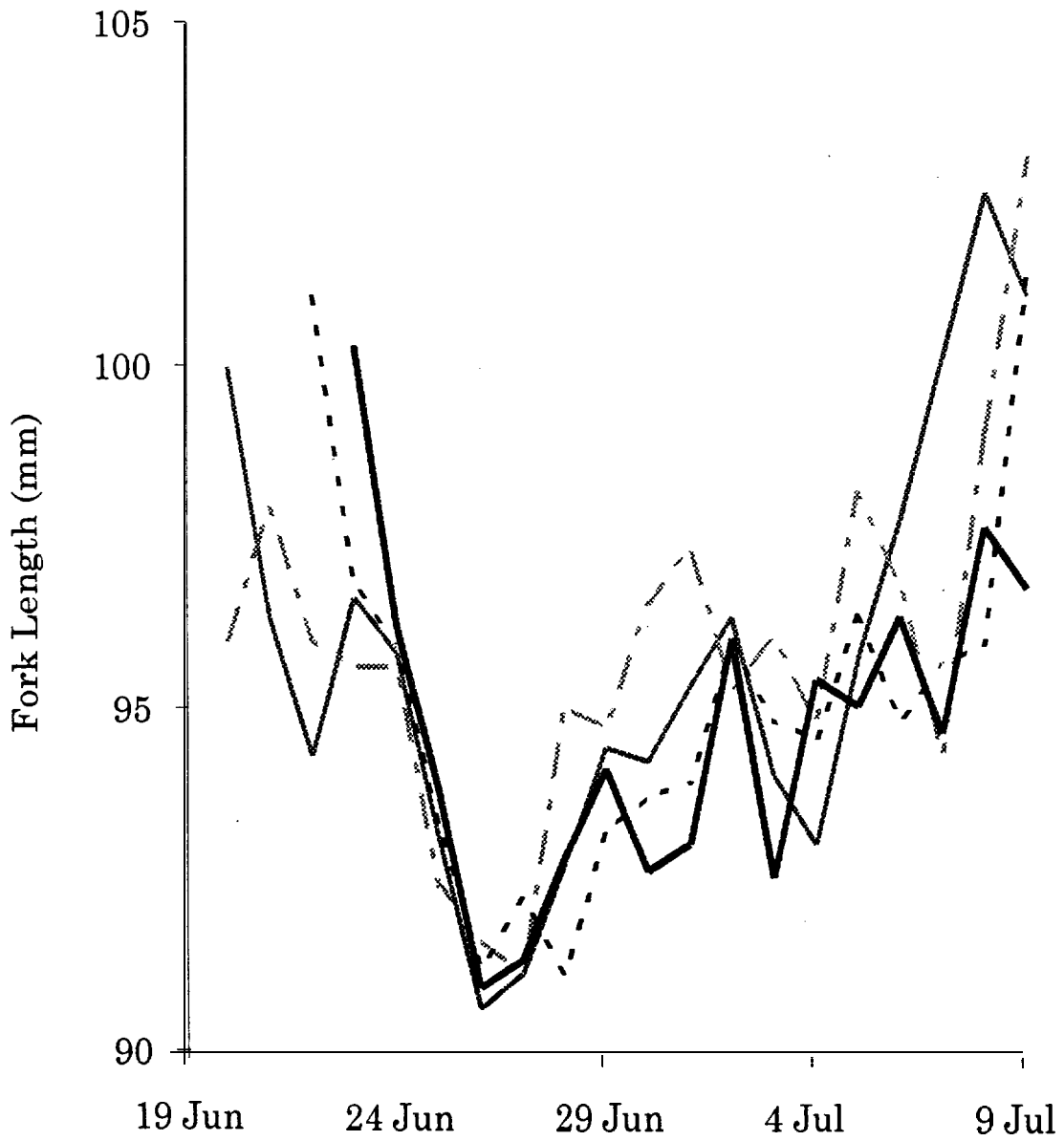
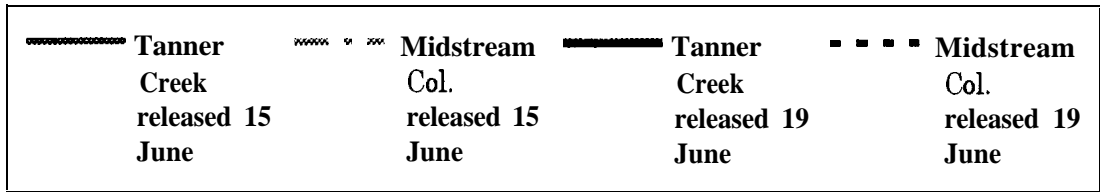


Figure 9.-- Daily mean fork lengths of subyearling chinook salmon recovered at Jones Beach, comparing midstream Columbia River to Tanner Creek release groups, 1992.

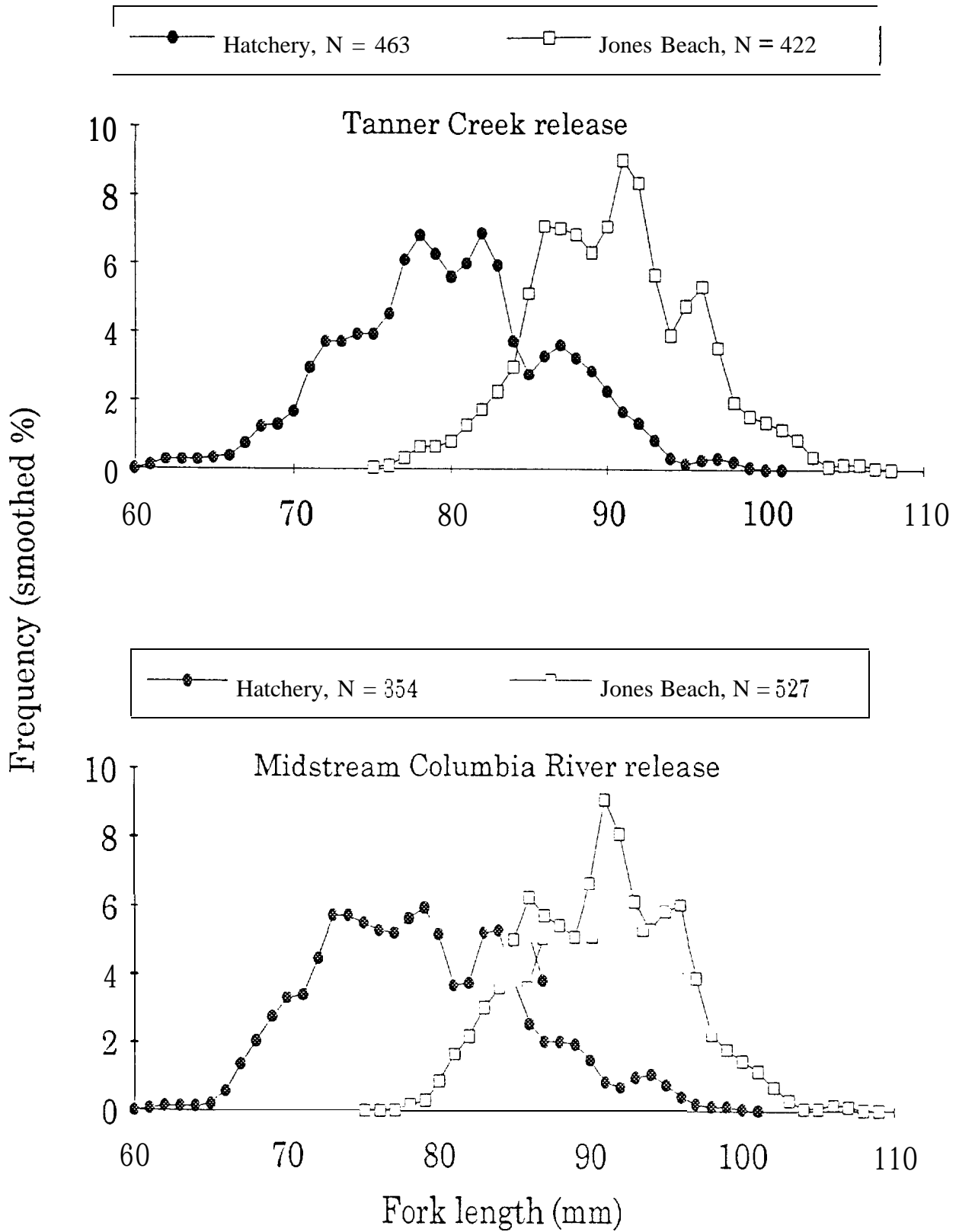


Figure 10.--Fork length distributions of study fish at release and after recovery at Jones Beach; fish released on 15 June 1992.

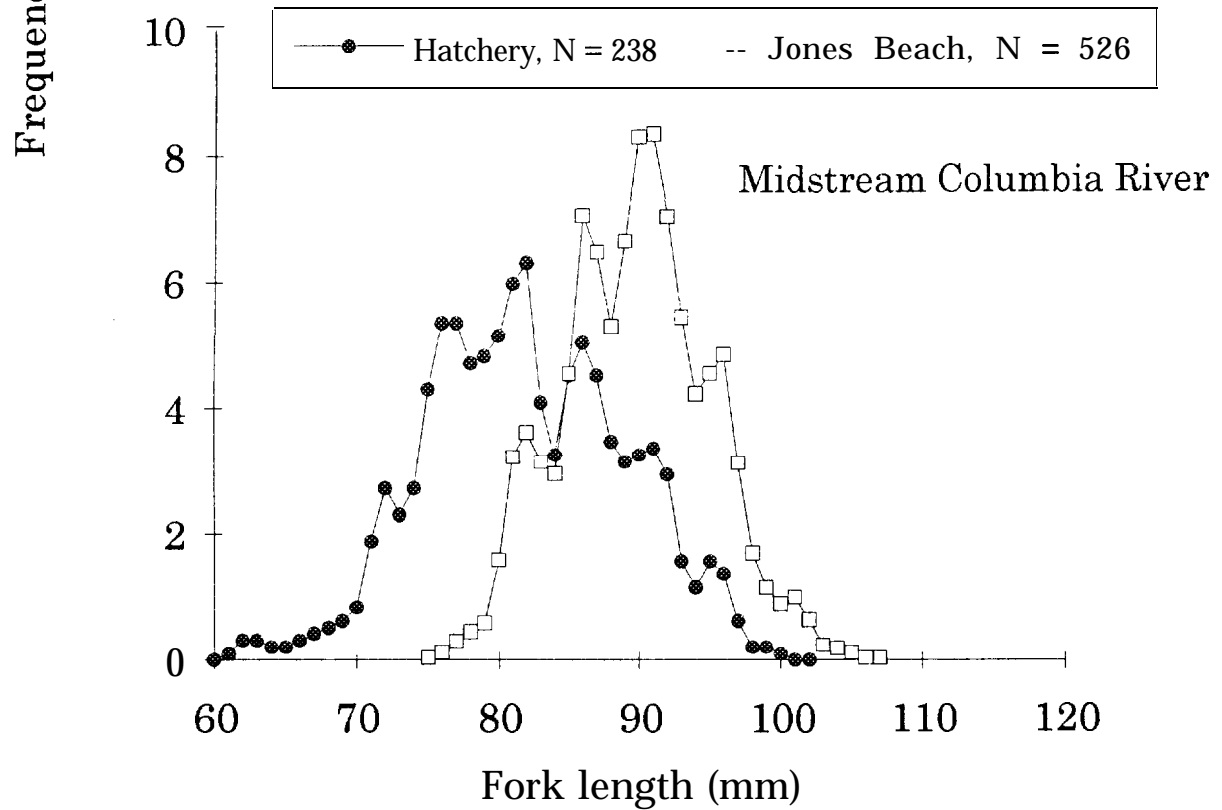
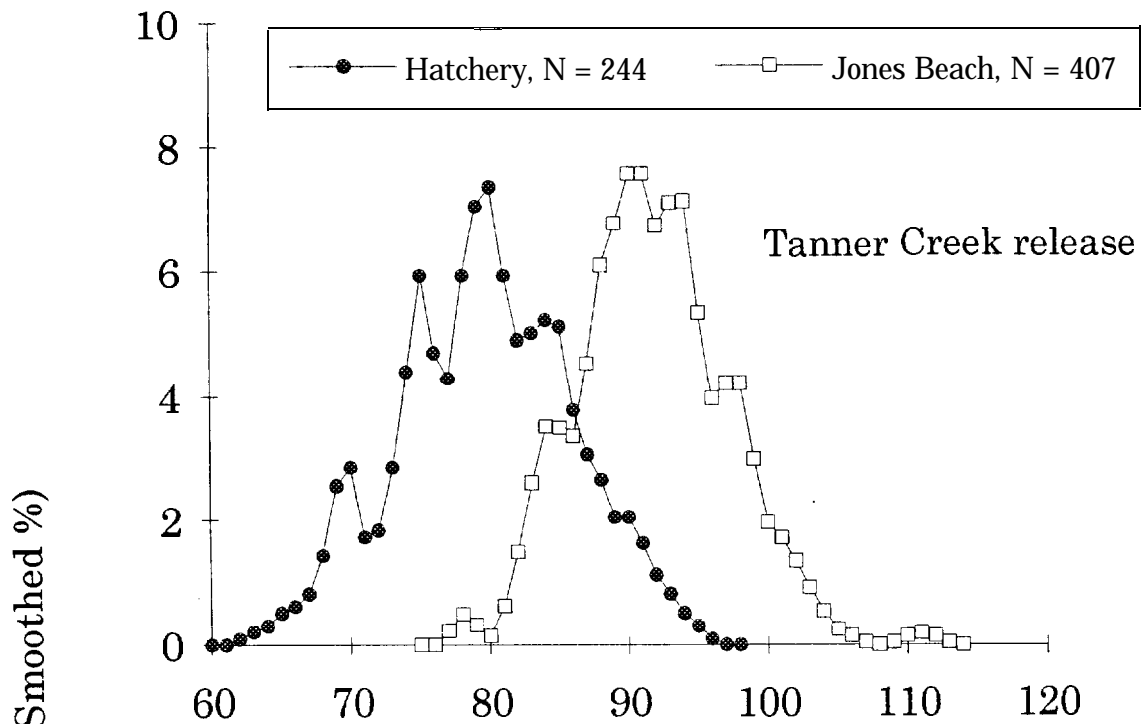


Figure 11.-- Fork length distributions of study fish at release and after recovery at Jones Beach; fish released on 19 June 1992.

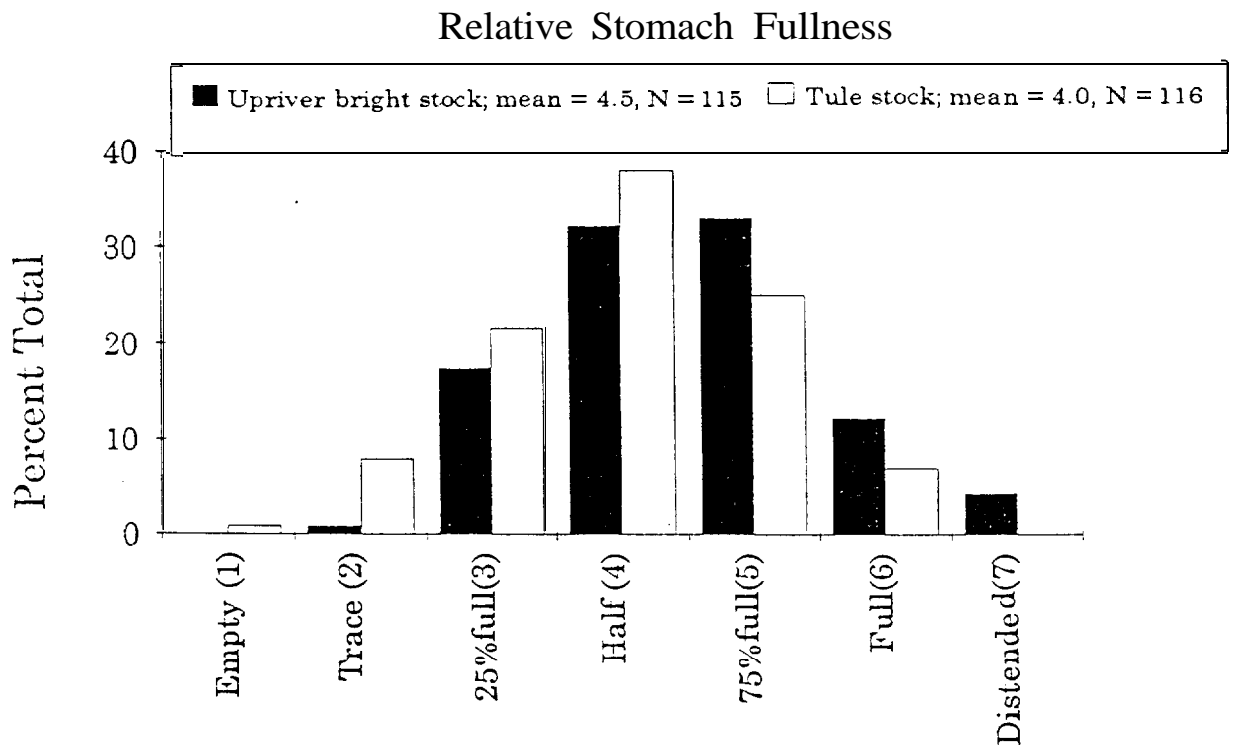
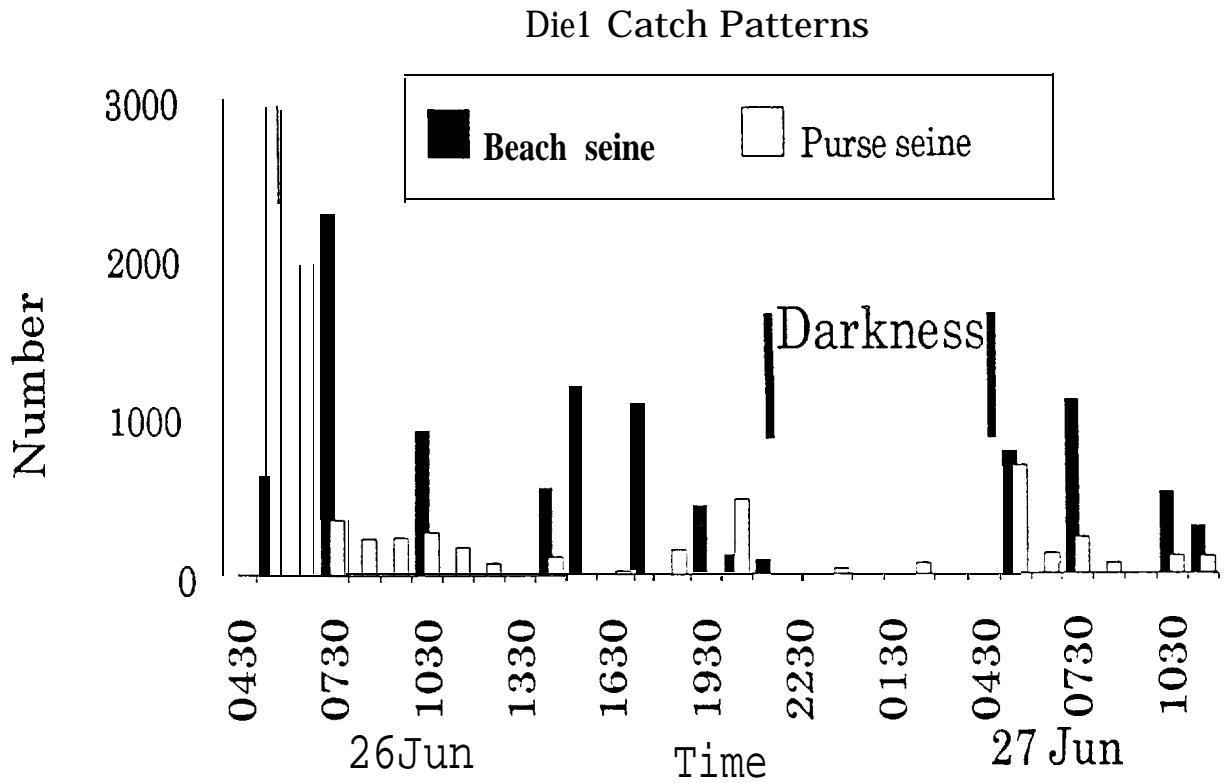


Figure 12.--Diel catch patterns (top) and relative stomach fullness (bottom) for subyearling chinook salmon captured at Jones Beach, 1992.

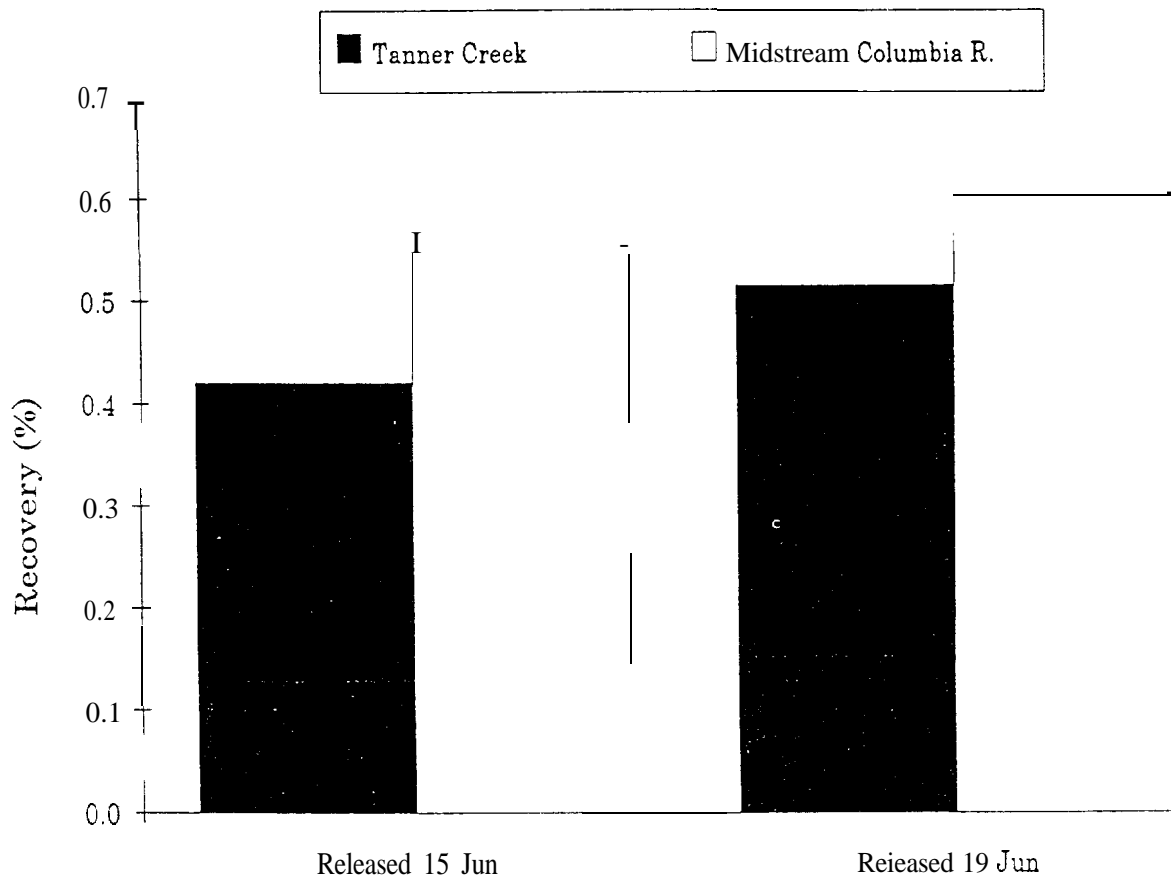


Figure 13.--Mean recovery percentages comparing midstream Columbia River to Tanner Creek release groups, 1992. Northern squawfish were removed by electrofishing between the two release dates. Recovery rates for the midstream releases were significantly higher ($P < 0.05$) than for the Tanner Creek release groups on both dates.

DISCUSSION

In 1992, recovery at Jones Beach of subyearling chinook salmon released from the midstream Columbia River was significantly higher ($P \leq 0.05$), averaging about 27% greater than for fish released from Bonneville Hatchery into Tanner Creek; there was also considerable, though not significant ($P = 0.19$), reduction in difference between the two release dates in 1992. Through the years of study, 1989-92, the differences in recovery percentages between midstream Columbia River releases and Tanner Creek releases have ranged from 65 % to 18 % (Table 5) with the low values following intensive electrofishing to remove northern squawfish from the migration routes of the Tanner Creek-released fish. One factor contributing to the variability in the data may be differences in the river flow at the time various groups were released. We speculate that higher flows disperse test fish more rapidly, reduce their exposure time to predation, and result in higher survival rates for Tanner Creek releases. The difference in recovery percentages for midstream releases was inversely correlated with the movement rate of Tanner Creek-released fish ($R' = 0.87$; Figure 14). Movement rate may be a function of both river flow and state of smoltification (Zaug and Mahnken 1991). Smoltification was assessed in 1992 (reported separately), but not in the earlier years. However, release dates were similar each year (between June 15 and July 1).

In 1992 and 1991, years when we attempted to evaluate the effects of localized removal of northern squawfish on survival of juvenile salmon, the Columbia River flows on the second release date were higher than on the first release date, about 8% higher in 1992 and 27% higher in 1991 (Table 4). About 2,000 northern squawfish were removed from the study area between the two release dates in both years, yet the decline in survival benefit for midstream Columbia River release was more than twice as great in 1992 as in 1991 (51% vs. 22% decline). The higher flows for the second release groups resulted in faster movement to Jones Beach and may have increased survival of the Tanner Creek-released fish regardless of predator removal efforts, particularly in 1991. In general, the effectiveness of localized northern squawfish removal at reducing the survival difference between midstream Columbia River and Tanner Creek release may be inversely related to river flow. River flows were substantially higher throughout the migration period in 1991 than in 1992 (Figure 8) and may better explain the difference in survival benefit for midstream Columbia River release groups following localized northern squawfish removal in these two years than removal efforts.

It is difficult to determine if the generally high numbers and catch rates of predators in the study area occurred because northern squawfish congregated near the hatchery release site or because high densities of northern squawfish were prevalent throughout the entire study area. The high catches of northern squawfish along the Oregon shoreline at Transect 04 support the latter explanation (Table 3). The observations that CWT recoveries were concentrated at transects closest to the Tanner Creek release site, and that nearly all the CWTs recovered were from the Tanner Creek release group, suggest that juvenile salmonids released from the hatchery were more vulnerable to predation by northern squawfish in the river region near Bonneville Hatchery than juveniles released in midstream. The CPUE for

northern squawfish fluctuated during the removal period, and was somewhat lower for the dates following the second pair of juvenile salmon releases. It is difficult to attribute the 52% decline in survival benefit for midstream Columbia River release to the removal of so few northern squawfish. Rather, a general decline in size of northern squawfish present in 1992 coupled with higher river flows during the second release pair may better explain the decline. In total, over 100,000 northern squawfish were removed from the tailrace area of Bonneville Dam during 1991 and 1992⁵, and the proportion of the larger (older) northern squawfish may be declining (Appendix E). The sharp drop in numbers of CWTs in the digestive tracts of northern squawfish by the final day of electrofishing suggests emigration of the released salmon.

CONCLUSIONS

1. Subyearling chinook salmon from Bonneville Hatchery released into the midstream Columbia River exhibited significantly higher survival rates than fish released into Tanner Creek. The difference in survival is in part related to predation by northern squawfish on fish released at the hatchery.
2. The predominance of CWTs from Tanner-Creek-released juvenile salmon in the digestive tracts of northern squawfish indicated that juvenile salmon released from the hatchery were more vulnerable to predation by northern squawfish located in the river region near Bonneville Hatchery than juveniles released in midstream.
3. The survival difference between midstream Columbia River and Tanner Creek release groups appears to be inversely related to the movement rate of Tanner Creek release groups. Faster movement rates for fish were associated with high river flows and may also have been influenced by smoltification differences between years.
4. It was difficult to determine if the high numbers and catch rates of predators at the transects nearest Tanner Creek occurred in response to the hatchery release or to high densities of northern squawfish throughout the study area.
5. Electrofishing efforts to remove northern squawfish from the migration route of juvenile salmon released from Bonneville Hatchery did not significantly reduce the survival difference between midstream Columbia River and Tanner Creek release groups.

⁵ Craig C. Burley, Washington Department of Wildlife, Olympia, pers. commun., May 1992.

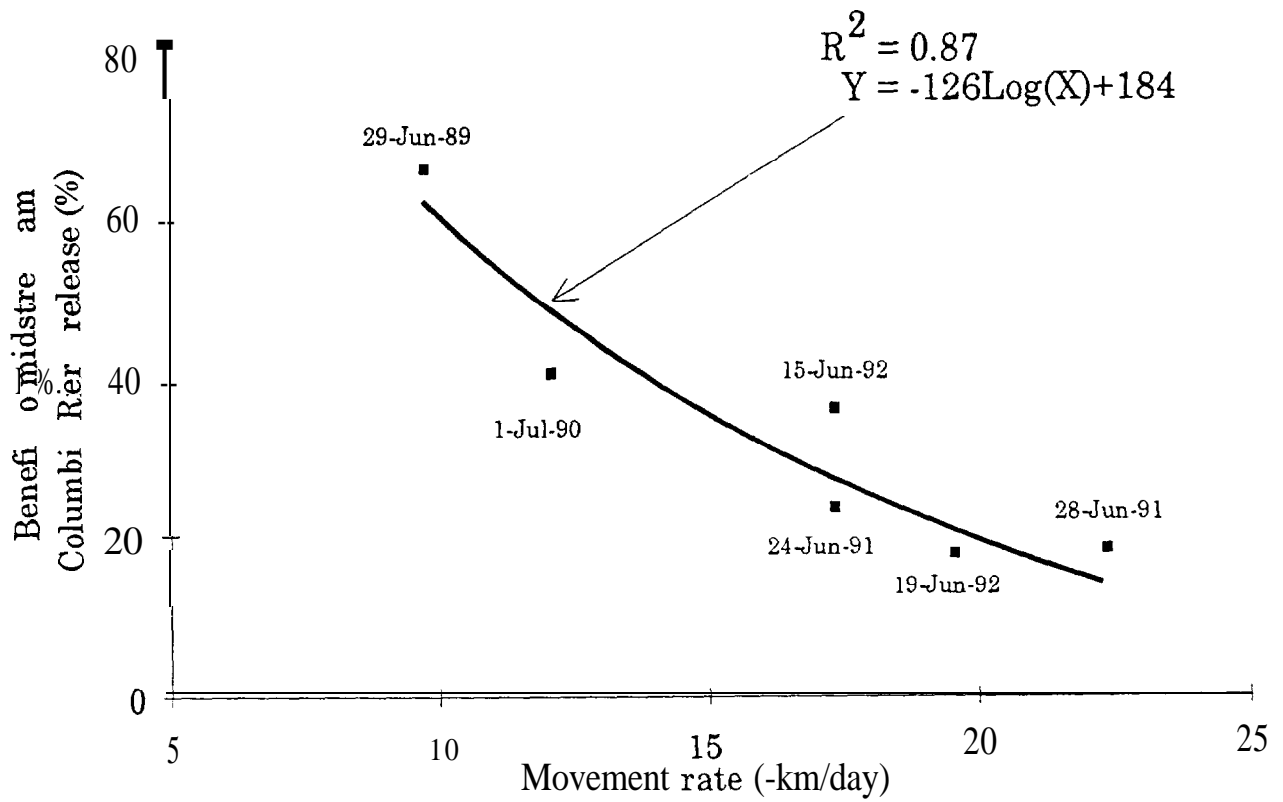


Figure 14.--Movement rate versus percent increase in survival benefit (Table 5, footnote a) for midstream Columbia River releases over Tanner Creek releases of subyearling chinook salmon, 1989- 1992.

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APPENDIX A

**Marking Information, Tag Loss Estimates, Release Information,
and River Conditions**

Appendix Table A-1. Short-term tag loss for subyearling chinook salmon, 1992.

Date marked	Time sampled	Released 15 June				Released 19 June			
		Tanner Creek		Midstream Columbia R.		Tanner Creek		Midstream Columbia R.	
		NT	Sample	NT	Sample	NT	Sample	NT	Sample
20 May	0645	8	100	2	100	0	100	3	100
"	0845	1	100	0	100	1	100	1	100
"	1050	0	100	43	100	--	--	1	100
"	1330	5	50	0	50	1	50	1	50
"	1500	0	50	0	50	0	50	1	50
"	1700	0	50	1	50	0	50	0	50
"	1900	0	50	0	50	0	50	0	50
21 May	0640	0	100	5	100	0	100	0	100
"	0840	1	100	7	100	11	100	2	100
"	1100	5	100	0	100	0	100	3	100
"	1245	9	100	2	100	0	100	1	100
"	1445	0	50	1	50	1	50	1	50
"	1645	0	50	6	50	3	50	1	50
"	1915	0	50	0	50	0	50	0	30
22 May	0630	1	100	0	100	1	100	2	100
"	0845	1	100	3	100	0	100	0	100
"	1100	0	100	0	50	0	100	4	50
"	1230	4	100	0	100	0	100	0	100
"	1945	0	50	--	--	1	50	2	50
27 May	0640	0	100	0	100	16	100	1	100
"	0830	0	100	0	100	2	100	3	100
"	1100	1	100	0	100	0	100	0	100
"	1230	1	100	0	100	0	100	0	100
"	1530	0	50	0	50	0	50	0	50
"	1700	0	50	2	50	1	50	0	50
"	1900	0	50	0	50	1	50	0	50
28 May	0830	0	50	1	50	0	50	1	50
"	1215	3	100	0	100	0	100	0	100
"	1500	0	50	1	50	0	50	1	50
"	1700	0	50	1	50	0	50	0	50
"	1930	0	50	1	50	0	50	0	50
29 May	0615	0	100	0	100	0	100	4	48
"	0800	0	100	--	--	0	100	0	100
"	1230	--	--	1	100	0	100	0	100
"	1430	0	50	0	50	2	50	2	50
"	1700	0	50	1	50	0	50	0	50
"	1900	0	50	0	50	2	50	0	50

Appendix Table A-1. Continued.

Date marked	Time sampled	Released 15 June				Released 19 June			
		Tanner Creek NT ^b	Sample ^c	Midstream Columbia R. NT	Sample	Tanner Creek NT	Sample	Midstream Columbia R. NT	Sample
1 June	0630	0	100	0	100	0	100	0	100
"	0830	1	100	1	100	1	100	2	100
"	1115	0	50	0	50	4	60	0	50
"	1300	3	100	0	100	0	100	0	100
"	1500	0	50	0	50	0	50	1	50
"	1700	0	50	2	50	3	50	0	50
"	1900	0	50	0	50	0	50	0	50
2 June	0630	0	100	0	100	0	100	0	100
"	0830	0	100	3	100	0	100	1	100
"	1130	0	50	1	50	0	50	0	50
"	1230	0	50	0	50	0	50	0	50
"	1500	0	50	0	50	0	50	7	50
"	1700	0	50	0	50	0	50	0	50
"	1900	0	50	0	50	3	50	0	50
3 June	0630	0	50	0	50	0	50	1	50
"	0830	1	50	3	50	0	50	0	50
"	1100	0	50	0	50	0	50	0	50
"	1230	0	50	0	50	0	50	0	50
Total		45	3,850	88	3,750	54	3,860	46	3,828
Percent			1.2		2.3		1.4		1

^a Samples taken from the outfall pipe from marking trailer immediately after tagging.

^b NT = Number of fish that passed through the tag detector and tested negative for a tag.

^c Number of fish sampled for tag loss.

Appendix Table A-2. Tag loss estimates among marked groups of subyearling chinook salmon after a 29-day holding period; Tanner Creek vs. midstream Columbia River, 1992.

Release dates	Coded Wire Tag (AG D1 D2) ^a	NT ^b	Sample ^c
Tanner Creek releases			
15 June	233007	23	468
19 June	233008	12	343
Midstream releases			
15 June	233009	34	463
19 June	233010	17	336

^a CWT code key: AG D1 D2 = Agency code, Data 1 code, Data 2 code.

^b NT = Number of branded fish in the sample with no coded wire tag.

^c Number of fish checked for the presence of coded wire tags.

APPENDIX B

Northern Squawfish Electrofishing Information

Appendix Table B-1. Northern squawfish electrofishing daily effort and catch results, 1992.

Electrofishing period	Electrofishing date	Electrofishing location ^b	Start time ^c	Effort (sec) ^d	Catch (no.)	CPUE (no./h) ^e
4	19 Jun	01	0020	809	12	53.4
4	18 Jun	01	2050	995	21	76.0
6	21 Jun	01	2323	1784	25	50.4
3	18 Jun	01	0035	1200	22	66.0
5	21 Jun	01	0100	1501	17	40.8
3	17 Jun	01	2055	1313	48	131.6
4	20 Jun	01	0455	840	30	128.6
2	17 Jun	01	0115	1197	21	63.2
6	21 Jun	01	2138	1623	44	97.6
1	16 Jun	01	0252	919	6	23.5
5	20 Jun	01	2100	855	13	54.7
2	16 Jun	01	2050	703	89	188.1
Subtotal				14,739	348	--
mean				1228.3	29.0	81.2
SE ^f				102.6	6.5	13.6
1	16 Jun	02	0400	2729	69	91.0
5	20 Jun	02	2253	1448	11	27.3
5	21 Jun	02	0156	2327	13	20.1
4	18 Jun	02	2054	2788	142	183.4
2	16 Jun	02	2043	1629	164	362.4
3	17 Jun	02	2200	2800	76	97.7
6	21 Jun	02	2200	1700	43	91.1
6	22 Jun	02	0115	2244	31	49.7
4	20 Jun	02	0457	2101	31	53.1
2	17 Jun	02	0300	3389	98	104.1
Subtotal				23,155	678	--
mean				2315.5	67.8	108.0
SE				195.4	16.8	31.9
5	20 Jun	03	2100	1017	16	56.6
4	18 Jun	03	2300	5647	86	54.8
4	20 Jun	03	0559	1109	24	77.9
2	16 Jun	03	2243	2168	119	197.6
5	21 Jun	03	0115	1121	1	3.2
4	18 Jun	03	2324	1902	102	193.1
Subtotal				12,964	384	--
mean				2160.7	58.0	97.2
SE				723.8	20.5	32.6

Appendix Table B-1. Continued,

Electrofishing period ^a	Electrofishing date	Electrofishing location ^b	Start time ^c	Effort (sec) ^d	Catch (no.)	CPUE (no. /h)
3	18 Jun	04	0310	2667	66	89.1
2	17 Jun	04	0122	1609	144	322.2
6	21 Jun	04	2050	414	5	43.5
5	20 Jun	04	2135	775	7	32.5
4	20 Jun	04	0650	1330	7	18.9
Subtotal				6,795	229	--
mean				1359.0	45.8	101.2-
SE				387.8	27.1	56.5
5	20 Jun	TC	2150	320	9	101.3
3	18 Jun	TC	0210	573	7	44.0
5	21 Jun	TC	0136	432	19	158.3
4	20 Jun	TC	0435	275	6	78.5
6	21 Jun	TC	2200	375	2	19.2
4	18 Jun	TC	2125	330	7	76.4
2	17 Jun	TC	0205	233	6	92.7
4	19 Jun	TC	0005	592	8	48.6
2	16 Jun	TC	2045	181	1	19.9
Subtotal				3,311	65.0	--
mean				367.9	7.2	71.0
SE				47.4	1.7	14.7
3	18 Jun	W1	0220	1787	21	42.3
6	21 Jun	W1	2130	1072	3	10.1
1	16 Jun	WI	025 1	2203	70	114.4
5	20 Jun	WI	2210	483	7	52.2
4	18 Jun	W1	2240	880	30	122.7
2	17 Jun	WI	0236	1659	73	158.4
6	22 Jun	WI	0122	941	15	57.4
4	20 Jun	WI	0317	1318	35	95.6
Subtotal				10,343	254	--
mean				1292.9	31.8	81.4
SE				198.5	9.5	17.4

Appendix Table B-1. Continued.

Electrofishing period	Electrofishing date	Electrofishing location ^b	Start time ^c	Effort (sec) ^d	Catch (no.)	CPUE (no./h) ^e
6	21 Jun	w 2	2320	2581	56	78.1
5	21 Jun	w 2	0240	1003	3	10.8
6	22 Jun	w 2	0209	1374	22	57.6
3	18 Jun	w 2	0350	2708	32	42.5
5	20 Jun	w 2	2225	1547	18	41.9
Subtotal				9,213	131	--
mean				1842.6	26.2	46.2
SE				339.6	8.8	11.0
3	17 Jun	w 3	2200	1928	14	26.1
1	16 Jun	w 3	0340	1869	8	15.4
Subtotal				3,797	22	--
mean				1898.5	11.0	20.8
SE				29.5	3.0	5.4
4	18 Jun	w 4	2215	2797	17	21.9
4	20 Jun	w 4	0605	1526	2	4.7
1	16 Jun	w 4	0440	1522	6	14.2
3	17 Jun	w 4	2300	2121	35	59.4
2	16 Jun	w 4	2215	2647	39	53.0
Subtotal				10,613	99	--
mean				2122.6	19.8	30.6
SE				268.9	7.5	10.8
Totals				94,930	2,174	--
mean				1947.9	33.0	70.9
SE				216.5	6.9	11.9

^a Sampling periods generally began at 9 p.m. and terminated the following morning about 9 a.m.

^b Locations codes (2 characters): TC = Tanner Creek transect; others Columbia River transects, where 1st character 0 = Oregon shoreline and W = Washington shoreline; 2nd character. 1-4. transects located progressively downstream (refer to Figure 3 for precise locations).

^c Time that the electrofishing effort began.

^d Time that the electrofishing unit was powered on.

^e CPUE = catch of northern squawfish per unit effort of electrofishing.

^f SE - Standard error.

Appendix Table B-2. Coded wire tags from ingested juvenile salmon recovered in the stomachs of northern squawfish during electrofishing efforts, 1992.

Electrofishing period ^b	Date	Start time ^c	Northern squawfish ^a		Location ^d	Tag code (AG D1 D2) ^e
			Collection no.	Predator no.		
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	8	7	233007
	16 Jun	0400	1502	8	7	233007
	16 Jun	0400	1502	8	7	233007
	16 Jun	0400	1502	8	7	233007
	16 Jun	0400	1502	8	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007

Appendix Table B-2. Continued.

Electrofishing period ^b	Date	Start time ^c	Northern squawfish ^a		Location ^d	Tag code (AG DI D2)
			Collection no.	Predator no.		
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	29	7	23 3007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	35	7	233007

Appendix Table B-2. Continued.

Electrofishing period ^a	Date	Start time ^b	Northern squawfish ^a		Location ^d	Tag code (AG D1 D2) ^e
			Collection no.	Predator no.		
1	16 Jun	0400	1502	35	7	233007
1	16 Jun	0400	1502	35	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	41	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	54	7	233007
1	16 Jun	0400	1502	54	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007

Appendix Table B-2. Continued.

Electrofishing period ^b	Date	Start time ^c	Northern squawfish ^a		Location ^d	Tag code (AG D1 D2)
			Collection no.	Predator no.		
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	59	7	233007
1	16 Jun	0400	1502	59	7	233007
1	16 Jun	0400	1502	59	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	62	7	233007
1	16 Jun	0400	1502	65	7	233007
1	16 Jun	0400	1502	65	7	233007
1	16 Jun	0400	1502	65	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
2	16 Jun	2043	1551	3	7	233007
2	16 Jun	2043	1551	10	7	233007
2	16 Jun	2043	1551	10	7	233007
2	16 Jun	2043	1551	10	7	233007
2	16 Jun	2043	1551	10	7	233007
2	16 Jun	2043	1551	11	7	233007
2	16 Jun	2043	1551	12	7	233007
2	16 Jun	2043	1551	12	7	233007
2	16 Jun	2043	1551	12	7	233007
2	16 Jun	2043	1551	13	7	233007

Appendix Table B-2. Continued.

Electrofishing period ^b	Date	Start time ^c	Northern squawfish		Location ^d	Tag code (AG D1 D2)
			Collection no.	Predator no.		
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	30	7	233007
2	16 Jun	2043	1551	30	7	233007
2	16 Jun	2043	1551	30	7	233007
2	16 Jun	2043	1551	30	7	233007
2	16 Jun	2043	1551	111	7	233007
2	16 Jun	2043	1551	134	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	145	7	233007
2	16 Jun	2043	1551	145	7	233007
2	16 Jun	2043	1551	145	7	233007
2	16 Jun	2043	1551	147	7	233007
2	16 Jun	2043	1551	147	7	233007
2	16 Jun	2043	1551	162	7	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	50	9	233007
2	16 Jun	2050	1052	50	9	233007
2	16 Jun	2050	1052	50	9	233007
2	16 Jun	2050	1052	50	9	233007

Appendix Table B-2. Continued.

Electrofishing period ^b	Date	start time ^c	Northern squawfish ^a		Location ^d	Tag code (AG D1 D2)
			Collection no.	Predator no.		
2	16 Jun	2050	1052	50	9	233007
2	16 Jun	2050	1052	71	9	233007
2	16 Jun	2243	1552	5	6	233007
2	16 Jun	2243	1552	56	6	233009
2	16 Jun	2243	1552	152	6	233007
2	16 Jun	2243	1552	152	6	233007
2	16 Jun	2243	1552	152	6	233007
2	16 Jun	2243	1552	152	6	233007
2	16 Jun	2243	1552	152	6	233007
2	17 Jun	0300	1056	8	7	233007
2	17 Jun	0300	1056	44	7	233007
2	17 Jun	0300	1056	44	7	233007
2	17 Jun	0300	1056	44	7	233007
3	17 Jun	2055	1101	19	9	233007
3	17 Jun	2055	1101	19	9	233007
3	17 Jun	2055	1101	19	9	233007
3	17 Jun	2055	1101	28	9	233007
3	17 Jun	2200	1601	308	7	233007
3	17 Jun	2200	1601	339		233007
3	18 Jun	0035	1104	12	9	634528
3	18 Jun	0210	1105	4	8	233007
3	18 Jun	0210	1105	4	8	233007
3	18 Jun	0210	1105	4	8	233007
3	18 Jun	0210	1105	5	8	233007
3	18 Jun	0210	1105	6	8	233007
3	18 Jun	0210	1105	6	8	233007
3	18 Jun	0350	1604	24	3	232753
4	18 Jun	2050	1151	12	9	233007
4	18 Jun	2054	1651	306	7	233007
4	19 Jun	0005	1154		8	233007
4	19 Jun	0020	1155	6	9	071429

^a Individual specimens of northern squawfish are identified as a combination of collection number and predator number.

^b Sampling periods generally began at 9 p.m. and terminated the following morning about 9 a.m.

^c Time that the electrofishing effort began.

^d Locations codes (2 characters): TC = Tanner Creek transect; others Columbia River transects, where 1st character 0 = Oregon shoreline and W = Washington shoreline; 2nd character, 1-4, transects located progressively downstream (refer to Figure 3 for precise locations).

^e CWT code key: AG D1 D2 = Agency code, Data 1 code, and Data 2 code.

APPENDIX C

Juvenile Salmon Recovery Information

Appendix Table C-1. Daily purse seine and beach seine fishing effort, water temperatures, and Secchi disk transparency measurements at Jones Beach, 1992.

Date	Number of sets		Temp. °C	Secchi depth (m)	Date	Number of sets		Temp. °C	Secchi depth (m)
	Purse	Beach				Purse	Beach		
15 Jun	1	2	18	-- ^a	9 Jul	9	9	20	1.5
16 Jun	3	6	17	0.9	10 Jul	6	3	21	1.4
17 Jun	4	7	17	1.1	11 Jul	8	9	20	1.2
18 Jun	5	5	18	1.1	12 Jul	7	6	20	1.1
19 Jun ^b	2	4	18	1.1	13 Jul	12	5	21	1.2
20 Jun	7	4	18	1.2	14 Jul	11	6	21	1.2
21 Jun	3	4	19	1.2	15 Jul	10	9	21	1.1
22 Jun	8	2	19	1.4	16 Jul	9	11	21	1.4
23 Jun	9	4	19	1.2	17 Jul	9	11	21	1.4
24 Jun	10	2	20	1.4	18 Jul	4	10	22	1.2
25 Jun	12	0	20	1.2	19 Jul	8	9	22	1.4
26 Jun	16	11	20	1.4	20 Jul	8	7	22	1.2
27 Jun	9	7	20	1.4	21 Jul	14	3	22	1.1
28 Jun	5	4	20	1.5	22 Jul	11	3	22	1.5
29 Jun	8	5	19	1.1	23 Jul	5	2	22	1.8
30 Jun	12	3	20	1.4	24 Jul	3	3	22	1.5
1 Jul	8	4	20	1.1	25 Jul	6	3	22	1.5
2 Jul	9	10	20	1.2	26 Jul	3	3	21	0.9
3 Jul	10	10	20	1.2	27 Jul	3	3	21	1.2
4 Jul	9	8	20	1.4	28 Jul	3	3	21	1.2
5 Jul	13	8	20	1.7	29 Jul	3	2	22	1.2
6 Jul	15	5	21	1.5	30 Jul	2	1	22	1.5
7 Jul	11	1	21	1.4	31 Jul	2	0	22	1.4
8 Jul	5	5	20	1.4					

^a Dashes indicate data not available.

^b First recovery of study fish.

Appendix Table C-2. Daily recoveries, recoveries standardized for effort, dates of median fish recovery, and movement rates to Jones Beach of marked subyearling chinook salmon released from Bonneville Hatchery into Tanner Creek and transported from the hatchery for release in midstream Columbia River, 1992.

Date of recovery	Released 15 June											
	Treatments and tag code (AG D1 D2)											
	Tanner Creek						Midstream Columbia					
	Beach		Purse		T o t a l		Beach		P u r		T o t a l e	
A ^b	S	A	S	A	S	A	S	A	S	A	S	
19 Jun	0	0	0	0	0	0	1	1	0	0	1	1
20 Jun	0	0	2	3	2	3	3	4	2	3	5	7
21 Jun	7	9	2	7	9	15	4	5	5	17	9	22
22 Jun	11	28	29	36	40	64	9	23	34	43	43	65
23 Jun	8	10^d	46	51	54	61	16	20^d	50	56	66	76
24 Jun	7	18	69	69^d	76	87^d	6	15	122	122^d	128	137^d
25 Jun	NE	12	64	53	64	65	NE	11	73	61	73	72
26 Jun	13	6	46	29	59	35	14	6	55	34	69	41
27 Jun	4	3	7	8	11	11	4	3	11	12	15	15
28 Jun	0	0	6	12	6	12	1	1	2	4	3	5
29 Jun	1	1	11	14	12	15	3	3	22	28	25	31
30 Jun	0	0	23	19	23	19	0	0	17	14	17	14
1 Jul	0	0	3	4	3	4	0	0	9	11	9	11
2 Jul	0	0	3	3	3	3	5	3	3	3	8	6
3 Jul	1	1	2	2	3	3	5	3	7	7	12	10
4 Jul	2	1	5	6	7	7	4	3	4	4	8	7
5 Jul	1	1	11	8	12	9	0	0	9	7	9	7
6 Jul	0	0	5	3	5	3	1	1	11	7	12	8
7 Jul	0	0	0	0	0	0	0	0	6	5	6	5
8 Jul	0	0	2	4	2	4	0	0	1	2	1	2
9 Jul	0	0	1	1	1	1	0	0	1	1	1	1
10 Jul	2	0	0	1	2	0	0	0	0	0	0	0
11 Jul	1	1	0	0	1	1	0	0	0	0	0	0
12 Jul	0	0	1	1	1	1	0	0	0	0	0	0
13 Jul	0	0	0	0	0	0	1	1	0	0	1	1
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	1	1	0	0	1	1	2	1	0	0	2	1
16 Jul	1	0	0	0	1	0	0	0	1	1	1	1
17 Jul	0	0	0	0	0	0	0	0	0	0	0	0
18 Jul	0	0	0	0	0	0	0	0	0	0	0	0
19 Jul	0	0	0	0	0	0	0	0	0	0	0	0

Appendix Table C-2. Continued.

Date of recovery	Released 15 June											
	Treatments and tag code (AG D1 D2) ^a											
	Tanner Creek						Midstream Columbia					
	Beach		Purse		T o t a l		Beach		Purse		T o t a l	
A ^b	S ^c	A	S	A	S	A	S	A	S	A	S	
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0	0	0	0	0	0	0
22 Jul	0	0	0	0	0	0	0	0	1	1	1	1
NA ^{''}	1				1							
Total		60	91	338	334	398	424	79	102	446	444	525
546												
Recovery %	0.06	0.10	0.36	0.35	0.42	0.45	0.09	0.11	0.48	0.48	0.57	0.59
Mvmt rate [']		19.6		15.7		17.4		19.6		17.4		17.4
19 Jun	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	0	0	0	0	0	0	0	0	0	0	0	0
22 Jun	0	0	1	1	1	1	0	0	1	1	1	1
23 Jun	2	3	10	11	12	14	0	0	13	14	13	14
24 Jun	1	3	64	64	65	67	3	8	78	78	81	86
25 Jun	NE	9	53	44	53	53	NE	10	88	73	88	83
26 Jun	33	15	77	48	110	63	27	12	90	56	117	69
27 Jun	8	6 ^d	17	19	25	25 ^d	12	9 ^d	19	21 ^d	31	30 ^d
28 Jun	1	1	5	10 ^d	6	11	7	9	8	16	15	25
29 Jun	3	3	27	34	30	37	4	4	27	34	31	38
30 Jun	1	2	36	30	37	32	1	2	33	27	34	29
1 Jul	3	4	8	10	11	14	1	1	15	19	16	20
2 Jul	9	5	12	13	21	18	1	1	15	17	16	17
3 Jul	12	6	22	22	34	28	12	6	15	15	27	21
4 Jul	4	3	8	9	12	11	7	4	12	13	19	18
5 Jul	4	3	19	15	23	17	2	1	18	14	20	15
6 Jul	1	1	19	13	20	14	2	2	19	13	21	15
7 Jul	0	0	10	9	10	9	1	5	12	11	13	16
8 Jul	1	1	6	12	7	13	1	1	13	26	14	27
9 Jul	2	1	1	1	3	2	0	0	5	6	5	6
10 Jul	0	0	0	0	0	0	0	0	0	0	1	2
11 Jul	0	0	4	5	4	5	1	1	1	1	2	2
12 Jul	4	3	2	3	6	6	1	1	1	1	2	2
13 Jul	0	0	0	0	0	0	0	0	2	2	2	2

Appendix Table C-2. Continued.

Date of recovery	Released 15 June											
	Treatments and tag code (AG D1 D2) ^a											
	Tanner Creek						Midstream Columbia					
	23 30 07			23 30 09			23 30 09			23 30 09		
	Beach		Purse		Total		Beach		Purse		Total	
	A ^b	S ^c	A	S	A	S	A	S	A	S	A	S
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	0	0	0	0	0	0	0	0	0	0	0	0
16 Jul	0	0	2	2	2	2	0	0	0	0	0	0
17 Jul	0	0	0	0	0	0	0	0	0	0	0	0
18 Jul	0	0	0	0	0	0	0	0	1	3	1	3
19 Jul	0	0	1	1	1	1	0	0	0	0	0	0
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0	0	0	0	0	0	0
22 Jul	0	0	0	0	0	0	0	0	0	0	0	0
NA ^e	1				1		1				1	
Total		90	66	404	376	494	442	85	77	486	461	571
538												
Recovery %	0.09	0.07	0.42	0.39	0.51	0.46	0.09	0.08	0.51	0.49	0.60	0.57
Mvmt rate ^f		19.6		17.4		19.6		19.6		19.6		19.6

^a AG D1 D2 = Agency code, Data 1 code, Data 2 code.

^b A = Actual daily purse seine or beach seine catch. NE = No sampling effort.

^c S = Standardized daily catch. Purse seine data standardized to a 10 set per day effort; beach seine data standardized to a 5 set per day effort.

^d Day that the median fish was captured (standardized effort).

^e Date of recovery unavailable. Not used in data standardization.

^f Mvmt. rate = Movement rate (km/day) = distance traveled (RK 232 to RK 75) divided by the travel time (days from release to median fish recovery).

Appendix Table C-3. Diel catch results from purse and beach seine sampling at Jones Beach through a 24-h period, June 26-27, 1992.

Gear--vessel	Date	Set time	Set	Subyearling chinook salmon
Beach	26 Jun	0455	01	606
Beach	26 Jun	0635	02	2260
Beach	26 Jun	0938	03	957
Beach	26 Jun	1113	04	839
Beach	26 Jun	1334	05	543
Beach	26 Jun	1512	06	1172
Beach	26 Jun	1702	07	1067
Beach	26 Jun	1912	08	423
Beach	26 Jun	2005	09	117
Beach	26 Jun	2108	10	87
Beach	26 Jun	2355	11	6
Beach	27 Jun	0300	01	19
Beach	27 Jun	0455	02	763
Beach	27 Jun	0730	03	830
Beach	27 Jun	0810	04	1333
Beach	27 Jun	0940	05	634
Beach	27 Jun	1030	06	378
Beach	27 Jun	1130	07	293
		Total beach seine	18	12,327
Purse--GW	26 Jun	0520	01	2940
Purse--GW	26 Jun	0700	02	333
Purse--GW	26 Jun	0829	03	228
Purse--GW	26 Jun	1008	04	300
Purse--GW	26 Jun	1117	05	199
Purse--GW	27 Jun	0506	01	871
Purse--GW	27 Jun	0647	02	223
Purse--GW	27 Jun	0822	03	64
		Subtotal	8	5,158
Purse--Rosa	26 Jun	0534	01	1937
Purse--Rosa	26 Jun	0723	02	347
Purse--Rosa	26 Jun	0845	03	236
Purse--Rosa	26 Jun	1013	04	243
Purse--Rosa	26 Jun	1119	05	152
Purse--Rosa	26 Jun	1227	06	76

Appendix Table C-3. Continued.

Gear--vessel	Date	Set time	Set		Subyearling chinook salmon
Purse--Rosa	26 Jun	1410	07		116
Purse--Rosa	26 Jun	1545	08		19
Purse--Rosa	26 Jun	1750	09		148
Purse--Rosa	26 Jun	2032	10		463
Purse--Rosa	26 Jun	2214	11		33
Purse--Rosa	27 Jun	0108	0	1	71
Purse--Rosa	27 Jun	0450	02		468
Purse--Rosa	27 Jun	0620	03		120
Purse--Rosa	27 Jun	0804	04		67
Purse--Rosa	27 Jun	0931	05		111
Purse--Rosa	27 Jun	1056	06		107
		Subtotal	17		4,714
		Total purse seine	25		9,872

APPENDIX D

Statistical Analyses of Juvenile Salmon Recovery Data

- A. Chi-square goodness of fit analysis was used to evaluate differences among observed recoveries (Appendix Table C-Z) through time for different treatment groups released on the same day (Sokal and Rohlf 1981). A non-significant result indicated that there was equal probability of capture at Jones Beach for each treatment group (i.e., that the groups were adequately mixed). Results of this analysis are shown below. For additional details of this procedure see Dawley et al. (1989), Appendix D.

H.: There was homogeneity between recovery distributions of treatments.

Release date	Seine type	Chi-square	df	P
15 June	purse	21.38	16	0.165
19 June	purse	16.92	18	0.529
15 June	beach	8.94	8	0.347
19 June	beach	12.05	8	0.149
15 June	total	24.05	18	0.154
19 June	total	19.45	19	0.428

Conclusion: No evidence to suggest there is non-homogeneity between treatment recovery distributions.

- B. Paired difference z-tests were used to evaluate the benefits of midstream Columbia River release over Tanner Creek release and to evaluate the effects of northern squawfish removal efforts on the difference between midstream and Tanner Creek releases. Similar analyses were performed on purse-seine plus beach-seine recoveries (Section 1a-1c) and purse-seine recoveries alone (Section 2a-2c). Recoveries in the beach seine were insufficient for a meaningful analysis ($< 0.1\%$).

Consider the following notation:

P_{w1} = true survival to and recovery at Jones Beach of fish released in Tanner Creek before squawfish removal on June 15.

p_{tc1} = estimate of P_{tc1} = recovery proportion at Jones Beach of fish released at Tanner Creek on June 15

Similar explanations follow for P_{tc2} , p_{tc2} , P_{mc1} , p_{mc1} , P_{mc2} and p_{mc2}

where: tc denotes Tanner Creek,
 mc denotes midstream Columbia River,
 1 denotes releases on June 15, before squawfish removal,
 2 denotes releases on June 19, after squawfish removal.

R_{ij} = release number for group i, j

where i = tc, mc and j = 1, 2

$v(p_{ij}) = p_{ij}(1-p_{ij}) \div R_{ij}$ is the estimated variance of p_{ij}

For the three null hypotheses tested below, we assumed z (as defined below) would follow a standard normal distribution.

1) Total catch--purse seine plus beach seine.

a) The null hypothesis for testing whether recoveries of midstream Columbia-River-released fish were different than Tanner Creek-released fish for the first release pair was:

$$H_0: (P_{mc1} - P_{tc1}) = 0$$

The test statistic was:

$$z = \frac{(p_{mc1} - p_{tc1})}{\sqrt{v(p_{mc1}) + v(p_{tc1})}}$$

The relevant statistics for the first release pair were:

$$P_{mc1} = 525 \div 92240 = 0.005692$$

$$p_{tc1} = 398 \div 94817 = 0.004198$$

Then,

$$z = \frac{(0.005692 - 0.004198)}{\sqrt{\frac{0.005692(0.994308)}{92244-1} + \frac{0.004198(0.995802)}{94817}}} = \frac{0.001494}{0.000324} = 4.6111, \text{ } p\text{-value} < 0.0001$$

Conclusion: The recovery rate for midstream Columbia-River-released fish was significantly higher than for Tanner-Creek-released fish; the difference was 35.7%.

- b) The null hypothesis for testing whether recoveries of midstream Columbia-River-released fish were different than Tanner Creek-released fish for the second release pair was:

$$H_0: (P_{mc2} - P_{tc2}) = 0$$

The test statistic was:

$$z = \frac{(P_{mc2} - P_{tc2})}{\sqrt{v(P_{mc2}) + v(P_{tc2})}}$$

The relevant statistics for the second release pair were:

$$P_{mc2} = 571 \div 94834 = 0.006021$$

$$P_{tc2} = 494 \div 96095 = 0.005141$$

Then,

$$z = \frac{(0.006021 - 0.005141)}{\sqrt{\frac{0.006021(0.993979)}{94834} + \frac{0.005141(0.994859)}{96095}}} = \frac{0.000880}{0.000341} = 2.5806, \text{ } p\text{-value} = 0.0099$$

Conclusion: The recovery rate for midstream Columbia-River-released fish was significantly higher than for Tanner-Creek-released fish; the difference was 17.6%.

- c) The null hypothesis for testing whether northern squawfish removal had a significant benefit for midstream Columbia-River-released fish was:

$$H_0: (P_{mc1} - P_{tc1}) - (P_{mc2} - P_{tc2}) = 0$$

The test statistic was:

$$z = \frac{(p_{mc1} - p_{tc1}) - (p_{mc2} - p_{tc2})}{\sqrt{v(p_{mc1}) + v(p_{tc1}) + v(p_{mc2}) + v(p_{tc2})}}$$

The relevant statistics for the study were:

$$P_{mc1} = 525 \div 92240 = 0.005692$$

$$P_{tc1} = 398 \div 94817 = 0.004198$$

$$P_{mc2} = 571 \div 94834 = 0.006021$$

$$P_{tc2} = 494 \div 96095 = 0.005141$$

Then,

$$z = \frac{(0.005692 - 0.004198) - (0.006021 - 0.005141)}{\sqrt{\frac{0.005692(0.994308)}{92240} + \frac{0.004198(0.995802)}{94817} + \frac{0.006021(0.993979)}{94834} + \frac{0.005141(0.994859)}{96095}}}$$

$$= \frac{0.000614}{0.000470} = 1.3064 \quad p\text{-value} = 0.1914$$

Conclusion: The effect of removing northern squawfish from the migration route of Tanner-Creek-released fish was insignificant; the reduction was 50.7% $((35.7\% - 17.6\% \div 35.7) * 100)$.

2) Purse seine recoveries.

- a) The null hypothesis for testing whether recoveries of midstream Columbia-River-released fish were different than Tanner-Creek-released fish for the first release pair was:

$$H_0: (P_{mc1} - P_{tc1}) = 0; z = 4.2475; p\text{-value} < 0.0001$$

- b) The null hypothesis for testing whether recoveries of midstream Columbia-River-released fish were different than Tanner-Creek-released fish for the second release pair was:

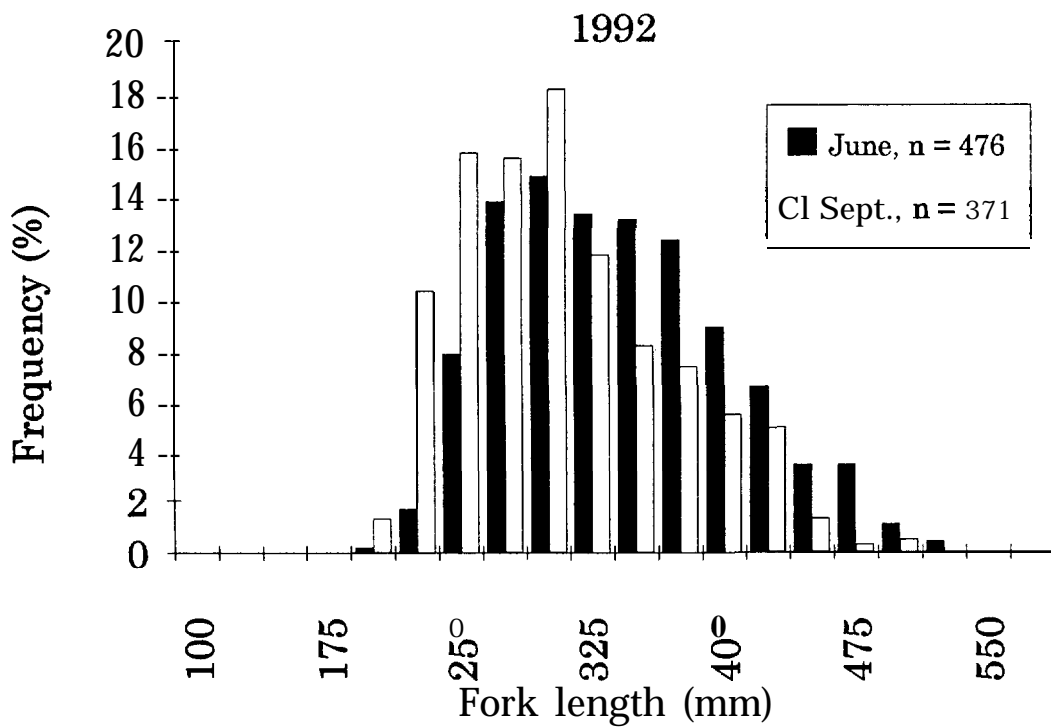
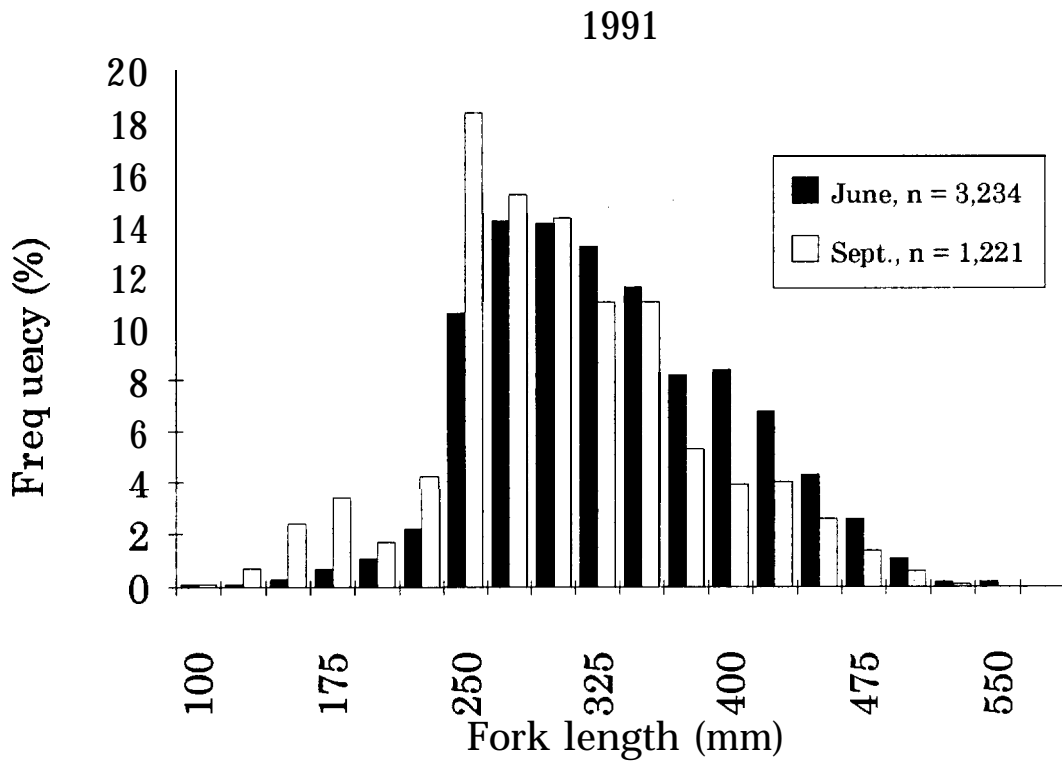
$$H_0: (P_{mc2} - P_{tc2}) = 0; z = 2.9475; p\text{-value} = 0.0030$$

- c) The null hypothesis for testing whether northern squawfish removal had a significant benefit for midstream Columbia-River-released fish was:

$$H_0: (P_{mc1} - P_{tc1}) - (P_{mc2} - P_{tc2}) = 0; z = 0.8125; p\text{-value} = 0.4165$$

APPENDIX E

**Length-Frequency Distributions for Northern Squawfish
Sampled in the Bonneville Dam Tailrace Area by ODFW,
1991 and 1992**



Appendix Figure E-1.--Fork length frequency of northern squawfish captured in the Bonneville Dam tailrace area comparing June and September, 1991 and 1992. Sport reward fishery; data provided by David Ward, ODFW, Clackamas, Or.

REPORT F

Northern Squawfish Sport Reward Payments

Prepared by

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1992 Annual Report

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INTRODUCTION

During 1992, the voucher payment project of the Squawfish Management Program paid a total of \$537,840 to anglers for 179,280 fish in the sport reward fishery. A total amount of \$52,108.50 was paid (for compensation of effort and for fish caught) to three fishers under contract in the commercial longline fishery.

SPORT REWARD FISHERY

A total of \$537,840 was paid for 179,280 fish documented in 16,578 sport reward vouchers in the 1992 program (Table 1). Sport anglers received a \$3 reward for each squawfish over 11 inches long as documented on a sport reward voucher issued by Washington Department of Wildlife check station staff. The anglers mailed their vouchers to our office for processing of payment. The first vouchers were received in May; the first payments were not processed until June. Payment activity was highest during June and July, with about 74% of total dollars paid during that time period.

Table 1. Total number of vouchers received, total numbers of fish represented by those vouchers, total funds paid in rewards, and average number of fish per voucher by month in the 1992 sport reward fishery.

Month	# Vouchers	# Fish	\$ Total	# Fish /Voucher
June	4,398	54,357	\$163,071	12.36
July	5,900	78,527	\$235,581	13.31
August	3,006	24,852	\$74,556	8.27
September	2,252	16,227	\$48,681	7.21
October	804	4,168	\$12,504	5.18
November	218	1,149	\$3,447	5.27
TOTAL	16,578	179,280	\$537,840	10.81

In general, processing proceeded smoothly. Initially, voucher processing time took about 10 days. The Pacific States Marine Fisheries Commission (PSMFC) then mailed checks to anglers and submitted bills to the Oregon Department of Fish and Wildlife (ODFW) for reimbursement, a process which took three to five weeks to be completed. Due to the high volume of payments being sent to anglers, PSMFC could not afford to continue mailing payments before reimbursement was received from ODFW. PSMFC began holding checks, in some cases up to five weeks after processing, until funds for those checks were received from ODFW. This caused quite a few disgruntled anglers, who expected payment within two to three weeks. To speed processing, PSMFC was able to reduce initial voucher processing time to within three days of receipt. Anglers were notified, both at check stations and on the voucher payment message line, that processing took from four to six weeks.

Those vouchers that had missing or incomplete information were returned to anglers for completion. In all, 1,736 vouchers were returned. To date, 239 vouchers worth approximately \$2,500 have not been resubmitted to PSMFC for payment. Table 2 outlines the reasons why vouchers were returned to anglers and the corresponding number of vouchers returned by reason.

Table 2. Summary of why 1,736 vouchers were returned to anglers by reason, number of vouchers by reason, and the percentage of the total. (Some vouchers were returned for multiple reasons.)

Reason Returned	Number Vouchers	% of Reason Returned Total		Number Vouchers	% of Total
Name Incomplete	147	8%	Trip Form Incomplete	1,120	65%
Address Incomplete	307	18%	Annual Form Incomplete	928	53%
Social Security Number Missing	333	19%	Voucher sent w/o Questionnaire	491	28%
No Angler Signature	40	2%	# Fish not indicated	37	2%

In addition to the 239 vouchers that were not resubmitted for payment, 29 vouchers representing 166 fish (\$198) were withheld from payment. These anglers did not submit an annual trip form questionnaire. All anglers in this group were notified of this missing

information, and did not resubmit their vouchers for payment. Thirty checks totalling \$300 were returned to PSMFC by the post office due to invalid addresses. PSMFC tried to correct address information where possible, but these anglers never submitted additional vouchers, nor did they call concerning non-payment of vouchers.

If the above totals are added to- the total number of vouchers paid, we can account for 16,846 vouchers representing approximately 182,524 fish caught, with a value of \$547,572. Thus, approximately \$9,732 of program dollars were never paid out for the 259 vouchers representing 3,244 fish.

Approximately 4,084 individual anglers received compensation from the sport reward program. An additional 116 individuals did not receive compensation, due to unreturned vouchers. These 116 anglers did not submit other vouchers during the 1992 season. Thus, 4,200 participating anglers can be accounted for in PSMFC's component of the program.

There were several requests by various agencies to withhold payment on anglers suspected of wrongdoing (i.e., fishing outside the program boundaries). There were 14 individuals for whom payment was withheld or delayed. A procedure was developed, with the help of the Oregon attorney general's office, whereby ODFW would send written notification to PSMFC instructing the commission to withhold or release payment for certain individuals.

A total of 41 checks for \$4,074 were mailed in calendar year 1992. In February of 1993, checks for 63 vouchers and 6,254 fish (\$19,362) were released to individuals for whom payments were being withheld. Thirteen vouchers for 2,249 fish (\$6,747) remain unpaid.

In January, PSMFC's programmer worked on cleaning up files and readying the payment information for magnetically filing IRS 1099-MISC forms. These forms were issued to anglers who made \$600 or more in income from the sport reward fishery. In all, 202 forms were filed for this group of individuals who made \$287,936.

Some individuals from whom money was being withheld pending investigation received a 1099-MISC that reflected only the actual dollars paid out as of December 31, 1992. These individuals were issued subsequent payments in February of 1993, as authorized by the Oregon Department of Fish and Wildlife. These monies will be reflected in the individuals' 1993 1099-MISC forms. As stated above, 13 vouchers for 2,249 fish (\$6,747) have not yet been paid for the 1992 season.

COMMERCIAL LONGLINE FISHERY

For the 14 weeks that the commercial longline fishery was open, PSMFC processed 144 vouchers totalling \$52,108.50. Longliners were compensated \$250 per day for a five-day work week or \$312.50 per day for a four-day work week. Compensation for effort totaled \$48,187.50. Reward payments for 1,307 fish caught for the season were \$3,921 (Table 3).

Table 3. Total compensation for commercial longline fishery by week, effort, number of fish caught, compensation for fish, and total dollars paid.

Week Number	Compensation for Effort	Number Fish Caught	#Fish @\$3 Each	Dollar Total by Week
1	\$3,250.00	76	\$228.00	\$3,478.00
2	\$3,687.50	77	\$231.00	\$3,918.50
3	\$4,062.50	117	\$351.00	\$4,413.50
4	\$2,498.00	48	\$144.00	\$2642.00
5	\$4,751.00	204	\$612.00	\$5,363.00
6	\$3,376.00	103	\$309.00	\$3,685.00
7	\$3,437.50	124	\$372.00	\$3,809.50
8	\$3,562.50	166	\$498.00	\$4,060.50
9	\$4,000.00	169	\$507.00	\$4,507.00
10	\$4,000.00	35	\$105.00	\$4,105.00
11	\$3,750.00	32	\$96.00	\$3,846.00
12	\$3,437.50	40	\$120.00	\$3,557.50
13	\$4,375.00	116	\$348.00	\$4,723.00
TOTAL	\$48,187.50	1,307	\$3,921.00	\$52,108.50

II. EVALUATION

Cooperators

Oregon Department of Fish and Wildlife
Research and Development Section

Oregon State University

Computer Sciences Corporation

EXECUTIVE SUMMARY

by David L. Ward

We report our results of studies to determine the extent to which northern squawfish predation on juvenile salmonids is a problem in the Columbia River Basin, and to evaluate how effectively fisheries can be used to control northern squawfish populations and reduce juvenile **salmonid** losses to predation. These studies were initiated as part of a basinwide program to control northern squawfish predation and reduce mortality of juvenile salmonids on their migration to the ocean. Modeling simulations based on work in the John Day Reservoir from 1982 through 1988 indicated that if northern squawfish were exploited at a **10-20%** rate, reductions in their numbers and restructuring of their populations could reduce their predation on juvenile salmonids by 50% or more.

We evaluated the success of three test fisheries conducted in 1992 -- a sport reward fishery, a dam angling fishery, and a commercial **longline** fishery -- to achieve a 20% exploitation rate on northern squawfish. We also gathered information regarding the economic., social, and legal feasibility of sustaining each fishery.

The evaluation team consists of the Oregon Department of Fish and Wildlife Research and Development Section (ODFW), Oregon State University (OSU), and the **Computer Sciences Corporation (CSC)**. ODFW is the lead agency and has subcontracted various tasks and activities to OSU and CSC based on expertise each brings to the evaluation. Objectives of each cooperator are as follows.

1. ODFW (Report G): Continue systemwide, **stepwise** implementation of the predation index; continue evaluation of test fisheries in the Columbia River Basin as they are implemented; and assist the U.S. Fish and Wildlife Service (USFWS) in developing and evaluating prey protection measures at Columbia and lower Snake River dam bypass systems.
2. OSU (Report H): Continue to evaluate the economic effectiveness of fisheries for northern squawfish; collect, transport, store, and distribute all northern squawfish collected during the 1992 fishing season; continue the development of value-added products; continue to explore new uses for northern squawfish; and continue the evaluation of regulatory and social issues related to the conduct of fisheries for northern squawfish.
3. CSC (Report I): Provide estimates of predation-related juvenile **salmonid** mortality for Columbia and Snake River projects based on the most recent research data, and revise estimates of **salmonid** mortality in response to existing and proposed predator control measures and other management actions; develop a user interface for versions of the Columbia River Ecosystem Model (**EZ-CREM**) to allow researchers and managers to operate the model to investigate the consequences of management

alternatives in the system; and provide estimates of the probable long-term consequences of the present and possible alternative predator control programs on northern squawfish populations and juvenile salmonid mortality.

Highlights of results of our work by report are as follows.

Report G
Development of a Systemwide Predator Control Program:
Indexing and Fisheries Evaluation

1. Density and abundance of northern squawfish 2250 mm fork length were higher downstream from the Bonneville Dam tailrace than in the John Day Reservoir. Northern squawfish consumption of juvenile salmonids was also higher downstream from the Bonneville Dam tailrace, therefore, the predation index was higher downstream from the Bonneville Dam tailrace.
2. Systemwide estimates of exploitation of northern squawfish ranged from 9.8-14.5% (all fisheries combined). Exploitation was 7.6-11.2% by the sport reward fishery, 2.2-3.2% by dam angling, and less than 0.1% by longlining.
3. Mean fork length of northern squawfish caught by each fishery was greater than 275 mm. Dam angling was most selective for catching large northern squawfish (392 mm mean fork length).
4. Incidental catch was highest in the longline fishery, and consisted mostly of white sturgeon (*Acipenser transmontanus*).
5. We collected information on northern squawfish population structure, fecundity, age and growth, sex ratio, size at maturity, mortality, and year-class strength. Sampling to collect similar information in future years will help us to evaluate changes in northern squawfish population structure in response to fisheries.

Report H
Economic, Social, and Legal Feasibility of
Commercial, Sport, and Bounty Fisheries on Northern Squawfish

1. Commercial fisheries as previously structured are not cost-effective, however, commercial fisheries do offer potential for efficient removal of northern squawfish if allowed to operate on a flexible experimental basis.

2. When adjusted for total administration and oversight costs and for time spent in activities not directly related to removals, the cost per northern squawfish is similar between dam angling and sport reward fisheries. The fisheries are complementary rather than competitive activities.
3. Fish handling plans should be developed that will minimize handling costs to the project as a whole **without** compromising removal goals. A portion of individual budgets should be dedicated to fish handling and not be counted as removal costs. A permanent quality control system should be implemented, including incentives to comply.
4. The greatest market potential for northern squawfish is in mince, fish meal, and fertilizer. The most cost-effective alternative for utilization is a food/rendering or a food/fertilizer combination.
5. Northern squawfish should be reclassified as a food fish in the state of Washington, and a license should be required for recreational capture of northern squawfish. Active coordination between enforcement and implementation personnel should continue. Public education materials should be developed that present activities of the Predator Control Program in the context of Columbia River issues.

Report I
Columbia River Ecosystem Model (CREM): Modeling Approach
for Evaluation of Control of Northern Squawfish Populations
Using Fisheries Exploitation

1. Modeling simulations indicated that mortality of juvenile salmonids will decrease in response to current predator control efforts.
2. A preliminary version of EZ-CREM was completed, including a preliminary user's guide.

REPORT G

Development of a Systemwide Predator Control Program: Indexing and Fisheries Evaluation

Prepared by

**Robert M. Parker
Mark P. Zimmerman
David L. Ward**

**Oregon Department of Fish and Wildlife
Research and Development Section
Clackamas, Oregon**

1992 Annual Report

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ABSTRACT

We are reporting progress on predation indexing and fisheries evaluation as part of the northern squawfish (*Ptychocheilus oregonensis*) predator control study in the lower Columbia and Snake rivers for 1992. Our objectives were to (1) continue systemwide, **stepwise** implementation of the predation index, and (2) continue evaluation of test fisheries in the Columbia River Basin as they are implemented.

We sampled with gillnets and an electrofishing boat to develop an index of northern squawfish abundance downstream from Bonneville Dam tailrace. The abundance index was integrated with a consumption index developed by the U.S. Fish and Wildlife Service (USFWS) to produce a predation index. Results were compared to those from John Day Reservoir. Density and abundance of northern squawfish 2250 mm fork length were higher downstream from Bonneville Dam **tailrace** than in the John Day Reservoir. Northern

squawfish consumption of juvenile salmonids was also higher downstream from Bonneville Dam tailrace; therefore, the predation index was higher downstream from Bonneville Dam tailrace.

We evaluated the efficiency of three test fisheries (public sport-reward, agency dam-angling, and commercial longlining) by comparing northern squawfish exploitation rates and size composition, and incidental catch of other fish species among fisheries. Systemwide estimates of exploitation in 1992 ranged from 9.8-14.5% (all fisheries combined). Exploitation of northern squawfish was 7.6-11.2 % by the sport-reward fishery, 2.2-3.2 % by dam-angling, and less than 0.1% by longlining.

Mean fork length of northern squawfish caught by each fishery was greater than 275 mm. Dam angling was most selective for catching large northern squawfish (mean fork length = 392 mm). Mean fork length of fish caught by the sport-reward fishery (349 mm) was greater than by longlining (323 mm). Incidental catch was highest in the longline fishery, and consisted mostly of white sturgeon (*Acipenser transmontanus*).

We also collected and analyzed data on northern squawfish population structure, fecundity, age and growth, sex ratio, size at maturity, mortality, and year-class strength. These data will be compared to similar data collected after sustained (3-5 years) fisheries.

INTRODUCTION

We began implementation of a predation index, predator control fisheries, and an evaluation plan for lower Columbia River reservoirs in 1990. In 1991 we continued implementation of the predation index and evaluation of fisheries for lower Snake River reservoirs. In 1992 the project expanded further to include the Columbia River downstream from Bonneville Dam (Figure 1). In this report we describe our activities and results in 1992.

The goal of predator control is to reduce in-reservoir mortality of juvenile salmonids to predation by northern squawfish (*Ptychocheilus oregonensis*). Our objectives in 1992 were to (1) continue systemwide, **stepwise** implementation of the predation index, and (2) continue evaluation of test fisheries in the Columbia River Basin as they are implemented. As part of Objective 2, we began a preliminary evaluation of the mechanisms driving the response of predator and prey fish species to sustained northern squawfish fisheries. Results of this preliminary evaluation are presented in Appendix A.

The predation index is the product of a northern squawfish abundance index and a consumption index (Vigg et al. 1990). We collected data on northern squawfish abundance in lower Columbia River reservoirs in 1990, in lower Snake River reservoirs in 1991, and downstream from Bonneville Dam in 1992. The U.S. Fish and Wildlife Service collected

data on northern squawfish consumption of juvenile salmonids in the same areas all three years. The envisioned product of the predation index is an assessment of the magnitude of predation in various reservoirs throughout the Columbia River Basin relative to baseline data in John Day Reservoir. This would ideally allow direction of predator control fisheries to places where predation is greatest.

Evaluation is necessary to compare relative efficiencies among predator control fisheries and to determine biological effects of the fisheries. In 1990, 1991, and 1992, fisheries included sport-reward, dam-angling, and longlining. Evaluating efficiency of the fisheries includes comparing northern squawfish exploitation rates and size composition, and comparing catch of incidental species.

Biological evaluation includes comparing northern squawfish population structure, fecundity, sex ratio, size and age at maturity, peak spawning times, age and growth, mortality, and year-class strength before and after sustained (approximately five years) fisheries. Examining mechanisms driving the response of predator and prey fish species to sustained northern **squawfish** fisheries is also important. Data collected in 1992 represents the final year for collecting baseline data that will be compared in subsequent years to data collected after sustained fisheries.

METHODS

Field Procedures

Predation Index

We used an electrofishing boat, bottom gillnets, and surface **gillnets** to collect northern **squawfish** and develop the abundance index portion of the predation index. We sampled the Columbia River downstream from Bonneville Dam **tailrace** and John Day Reservoir (Figure 1). The Columbia River downstream from Bonneville Dam **tailrace** was divided into three zones: (1) River Kilometer (RK) 71 to RK 121, (2) RK 122 to RK 177, and (3) RK 178 to RK 224. Each zone was further divided into lower, middle, and upper areas. The John Day Reservoir was divided into **forebay**, midreservoir, tailrace, and **tailrace** restricted zone (BRZ) areas. We **sampled** each area in spring (May-June) and summer (July-August). Gillnetting was conducted by the Oregon Department of Fish and Wildlife (ODFW), whereas electrofishing was conducted by both ODFW and USFWS. Sampling schedules and methods, effort, and gear specifications were described by Vigg et al. (1990). Other than areas sampled, effort was similar to that in 1990.

The USFWS collected data to develop the consumption portion of the predation index by examining gut contents of northern **squawfish**. Details of their methods are given in Peterson et al. (1991).

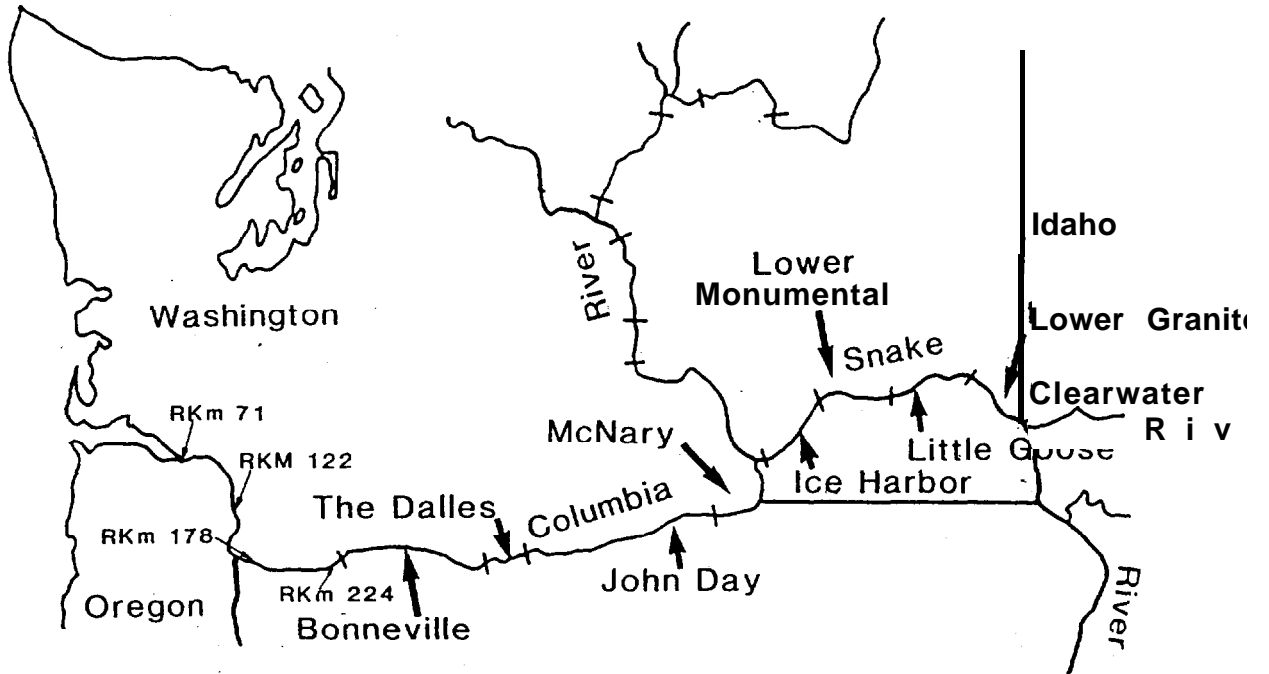


Figure 1. Reservoirs and zones of the lower Columbia and Snake rivers sampled from 1990 through 1992.

Fishery Evaluation

We used mark and recapture data to evaluate movements of northern **squawfish** and to compare exploitation rates of northern **squawfish** among fisheries. We tagged and released northern squawfish in all lower Columbia and Snake River reservoirs and downstream from Bonneville Dam prior to implementation of the fisheries. Sampling effort was randomly allocated throughout the Columbia River downstream from Bonneville Dam. Size of the area and time limitations precluded our sampling the entire area upstream from Bonneville Dam; therefore, we randomly sampled the **forebay**, midreservoir, **tailrace** and **BRZs** of each reservoir.

We used electrofishing boats, bottom **gillnets** and surface **gillnets** to collect northern squawfish fish from March 2 to May 25. Fish greater than 200 mm fork length were tagged with a serial numbered spaghetti tag and given a secondary mark so we could estimate tag loss. Sampling procedures were similar to those described for the predation index, and tagging procedures were described by Vigg et al. (1990). Tags were recovered from April 21 through September 26 from the sport-reward, dam-angling and commercial **longline** fisheries, and during ODFW index sampling. Additional tags were recovered from USFWS index sampling and during harvest technology experiments conducted by the University of Washington.

The sport-reward, dam-angling, and commercial **longline** fisheries were described by Vigg et al. (1990). The sport-reward fishery was conducted from May 25 through September 27 throughout the lower Columbia and Snake rivers. Dam angling was conducted from April 20 through September 3 at Bonneville, The Dalles, John Day, **McNary**, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams. The commercial **longline** fishery was conducted from May 18 through August 14 downstream from Bonneville Dam (Figure 1).

We collected biological data from a subsample of northern squawfish caught in each fishery. **Each** sport-reward check station was sampled at least one weekday per week and one weekend day per month. Each dam was sampled at least one day per week. Catches from each of four **longline** boats were sampled weekly. We measured fork length (mm) and total body weight (g); we determined sex and maturity (undeveloped or immature, developing, ripe, or spent); and we collected scale samples and gonad samples (ripe females only) from northern squawfish. We removed and weighed gonads from both male and female northern squawfish to determine weekly gonosomatic index (GSI).

We also collected baseline biological data on northern squawfish populations while index sampling. Data collected were the same as described for predator control fisheries.

Laboratory Procedures

We used gravimetric quantification (Bagenal 1968) of developed and undeveloped eggs to estimate fecundity of northern squawfish in the John Day Reservoir and downstream from Bonneville Dam. Ripe ovaries were placed in Gilson's solution and allowed to fix for a minimum of four weeks. Ovary samples were then prepared for analysis as described by Vigg et al. (1990). Ovary subsamples were weighed and egg counts in the subsamples were extrapolated to total ovarian weight. To assure accurate egg production estimates, we enumerated both developed and undeveloped eggs. Only counts of developed eggs, characterized by their relatively large size and yellow or orange color, were used in calculating fecundity estimates and describing fecundity relationships with length and weight. To determine accuracy of fecundity estimates, we counted the total number of developed and undeveloped eggs in five ovary samples and compared the number to extrapolated estimates.

We used scale samples from northern squawfish collected primarily while index sampling for age determinations. When needed, we supplemented sample sizes with scales from fish caught in predator control fisheries. For both the John Day Reservoir and the Columbia River downstream from Bonneville Dam, we randomly selected scale samples from 20 individuals from each 25-mm length group. If the initial random sample was not comprised of scales from 10 males and 10 females, we added scales to obtain 10 samples from each sex if possible. Scale collection and aging techniques followed established methods (Jearld 1983).

Data Analysis

Predation Index

We used the square root of the percent of zero catches of ODFW and USFWS electrofishing runs ($\text{SQRT } \% 0$) as an index of density of northern squawfish (Ward et al. 1992). Differences in the density index were compared among the zones downstream from Bonneville Dam, and among areas of John Day Reservoir. Although sampling was stratified by season, density for each zone or area included data from both spring and summer. An index of northern squawfish abundance was calculated as the product of density and surface area. Main-channel, midreservoir areas deeper than about 40 ft were excluded when estimating surface areas because Nigro et al. (1985) showed that northern squawfish rarely are found in these areas.

The consumption index was developed by USFWS (Petersen et al. 1991). The consumption index is not a rigorous estimate of the number of juvenile salmonids eaten per day by an average northern squawfish; however, it is linearly related to the consumption rate of northern squawfish (Petersen et al. 1991). Consumption data was summarized for spring and summer.

We computed the predation index as the product of the abundance and consumption indices. We compared predation indices among the zones downstream from Bonneville Dam **tailrace** and the areas in John Day Reservoir for spring and summer.

Fishery Evaluation

Relative Efficiency

We used mark and recapture data to compare exploitation rates of northern squawfish among fisheries. We evaluated movements of recaptured northern squawfish to determine the extent of mixing among marked and unmarked fish so -we could define areas containing discrete populations. Exploitation was calculated for each one-week period and summed to yield total exploitation for each fishery (Beamesderfer et al. 1987). We adjusted exploitation estimates to reflect tag loss during the season (4.8 %).

Logistical problems precluded our marking fish throughout each reservoir upstream from Bonneville Dam, increasing the potential for bias in our exploitation estimates. Therefore we estimated sport-reward and dam-angling exploitation for each reservoir in two ways to establish a range. The first scenario assumed full mixing of tagged and untagged fish and random allocation of fishing effort throughout each reservoir. This gave us a maximum exploitation estimate. The second scenario assumed no mixing of fish outside the areas they were tagged and that fishing occurred only in the same areas fish were tagged. Because we sampled the entire **forebay** and **tailrace** of each reservoir, but only a relatively small proportion of each midreservoir, we adjusted the number of tagged fish in midreservoir by dividing the number of fish actually tagged by the proportion of midreservoir area sampled. We used the adjusted number of tags when calculating exploitation, giving us a minimum estimate.

We compared mean fork lengths and length frequency histograms for northern **squawfish** among fisheries and ODFW indexing in John Day Reservoir and downstream from Bonneville Dam to evaluate fishery selectivity for large individuals. We also plotted monthly mean fork lengths of northern **squawfish** collected by angling at each dam and by the sport-reward fishery in each reservoir and downstream from Bonneville Dam to determine if size declined over time within the season..

We compared incidental catch among fisheries to determine selectivity of each fishery for northern squawfish. We compared total number of fish caught and the percentage of northern **squawfish** captured in each fishery. We also compared the various species that made up the incidental catch for each fishery.

Baseline Biological Data

We tabulated the ratio of female to male northern squawfish less than and greater than 350-mm fork length from each fishery and index sampling to compare sex ratio of the catch among fisheries. For each fishery we also plotted the percentage of the catch composed of

females each month. We estimated size at maturity for male and female northern squawfish by plotting the percentage of fish in each 25-mm fork length increment that were mature for all fisheries combined. We also calculated the GSI of male and female northern squawfish for all fisheries combined. We plotted GSI by week from May through September to determine reproductive peaks. GSI was calculated as

$$(GW/BW) \cdot 100$$

where

GW = gonad weight (g), and

BW = total body weight (g).

We estimated average fecundity and average relative fecundity of northern squawfish for John Day Reservoir and the Columbia River downstream from Bonneville Dam. Relative fecundity was defined as the number of developed eggs per gram of total body weight. We used least squares regression analysis (SAS Institute, Inc. 1987) to examine the relationship between log_e (fecundity) and log_e (fork length) and log_e (body weight) for John Day Reservoir and downstream from Bonneville Dam.

We determined backcalculated fork lengths at formation of annuli for northern squawfish in John Day Reservoir and downstream from Bonneville Dam tailrace to develop age-at-length keys. We summarized fork lengths of northern squawfish collected while index sampling and used the age-at-length keys to estimate age composition in each area. We also plotted length at age of northern squawfish for John Day Reservoir and downstream from Bonneville Dam tailrace. We used linear regression (SAS Institute, Inc. 1987) to examine the relationship between log_e (fork length) and log_e (body weight) for each of these areas. We further examined growth of northern squawfish by fitting the von Bertalanffy growth model (Ricker 1975) to estimated mean length at age.

We used age frequencies from indexing data (electrofishing and gillnetting combined) to generate catch curves (Ricker 1975). We plotted log_e (% catch) against age to establish catch curves for John Day Reservoir and downstream from Bonneville Dam tailrace. Total instantaneous mortalities and annual mortality rates were estimated by linear regression (SAS Institute, Inc. 1987) of the descending limb of the catch curves (Ricker 1975).

We evaluated year-class strength of northern squawfish in John Day Reservoir by methods described by El Zarka (1959). We plotted the index of year-class strength from 1975 through 1989 using aging data from 1990, 1991, and 1992 to determine the relative success of each cohort.

RESULTS

Predation Index

Density of northern squawfish 2250 mm was higher downstream from Bonneville Dam **tailrace** than in John Day Reservoir (Table 1); however, because of its large size, abundance was higher in the John Day Reservoir than in any of the zones downstream from the Bonneville Dam **tailrace** (Figure 2). Density and abundance were similar among the three zones, but increased slightly with distance from Bonneville Dam tailrace.

Northern squawfish consumption indices differed among the zones downstream from Bonneville Dam **tailrace** and among areas in John Day Reservoir (Table 2). Because of differences in abundance and consumption, relative predation on juvenile salmonids by northern squawfish differed among areas and time of year (Figure 3). Predation was highest in the Columbia River between RK 178 and RK 224, especially in summer. Predation in each zone downstream from Bonneville Dam was higher than in John Day Reservoir. We found no evidence of predation in the midreservoir or **tailrace** of John Day Reservoir.

Table 1. Index of northern squawfish density (1 divided by the square root of the percentage of electrofishing runs in which no northern squawfish were caught) in the Columbia River downstream from Bonneville Dam **tailrace** and in John Day Reservoir. BRZ = boat restricted zone.

Location, zone	Number of electrofishing runs	Index
Downstream from Bonneville Dam tailrace		
RK 71 to RK 121	204	1.597
RK 122 to RK 177	202	1.458
RK 178 to RK 224	203	1.390
John Day Reservoir		
Forebay	68	1.243
Midreservoir	62	1.174
Tailrace	47	1.045
Tailrace BRZ	17	2.380

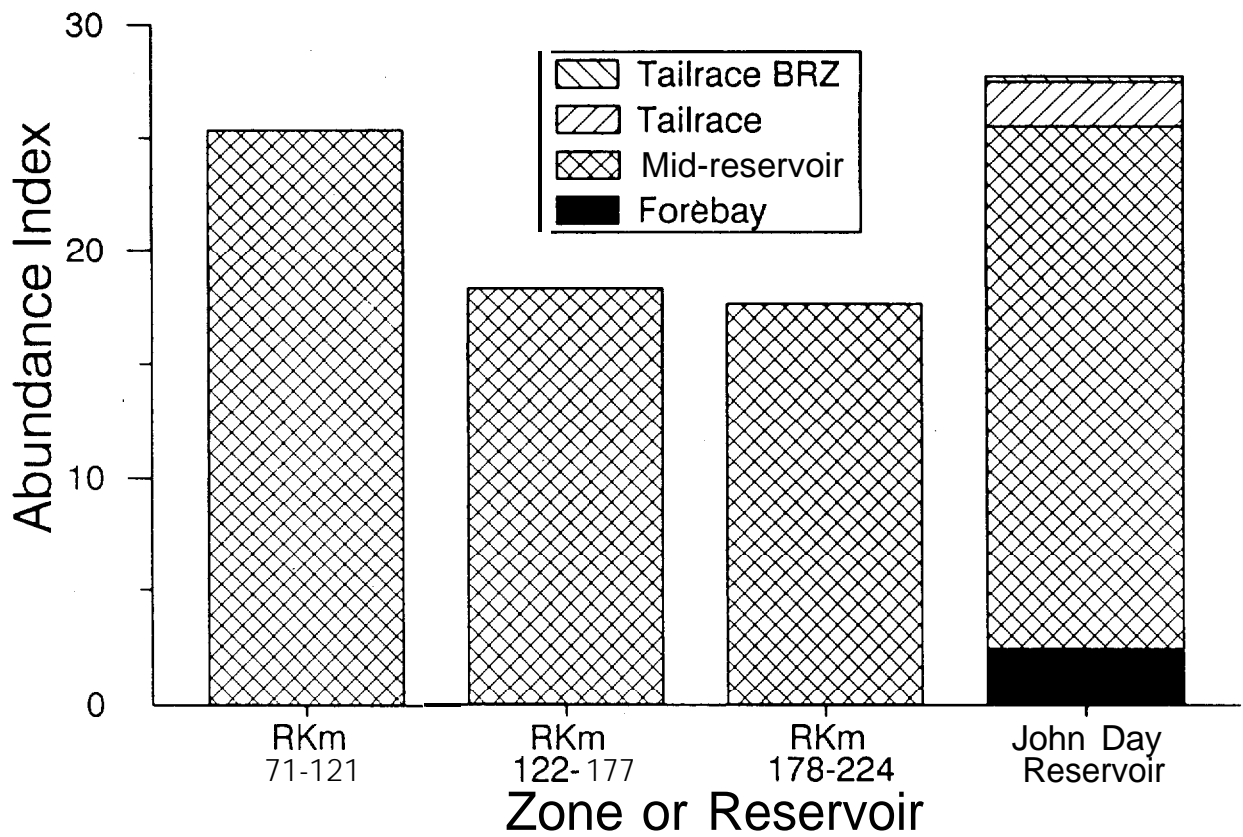


Figure 2. Index of northern squawfish abundance in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

Table 2. Index of northern squawfish consumption of juvenile salmonids in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir (summarized from Petersen et al. 1992). BRZ = boat restricted zone. N equals the number of northern digestive tracts examined.

Location, zone	Spring		Summer	
	N	Index	N	Index
Downstream from Bonneville Dam tailrace				
RK 71 to RK 121	102	0.522	117	0.305
RK 122 to RK 177	189	1.033	136	1.334
RK 178 to RK 224	126	1.122	59	1.886
John Day Reservoir				
Forebay	38	1.868	27	0.745
Midreservoir	8	0	13	0
Tailrace	9	0	1	0
Tailrace BRZ	35	9.336	67	4.550

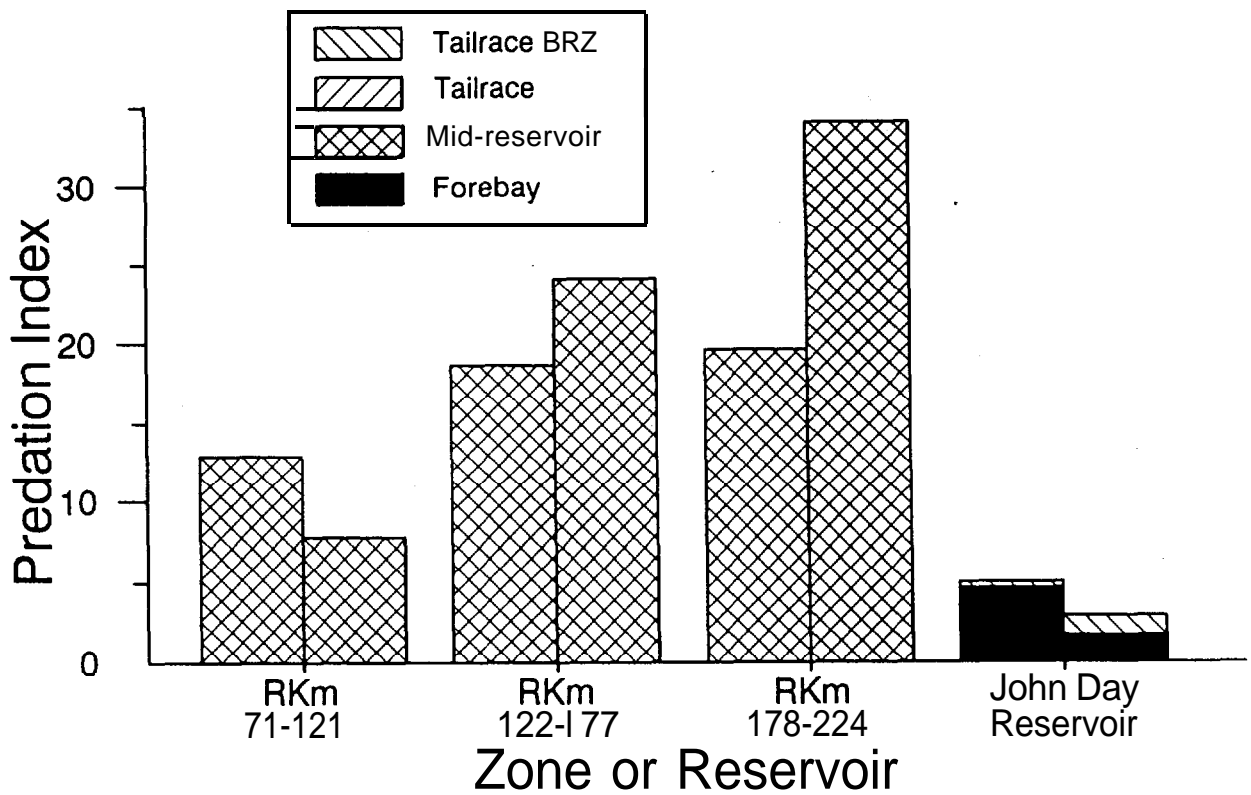


Figure 3. Index of northern squawfish predation on juvenile salmonids in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir. The first bar represents spring predation, the second bar represents summer predation.

Fishery Evaluation

Relative Efficiency

We tagged and released 4,171 northern squawfish throughout the lower Columbia and Snake rivers (Table 3). A total of 552 marked northern squawfish were recaptured in the three fisheries; 442 by sport-reward anglers, 108 by dam-anglers, and two by longliners. An additional 63 tags were recovered during ODFW (20) and USFWS (43) index sampling. The University of Washington recaptured another nine tags. Of the 624 marked fish recaptured, 59 (9.5%) had migrated past a dam. Except for Ice Harbor Reservoir, the percentage of tagged fish recaptured by all fisheries varied among reservoirs from approximately 8% to 20% (Table 3).

Northern squawfish movement differed among reservoirs and areas (Table 3). Except for Bonneville and McNary reservoirs, we found that 90-100% of recaptured fish remained in the reservoir they were originally tagged. Only 59% of the recaptured fish originally tagged in Bonneville Reservoir were recaptured in Bonneville Reservoir. Because results precluded easy definition of discrete populations, we estimated exploitation for each reservoir and for the Columbia River downstream from Bonneville Dam. We also pooled data to estimate exploitation for the entire study area.

Table 3. Percentage of tagged northern **squawfish** that were recaptured in each reservoir. DB = downstream from Bonneville Dam, Bon = Bonneville Reservoir, Dal = The Dalles Reservoir, JD = John Day Reservoir, **McN** = McNary Reservoir, Ice = Ice Harbor Reservoir, **LoMo** = Lower Monumental Reservoir, Goo = Little Goose Reservoir and Gran = Lower Granite Reservoir.

Location marked	Number marked	Location Recaptured									
		DB	Bon	Dal	JD	McN	Ice	LoMo	Goo	Gran	Total
DB	2135	10.6	0.2	0.1	0	0	0	0	0	0	10.9
Bon	565	3.5	8.3	1.8	0.5	0	0	0	0	0	14.1
Dal	194	0	0	7.7	0	0	0	0	0	0	7.7
JD	259	0	0	0.4	18.9	0	0	0	0	0	19.3
McN	112	0	0	0	0	6.3	1.8	0	0	0	8.1
Ice	7	0	0	0	0	0	0	0	0	0	0
LoMo	226	0	0	0	0	0.4	0	8.4	0	0	8.8
Goo	545	0	0	0	0	0	0	1.8	18.0	0	19.8
Gran	128	0	0	0	0	0	0	0	0	12.5	12.5

Exploitation of northern **squawfish** differed among fisheries and reservoirs (Table 4). These estimates are conservative because they exclude fish that were recaptured in reservoirs other than where marked. The sport-reward fishery had the highest exploitation of northern **squawfish** > 250 mm in nearly all reservoirs and downstream from Bonneville Dam. The **longline** fishery contributed little to exploitation and dam angling exploitation was intermediate. Low numbers of tagged fish present in Ice Harbor Reservoir resulted in no subsequent recaptures, and an exploitation estimate of zero.

Dam angling was the most selective fishery for large northern squawfish (Figure 4). The mean fork length of northern squawfish caught by the **longline** fishery was lower than either the dam-angling or sport-reward fisheries. The greatest size range of northern squawfish was collected during index sampling. The fisheries harvested a disproportional number of large individuals compared to their relative abundance in ODFW index sampling.

Table 4. Minimum and maximum estimated exploitation rates of northern **squawfish** 2250 mm. Randomly allocated tagging effort downstream from Bonneville Dam resulted in only one exploitation estimate for each fishery. All exploitation estimates are adjusted for tag loss (4.8%).

Location	Sport-Reward		Dam-Angling		Longline		Total	
	Min	Max	Min	Max	Min	Max	Min	Max .
Downstream from Bonneville Dam	11.5		0.2		0.1		11.8	
Bonneville	2.3	5.8	1.5	4.0	--	--	3.8	9.8
The Dalles	4.8	7.7	0.7	1.2	--	--	5.5	8.9
John Day	2.7	4.2	8.4	13.4	--	--	11.1	17.6
McNary	4.0	7.2	--	--	--	--	4.0	7.2
Ice Harbor	--	--	--	--	--	--	--	--
Lower Monumental	1.0	2.5	3.2	8.7	--	--	4.2	11.2
Little Goose	9.9	14.1	5.1	7.1	--	--	15.0	21.2
Lower Granite	11.2	18.1	--	--	--	--	11.2	18.1
Systemwide	7.6	11.2	2.2	3.2			9.8	14.5

Northern squawfish exceeding 250-mm fork length comprised the majority of the catch in all fisheries (Table 5). Indexing samples were generally smaller and only 50 % of the ODFW indexing catch downstream from Bonneville Dam exceeded 250 mm. Monthly mean fork lengths of fish harvested by dam-angling and sport-reward anglers fluctuated throughout 1992. Monthly mean fork lengths of sport-reward catches were variable among reservoirs (Figure 5). Generally, the mean size of the dam-angling catch declined from May to September by 30-75 mm except at The Dalles and Lower Monumental dams, where mean size stayed relatively stable (Figure 6).

Incidental catch of species other than northern squawfish varied among fisheries. The sport-reward fishery had the lowest percentage of incidental catch (Table 6). Dam angling incidental catch was also **relatively** low, and consisted mostly of channel catfish (*Ictalurus punctatus*). The commercial **longline** fishery had the highest percentage of incidental catch, composed mostly of white sturgeon..

Baseline Biological Data

Female northern squawfish captured by each of the fisheries generally outnumbered males almost 3 to 1 (Table 7). The sex ratio of northern squawfish less than 350-mm fork length captured by the sport-reward and dam-angling fisheries was 1 to 1. Almost all fish greater than 350 mm were females. The percentage of northern squawfish females remained relatively stable from May through September in each of the fisheries (Figure 7). The ODFW index sampling catch consisted of a lower percentage of females than the catch in each of the removal fisheries.

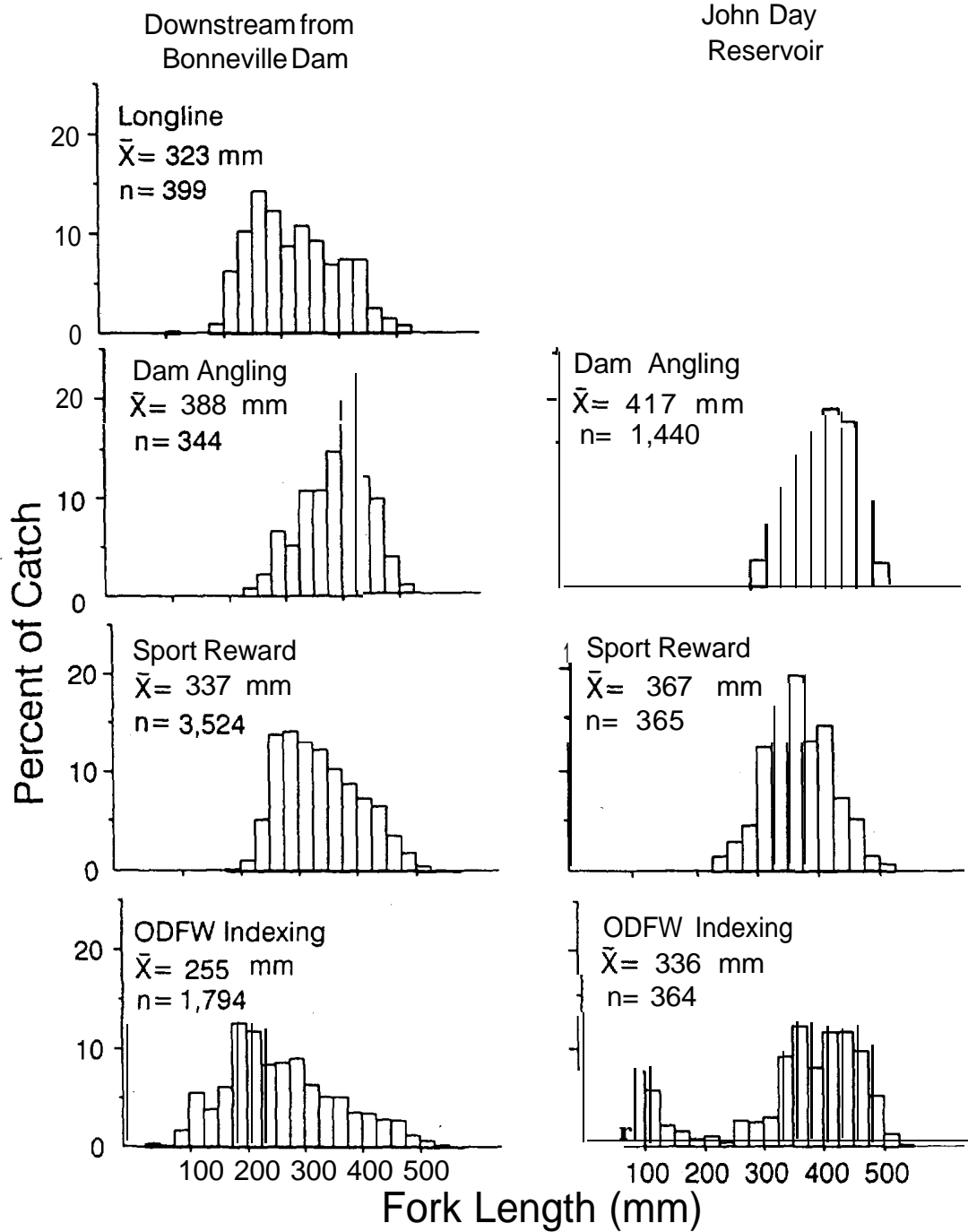


Figure 4. Size composition of the northern squawfish catch in the Columbia River downstream from Bonneville Dam and in John Day Reservoir in each fishery and in ODFW indexing samples.

Table 5. Percentage of northern squawfish exceeding various fork lengths in each fishery and in ODFW indexing samples in the Columbia River downstream from Bonneville Dam and in John Day Reservoir.

Location, fishery	Percentage greater than				
	200 mm	250 mm	300 mm	350 mm	400 mm
Downstream from Bonneville Dam					
Sport-Reward	99.6	92.7	63.9	39.0	20.0
Dam-Angling	100.0	99.1	90.1	73.8	46.8
Longline	98.5	81.0	55.6	36.1	19.5
ODFW Indexing	69.5	49.2	31.4	20.0	11.3
John Day Reservoir					
Sport-Reward	100.0	98.1	90.7	60.5	28.3
Dam-Angling	100.0	99.9	99.3	89.2	63.8
ODFW Indexing	80.2	78.3	73.4	59.9	39.6

Table 6. Northern squawfish and incidental catch for each fishery.

Species	Sport Reward	Dam Angling	Longline
Northern squawfish	200,796	27,868	2,158
Smallmouth bass'	693	294	1
Channel catfish	141	1,081	37
Walleye'	231	8	0
Sturgeon	17	217	3,660
Peamouth'	588	0	48
Salmonids	73	24	7
Other	606	82	124

* Smallmouth bass = *Hicropterus dolomieu*, walleye = *Stizostedion vitreum vitreum*, peamouth = *Mylocheilus caurinus* *

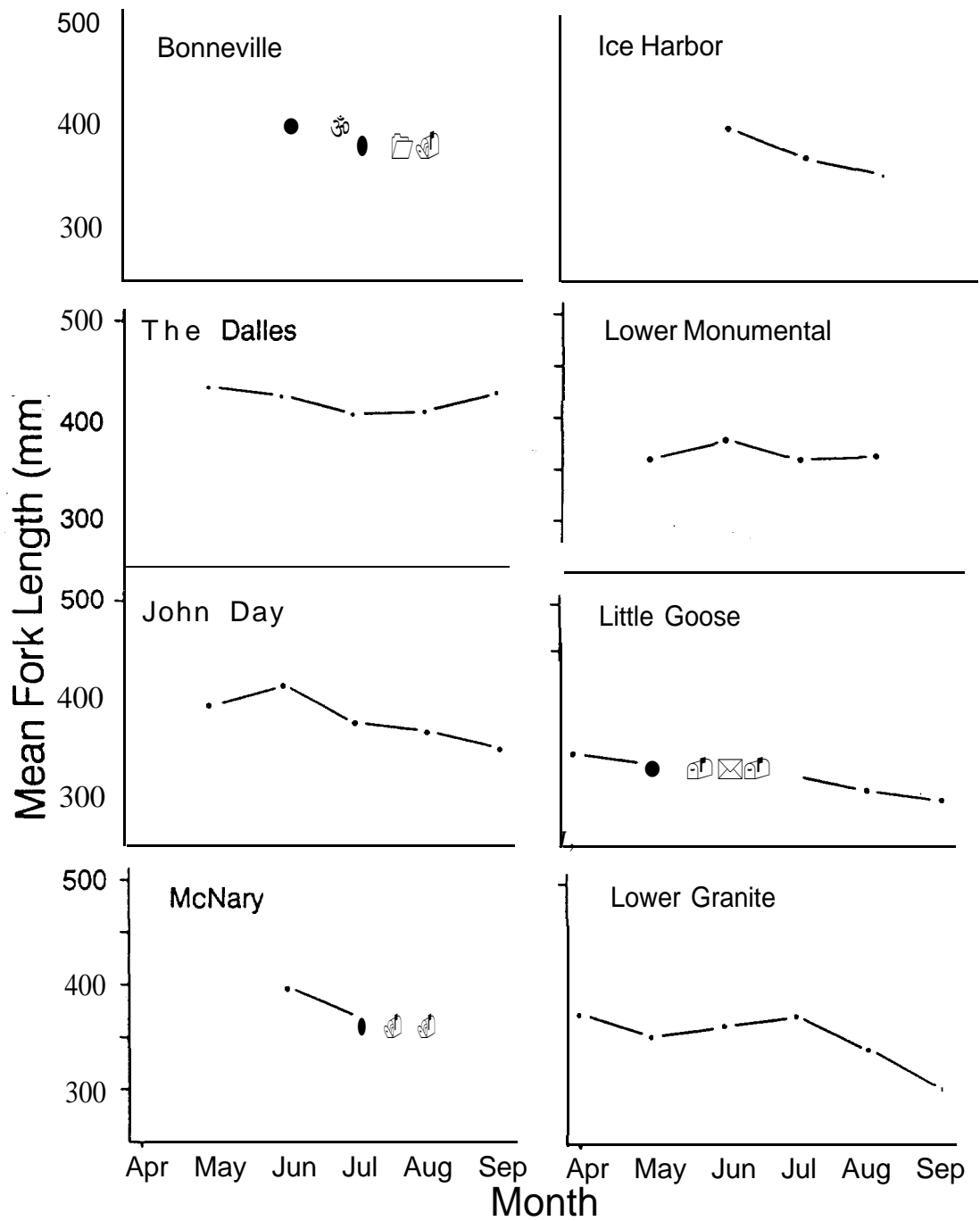


Figure 5. Monthly mean fork length of northern squawfish sampled from the dam angling catch at lower Columbia and Snake River dams.

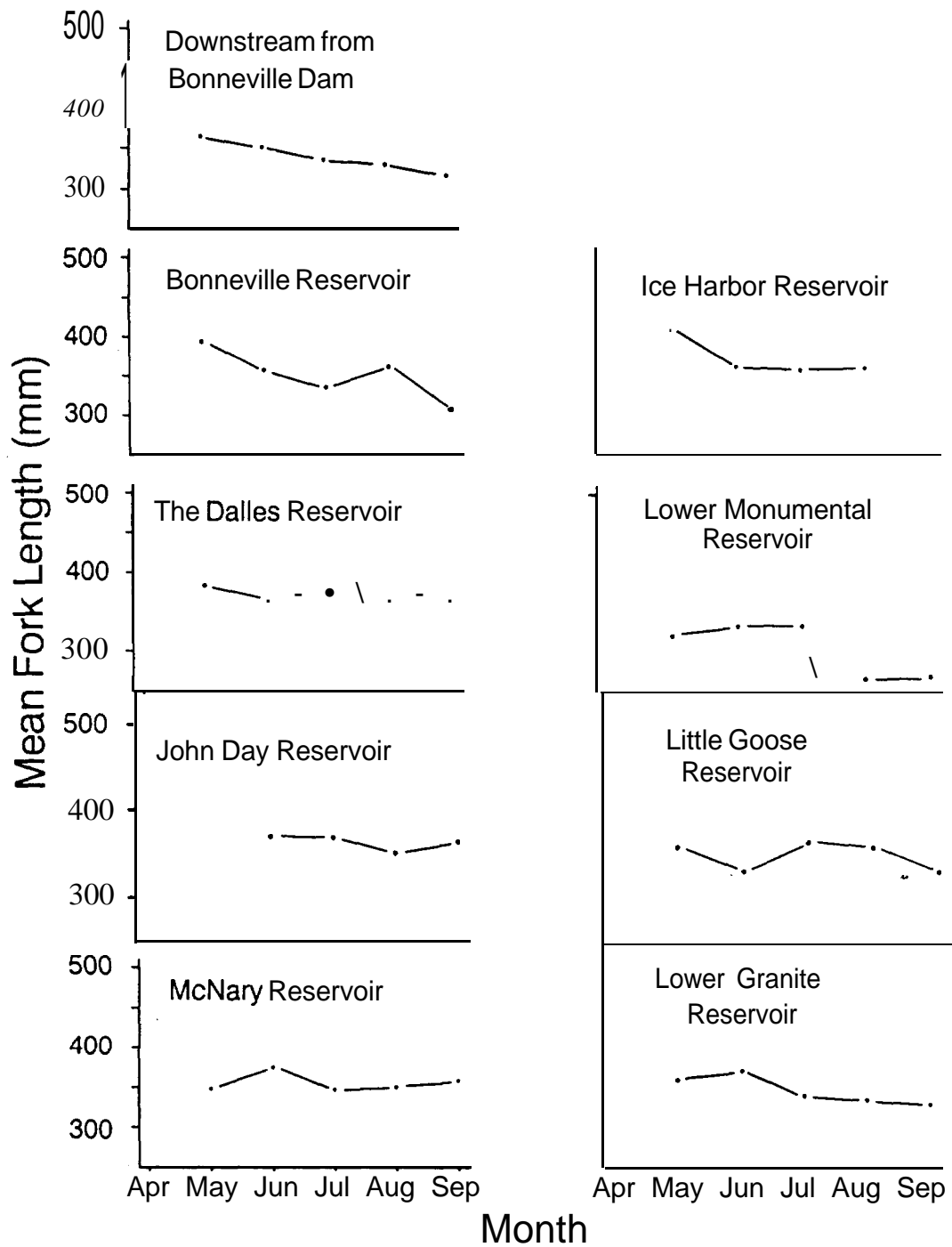


Figure 6. Monthly mean fork length of northern squawfish sampled from the sport-reward fishery in the lower Columbia and Snake rivers.

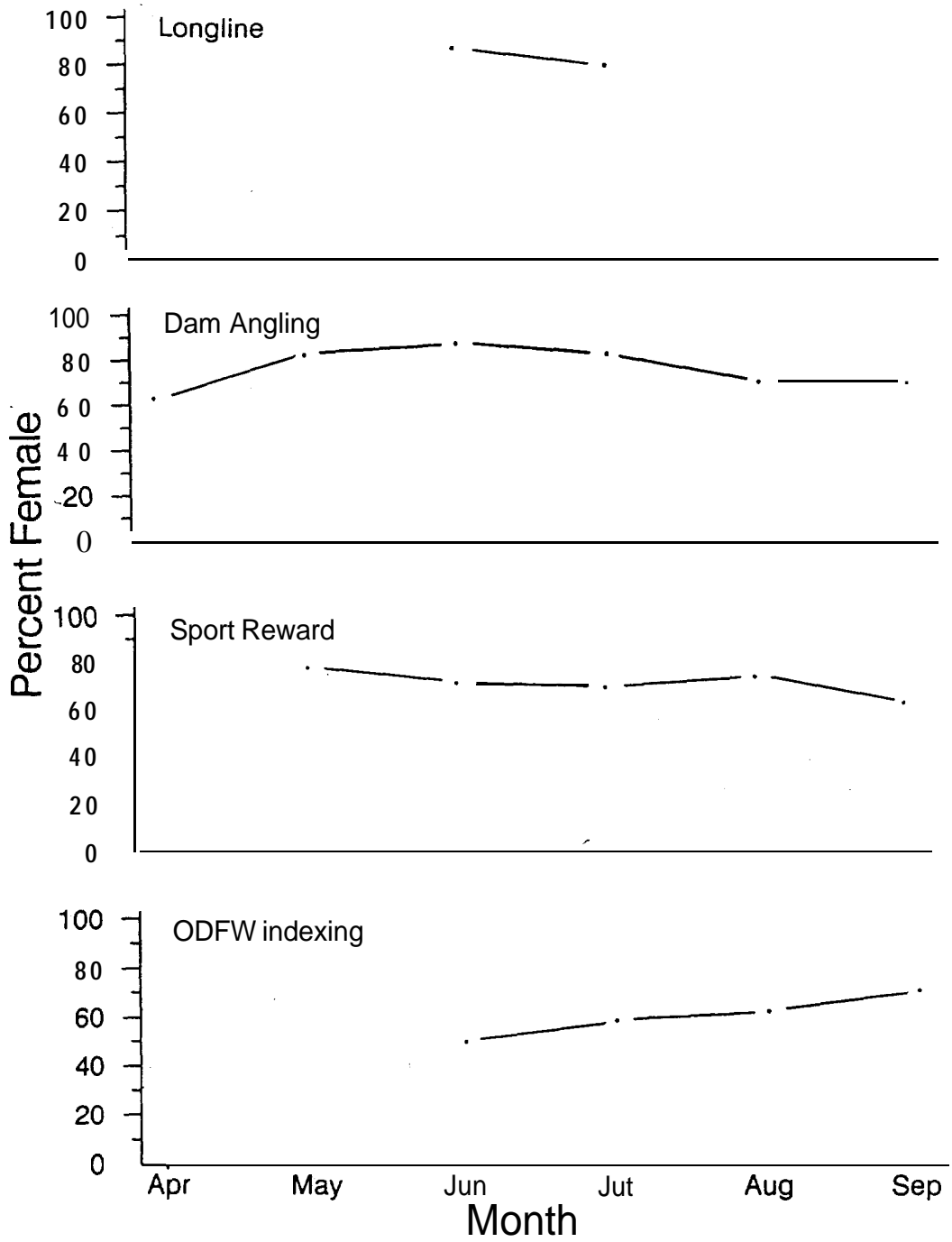


Figure 7. Percent of the northern squawfish catch composed of females in each fishery and ODFW index sampling by month, all areas combined.

Table 7. Sex ratio of northern squawfish catch by fishery.

Fishery	Female to male ratio		
	<350 mm	>350 mm	Total
Sport reward	1:1	9:1	3:1
Dam angling	1:1	12:1	4:1
Longline	3:1	22:1	6:1
ODFW indexing	1:2	9:1	1:1
Total	1:1	10:1	3:1

A few northern squawfish matured as small as 150-199 mm, however, the proportion of fish showing strong signs of reproductive maturity dramatically increased when fish reached 250-274 mm. (Figure 8). Using ages estimated from backcalculated length at age keys, it appears that some northern squawfish mature as early as age 3, but most were not sexually mature until age 5. The percentage of male northern squawfish mature at 200-224 mm was greater than that of similar sized females.

The gonosomatic index (GSI) of northern squawfish indicated that peak spawning activity occurred in late May and then gradually declined (Figure 9). Low GSI values representing post-spawning condition were observed by early to mid-August. Female GSI values were generally twice that of males throughout the season. Male and female GSI indices showed concomitant peaks in gonadal development.

Total egg counts from five northern squawfish ovaries indicated that the subsample method estimated total fecundity within 5% to 10%. Because fecundity was not consistently over- or underestimated, no correction factor was applied to extrapolated fecundity estimates. We estimated mean fecundity for 412 female northern squawfish collected from the Columbia River downstream from Bonneville Dam and in John Day Reservoir to be 26,948 developed eggs (Table 8). Estimates ranged from 5,117 eggs (fork length = 286 mm) to 91,967 eggs (fork length = 530 mm). The mean fork length of fish used in fecundity estimates was 389 mm (range = 242 to 540 mm). Mean relative fecundity was 35.5 developed eggs per gram of body weight. Variability in fecundity was higher downstream from Bonneville Dam than in John Day Reservoir. The number of developed eggs was positively, but not highly, correlated ($r^2 = 0.31$ to 0.40) with fork length and body weight (Figures 10 and 11).

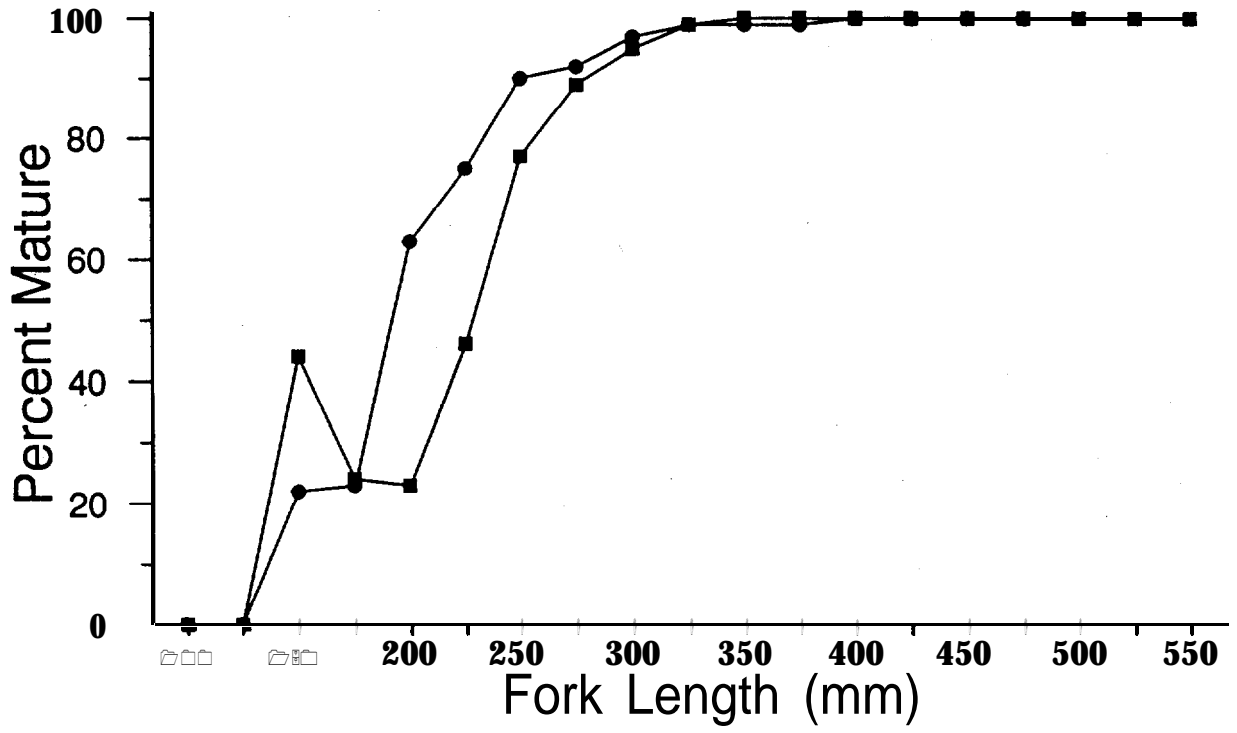


Figure 8. Percent catch found to be mature by 25-mm size classes for male (circles) and female (squares) northern squawfish sampled from all fisheries.

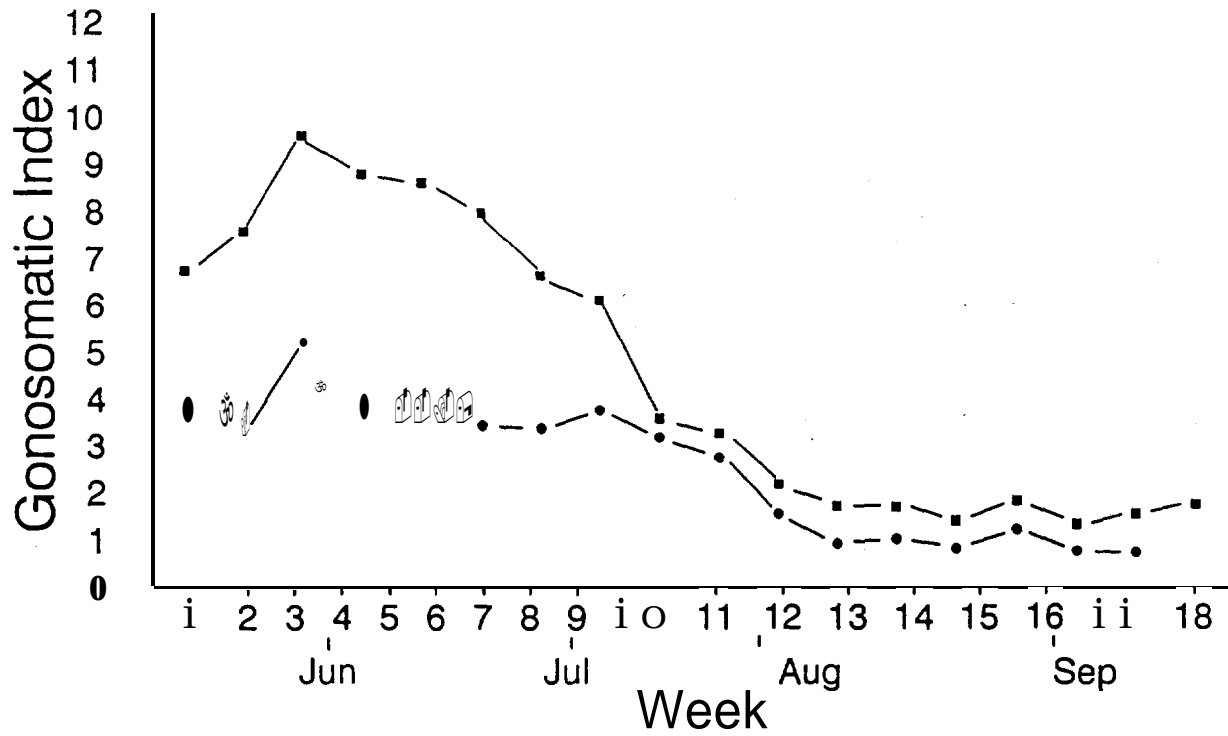


Figure 9. Weekly mean gonosomatic index (GSI) of male (circles) and female (squares) northern squawfish sampled from all fisheries.

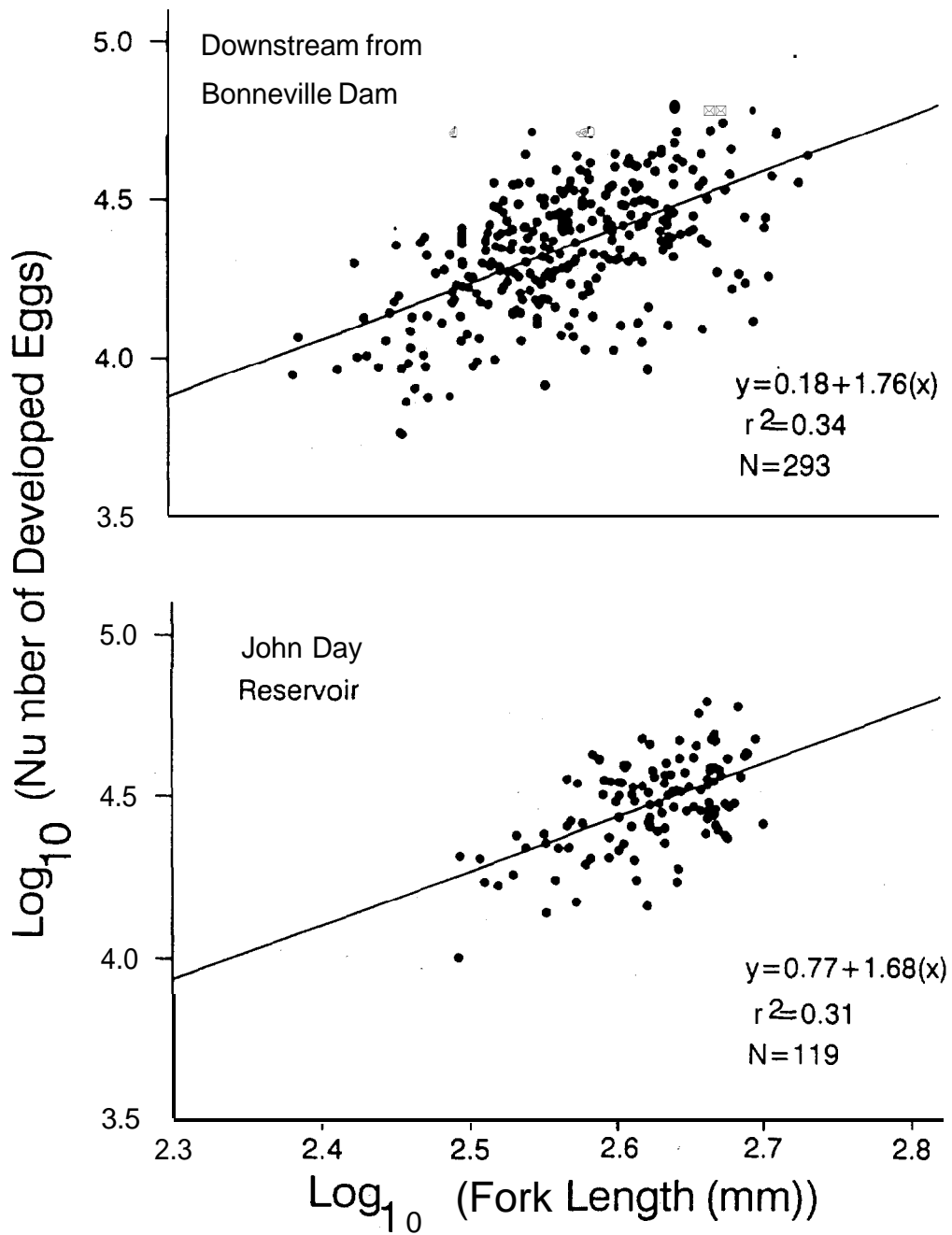


Figure 10. Relationship of fecundity to fork length for female northern squawfish in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

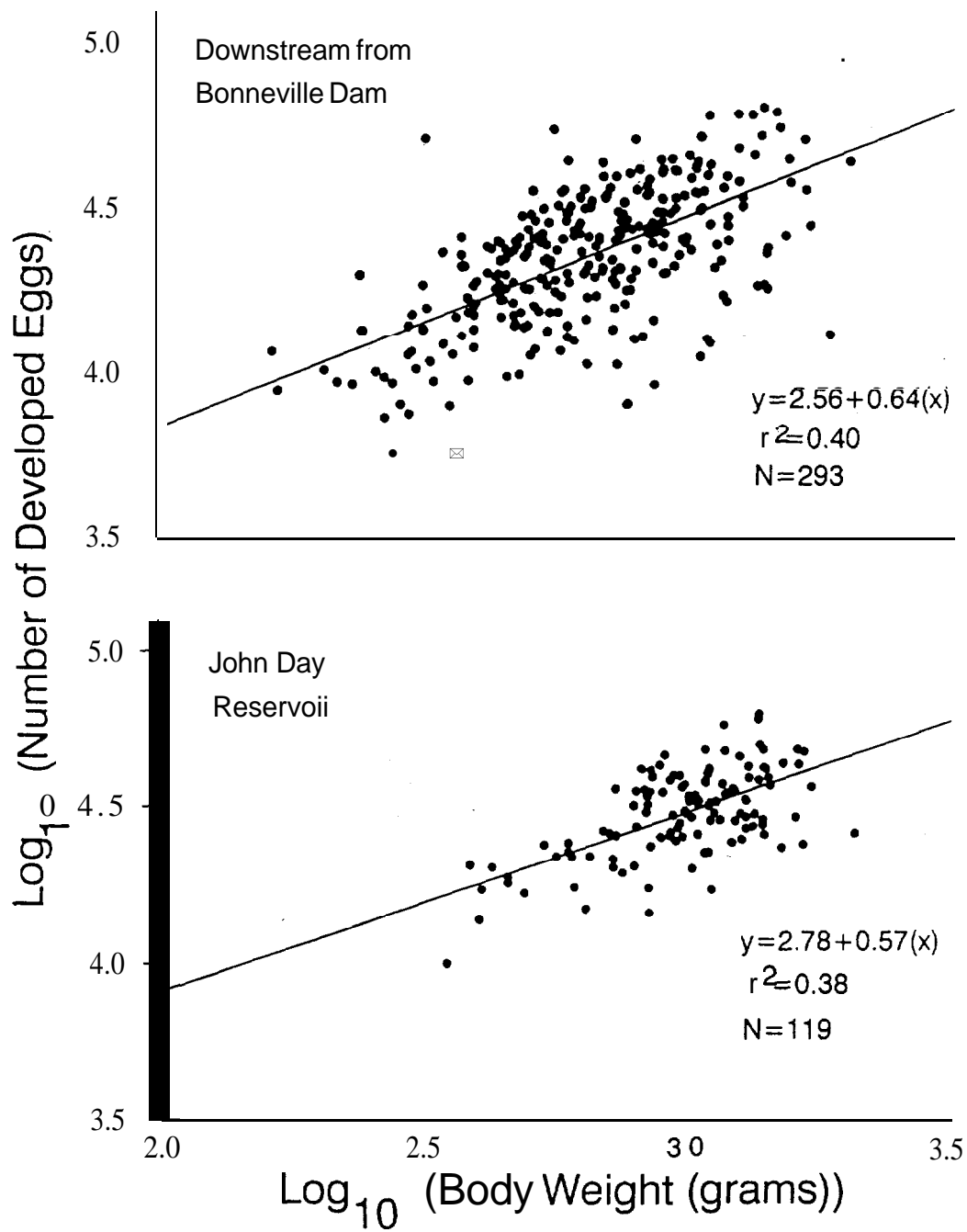


Figure 11. Relationship of fecundity to weight for female northern squawfish in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

Table 8. Mean fecundity estimates for female northern squawfish sampled from all fisheries. N = sample size.

Location	N	Developed eggs	Undeveloped eggs
Downstream from Bonneville Dam	293	25,097	10,831
John Day Reservoir	119	31,504	15,291

The maximum age of northern squawfish in our samples was 16 years old; age composition varied widely between locations. Many more younger fish were captured downstream from Bonneville Dam **tailrace** than in John Day Reservoir (Figure 12). Mean backcalculated fork lengths at age were similar between locations (Figure 13). Von Bertalanffy growth parameters were variable, but also similar between locations (see Appendix D). Relationships between weight and fork length were also similar between locations (Figure 14).

Northern squawfish appeared fully vulnerable to our indexing gear (electrofishing, bottom gillnets, and surface **gillnets** combined) by age 4 downstream from Bonneville Dam **tailrace** and age 9 in John Day Reservoir (Figure 15). The annual mortality rate was higher in John Day Reservoir.

Cyclical variations were observed in northern **squawfish** year-class strength in John Day Reservoir (Figure 16). Very weak year classes occurred in 1979 and 1987. Stronger year-classes occurred in 1976 and 1984.

DISCUSSION

Results from index sampling indicate that predation on juvenile salmonids by northern **squawfish** occurs throughout the Columbia River downstream from Bonneville Dam **tailrace**, and exceeds predation in John Day Reservoir. In fact, northern **squawfish** predation downstream from Bonneville Dam exceeds that in any lower Columbia or Snake River impoundment (Ward et al. 1992).

Sampling to collect baseline information on predation before fisheries for northern squawfish were implemented is now complete. Sampling in 1993 will represent the first year

of monitoring after removal fisheries have been sustained. We will sample to evaluate northern **squawfish** size structure and consumption in the same areas we sampled in 1990 (Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs). If fisheries are successful in removing large northern squawfish, we expect populations to eventually consist of a higher percentage of smaller fish. If consumption of juvenile salmonids by smaller fish does not increase, the program will have succeeded in reducing predation.

It appears that the various fisheries combined exploited 10-15% of the northern squawfish population in the lower Columbia and Snake rivers. Sport-reward exploitation estimates depend largely upon the accuracy and willingness of sport anglers to return tags and divulge accurate catch location information. Sport-reward exploitation in some reservoirs appears to be low considering the relatively large number of northern squawfish removed. It is possible that sport anglers captured fish outside designated fishing locations and returned fish to lower Columbia and Snake River registration areas. Dam angling appears to have effectively exploited northern squawfish in reservoirs where sport-reward exploitation was low. Longlining does not appear to be an efficient method of large-scale northern squawfish removal.

In past years, we primarily marked and released fish collected by dam anglers. Although we were able to mark and release a considerable number of fish this way, estimates of exploitation in the early part of the fishery season were limited because relatively few fish were caught, marked, and released until the season was well under way. Additionally, marking fish at dams may have biased our estimates of exploitation for each fishery. To improve our exploitation estimates in 1992, we marked and released fish in all reservoir areas prior to the start of fisheries. This "pre-season" tagging appears to be a much better way to obtain accurate exploitation data. In 1993 we will again tag fish prior to the start of removal fisheries and we will attempt to increase precision by sampling throughout the lower Columbia and Snake rivers.

It appears that fish are smaller and younger downstream from Bonneville Dam than in John Day Reservoir. We also found differences in the size of northern squawfish removed among fisheries. Although all three fisheries captured large, predaceous-sized fish, **dam**-angling harvests had the largest mean fork length. Monthly mean fork lengths of northern squawfish harvested by the sport-reward fishery were variable and we observed no obvious decrease in fork length. However, monthly mean fork lengths of northern squawfish captured by dam angling declined in nearly all reservoirs. We will continue to monitor monthly fork **length trends** in 1993 to evaluate **inseason** effects of harvest on northern squawfish populations.

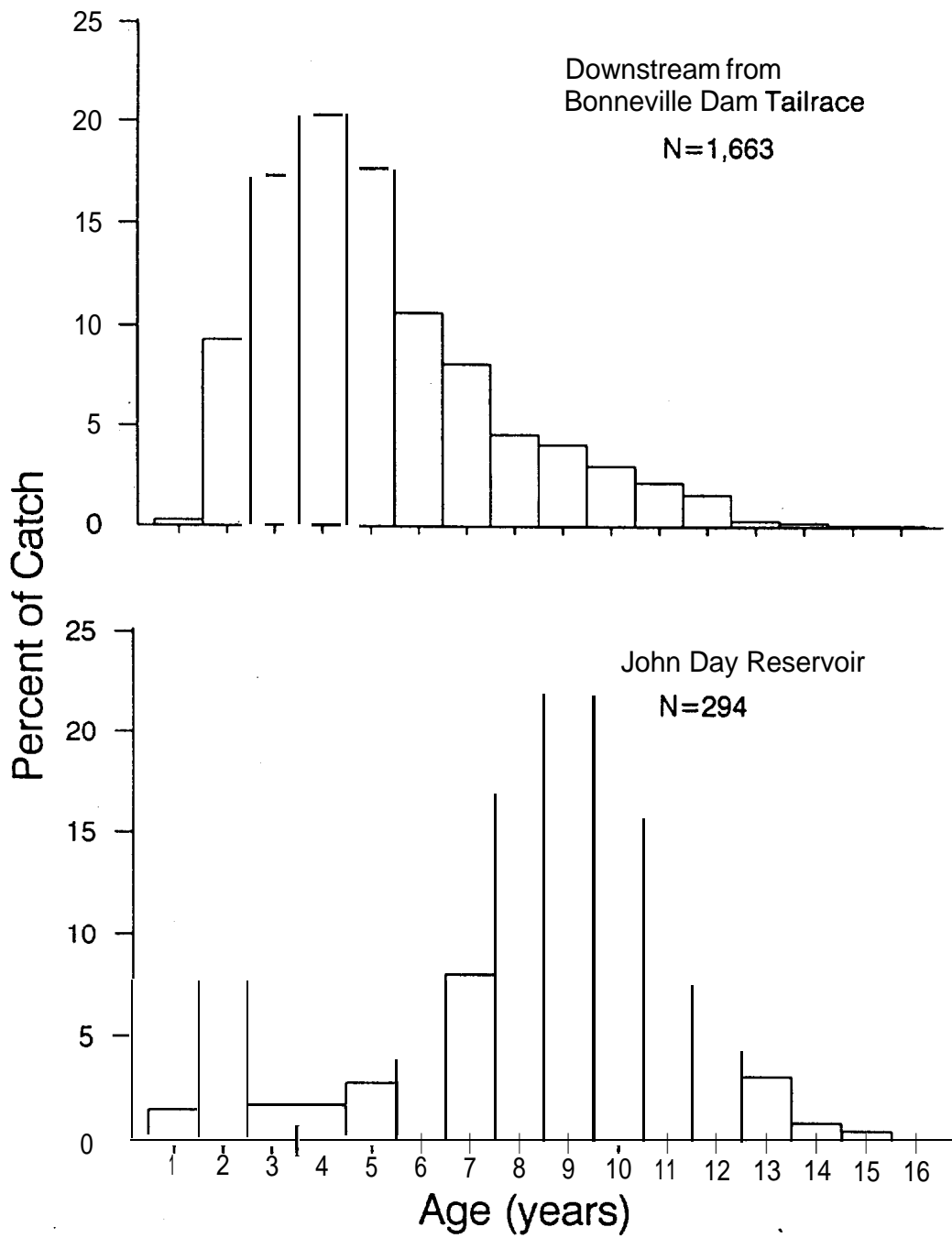


Figure 12. Age composition of northern squawfish in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

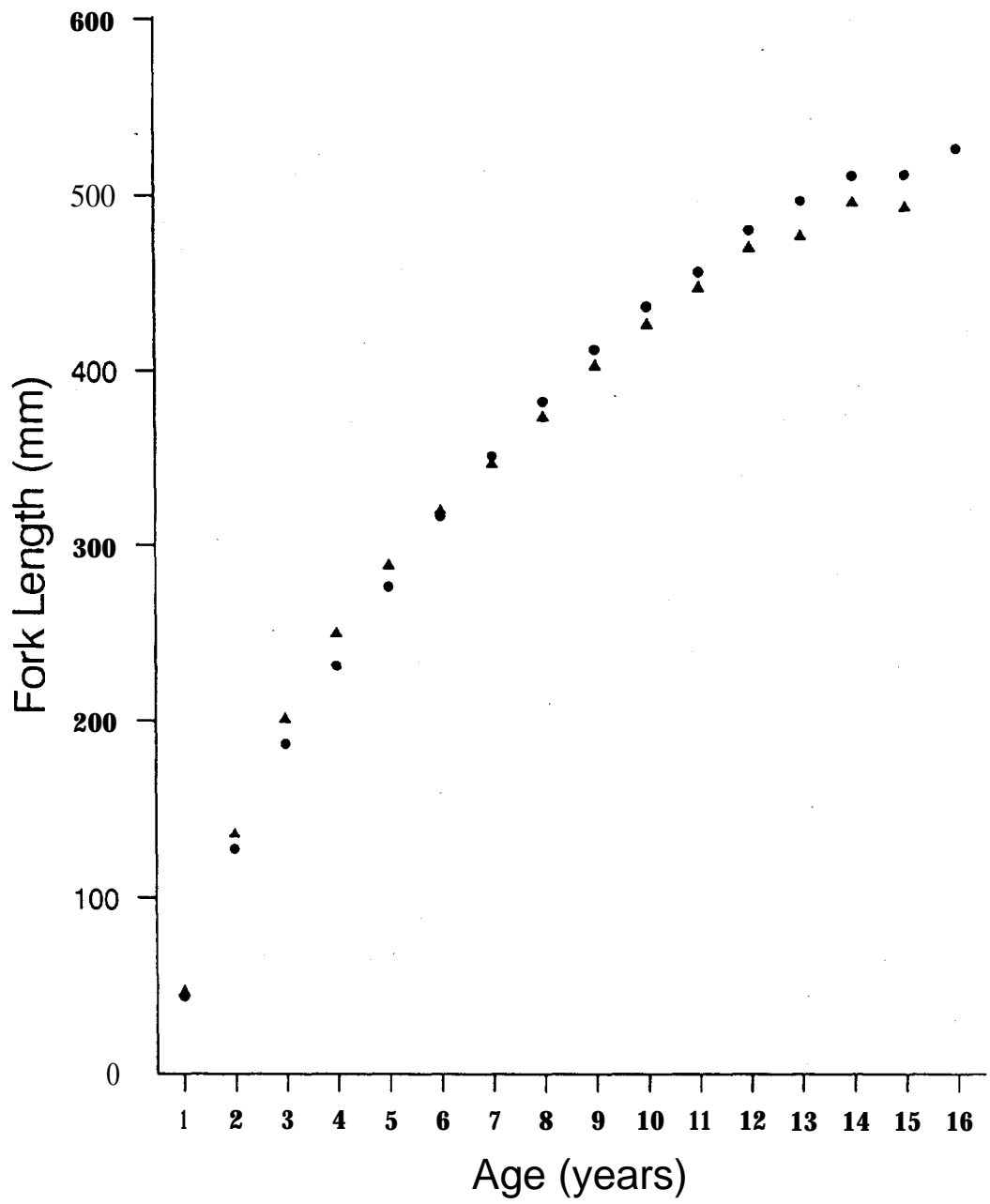


Figure 13. Backcalculated fork lengths at age for northern squawfish in the Columbia River downstream from Bonneville Dam tailrace (circles) and in John Day Reservoir (triangles).

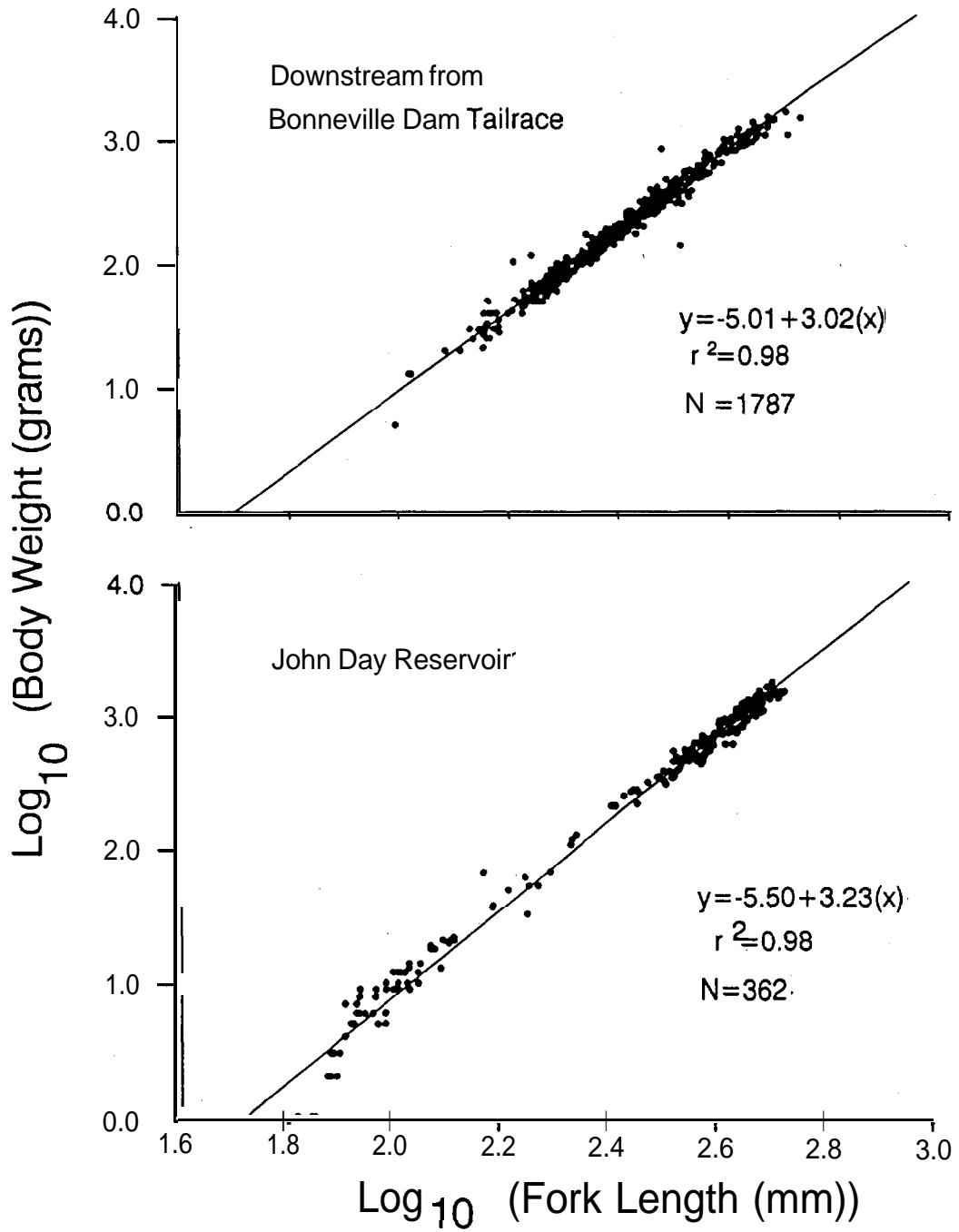


Figure 14. Relationship of weight to fork length for northern squawfish in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

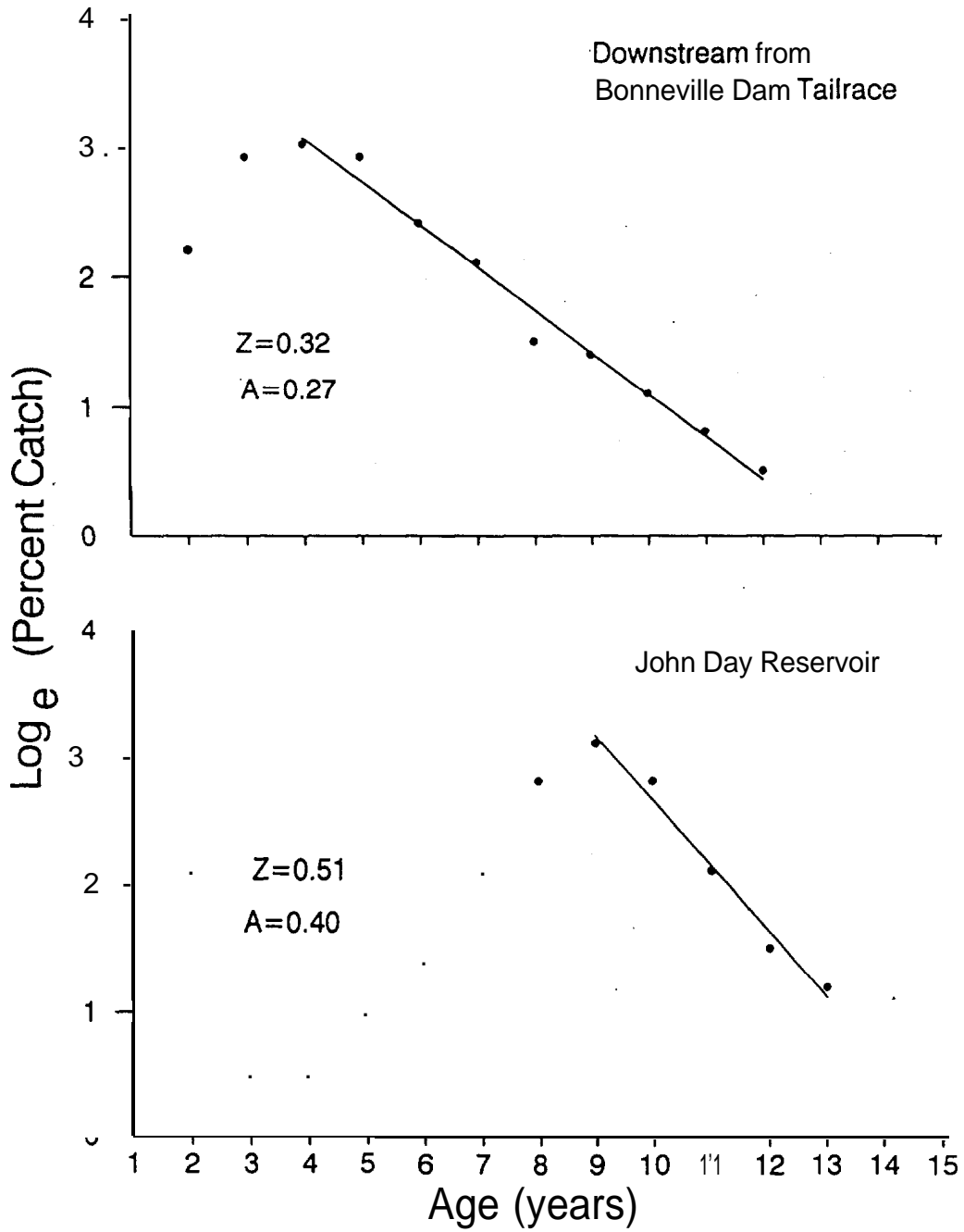


Figure 15. Catch curves for northern squawfish collected while index sampling in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir. Z = total instantaneous mortality, A = annual mortality rate.

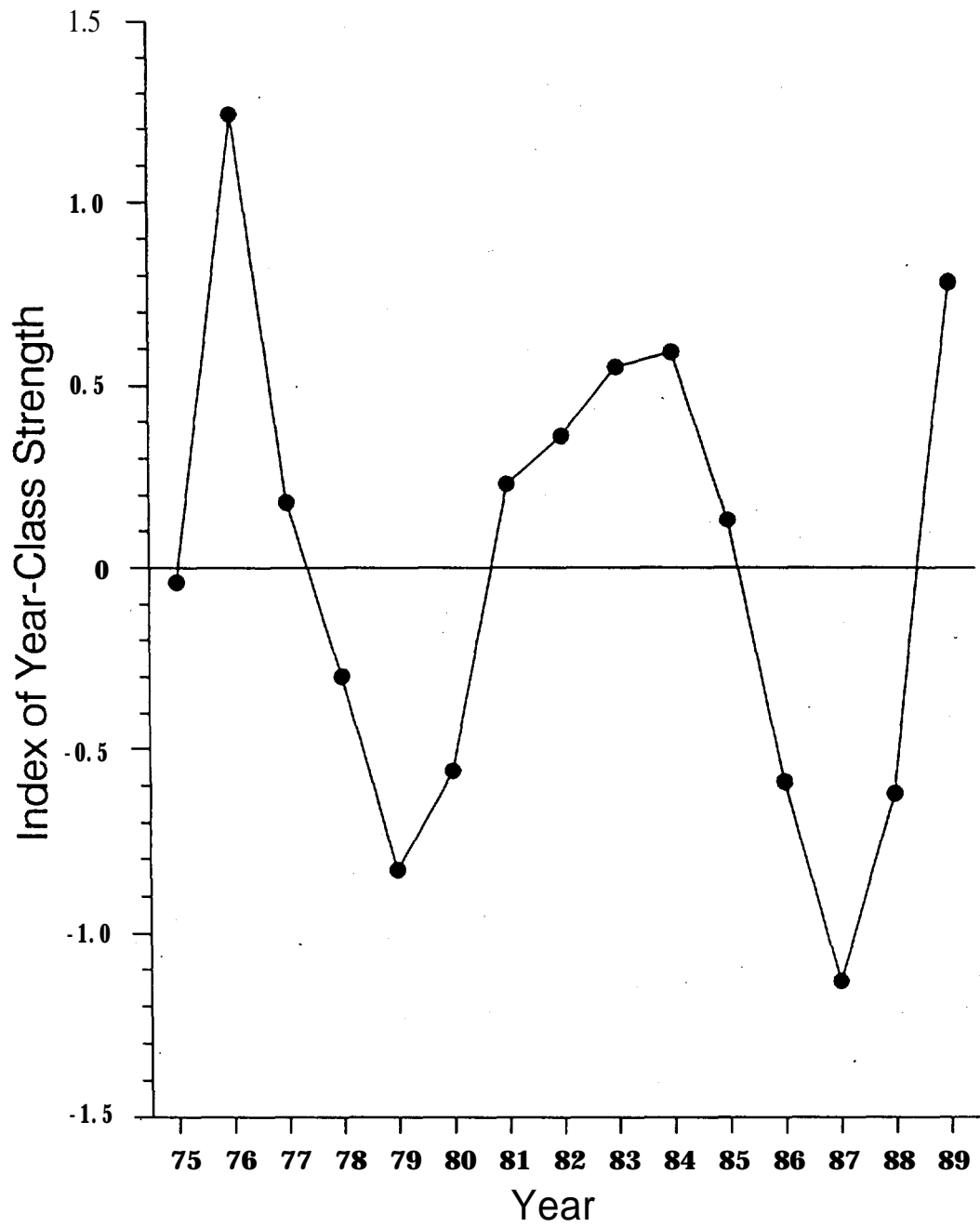


Figure 16. Index of year-class strength by year for-northern squawfish in John Day Reservoir.

Both male and female northern **squawfish** exhibited an increase in GSI in May. Escalation and peaking of GSI indicates reproductive preparedness if not actual spawning activity. Peak GSI values were followed by a relatively rapid decline to near resting levels in June. Spawning appears to occur over a period of eight or nine weeks from early May to late July. No evidence of a secondary spawning was indicated by our data; however, we did not sample over the entire year. GSI will continue to be monitored during 1993 to determine if changes in peak spawning activity are occurring. We will also continue to monitor sex ratio to determine if the percentage of females removed from the lower Columbia and Snake rivers changes with increased harvest.

Age, growth, mortality, and year-class strength were estimated using data obtained from northern squawfish scales, and sufficient ovary samples were collected to determine baseline fecundity information. Additional ovary and scale samples will be collected in 1993. Estimates of mortality using catch curve analysis are subject to bias associated with reading scales. The **accuracy** and precision of using scales to age northern squawfish has not been adequately determined. Preliminary sampling for young-of-the-year northern squawfish in 1992 indicated that placement of the first **annulus** is consistent with assigned backcalculated fork lengths. However, validation of aging techniques should be addressed further since scales have historically underestimated fish age (**Beamish and McFarlane 1983**). We will attempt to examine otoliths and identify methods of validation in 1993.

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APPENDIX A

Preliminary Evaluation of the Mechanisms Driving Response of Predator and Prey Fish Species to Sustained Northern Squawfish Fisheries in John Day Reservoir

Introduction

Subobjective 2.3 in our 1992 Statement of Work directed us to “work with the USFWS to begin detailed evaluation of the mechanisms driving response of predator and prey fish species to sustained northern squawfish fisheries in John Day Reservoir.” We considered (1) response of year-class strengths for resident predator species, (2) response of northern squawfish distribution, and (3) response of prey species abundance. Our approach for each potential response was to (1) examine the adequacy of existing data to evaluate responses, (2) conduct a literature search to evaluate the feasibility of studying the mechanisms driving each response, and (3) if deemed feasible, develop an experimental design and sampling plan for future work.

Year-Class Strength

Our current data will enable us to examine year-class strength of northern **squawfish** and smallmouth bass. Age and growth analysis of northern **squawfish** has revealed that the youngest fish in our samples are 3 to 4 years of age. Year-class analysis gives us a 3 to 4 year old picture of year-class strength, which is adequate to characterize annual variation in northern squawfish year-class strength prior to predator control implementation. Although we have not yet aged smallmouth bass scale samples, we think the youngest fish in our samples will be 2 or 3 years of age, providing us with a more current picture of year-class strength. We have not collected spines from channel catfish for age and growth analysis. Catch rates of channel catfish and walleye in John Day Reservoir have been low and our sample sizes are inadequate for analysis of year class-strengths.

Although the literature on mechanisms affecting year-class strength of northern squawfish, smallmouth bass, and walleye is diverse, the effects of harvest on year-class strength have not been widely addressed. Modeling simulations on populations of northern squawfish (Rieman and Beamesderfer 1988) and smallmouth bass and walleye (Connolly and Rieman 1988) in John Day Reservoir indicated that variation in year-class strength had a marked impact on the magnitude of predation on juvenile salmonids. They concluded that any variable that affected year-class strength will influence predation. Of many variables examined, only the concurrent year-class strength of walleye was strongly correlated (negatively) with northern squawfish year-class strength (Rieman and Beamesderfer 1988). Year-class strength of smallmouth bass has been related to first year growth (Connolly and Rieman 1988), cold temperatures during spawning (Henderson and Foster 1957, Christie and

Regier 1973), and annual variation in water level (Montgomery et al. 1980). Year-class strength of walleye has been correlated with environmental variables such as flow and temperature (Machniak 1975; Fomey 1976; Huh et al. 1976; Colby et al. 1979; Toney and Coble 1979; Connolly and Rieman 1988).

We tested the feasibility of sampling young predators in the non-restricted zone of the tailrace of John Day Reservoir during September 1992. We sampled embayments and beaches with an electrofishing boat and a beach seine for four days, two during daylight hours (9 a.m. to 7 p.m.) and two during night (7 p.m. to 1 a.m.). We compared total catch and catch per unit of effort (CPUE) of each predator, and examined length-frequency histograms to evaluate gear selectivity for small fish.

Catch rate for northern squawfish was greatest during nighttime beach seining (Appendix Table A-1). Beach seining was less effective than electrofishing for smallmouth bass, regardless of sampling time. No walleye or channel catfish were captured. Effective sampling for young walleye and channel catfish is probably limited by their relatively low abundance, and occurrence of channel catfish in habitats that are difficult to sample regardless of gear type. The 50-74 mm fork length interval comprised the largest proportion of the catch of northern squawfish (Appendix Figure A-1) and smallmouth bass (Appendix Figure A-2). A smaller peak was evident for northern squawfish at 125-149 mm. Estimated mean lengths of age 1 and age 2 northern squawfish in John Day Reservoir are 66 mm and 133 mm (Ward et al. 1992), which correspond to peaks in the length frequency histograms.

Appendix Table A-1. Catch rate (CPUE) of northern squawfish and smallmouth bass by beach seining and electrofishing during day (9 a.m. to 7 p.m.) and night (7 p.m. to 1 a.m.). "n" is the number of seine hauls or 900 second electrofishing runs.

Species	Sampling time	Sampling gear			
		Beach Seine		Electrofishing	
		CPUE	(n)	CPUE	(n)
Northern squawfish	Day	0.7	(24)	4.3	(23)
	Night	18.9	(11)	6.3	(9)
Smallmouth bass	Day	1.8	(24)	9.7	(23)
	Night	2.6	(11)	19.0	(9)

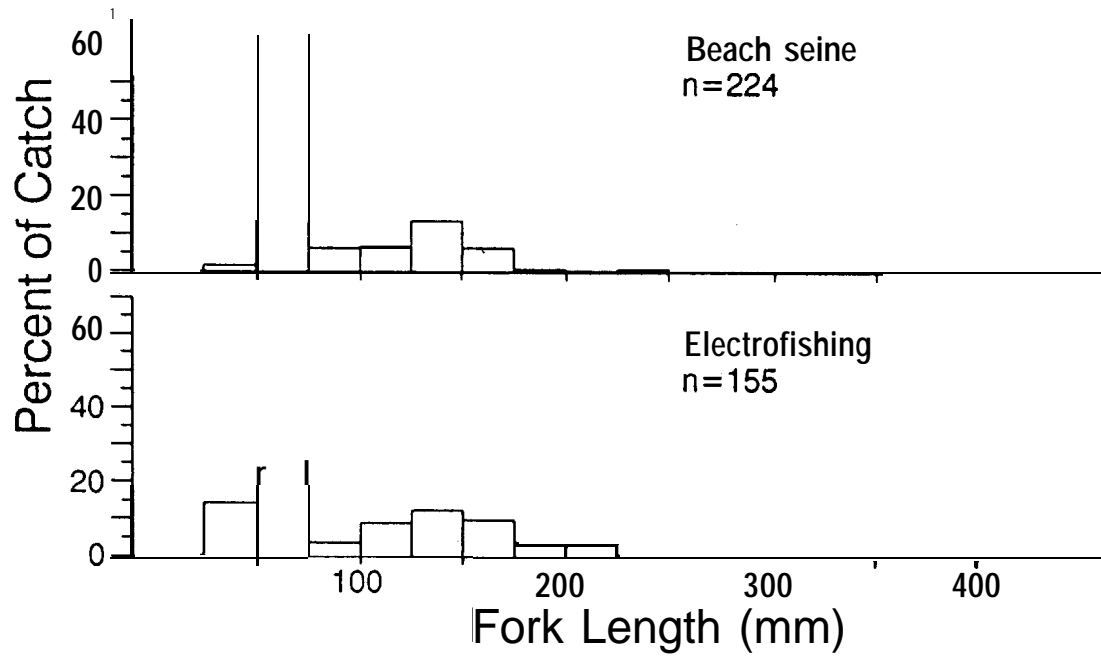
Sampling younger predators would facilitate examination of the strength of the current year class. However, we do not expect to see significant responses in year class strength to predator control until fisheries have been sustained for at least four to five years at a 10-20% exploitation rate. Additionally, it is unlikely that we could distinguish between environmental and harvest-related effects on recruitment.

Northern Squawfish Distribution

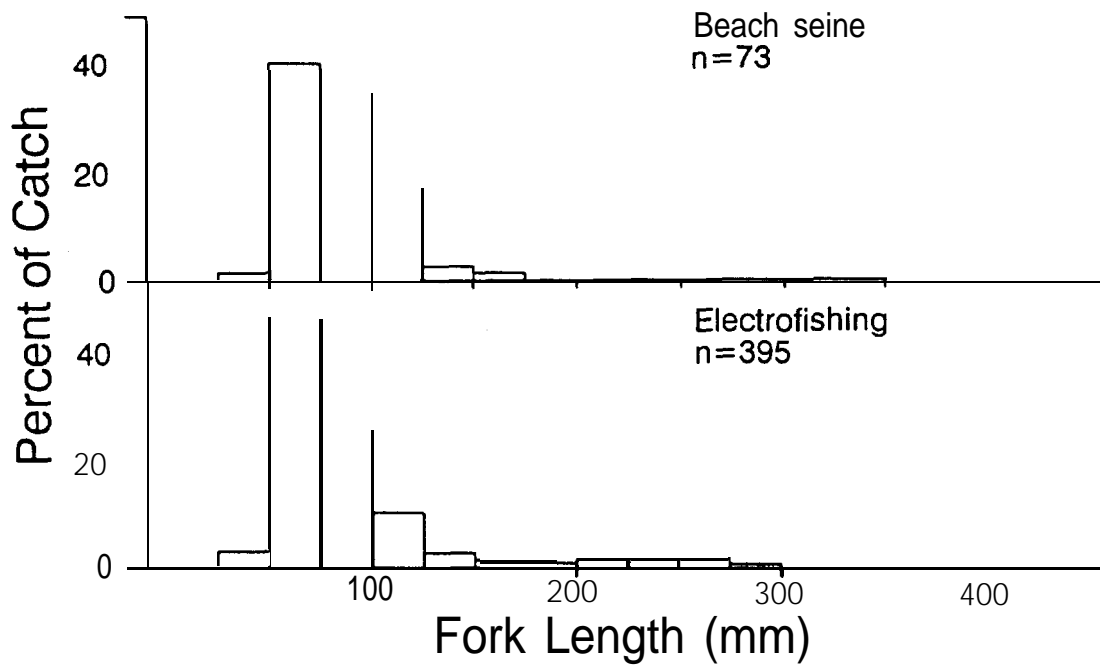
Our current data provides limited information on changes in northern squawfish distribution, although we cannot attribute changes to sustained fisheries. Dam-angling and sport-reward fishing effort has been concentrated in or near tailraces. We have examined movement of fish into and out of tailraces based on recapture locations of tagged fish. Previous research on northern squawfish movements in John Day Reservoir (Beamesderfer and Rieman 1988) supports our conclusion that fish range widely among reservoir areas. This implies that although fisheries are often concentrated near areas of easy access, all northern **squawfish** are potentially vulnerable to harvest. Conversely, fisheries may be exploiting localized, discrete populations within the reservoir to some extent. Reality probably lies somewhere in between these two extremes, and the question bears on the assumptions associated with our estimates of exploitation. We have addressed this uncertainty by expressing our exploitation estimates within a range that encompasses both situations, although a better understanding of northern squawfish distribution would be useful.

Uncertainties regarding northern squawfish distribution are also relevant to assumptions underlying simulated exploitation of northern squawfish in the Columbia River Ecosystem Model (Bledsoe 1990). The model assumes that northern squawfish harvested in a particular reservoir area are immediately replaced by fish from adjacent areas, maintaining an “equilibrium” density and abundance that reflects results of our abundance index sampling. In this scenario, intense fishing in one area (a “northern squawfish sink”) could deplete the entire population of the reservoir.

We believe that telemetry experiments could help fill gaps in our understanding of distributional changes, although attributing changes to localized fishing pressure in a cause-effect way is unlikely. We have proposed extensive telemetry work for 1993 in conjunction with the U.S. Fish and Wildlife Service (USFWS). The USFWS will concentrate on tracking short-term movements in The Dalles and John Day Dam tailraces. We propose to examine movements throughout Bonneville and The Dalles reservoirs to (1) evaluate our assumption that northern squawfish occur mainly near shore, (2) evaluate movement among reservoir areas (forebay, midreservoir, **tailrace** non-restricted zone, and **tailrace** restricted zone) and (3) evaluate the extent of movement toward or away from areas of intensive harvest, such as the **tailrace** boat restricted zone. If necessary, we could simulate intense fishing by conducting short-term electrofishing removal similar to the Tanner Creek experiments conducted jointly by ODFW and USFWS in 1991 and 1992.



Appendix Figure A-1. Size composition of northern squawfish in beach seine and electrofishing samples. "n" is the total catch.



Appendix Figure A-2. Size composition of smallmouth bass in beach seine and electrofishing samples. "n" is the total catch.

Prey Species Abundance

From 1990 to 1992, we have collected data on relative abundance of non-predator species in John Day Reservoir during the course of northern squawfish abundance index sampling using electrofishing and gillnets. Although we did not effectively sample the entire fish community, we gathered data on the relative abundance of many species. Our ability to sample small individuals of most species has been limited, and some potential prey species, such as sculpins, were not sampled effectively due to gear selectivity.

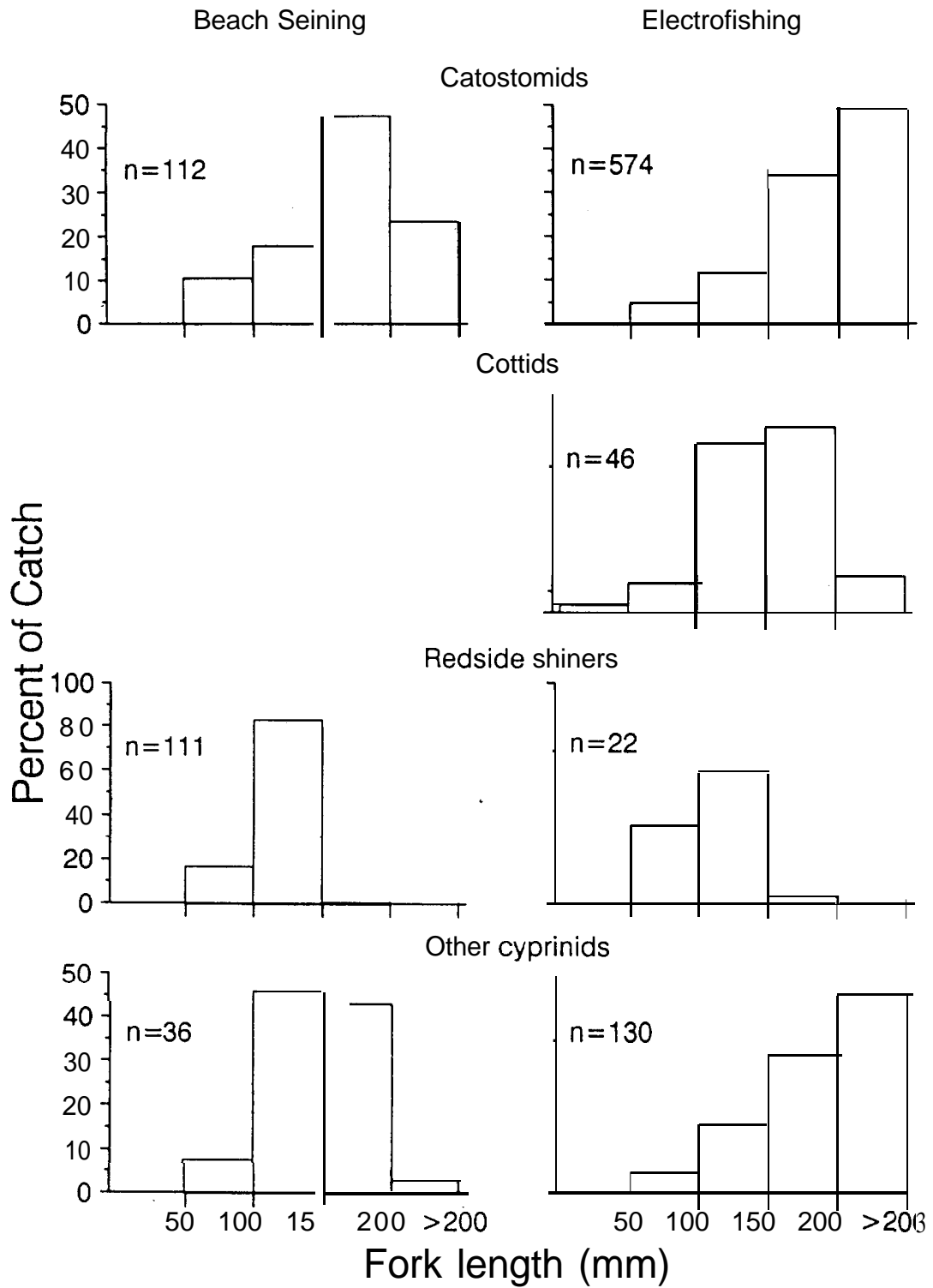
As part of our September beach seining feasibility test (see “Year-Class Strength”), we identified, counted, and measured (50-mm fork length intervals) all fish. We calculated catch rates from pooled day and night samples, and examined size composition of potential prey species to evaluate gear effectiveness. Important prey groups include catostomids, cottids, cyprinids, and percopsids, which together comprised 80-97% by weight of the non-salmonid component in the diets of resident predators in John Day Reservoir (Poe et al. 1988). Among predator species, only northern squawfish consume significant numbers of juvenile American shad when they become available in August. Nevertheless, American shad have increased in abundance since the mid-1980s. Their seasonal importance to predators may have grown as well.

Electrofishing catch rates were greater than beach seine catch rates for all taxa except northern squawfish and redbside shiner (Appendix Table A-2). Catch rates were highest for juvenile American shad for both gears. Among other potential prey taxa, largescale sucker, northern squawfish, chiselmouth, carp, and redbside shiner were effectively sampled by a combination of both gears. Catch rate of goldfish, peamouth, bridgelip sucker, sand roller, and cottids were very low for both gears. Size composition of catostomids, redbside shiners, cyprinids (chiselmouth and peamouth), and cottids are summarized in Appendix Figure A-3. Beach seining captured a larger proportion of small (< 200 mm) catostomids, although beach seine catch rates were much lower than electrofishing. Electrofishing and beach seining were equally selective for 50-150 mm redbside shiners. Among cyprinids, small (< 200 mm) peamouth and chiselmouth were more effectively sampled by beach seining. However, the total catch by electrofishing was much greater than in seine hauls. Carp and goldfish were not included because 96% were greater than 200 mm. Most northern squawfish were less than 100 mm (see Appendix Figure A-1 in “Year-Class Strength”). A wide size range of cottids was sampled with electrofishing, although the total catch was very low. Too few cottids were captured in seine hauls to be included in Appendix Figure A-3.

Extensive sampling of prey species would provide information on the relative abundance of some prey species; however, obtaining adequate and representative samples demands considerable sampling effort. Using only electrofishing and beach seines, cottids, sandrollers, and small peamouth, bridgelip suckers, and carp may be poorly represented in samples. Additional gears would be required to effectively sample all prey species of appropriate sizes. Staffing and sampling requirements associated with research of this scope are prohibitive, given our present tasks associated with biological evaluation of the predator control program.

Appendix Table A-2. Mean CPUE of various species by beach seining and electrofishing. Effort was 35 seine hauls and 32 electrofishing runs.

Common name, scientific name	Mean CPUE	
	Beach seine	Electrofishing
American shad, <i>Alosa sapidissima</i>	99.7	106.9
Mountain whitefish, <i>Prosopium williamsoni</i>	0.2	0.5
Carp, <i>Cyprinus carpio</i>	--	5.4
Goldfish, <i>Carassius auratus</i>	--	0.8
Peamouth, <i>Mylocheilus caurinus</i>	0.3	0.6
Northern squawfish, <i>Ptychocheilus oregonensis</i>	6.4	4.8
Chiselmouth, <i>Acrocheilus alutaceus</i>	0.8	3.4
Redside shiner, <i>Richardsonius balteatus</i>	3.2	0.7
Bridgelip sucker, <i>Catostomus columbianus</i>	0.1	0.1
Largescale sucker, <i>Catostomus macrocheilus</i>	3.1	17.8
Brown bullhead, <i>Ictalurus nebulosus</i>	--	0.1
Sand roller, <i>Columbia transmontana</i>	0.1	--
Threespine stickleback, <i>Gasterosteus aculeatus</i>	co.1	--
Sculpin spp., Cottidae	0.1	1.4
Pumpkinseed, <i>Lepomis gibbosus</i>	0.2	0.9
Bluegill, <i>Lepomis macrochirus</i>	1.0	1.7
Black crappie, <i>Pomoxis nigromaculatus</i>	0.1	0.2
White crappie, <i>Pomoxis annularis</i>	co.1	0.1
Smallmouth bass, <i>Micropterus dolomieu</i>	2.1	12.3
Largemouth bass, <i>Micropterus salmoides</i>	1.7	12.9
Yellow perch, <i>Perca flavescens</i>	2.8	10.5



Appendix Figure A-3. Size composition of catostomids, **redside** shiners, other cyprinids (chiselmouth and peamouth), and cottids in beach seine and electrofishing samples. "n" is the total catch.

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APPENDIX B

Estimates of Exploitation Assuming Complete Mixing of Marked and Unmarked Fish and Random Allocation of Fishing Effort

T is the number of fish marked, M is the number of marked fish at large, LL is commercial longline, and Misc. are marked fish recaptured outside predator control fisheries or in other areas. P is time period. Dates for each period are as follows.

Period	Dates
1	before April 19
2	April 19 - April 25
3	April 26 - May 2
4	May 3 - May 9
5	May 10 - May 16
6	May 17 - May 23
7	May 24 - May 30
8	May 31 - June 6
9	June 7 - June 13
10	June 14 - June 20
11	June 21 - June 27
12	June 28 - July 4
13	July 5 - July 11
14	July 12 - July 18
15	July 19 - July 25
16	July 26 - August 1
17	August 2 - August 8
18	August 9 - August 15
19	August 16 - August 22
20	August 23 - August 29
21	August 30 - September 5
22	September 6 - September 12
23	September 13 - September 19
24	September 20 - September 26
25	September 27 - October 3

Appendix Table B-1. Exploitation of northern squawfish downstream from Bonneville Dam.

P	T	Recaptures				M	Exploitation		
		Sport	Dam	LL	Misc.		Sport	Dam	LL
1	590	--	--	--	3	--	--	--	
2	209	--	--	--	--	587	--	--	
3	290	--	--	--	--	796	--	--	--
4	135	--	--	--	5	1,086	--	--	--
5	211	--	--	--	1	1,216	--	--	--
6	250	20	--	--	2	1,426	0.0140	--	
7	180	20	--	--	1	1,654	0.0121		--
8	--	24	--	1	4	1,813	0.0132	--	0.0006
9	--	22	--	--	2	1,784	0.0123	--	--
10	--	26	--	1	11	1,760	0.0148	--	0.0006
11	--	18	3	--	2	1,722	0.0105	0.0017	
12	--	11	--	--	4	1,702	0.0065	--	--
13	--	12	--	--	1	1,687	0.0071	--	--
14	--	8	--	--	1	1,674	0.0048	--	
15	--	9	1	--	4	1,665	0.0054	0.0006	
16	--	3	--	--	1	1,651	0.0018		
17	--	3	--	--	1	1,647	0.0018		
18	--	2	--	--	3	1,643	0.0012	--	--
19	--	1	--	--	--	1,638	0.0006	--	--
20	--	2	--	--	--	1,637	0.0012	--	--
21	--	1	--	--	1	1,635	0.0006	--	
22	--	1	--	--	--	1,633	0.0006	--	
23	--	1	--	--	--	1,632	0.0006	--	--
24	--	1	--	--	--	1,631	0.0006		--
25	--	--	--	--	--	1,630	--		
Total	1,865	185	4	2	--	--	0.1097	0.0023	0.0012
Adjusted for tag loss							0.1149	0.0024	0.0013

Appendix Table B-2. Exploitation of northern squawfish in Bonneville Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	419	--	--	1	--	--	--
2	--	--	--	--	418	--	--
3	--	--	--	--	418	--	--
4	--	--	--	--	418	--	--
5	--	--	3	--	418	--	0.0072
6	--	1	2	1	415	0.0024	0.0048
7	122	4	--	2	527	0.0076	--
8	--	4	1	3	521	0.0077	0.0019
9	--	5	2	4	513	0.0097	0.0039
10	--	2	3	5	502	0.0040	0.0060
11	--	--	--	7	492	--	--
12	--	--	4	5	485	--	0.0082
13	--	3	--	1	476	0.0063	--
14	--	2	1	1	472	0.0042	0.0021
15	--	1	--	--	468	0.0021	--
16	--	2	--	2	467	0.0043	--
17	--	1	--	--	463	0.0022	--
18	--	--	1	1	462	--	0.0022
19	--	1	--	--	460	0.0022	--
20	--	1	1	1	459	0.0022	0.0022
21	--	--	--	--	456	--	--
22	--	--	--	--	456	--	--
23	--	--	--	--	4 5 6	--	--
24	--	--	--	--	456	--	--
25	--	--	--	--	456	--	--
Total	541	27	18	6	--	0.0549	0.0385
Adjusted for tag loss						0.0575	0.0403

Appendix Table B-3. Exploitation of northern squawfish in The Dalles Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	157	--	--	--	--	--	--
2	28	--	--	--	157	--	--
3	--	--	--	2	185	--	--
4	--	--	--	--	183	--	--
5	--	--	--	--	183	--	--
6	--	2	--	--	183	0.0109	--
7	--	2	--	--	181	0.0110	--
8	--	--	1	--	179	--	0.0056
9	--	2	--	--	178	0.0112	--
10	--	2	--	--	176	0.0114	--
11	--	1	1	--	174	0.0057	0.0057
12	--	1	--	--	172	0.0058	--
13	--	--	--	--	171	--	--
14	--	--	--	--	171	--	--
15	--	1	--	--	171	0.0058	--
16	--	--	--	--	170	--	--
17	--	--	--	--	170	--	--
18	--	--	--	--	170	--	--
19	--	--	--	--	170	--	--
20	--	1	--	--	170	0.0059	--
21	--	1	--	--	169	0.0059	--
22	--	--	--	--	168	--	--
23	--	--	--	--	168	--	--
24	--	--	--	--	168	--	--
25	--	--	--	--	168	--	--
Total	185	13	2	--	--	0.0736	0.0113
Adjusted for tag loss						0.0771	0.0118

Appendix Table B-4. Exploitation of northern squawfish in John Day Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	129	--	--	--	--	--	--
2	--	--	--	--	129	--	--
3	--	--	--	--	129	--	--
4	--	--	--	1	129	--	--
5	130	--	--	--	128	--	--
6	--	--	--	--	258	--	--
7	--	4	--	--	258	0.0155	--
8	--	1	3	1	254	0.0039	0.0118
9	--	--	1	--	249	--	0.0040
10	--	1	1	--	248	0.0040	0.0040
11	--	1	2	--	246	0.0041	0.0081
12	--	2	6	2	243	0.0082	0.0247
13	--	1	2	--	233	0.0043	0.0086
14	--	--	9	1	230	--	0.0391
15	--	--	2	--	220	--	0.0091
16	--	--	3	--	218	--	0.0138
17	--	--	1	--	215	--	0.0047
18	--	--	--	--	214	--	--
19	--	--	--	--	214	--	--
20	--	--	--	--	214	--	--
21	--	--	--	4	214	--	--
22	--	--	--	--	210	--	--
23	--	--	--	--	210	--	--
24	--	--	--	--	210	--	--
25	--	--	--	--	210	--	--
Total	259	10	30	--	--	0.0400	0.1279
Adjusted for tag loss						0.0419	0.1340

Appendix Table B-5. Exploitation of northern squawfish in McNary Reservoir.

P	T	Recaptures			M	Exploitation	
		'Sport	Dam	Misc.		Sport	Dam
1	34	--	--	--	--	--	--
2	--	--	--	--	34	--	--
3	--	--	--	--	34	--	--
4	--	--	--	--	34	--	--
5	73	--	--	1	34	--	--
6	--	--	--	--	106	--	--
7	--	1	--	--	106	0.0094	--
8	--	--	--	--	105	--	--
9	--	--	--	1	105	--	--
10	--	1	--	--	104	0.0096	--
11	--	--	--	--	103	--	--
12	--	--	--	--	103	--	--
13	--	2	--	--	103	0.0194	--
14	--	1	--	--	101	0.0099	--
15	--	--	--	--	100	--	--
16.	--	--	--	--	100	--	--
17	--	--	--	--	100	--	--
18	--	1	--	--	1 0 0	0.0100	--
19	--	--	--	--	99	--	--
20	--	--	--	--	99	--	--
21	--	--	--	--	99	--	--
22	--	--	--	--	99	--	--
23	--	--	--	--	99	--	--
24	--	1	--	--	99	0.0101	--
25	--	--	--	--	98	--	--
Total	107	7	0	--	--	0.0684	0.0000
Adjusted for tag loss						0.0717	0.0000

Appendix Table B-6. Exploitation of northern squawfish in Ice Harbor Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	7	--	--	--	--	--	--
2	--	--	--	--	7	--	--
3	--	--	--	--	7	--	--
4	--	--	--	--	7	--	--
5	--	--	--	--	7	--	--
6	--	--	--	--	7	--	--
7	--	--	--	--	7	--	--
8	--	--	--	--	7	--	--
9	--	--	--	--	7	--	--
10	--	--	--	--	7	--	--
11	--	--	--	--	7	--	--
12	--	--	--	--	7	--	--
13	--	--	--	--	7	--	--
14	--	--	--	--	7	--	--
15	--	--	--	--	7	--	--
16	--	--	--	--	7	--	--
17	--	--	--	--	7	--	--
18	--	--	--	--	7	--	--
19	--	--	--	--	7	--	--
20	--	--	--	--	7	--	--
21	--	--	--	--	7	--	--
22	--	--	--	--	7	--	--
23	--	--	--	--	7	--	--
24	--	--	--	--	7	--	--
25	--	--	--	--	7	--	--
Total	7	0	0	--	--	0.0000	0.0000

Appendix Table B-7. Exploitation of northern squawfish in Lower Monumental Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	93	--	--	--	--	--	--
2	--	--	--	--	93	--	--
3	--	--	3	--	93	--	0.0323
4	121	--	1	--	90	--	0.0111
5	--	--	--	--	210	--	--
6	--	--	--	--	210	--	--
7	--	3	1	--	210	0.0143	0.0048
	--	--	1	--	206	--	0.0049
E	--	1	--	--	205	0.0049	--
10	--	--	--	2	204	--	--
11	--	1	--	--	202	0.0050	--
12	--	--	--	--	201	--	--
13	--	--	--	--	201	--	--
14	--	--	1	--	201	--	0.0050
15	--	--	--	--	200	--	--
16	--	--	1	--	200	--	0.0050
17	--	--	1	1	199	--	0.0050
18	--	--	1	--	197	--	0.0051
19	--	--	--	--	196	--	--
20	--	--	1	--	196	--	0.0051
21	--	--	--	--	195	--	--
22	--	--	1	--	195	--	0.0051
23	--	--	--	--	194	--	--
24	--	--	--	--	194	--	--
25	--	--	--	--	194	--	--
Total	214	5	12			0.0242	0.0834
Adjusted for tag loss						0.0254	0.0874

Appendix Table B-8. Exploitation of northern squawfish in Little Goose Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	D a m	Misc.		Sport	Dam
1	48	--	--	--	--	--	--
2	315	--	--	--	4a	--	--
3	176	--	--	--	363	--	--
4	--	--	3	--	539	--	0.0056
5	--	--	1	--	536	--	0.0019
6	--	1	--	1	535	0.0019	--
7	--	4	11	1	533	0.0075	0.0206
a	--	3	3	2	517	0.0058	0.0058
9	--	11	4	--	509	0.0216	0.0079
10	--	10	2	3	494	0.0203	0.0041
11	--	3	--	1	479	0.0063	--
12	--	2	--	--	475	0.0042	--
13	--	2	1	--	473	0.0042	0.0021
14	--	2	6	1	470	0.0043	0.0128
15	--	1	--	--	461	0.0022	--
16	--	4	--	--	460	0.0087	--
17	--	4	--	--	456	0.0088	--
1a	--	5	--	1	452	0.0111	--
19	--	4	2	--	446	0.0090	0.0045
20	--	1	1	--	440	0.0023	0.0023
21	--	2	--	--	438	0.0046	--
22	--	2	--	--	436	0.0046	--
23	--	2	--	--	434	0.0046	--
24	--	1	--	--	432	0.0023	--
25	--	--	--	--	431	--	--
Total	539	65	34	--	--	0.1343	0.0676
Adjusted for tag loss						0.1407	0.0708

Appendix Table B-9. Exploitation of northern squawfish in Lower Granite Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	120	--	--	--	--	--	--
2	--	--	--	--	120	--	--
3	--	--		--	120	--	--
4	--			--	120	--	--
5	--		--	--	120	--	--
6	--	2	--	--	120	0.0167	
7	--	--	--	--	118	--	
8	--	2		--	118	0.0169	--
9	--			--	116	--	--
10	--	4	--	--	116	0.0345	--
11	--	2	--	--	112	0.0179	
12	--	--	--	--	110	--	--
13	--	1		--	110	0.0091	--
14	--	2		--	109	0.0183	--
15	--			--	107	--	--
16	--	1	--	--	107	0.0093	--
17	--	2	--	--	106	0.0189	--
18	--	1	--	--	104	0.0096	--
19	--		--	--	103	--	--
20	--	--		--	103	--	--
21.	--	2		--	103	0.0194	--
22	--	--		--	101	--	--
23	--	--		--	101	--	--
24	--			--	101	--	--
25	--	1	--	--	101	0.0099	--
Total	120	20	0	--	--	0.1805	0.0000
Adjusted for tag loss						0.1891	0.0000

Appendix Table B-10. Exploitation of northern sguawfish systemwide.

P	T	Recaptures				M	Exploitation		
		Sport	Dam	LL	Misc.		Sport	Dam	LL
1	1,597	--	--	--	4	--	--	--	--
2	552	--	--	--	--	1,593	--	--	--
3	466	--	3	--	2	2,145	--	0.0014	--
4	256	--	4	--	6	2,606	--	0.0015	--
5	414	--	4	--	2	2,852	--	0.0014	--
6	250	27	3	--	1	3,260	0.0083	0.0009	--
7	302	43	12	--	--	3,479	0.0124	0.0034	--
8	--	39	10	1	6	3,726	0.0105	0.0027	0.0003
9	--	46	7	--	2	3,670	0.0125	0.0019	--
10	--	54	7	1	12	3,615	0.0149	0.0019	0.0003
11	--	32	4	--	4	3,541	0.0090	0.0011	--
12	--	21	10	--	6	3,501	0.0060	0.0028	--
13	--	23	3	--	1	3,464	0.0066	0.0009	--
14	--	16	18	--	2	3,437	0.0047	0.0052	--
15	--	12	3	--	4	3,401	0.0035	0.0009	--
16	--	11	5	--	1	3,382	0.0033	0.0015	--
17	--	10	2	--	2	3,365	0.0030	0.0006	--
18	--	9	3	--	3	3,351	0.0027	0.0009	--
19	--	9	2	--	--	3,336	0.0027	0.0006	--
20	--	5	3	--	--	3,325	0.0015	0.0009	--
21	--	6	--	--	5	3,317	0.0018	--	--
22	--	3	1	--	--	3,306	0.0009	0.0003	--
23	--	3	--	--	--	3,302	0.0009	--	--
24	--	3	--	--	--	3,299	0.0009	--	--
25	--	1	--	--	--	3,396	0.0006	--	--
Total	3,837	373	104	2	--	--	0.1067	0.0308	0.0006
Adjusted for tag loss							0.1118	0.0323	0.0006

APPENDIX C

Estimates of Exploitation Assuming no Mixing of Fish Outside Areas They were Marked, and Fisheries Effort Limited to Areas Where Fish Were Marked

Abbreviations and time periods are as described in Appendix B.

Appendix Table C-1. Exploitation of northern squawfish in Bonneville Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	1,160	--	--	1	--	--	--
2	--	--	--	--	1,159	--	--
3	--	--	--		1,159		--
4	--	--			1,159	--	--
5	--		3	--	1,159		0.0026
6	--	1	2	1	1,156	0.0009	0.0017
7	122	4	--	2	1,152	0.0035	--
8	--	4	1	3	1,268	0.0032	0.0008
9		5	2	4	1,260	0.0040	0.0016
10		2	3	5	1,249	0.0016	0.0024
11	--	--	--	7	1,239	--	--
12	--	--	4	5	1,232	--	0.0032
13	--	3	--	1	1,223	0.0025	--
14	--	2	1	1	1,219	0.0016	0.0008
15	--	1		--	1,215	0.0008	--
16	--	2	--	2	1,214	0.0016	--
17	--	1	--	--	1,210	0.0008	--
18	--	--	1	1	1,209	--	0.0008
19	--	1	--		1,207	0.0008	--
20	--	1	1	1	1,206	0.0008	0.0008
21	--	--	--	--	1,203	--	--
22	--	--	--		1,203	--	--
23	--	--	--	--	1,203	--	--
24	--	--	--	--	1,203		--
25	--	--	--		1,203		--
Total	1,282	27	18	--	--	0.0221	0.0147
Adjusted for tag loss						0.0232	0.0154

Appendix Table C-2. Exploitation of northern squawfish in The Dalles Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	232	--	--	--	--		
2	58	--	--	--	232		
3	--	--	--	2	290	--	--
4	--	--	--	--	288	--	--
5	--	--	--	--	288		
6		2	--	--	288	0.0069	
7		2	--	--	286	0.0070	
8	--	--	1	--	284	--	0.0035
9	--	2	--	--	283	0.0071	--
10	--	2	--	--	281	0.0071	
11	--	1	1	--	279	0.0036	0.0036
12	--	1	--	--	277	0.0036	--
13	--	--	--	--	276	--	--
14	--	--	--	--	276	--	
15		1	--		276	0.0036	
16		--	--	--	275	--	--
17	--	--	--	--	275	--	--
18.	--	--	--	--	275	--	--
19	--	--	--	--	275	--	--
20		1			275	0.0036	
21	--	1			274	0.0036	
22		--	--	--	273	--	--
23	--	--	--	--	273	--	--
24	--	--	--	--	273	--	--
25	--	--			273		
Total	290	13	2		--	0.0461	0.0071
Adjusted for tag loss						0.0483	0.0074

Appendix Table C-3. Exploitation of northern squawfish in John Day Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	271	--		--	--		
2			--	--	271		
3			--	--	271		
4	--		--	1	271	--	
5	130	--	--	--	270		--
6	--		--		400	--	--
7		4	--	--	400	0.0100	--
a		1	3	1	396	0.0025	0.0076
9	--	--	1	--	391	--	0.0026
10	--	1	1	--	390	0.0026	0.0026
11	--	1	2	--	388	0.0026	0.0052
12		2	6	2	385	0.0052	0.0156
13		1	2	--	375	0.0027	0.0053
14	--	--	9	1	372	--	0.0242
15	--	--	2	--	362	--	0.0055
16	--	--	3	--	360	--	0.0083
17			1	--	357	--	0.0028
1 a		--		--	356	--	--
19	--	--	--	--	356	--	--
20	--	--	--	--	356	--	--
21	--		--	4	356		
22	--		--	--	352	--	
23		--	--		352	--	
24	--	--	--	--	352	--	--
25	--	--	--	--	352	--	--
Total	401	10	30	--	--	0.0256	0.0797
Adjusted for tag loss						0.0268	0.0835

Appendix Table C-4. Exploitation of northern squawfish in McNary Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	116	--	--	--	--	--	--
2	--	--	--	--	116	--	--
3	--	--	--	--	116	--	--
4	--	--	--	--	116	--	--
5	73	--	--	1	116	--	--
6	--	--	--	--	188	--	--
7	--	1	--	--	188	0.0053	--
8	--	--	--	--	187	--	--
9	--	--	--	1	187	--	--
10	--	1	--	--	186	0.0054	--
11	--	--	--	--	185	--	--
12	--	--	--	--	185	--	--
13	--	2	--	--	185	0.0108	--
14	--	1	--	--	183	0.0055	--
15	--	--	--	--	182	--	--
16	--	--	--	--	182	--	--
17	--	--	--	--	182	--	--
18	--	1	--	--	182	0.0055	--
19	--	--	--	--	181	--	--
20	--	--	--	--	181	--	--
21	--	--	--	--	181	--	--
22	--	--	--	--	181	--	--
23	--	--	--	--	181	--	--
24	--	1	--	--	181	0.0055	--
25	--	--	--	--	180	--	--
Total	194	7	--	--	--	0.0380	0.0000
Adjusted for tag loss						0.0398	0.0000

Appendix Table C-5. Exploitation of northern squawfish in Ice Harbor Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	19						--
3	--				19	--	--
4	--				19		
5	--	--	--	--	19		
6	--	--	--	--	19		
7	--	--			19		--
8	--				19		
9	--	--	--	--	19		--
10	--	--	--	--	19	--	--
11	--				19	--	
12	--	--	--		19		
13	--				19		
14	--	--	--	--	19	--	--
15	--	--	--	--	19	--	--
16	--	--	--	--	19	--	--
17	--	--	--	--	19		--
18	--	--	--	--	19		--
19	--		--	--	19		
20	--	--	--	--	19	--	--
21	--	--	--	--	19	--	--
22	--				19		
23	--		--	--	19		--
24	--	--	--	--	19	--	--
25	--	--	--	--	19	--	--
Total	19	0	0	--		0.0000	0.0000

Appendix Table C-6. Exploitation of northern sguawfish in Lower Monumental Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	D a m	Misc.		Sport	Dam
1	270	--	--	--	--	--	
2	--	--	--	--	270	--	
3	--	--	3	--	270		0.0111
4	254		1		267	--	0.0037
5		--	--	--	520	--	--
6	--	--	--		520	--	
7	--	3	1	--	520	0.0058	0.0019
8	--		1	--	516		0.0019
9		1	--	--	515	0.0019	--
10				2	514	--	--
11	--	1			512	0.0020	
12	--	--			511		
13					511	--	--
14			1	--	511	--	0.0020
15			--	--	510	--	--
16	--	--	1	--	510	--	0.0020
17	--	--	1	1	509		0.0020
18			1		507	--	0.0020
19	--		--	--	506	--	--
20			1	--	506	--	0.0020
21		--	--	--	505	--	
22	--	--	1	--	505	--	0.0020
23	--	--		--	504	--	--
24			--	--	504	--	
25	--	--	--	--	504	--	
Total	524	5	12			0.0097	0.0306
Adjusted for tag loss						0.0102	0.0321

Appendix Table C-7. Exploitation of northern squawfish in Little Goose Reservoir;

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	227	--	--	--	--	--	--
2	315	--	--	--	227	--	--
3	198	--	--	--	542	--	--
4	--	--	3	--	740	--	0.0041
5	--	--	1	--	737	--	0.0014
6	--	1	--	1	736	0.0014	--
7	--	4	11	1	734	0.0054	0.0150
8	--	--	--	--	--	--	--
9	--	11 3	a	11	718 710	0.0042 0.0155	0.0042 0.0056
10	--	10	-2	3	694	0.0144	0.0029
11	--	3	--	1	679	0.0044	--
12	--	2	--	--	675	0.0030	--
13	--	2	1	--	673	0.0030	0.0015
14	--	2	6	1	670	0.0030	0.0090
15	--	1	--	--	661	0.0015	--
16	--	4	--	--	660	0.0061	--
17	--	4	--	--	656	0.0061	--
18	--	5	--	1	652	0.0077	--
19	--	4	2	--	646	0.0062	0.0031
20	--	1	1	--	640	0.0016	0.0016
21	--	2	--	--	638	0.0031	--
22	--	2	--	--	636	0.0031	--
23	--	2	--	--	634	0.0032	--
24	--	1	--	--	632	0.0016	--
25	--	--	--	--	631	--	--
Total	740	65	34			0.0945	0.0484
Adjusted for tag loss						0.0990	0.0507

Appendix Table C-8. Exploitation of northern squawfish in Lower Granite Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	196	--	--	--	--	--	--
2	--	--	--	--	196	--	--
3	--	--	--	--	196	--	--
4	--	--	--	--	196	--	--
5	--	--	--	--	196	--	--
6	--	2	--	--	196	0.0102	--
7	--	--	--	--	194	--	--
8	--	2	--	--	194	0.0103	--
9	--	--	--	--	192	--	--
10	--	4	--	--	192	0.0208	--
11	--	2	a-	--	188	0.0106	--
12	--	--	--	--	186	--	--
13	--	1	--	--	186	0.0054	--
14	--	2	--	--	185	0.0108	--
15	--	--	--	--	183	--	--
16	--	1	--	--	183	0.0055	--
17	--	2	A-	--	182	0.0110	--
18	--	1	--	--	180	0.0056	--
	--	--	--	--	179	--	--
21	--	--	--	--	179	--	--
21	--	2	--	--	179	0.0112	--
22	--	--	--	--	177	--	--
23	--	--	--	--	177	--	--
24	--	--	--	--	177	--	--
25	--	1	--	--	177	0.0056	--
Total	196	20	0	--	--	0.1070	0.0000
Adjusted for tag loss						0.1121	0.0000

Appendix Table C-9. Exploitation of northern squawfish systemwide.

P	T	Recaptures				M	Exploitation			
		Sport	Dam	LL	Misc.		Sport	Dam	LL	
1	3,081	--	--	--	4	--	--	--		
2	582	--	--	--	--	3,077	--	--		
3	488	--	3	--	2	3,659	--	0.0008		
4	389	--	4	--	6	4,142	--	0.0011		
5	414	--	4	--	2	4,521	--	0.0009		
6	250	27	3	--	1	4,929	0.0055	0.0006	--	
7	302	43	12	--	--	5,148	0.0084	0.0023	--	
8	--	39	10	1	6	5,395	0.0072	0.0019	0.0002	
9	--	47	7	--	2	5,339	0.0088	0.0013	--	
10	--	54	7	1	12	5,283	0.0102	0.0013	0.0002	
11	--	32	4	--	4	5,209	0.0061	0.0008		
12	--	21	10	--	6	5,169	0.0041	0.0019	--	
13	--	23	3	--	1	5,132	0.0045	0.0006	--	
14	--	16	18	--	2	5,105	0.0031	0.0035	--	
15	--	12	3	--	4	5,069	0.0024	0.0006		
16	--	11	5	--	1	5,050	0.0022	0.0010	--	
17	--	10	2	--	2	5,033	0.0020	0.0004	--	
18	--	9	3	--	3	5,019	0.0018	0.0006		
19	--	9	2	--	--	5,004	0.0018	0.0004	--	
20	--	5	3	--	--	4,993	0.0010	0.0006	--	
21	--	6	--	--	5	4,985	0.0012	--		
22	--	3	1	--	--	4,974	0.0006	0.0002		
23	--	3	--	--	--	4,970	0.0006	--	--	
24	--	3	--	--	--	4,967	0.0006	--	--	
25	--	1	--	--	--	4,964	0.0004	--		
Total	3,837	374	104	2	--	--	0.0725	0.0208	0.0004	
Adjusted for tag loss								0.0760	0.0218	0.0004

APPENDIX D

Tables of Backcalculated Lengths, Age at Length Keys, and Von Bertalanffy Growth Parameters

Appendix Table D-1. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from John Day Reservoir, 1992.

Year Class	Age														
	12	3	4	5	6	7	8	9	10	11	12	13	14	15	
1991	78														
1990	62	119													
1989	50	87	133												
1988	57	99	142	184											
1987	49	130	176	218	256										
1986	45	123	180	216	245	283									
1985	50	127	190	236	266	291	314								
1984	47	144	207	253	287	312	334	354							
1983	45	145	215	260	298	329	353	376	397						
1982	44	146	218	270	309	341	366	389	409	426					
1981	43	129	195	251	296	330	357	379	404	422	442				
1980	45	155	216	256	309	338	365	390	416	440	459	480			
1979	48	144	203	249	288	322	351	380	407	426	445	460	474		
1978	43	166	209	247	287	319	342	370	395	425	450	472	490	506	
1977	59	108	162	228	265	291	317	347	370	398	422	445	463	480	493
N	201	200	190	185	180	173	162	144	110	68	39	24	13	5	2
Mean	47	137	202	250	289	320	347	375	403	427	447	469	476	495	493
SD	9	30	35	35	35	36	35	34	32	31	28	26	27	28	23
Increment	47	90	65	48	39	31	27	28	28	24	20	22	7	19	--

Appendix Table D-2. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from the Columbia River downstream from Bonneville Dam tailrace, 1992.

Year Class	Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1991	85															
1990	47	103														
1989	43	116	165													
1988	43	117	162	198												
1987	44	135	188	223	256											
1986	46	137	201	240	267	295										
1985	45	147	202	242	279	310	339									
1984	46	144	200	246	286	322	346	368								
1983	47	142	199	241	283	323	357	384	409							
1982	47	144	202	251	292	328	360	391	415	440						
1981	46	146	206	250	293	328	360	389	414	435	453					
1980	46	131	201	250	291	327	357	386	412	437	458	479				
1979	47	129	201	260	306	345	378	404	428	447	469	490	503			
1978	49	158	220	253	297	323	349	389	417	450	475	495	511	529		
1977	47	112	165	225	250	288	320	352	380	404	432	454	472	491	512	
1976	38	130	164	201	246	293	324	348	373	395	418	444	471	495	510	526
N	421	419	362	305	244	191	157	122	98	72	49	31	11	6	3	1
Mean	45	128	187	232	277	317	352	383	412	437	456	480	497	511	511	526
SD	8	27	31	34	32	32	31	30	28	30	29	31	23	32	19	--
Increment	45	83	59	45	45	40	35	31	29	25	19	24	17	14	0	15

Appendix Table D-3. Age-frequency distribution by length interval for a subsample of northern squawfish from John Day Reservoir, 1992.

Fork length interval (mm)	Age														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
50-74															
75-99															
100-124	1	4													
125-149		4	3												
150-174		2		21											
175-199				2	1										
200-224				2											
225-249					1										
250-274					13		5								
275-299					3	6									
300-324					1	1	3	4	1						
325-349							6	12	3						
350-374						1	3	11	8	1					
375-399							1	4	10	5	2				
400-424								1	10	8	1	1			
425-449								2	6	4	8				
450-474									2	10	1	5	2		
475-499									2		3	5	3	2	1
500-524										1		1	2		1
525-549														1	

Appendix Table D-4. Age-frequency distribution by length interval for a subsample of northern squawfish from the Columbia River downstream from Bonneville Dam tailrace, 1992.

Fork length interval (mm)	Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
50-74		5														
75-99		20														
100-124	1	17	1	1												
125-149		8	7	4												
150-174		7	18	8												
175-199			18	13												
200-224			10	16	6	1										
225-249			4	9	15											
250-274				7	12	7										
275-299				3	9	10	3									
300-324					5	8	8	1								
325-349					6	6	5	4								
350-374						1	12	9	1	1						
375-399						1	6	3	10	1						
400-424							16	8	2	2						
425-449								14	6	5	4					
450-474									2	10	7	1				
475-499									1	3	3	10	1	1	1	
500-524											13	4				
525-549												1		1	1	1
550-574												1		1		

Appendix Table D-5. Von Bertalanffy growth parameters for northern squawfish captured in 1992. Linf = maximum asymptotic fork length, K = growth coefficient, and t0 = theoretical age at which fish length = 0.

Location	Linf	K	t0
Downstream from Bonneville Dam tailrace	586	0.147	0.548
John Day Reservoir	528	0.191	0.845

REPORT H

Economic, Social, and Legal Feasibility of Commercial, Sport, and Bounty Fisheries on Northern Squawfish

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1992 Annual Report

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We thank the many people who worked on and contributed to this project throughout the season: Dan File, Rich Coparanis, Tom Lorz, Ron Smith, Dolly Hughes, Josiah Akinsanmi, and Anna Cox.

ABSTRACT

We report on our research conducted from April 1, 1992, through March 31, 1993, to analyze the economic, social and legal feasibility of commercial, sport, and bounty fisheries on northern squawfish (*Ptychocheilus oregonensis*). Northern squawfish were provided to this project from three removal fisheries -- the commercial longline fishery, the sport-reward fishery, and the dam angling fishery.

We evaluated the operations of the three fisheries -- commercial longline, sport-reward, and dam angling. We developed an extensive collection, transportation, storage and delivery system for northern squawfish landed by the commercial longline, sport-reward, and dam angling fisheries.

We continued to evaluate a range of alternative end uses for northern squawfish. These included minced food products, roe, fish meal, export food markets, and liquid fertilizer.

We conducted an assessment of social issues related to the four fisheries, including positive interactions as well as conflicts. We surveyed participants and employees of each fishery as well as enforcement personnel to identify areas of potential concern in the continued operation of these fisheries.

INTRODUCTION

The 1992 season continued our research of the feasibility of alternative fisheries for northern squawfish (*Ptychocheilus oregonensis*) first begun in February 1989. This report summarizes our research activities and results during the 1992 performance period, from April 1, 1992, until March 31, 1993. The 1992 project has five objectives related to the continued evaluation of the economic feasibility of commercial and bounty fisheries on northern squawfish. These five objectives are listed below.

1. Continue to evaluate the economic effectiveness of sport, bounty, and commercial fisheries on northern squawfish.
2. Collect, transport, store, and distribute all northern squawfish collected during the 1992 fishing season.
3. Continue the development of value-added products.
4. Continue to explore new uses for northern squawfish.
5. Continue the evaluation of regulatory and social issues related to the conduct of sport, bounty, and commercial fisheries for northern squawfish.

This report presents results of research activities conducted under the five project objectives. Discussions are presented on five subject areas -- fishery operations, distribution of catch, catch utilization, social issues, and regulatory issues.

METHODS

Fishery Operations

Sites of fishery operations expanded in 1992. Harvest sites included eight **mainstem** dams and the John Day Reservoir of the Columbia River. Northern squawfish were harvested by three different types of fisheries -- commercial longline, sport-reward, and dam angling.

Northern squawfish harvested by these fisheries were provided to this project during different time periods. The dam angling fishery was conducted between April 19 and September 6. The sport-reward fishery operated between May 18 and September 27. The commercial **longline** fishery operated between May 16 and August 31.

Operations of the three northern squawfish test fisheries were monitored by this project for logistics of operations, collection and handling systems, total catch per site, agency expenditures, total expenditures, and actual or potential conflicts.

Sources of data to assess fishery operations varied by fishery. Commercial fishery operations were monitored by two data sources -- operating costs per fishing trip and agency expenditures. Data on operating costs were collected per trip and incorporated into a trip logbook form developed by the Oregon Department of Fish and Wildlife (ODFW). Data elements include catch, effort, incidental catch, operating expenses, and administrative expenses. The curtailed commercial fishery season precluded a telephone survey of commercial fishery observers or fishermen. Data on expenditures incurred by the ODFW to set up and operate the commercial fishery were provided by the project manager.

Operations of the dam angling fishery were monitored by two sources of data -- catch data and agency expenditures. Further assessments of dam angling fishery operations will be made through a survey of dam supervisors. The major questions of interest to the feasibility project concerning the dam angling removal method are the effectiveness (in terms of northern squawfish removals) per unit cost and the interactions with other project components, dam operations, and the general public. Data elements required for the feasibility analysis are fishing effectiveness expressed in catch per unit effort, incidental catch, gear, bait, time spent fishing, labor costs, and equipment costs.

Six sources of data provided monitoring of the sport-reward fishery -- vouchers, registration forms, catch weight, agency expenditures, a survey of creel clerks, and a survey of non-returning anglers. We revised the survey instrument used in 1991 to collect data from the sport-reward fishery. The angler survey included questions on time spent fishing, fishing method, gear used, catch, incidental catch, residence, distance travelled to fish, fishing experience, expenditures associated with fishing, experience with northern squawfish, and opinions about the northern squawfish sport-reward fishery. Data were entered throughout the 1992 fishing season; approximately 15,000 survey forms have been coded and processed to date. The design of the survey instrument was coordinated with the Washington Department of Wildlife (WDW). The sport-reward fishery survey form is presented in Appendix D.

The survey was administered to every participant in the sport-reward fishery returning to a registration site. The payment voucher certifying the number of northern squawfish caught was incorporated into the survey form to ensure a high level of survey response. Receipt of payment for landed squawfish was dependent on the completion of the survey form.

A significant number (approximately 65%) of anglers did not return to the registration site. The 1991 survey form was revised to be administered by telephone to a sample of non-returning anglers. The survey form is presented in Appendix D.

We were also interested in the creel clerks' perspective on fishery operations and suggestions for improvement. **Creel** clerk supervisors at each registration site were surveyed. Supervisors were contacted by telephone, interviewed about any problems encountered, and asked to identify any areas of needed change in the operations of the sport-reward fishery. The 1992 telephone survey form used to interview creel clerk supervisors is presented in Appendix D.

Distribution of Catch

1992 is the second year of the Northern **Squawfish** Predator Control Program that has required an extensive fish handling and transportation network. The 1992 handling network was designed to accomplish two principal goals: (1) collect food-grade northern squawfish, and (2) accommodate the handling **needs** of the removal fisheries.

To satisfy these requirements, the handling network operated with the following components.

1. Oregon State University (OSU) purchased handling equipment from 1990-1992 including chest freezers, insulated and non-insulated commercial fishing totes, and coolers. This equipment was distributed to participating agencies and subcontractors.
2. OSU subcontracted five private fish processors who received, packaged, and froze the squawfish harvested by the sport reward and dam angling fisheries. The fish processors were at these locations:

<u>Location</u>	<u>Processor Name</u>
Longview, WA	Tri-River Smelt
Portland, OR	Point Adams Packing Company
Cascade Jocks, OR	Bonneville Fisheries
The Dalles, OR	Kingfish Trading Company
Richland, WA	Wellsian Cold Storage

3. Sport-reward technicians delivered their daily catch to the processors and picked up fresh coolers and ice for the next day. OSU employees picked up full coolers from Bonneville, The Dalles, and **McNary** dams and delivered them to Kingfish or Bonneville Fisheries.
4. For logistical and cost reasons, low volume and distant harvest locations (John Day Dam, Snake River dams, Snake River sport-reward sites) were not serviced by fish processors. The squawfish from these areas were either frozen in chest freezers and collected by OSU employees **later** or were delivered daily by Washington Department of Wildlife technicians to a local subcontractor who made arrangements for a rendering pick-up.

5. OSU subcontracted Americold Cold Storage in Wallula, Washington, and Nampa, Idaho, and Pacific Cold Storage in Portland. These facilities stored frozen squawfish and served as the pick-up locations for shipment to end-users.
6. OSU rented a **30,000-pound** truck for delivering equipment to processors (coolers and totes), picking up frozen fish from remote locations, and transferring frozen fish from processors to cold storage facilities.
7. OSU subcontracted May Trucking in Portland to handle deliveries to Inland Pacific Fisheries in Payette, Idaho.
8. Stoller Fisheries picked up boxed fish from the cold storage facilities for delivery to the Spirit Lake, Iowa, processing plant.
9. OSU currently rents warehouse space from Intermountain Industrial Supply for storing equipment.

Catch Utilization

Catch of northern squawfish was utilized in five ways in the 1992 season -- two different minced food fish products, roe, food fish exports, fish meal, liquid organic fertilizer.

OSU Value-Added Product Experiments

Approximately 2,000 pounds of fresh and frozen northern squawfish were delivered to the Oregon State University Seafood Lab in Astoria, Oregon, for experimentation.

The first objective of the 1992 experimental work at the OSU Seafood Laboratory was to study the feasibility of using northern squawfish for surimi production and to evaluate the yields and compositional characteristics of surimi prepared from this species of fish. The effect of fish preprocessing storage time (freshness of raw materials) and surimi frozen storage time on the gel-forming ability and whiteness of surimi products was investigated. The interaction between frozen storage time and preprocessing storage time was also studied. An additional objective was to evaluate the roe from northern squawfish. A final objective was to evaluate mince made from frozen squawfish for texture characteristics and determine the shelf-life stability of the mince made with and without cryoprotectants.

About 350 kg northern squawfish were gathered at dam sites along the Columbia River through the sport bounty program in July 1992. Fish were packed in ice after capture and transported to the OSU Seafood Lab in Astoria within 24 hours. All fish were packed in ice chests with three layers of fish per chest. Each layer of fish was covered with a layer of ice. Excess water was continuously drained and additional fresh ice was added only to the top layer of fish during the storage period to replenish melted ice. The chests of iced fish

were held in a thermostatically controlled cool room (4° C). At intervals of 0, 3, 6, 9, and 13 days, about 70 kg fish were taken from storage for surimi production. The **K** value, an index of fish freshness calculated as the ratio of the sum of hypoxanthine and inosine to the total amount of adenosine 5'-triphosphate (ATP) related compound, was determined by a modified HPLC procedure (Ryder 1985).

Surimi Production

The fish were hand planked (separation of musculature and bone from head, backbone, tail and viscera) prior to deboning to avoid contamination by the viscera and notochord material, which could influence color and flavor and catalyze rancidity. The planks were deboned with an Acacia Deboner Model 805; drum perforations were 0.4 cm in diameter (Acacia Tekkosho, Ltd., Japan). The belt tension was adjusted to remove skin from plank as well. The minced flesh was washed in polyethylene tanks with water and ice at a ratio of 1 part flesh to 3 parts water (w/w) and gently stirred for 5 minutes, followed by holding for 5 minutes. Washed mince was dewatered in a Sano-Seisakusho screw press Model SD-8 (Acacia Tekkosho, Ltd., Japan). Two wash and three wash procedures were run to compare washing efficiency for squawfish surimi production. The last wash in both cases included 0.1% NaCl to facilitate dewatering. The press was operated slowly during the last wash to produce the lowest possible moisture content in the flesh. The dewatered flesh was refined with an Akashi strainer Model S- 1 (Akashi Tekkosho Co., Japan) to remove connective tissue, bone particles and skin. The refined flesh was cooled in the freezer for about 45 minutes to keep flesh at low temperature for the next mixing step. Surimi was prepared by mixing the refined flesh with 4.0% sucrose, 4.0% sorbitol, and 0.3% Brifosol 512 (B.K. Ladenburg Corp. North Hollywood, CA) in a Hobart Silent Cutter, Model VCM (Hobart Manufacturing Co., Troy, OH) for 2 minutes. Product temperatures were maintained near or below 10° C. Aliquot of 400 g surimi were packed into individual plastic trays, vacuum packaged and frozen at -18° C. The freshness of fish for surimi production was measured each time. Samples were taken during each surimi production unit operation for proximate analysis. Surimi quality was monitored by torsion test and color measurement after frozen storage for 0, 30, 90, 150, and 180 days.

Surimi Gel Preparation

Partially thawed surimi was used for the preparation of all gels. The moisture content of surimi was determined by microwave method developed by our lab. The formulations were calculated based on the percentage of moisture in the surimi. Seventy-eight percent moisture content was adjusted and 2% NaCl (total weight) was included in each formulation.

All formulations were chopped in a Stephan Vacuum Chopper/mixer (Stephan Machinery Corporation, Model UM-5) for 4 minutes. During the first minute, salt and ice was added. During the last three minutes, mixing was carried out under vacuum conditions. Caution was taken to keep the temperature below 10° C to diminish protein denaturation. The batters were extruded into stainless steel tubes (1.87 cm internal diameter by 17.75 cm length) using a sausage stuffer (Sausage Maker, Model 14208, Buffalo, N.Y.) without air

pockets. The tubes had previously been sprayed with a lecithin-base release agent. The tubes were sealed at one end by a threaded cup and on the other by rubber stoppers and cooked in 90° C water bath for 15 minutes. The tubes were immediately cooled in ice water after cooking. The gels were removed from the tube and stored in sealed plastic bags under refrigeration (4°C). Gel forming ability was evaluated within 24 hours by torsion test.

Evaluation of Gel Properties

Torsion Test

Gel sample was cut into a dumbbell geometry and subjected to torsional shear in the modified Brookfield viscometer (Kim et al. 1986). The results were reported as shear strain and shear stress, which were calculated using the equation developed by Hamann and Lanier (1987). Stress values are indicative of gel strength and are affected by moisture and protein content while strain value is related to gel cohesiveness and is a better measure of gel-forming ability and protein quality.

ph Measurement

A 10-g sample of each gel was blended with 90 mL distilled water for 1 min using Osterizer pulsematic 10 blender (Oster Corporation, Milwaukee, WI) at frappe' speed. The pH was measured using a standardized Corning Ph meter Model 250 (Corning Ciba Diagnostics Co., Corning, NY).

Color Evaluation

Color of the gels was measured using Minolta Chroma Meter CR-300 (Minolta Camera Co. Ltd., Osaka, Japan), which gave output in L*, a*, b* color coordinates, as described by the manual. This instrument was standardized by using a black plate and a standard white plate (perfect diffuse reflector; L*=82.13; a*=-5.24; b*=-0.55). In the CIE L*a*b* system, L* is a measure of light intensity, a* values represent the chromatic scale from green(negative a* values) to red (positive a*), and b* values represent the chromatic scale from blue (negative b*) to yellow (positive b*). Whiteness was calculated as $100 - ((100-L^*)^2 + a^{*2} + b^{*2})^{1/2}$.

Proximate Composition

The total protein, lipid, ash, and moisture content of flesh at each stage of processing was determined for each of the five lots of surimi prepared (AOAC 1984). Composition after each stage of processing was determined -- deboned flesh, flesh after the first, second and third wash, refined flesh and prepared surimi.

Squawfish Roe

Thirty-one squawfish were sampled for roe in late spring. Fish samples were collected from holding pens below the dams and were transported in ice to the OSU Seafood Laboratory. The fish arrived at the laboratory in excellent condition and were samples immediately.

Use of Frozen Squawfish for Mince

The objective of this experiment was to determine the potential for a mince being prepared from frozen squawfish. The mince was frozen with and without cryoprotectants and analyzed for texture qualities. Frozen **squawfish** was transported to OSU Seafood **Lab** in the frozen state. The fish were planked and a minced was obtained by the use of a deboner mentioned in previous sections. A K-value to determine freshness was run on the thawed fish.

Stoller Minced Food Product

On the basis of the successful 1991 experience with production of minced food products from northern squawfish, Stoller Fisheries of Spirit Lake, Iowa, requested access to large quantities of food grade northern **squawfish** in 1992. Stoller Fisheries processes freshwater rough fish primarily for the kosher market. Approximately 88,000 pounds of frozen food grade northern squawfish were shipped to Stoller Fisheries during the 1992 season.

Liquid Fertilizer

A total of 126,000 pounds of northern squawfish were shipped to Inland Pacific Fisheries Inc., Payette, Idaho, for liquid fertilizer processing.

Seafood Brokers

Approximately 600 pounds of frozen food grade northern squawfish were provided to two seafood exporters for market tests.

Mink Food

On the basis of successful 1991 feeding experiments, the OSU Experimental Fur Farm again requested northern squawfish. Approximately 9,500 pounds of industrial grade northern squawfish were delivered to the farm for feed.

Salmon Habitat Restoration Experiments

Approximately 320 pounds of northern squawfish were provided to the Oregon Department of Fish and Wildlife for stream enrichment research. Initial quantities of

northern squawfish were used to test for research suitability. On the basis of the 1992 tests, requests for further supplies of northern squawfish will be received in 1993.

Rendering

Northern squawfish that were not of sufficient quality to be processed as either food or fertilizer were transported to a renderer. Approximately 44,400 pounds of northern squawfish were rendered in 1992.

Social and Regulatory Issues

The 1992 assessment of social issues and regulatory associated with the **development** of full-scale fisheries for northern squawfish is based on information from the operation of the three removal fisheries and on issues raised during the environmental. assessment process. Information on conflicts or other social issues occurring either on the water or on shore during the 1992 season was collected through surveys of participants and employees in each fishery.

Issues related to dam angling were identified by asking staff of the Columbia River Inter-Tribal Fish Commission (CRITFC) to summarize their experiences with the fishery, surveying the dam crew supervisors, and by contacting representatives of the U.S. Army Corps of Engineers in the Portland and **Walla Walla** districts.

Sport-reward fishery conflicts were identified through a summarization of angler comments on voucher forms, the survey of non-returning anglers, and a telephone survey of creel clerk supervisors. Enforcement issues were identified through survey comments, summaries of enforcement personnel, and project meeting summaries.

Concerns about the safety of human consumption of northern squawfish were addressed in 1990 through the provision of 11 samples of northern squawfish to the Oregon Department of Environmental Quality ,(DEQ) Division of Water Quality Planning, to test northern squawfish tissue and organs for dioxin contamination. Previous tests performed by the DEQ for pesticides (**PCBs**, chlordane, DDT derivatives) and heavy metals (mercury, aluminum, lead, arsenic) revealed levels safe for human consumption (Hanna 1990).

Samples of northern squawfish and sediments taken from eleven Columbia River sites (Hanna and **Pampush** 1991) were sent to the Environmental Protection Agency (EPA) Laboratory in Duluth, Minnesota, for dioxin tests in 1991. Due to several processing delays at the laboratory, dioxin test results were not received until October 1992.

RESULTS

Fishery Operations

Commercial Fishery

The commercial **longline** fishery was conducted by three contracted fishing crews and an ODFW vessel with three seasonal employees. Fishery oversight and management was provided by ODFW. The fishery was operated as a subsidized "reward" fishery. Fishermen were compensated \$250 per day for each fishing day that met minimum requirements of time and gear in the water. In addition to the daily compensation, fishermen were paid \$3 per fish for all fish over 11 inches long. Gear and bait were provided to the fishermen by the University of Washington project and by ODFW.

A total of 1,758 longlines and 161,458 hooks were set during the 1992 season. Harvested catch totaled 2,150 northern squawfish, of which 1,340 met the minimum size requirement and qualified for payment. This resulted in direct payments for northern squawfish of \$4,020.

Direct agency expenditures made by ODFW for the commercial **longline** fishery through August 1992 are summarized by category in Appendix B. Direct expenditures **totalled** \$113,725. Indirect expenditures made by ODFW and other projects for the operation of this fishery (primarily in time) are acknowledged, but unquantified.

The low levels of catch in the 1992 **longline** fishery (1340 qualifying fish) resulted in a high level of expenditure-per-squawfish removed at \$84.87 per fish.

Dam Angling Fishery

The 1992 dam angling fishery was again conducted on eight Columbia and Snake River dams -- Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville. Management and oversight of the dam angling fishery was provided by the Columbia River Inter-Tribal Fish Commission, which subcontracted operations on some dams to tribal fishing crews. The focus of interest for the feasibility project in this fishery are fishing effectiveness (CPUE), incidental catch, and costs for gear, bait, and labor and equipment.

Total agency (CRITFC) expenditures and expenditure per fish removed by fishing crew in the dam angling fishery are presented in Appendix C. Expenditures include all expenditures dedicated to the operation and oversight of nine fishing crews -- crews located at Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental dams, a combined Little Goose and Lower Granite dams crew, a mobile crew and a volunteer angling group. Some crews were supervised directly by CRITFC and some through subcontractors.

Most crews are associated with dams, but some (Little Goose and Lower Granite combination, the mobile crew, and the volunteer crew) were not.

Catch figures in Appendix Table C-2 represent each crew's catch and may therefore not exactly correspond to catches reported for each dam. For example, the Lower Monumental crew fished Lower Monumental Dam and Ice Harbor Dam, The Dalles Dam, and John Day Dam at various times in the season. The crew's catch represents their catch from all dams at which they fished.

Total expenditure figures reported for each fishing crew in Appendix Table C-1 include costs of project administration. Administrative costs associated with the dam angling fishery not directly allocable to particular crews were distributed among the crews on a proportional basis. Proportions of total administrative costs assigned to each crew ranged from .01 for the volunteer angling crew, to .17 to the combined Little Goose and Lower Granite crews. Crews that were supervised directly by CRITFC and crews that required extra oversight attention accounted for a higher proportion of total administrative costs.

Examples of total administrative costs apportioned among fishing crews include centrally procured supplies, CRITFC data processing equipment, CRITFC storage rental and project vehicle lease, administrative time spent drafting subcontractor agreements and work statements, attending coordination meetings, processing data, and writing reports.

Subtracted from total cost figures in Appendix Table C-1 are fish handling costs, estimated at \$.42 per fish. The fish handling costs, calculated at an estimated handling time of two minutes per fish, are those costs in excess of the cost of disposing of caught fish into the river. Fish handling costs are considered an "opportunity cost" of foregone catch through not being able to fish during the time fish are being processed.

Also not included in total costs are costs of developing work plans, which were unfunded, and costs of developing the 1993 statement of work, a total of approximately \$37,000.

Costs per fish when all administrative costs are included ranged from a low of \$14 per fish for The Dalles and McNary crews, to a high of \$106 per fish for the Lower Monumental crew. Because most operating costs are fixed, cost per fish depends on the size of the catch; the larger the catch, the larger the number of fish among which to distribute the fixed costs, and the smaller the average cost per fish.

Appendix Table C-2 presents per-site operating costs, total catch, and costs per fish without administrative costs apportioned among sites. This cost calculation is made to present a cost-per-fish estimate that is comparable to those of the sport-reward fishery, which does not include project administrative costs in its estimates.

Without apportioned administrative costs, expenditures by crew per fish removed at several sites decrease to levels that are comparable to the per-site expenditures per fish

removed in the sport-reward fishery. Removing the two most extreme cases -- the Lower Monumental and the combined Little Goose and Lower Granite crews -- from the calculation results in an average fishery-wide expenditure of \$12.86 per fish removed, as compared to a fishery-wide figure of \$9.68 in the sport-reward fishery (Appendix Table D-2).

Comparisons of expenditures per **fish** removed between fisheries should appropriately be done on the basis of total project expenditures related to implementation of each fishery. Costs for monitoring, enforcement, avoidance of negative impacts, and quality control should be included in the assessment of total costs so that comparable calculations are made. These costs have not been accounted for by all fisheries to date.

Sport-Reward Fishery

The sport-reward fishery began on May 18 and encompassed 20 check stations along the Columbia and Snake rivers. We again used a combined voucher-survey form to collect information from participating anglers. Information collected included fishing time and methods, expenditures, distance travelled, fishing experience, reasons for participating in the program, and various demographic variables. The 1992 survey-voucher form is shown in Appendix Figure D-1.

The sport-reward fishery involved agency expenditures for creel clerk wages, reward payments, uniforms, vehicles, fuel, oil, and miscellaneous equipment. These costs are summarized by registration check station through September in Appendix Table D-2 and Appendix Figure D-4. Expenditures at each registration site included basic labor and operating costs and thus did not vary much among sites. Catch rates did vary widely among sites, resulting in wide disparities in check station expenditures per fish removed. Average expenditures per fish removed varied between a low of \$4.68 for **LePage** Park (Check Station 11) and a high of \$45.66 for St. Helens (Check Station 3). Program costs not directly associated with check station operations are excluded from the calculations. These costs include various administrative and implementation costs for the program as a whole.

Analysis of the voucher-survey data reveals several areas in which angler participation varied among check stations. Not surprisingly, residence of anglers varied according to the location of the check station (Appendix Figure D-5). Anglers tended to use check stations closest to their homes.

Anglers varied in age from 14 to over 60, with the largest proportion of anglers in the 30-50 age bracket (Appendix Figure D-6). There were no apparent differences in age distributions among sites. A majority of anglers had high school and some college education (Appendix Figure D-7).

At all sites, the majority of anglers were experienced fishermen who had fished for over 10 years (Appendix Figure D-8). Most made over 21 trips per year; almost none were people who had begun to fish solely for the northern squawfish program (Appendix Figure

D-9). Anglers tended to be familiar with the fishing location at which they registered, with almost all making at least six trips per year to that location (Appendix Figure D-10).

The number of anglers in the fishing party varied very little across check stations. Most people fished in a party of two (Appendix Figure D-11). Similarly, the average number of hours fished also varied little, ranging 5-6 hours per day (Appendix Figure D-12). The number of northern squawfish caught per trip did vary across check stations. The lowest average catches were at St. Helens (Site 3); the highest at Columbia Point Park (Site 14; Appendix Figure D-13).

The ways anglers spent money varied across check stations (Appendix Figure D-14). Expenditures on accommodation were a relatively small part of total expenditures for all sites except Columbia Point Park, Hood Park and **Maryhill** Park. Fishing supplies were a relatively small component of expenditures except for those fishing at **LePage** Park. For most sites, money spent on restaurants, groceries and accommodations comprised about half of total expenditures associated with the fishing trip.

The majority of anglers were repeat participants from the 1991 fishery. However, some sites attracted large numbers of new participants, notable M. James Gleason, Hamilton Island Boat Ramp, Bingen Marina, Dalles Boat Basin, LePage Park, Hood Park, and Green Belt Boat Ramp.

We asked anglers about their motivations for participating in the northern squawfish fishery. We asked anglers to assess the importance of four different factors in their decision to participate -- receiving a payment for squawfish, access to a recreational opportunity, covering expenses for other target species, and participating in a salmon enhancement activity. Results are presented in Appendix Figures D-16 through D-19. Receiving a payment for squawfish was seen to be very or somewhat important to the large majority of anglers, as was the access to a recreational fishing opportunity. The majority of anglers said the opportunity to cover fishing expenses was either very or somewhat important, although about 25% at each site said this was not important. The opportunity to participate in a salmon enhancement activity was very important to the large majority of anglers.

The survey of non-returning anglers covered each registration site with as close to a 2% sample as possible. Telephone contacts were often difficult; if repeated tries to contact a sample member were unsuccessful, a substitute name was drawn from a "back up" sample. The number of completed surveys for each site ranged from seven at **Windust** Park to 50 at **Covert's Landing** (Appendix Table D-3).

Non-returning anglers spent an average of four hours fishing for northern squawfish and an average of one hour fishing for other species on the same trip. Fishing time for **non-returning** anglers was slightly less than time spent by anglers who returned their catch to the registration site. Average time spent fishing for northern squawfish varied little among sites (Appendix Figure D-20).

The primary target species of non-returning anglers was northern squawfish at **all** sites. Other important target species for this group were salmon, bass, shad, sturgeon, and steelhead (Appendix Figure D-21).. The proportion of non-returning anglers catching other species incidentally to northern **squawfish** varied from 14.3% at Columbia Point and **Windust** Park to 75% at **Ringold** (Appendix Table D-5). The species composition of incidental catch is listed in Appendix Table D-6; bass was the most common incidentally caught species at all sites (239 caught by the sample contacted), followed by catfish (**109**), perch (**59**), carp (**52**), and sturgeon (45). Target species caught in combination with northern **squawfish** trips included bass (**89**), shad (**73**), catfish (**30**), sturgeon (**19**), and salmon (15; Appendix Table D-7).

An average of 26.1% of all non-returning anglers sampled caught northern squawfish. The percentage of that catch which qualified for payment (> 11") ranged from 0 to 100% (Appendix Table D-4).

Overall, non-returning anglers favored bank fishing (61.3 %) over boat fishing (38.7%), although the mix of fishing methods varied by site (Appendix Figure D-22). The bait most commonly used was nightcrawlers (43.2%; Appendix Table D-8).

The most pressing question about non-returning anglers from the fishery operation perspective was why they did not return to the registration site. For 82.6% of the **non**-returning anglers sampled, the reason was that they had not caught any fish to register. Other reasons given by a small percentage of anglers included too far to travel, too late to return when they stopped fishing, not worth the time for their small catch, and failure to fish for northern squawfish at all. Patterns were similar across sites (Appendix Figure D-23) with the exception of Cascade Locks (Station **8**), where a larger percentage failed to return because it was too late when they stopped fishing than at any other site.

'We asked non-returning anglers the same questions about motivations for participating in the northern squawfish fishery as we asked returning anglers. A fair amount of variation among sites was evident in responses to questions about the importance of payment, having a recreation opportunity, a chance to cover fishing expenses, and participation in salmon enhancement (Appendix Figures D-24 through D-27). Overall, 54% of non-returning anglers said that payment for northern squawfish was important to their participation in the fishery, while only 14.6% felt payment was not important. The opportunity to cover fishing expenses was considered very important by a smaller proportion of non-returning anglers; only 24.6% thought it was very important in terms of their participation, while 37.5% thought it was not important at all. The recreational opportunity offered by northern squawfish was very important to the large majority (74.3%) of non-returning anglers. Contributions to salmon enhancement was very important to an even larger proportion of anglers, 84.3%. Answers to the motivation questions are very similar to those given by returning anglers.

We were interested to know if those anglers who did not return to the registration site were one-time participants in the northern squawfish program or whether they participated at

other times. Of all anglers in the non-returning sample, participation and non-participation were split about evenly; 52% did not return northern squawfish for payment at any other time in 1992 and 48% did (Appendix Table D-9). Some anglers who did participate at other times during 1992 were responsible for large catches, as illustrated in Appendix Table D-9.

As a group, the sample of non-returning anglers took more fishing trips per year than the returning anglers. Non-returning anglers averaged **34** trips per year overall (Appendix Table **D-10**), as compared to 21 trips per year for returning anglers (Appendix Figure D-9).

We were interested to know whether the location of check stations were inconvenient to those anglers who did not return. As Appendix Table D-11 illustrates, check stations were judged inconvenient by only a small proportion of non-returning anglers -- 10.7% over all stations. The highest proportion of non-returning anglers judging check stations inconvenient were at **Maryhill State Park** (29.6%).

We also wanted to know whether those anglers who did not return to the check station in 1992 would be discouraged from participation in the fishery in 1993. The overwhelming majority of anglers (92.8% overall) said that they planned to participate in the fishery in 1993, giving a variety of reasons for their plans to participate (Appendix Table D-12).

The survey of creel clerks working in the sport-reward fishery supported the general conclusions of the two angler surveys. In questions about the adequacy of station operating hours, the registration process, the data collection process, staffing, equipment, and station security, the majority of creel clerks evaluated these program elements as good (Appendix Table D-13). Equipment, data forms, staffing, station security and the registration process received more "fair" or "poor" ratings than other program elements.

In terms of complaints heard by creel clerks from anglers, the most frequently heard complaints concerned registration time at sites and the quality requirements, which dictated their fish handling procedures. Check-in times, check-in paperwork, and litter in fishing areas also were subjects of complaints (Appendix Table D-14).

Distribution of Catch

The 1992 Northern Squawfish Predator Control Program harvested about 292,000 pounds of northern squawfish. Of that total, **OSU attempted** to collect food-grade squawfish from collection areas that received a total of 214,500 pounds. For the remaining 77,800 pounds, no attempt was made to collect food-grade fish; it was treated as industrial grade and converted to liquid fertilizer or animal feed (rendered).

Every northern squawfish received at a processing facility was graded according to quality (food-grade/industrial-grade). Food-grade fish were boxed and frozen. **Industrial-grade** fish were frozen in large totes. The condition of the **squawfish** upon arrival to the processing facility, and consequently the volume of food-grade fish collected, was affected by

the handling practices of the sport anglers, Washington Department of Wildlife technicians, and anglers on the dams.

Overall, the food-grade collection network was successful; 42% of the fish handled by the processors were food-grade. Considering the nature of the fishery (most fish are caught by sport anglers) and the large number of collection points (19), 42% is slightly better than expected for a start-up effort.

Collection System

Total Volume Harvested in 1992	292,300 lbs
Total Volume Handled by Food-Grade Network	214,500 lbs

<u>Quality</u>	<u>Volume (lbs)</u>	<u>% Total</u>
Food-Grade	91,030	42.4
Industrial-Grade	123,470	57.6

Distribution System

We distributed northern squawfish to nine end-users. The potential value of the end-users examined in 1992 ranged from fairly high (minced fish food products, whole fresh fish) to very low (liquid fertilizer, rendered animal feed).

<u>End-User</u>	<u>Product</u>	<u>Lbs rec'd</u>
Inland Pacific Fisheries Payette, Idaho	liquid fertilizer	126,000
Stoller Fisheries Spirit Lake, Iowa	minced fish	88,000
Rendering 3 collection sites	animal feed	44,400
OSU Mink Farm Corvallis, Oregon	mink food	6,000
Astoria Seafood Lab Spirit Lake, Iowa	value-added products	2,000
Richard Young Portland, Oregon	market testing	660
Oregon Fish and Wildlife Corvallis, Oregon	stream research	320
Thomas Mc lean Seattle, Washington	market testing	55

Service Contracts

Preparing for the 1992 field season and the unknowns associated with implementing the food-grade collection network proved to be a difficult task. Intense media coverage of the sport-reward program before the 1992 season compelled OSU to set up a network capable of handling two or three times the 1991 harvest. Decisions concerning service contracts, renting vehicles, and appropriate staffing were made difficult because of the unknown potential of the sport-reward fishery. The following discussion explains and summarizes OSU 1992 handling expenditures.

Service contracts were developed with fish processors, renderers, cold storage facilities, trucking companies, and building owners.

Five processors participated in the 1992 program. They were located in Longview, Wash.; Portland, Ore.; Cascade Locks, Ore.; The Dalles, Ore.; and Richland, Wash., and all served as receiving, packaging, and freezing areas. These contracts were based on the level of services offered and ranged from \$140/day to \$250/day. Charges included

overhead, freezing, packaging materials, ice, drop-box rent, trucking (if any), and four hours of labor. Because none of these processors were familiar with the program and the potential volume to be handled was completely unknown, the processing contracts were negotiated on a daily fee rather than a volume handled basis. The 1992 season has provided considerable insight as to how to set up future processor contracts.

Rendering was the preferred alternative at locations where processing facilities were not available and the harvest was expected to be low. Rendering contracts were set up with a butcher in Clarkston, Wash., and a market in Pullman, Wash. Squawfish from the sport-reward fishery were taken nightly to these locations and dumped into **55-gallon** drums. The merchants made arrangements **with** a regional rendering company to pick up the carcasses a few times a week. The Pullman location charged a total amount for the season of \$400 (a very low volume area) and the Clarkston location charged **\$10/55-gallon** drum. A one-time rendering charge of \$225 was paid to a Portland outfit for handling 9,000 pounds of poor quality squawfish that resulted from a freezer van breakdown.

Three cold storage facilities stored frozen squawfish -- Americold in Wallula, Wash.; Americold in Nampa, Idaho, and Pacific Cold Storage in Portland. These facilities charge by the volume handled and the length of time in the freezer.

May Trucking in Portland was contracted to transfer loads of frozen fertilizer-grade **squawfish** to cold storage in Nampa, Idaho, for later processing by Inland Pacific Fisheries.

OSU rented a fish drop-off location in Kahlotus, Wash.; an apartment in The Dalles to serve as a field station and an overnight stop for employees; and industrial warehouse space in Portland for equipment storage.

Personnel

The 1992 OSU handling crew totaled four technicians and one tech/administrator. **The crew** operated across the entire project area where they picked up frozen fish, delivered ice, picked up coolers from dams, delivered fish to end-users, repaired equipment, and investigated handling problem, areas. When on the road, personnel were given a travel per diem to cover meal costs (and motels when not staying at the field station/apartment).

Vehicles

A **30,000-pound** truck was **leased** from Rollins Truck Rental in Portland and was used to deliver and retrieve equipment, deliver large totes of ice, pick up fish from chest freezer locations, and deliver frozen fish to cold storage facilities. This truck is non-refrigerated, has a **15,000-pound** capacity, a 20-foot long cargo area, and costs about **\$2,300/month** to operate.

Two half-ton pickups and a one-ton flatbed were leased from the OSU Motor Pool and used to pick up coolers from the dams, deliver coolers and ice, and commute employees to various work locations.

Equipment

The only significant equipment purchase made by OSU in 1992 was 550 48-quart coolers for use by the removal fishery personnel. Other equipment used during the field season was purchased in previous years (totes, freezers, pallet jacks, etc.). Other minor purchases included plastic bags, rope, duct tape, keys, hard hats, tools, and hardware.

Handling and Distribution Costs

A summary of the 1992 expenditures for fish handling and distribution appears in Appendix Table E-1.

Catch Utilization

OSU Value-Added Product Experiments

Product Yield in Surimi Unit Operations

Northern squawfish yielded 39.2% planks, which produced 27.5% machine-separated minced flesh based upon round weight (Appendix Table F-1). Two 3: 1 (water:flesh) wash procedures yielded 17.3% pressed flesh, which produced 16.2% refined product and 17.9% surimi (91.7% refined flesh plus 8.3% cryoprotectants) based upon round fish weight. The yield of surimi observed was lower than 22% that Thrash reported to be economically feasible. The lower yield may be attributed to the small amount of fish used for surimi production in each lot. The small size of fish also effected the surimi yield.

Composition of Processed Flesh

The composition of flesh through processing is summarized in Appendix Table F-2. The difference in flesh moisture content among first, second, and third wash/press exchange reflected different operation procedures. The wash procedure removes water soluble components, particularly sarcoplasmic protein, which impedes the gel-forming potential of surimi. It also removes fat, ash, pigment and substances that affect the stability of proteins during subsequent frozen storage. After two washes, lipids were reduced by 22.3 % and ash by 50%. There was little difference between the second and third wash. The gel-forming ability of the surimi, measured by torsion test for the second wash and the third wash samples, showed no significant differences (data not shown). It is suggested that the two-wash regime was suitable for squawfish surimi production. We also found that moisture content of the flesh was higher after refining for both the two-wash and three-wash regime. This is probably due to the refining process causing elevated moisture content by separating

connective tissue, bone particles and skin residue **that** was lower in moisture content. Removal of these constituents also increased protein content by dry weight from 88.7% to 90.8%. The moisture content of refined flesh decreased in the surimi due to the incorporation of cryoprotectants. A net reduction of 50.2% in lipid and 65.5 % in ash content was observed by processing minced flesh into refined flesh.

Effect of Preprocessing Ice Storage on pH and Gel-forming Ability of Surimi During Frozen Storage

Fish freshness was affected by preprocessing ice storage. The K value against ice storage time is shown in Appendix Figure F-1. The K value increased rapidly in the first six days. After fish was stored in ice for nine days, the K value reached 74.3%. It is not recommended to process fish if the K value of fish exceed 75% (Ehira 1976).

However, there was little correlation between K value and gel strength measurements of the squawfish surimi. In most species, a high K value indicates breakdown of metabolic products including protein. This does not appear to be the case for **squawfish** since gel strength remained relatively high even using fish kept nine days on ice. Since different fish species have different K value patterns, our results suggest that squawfish could be used for processing although K value reached 75% after storage in ice for nine days.

There was no significant difference in strain and stress value when K value was increased with time although the Day 0 and Day 3 sample have higher strain and stress values (Appendix Figures F-2 and F-3). All treatments maintain gel-forming ability well during three months of storage except Day 13 sample, which decreased to 1.71 in strain value. According to the traditional Japanese standard, a strain of 1.8 could be considered as an acceptable grade of surimi.

Our results demonstrated that approximately nine days preprocessing time may be the acceptable time that squawfish can be stored in ice before it is made into an acceptable grade of surimi after long-time frozen storage. There were no significant differences in pH of surimi due to preprocessing ice storage. pH values remain between 6.7 to 6.9 and do not change during frozen storage.

Color of the Gels and Changes During Frozen Storage

Hunter L*, a*, b* values of gel derived from surimi made from 0 day fish are shown in Appendix Table F-3. The squawfish surimi was more red and yellow and less lighter in color compared to standard surimi color. The preprocessing time did not change the color of the gel. There was little change in whiteness during the first three-month storage period. However, the b* was a little higher than the initial value, which served as the best single indicator of color changes (Wasson 1992).

The washing process of surimi is apparently an efficient means of preventing browning reactions during frozen storage, probably by the removal of water soluble

compounds, such as enzymes, proteins, and **haem** pigments. The color of squawfish could be improved by using fillet instead of plank with skin for deboning.

Squawfish Roe

Of the 31 fished sampled, eight were males and 23 were females. The average length of the female fish was 15.77 inches and the average weight was 2.2 lbs. The average weight of the roe in the female fish was 0.26 lbs or 12% of the body weight. For the most part the roe was non-uniform in color varying from a gray color to olive green. Several of the roe had non-uniform color within the same sample.

The size of the roe was variable as well, from 1 to 2.5 mm. An organoleptic evaluation was undertaken for the roe and scored on the basis of appearance (combination of color, defects and overall appearance). On a scale of 0 to 5, the highest score was 4 while the lowest was 2. Lack of uniformity for color and size were considered some of the greater defects. These investigators feel that it would be difficult to harvest and sell squawfish mainly for the roe content. The low percent of roe to body weight, the non-uniform color and size would make it difficult to be economically feasible for a commercial venture. Results are shown in Appendix Table F-4.

Use of Frozen Squawfish for Mince

The K-value was **68%**, which is high and indicates that there was serious deterioration of the fish before freezing. Torsion tests were run on the mince fish and were found to be:

Shear Stress 28,800

Shear Strain 1.45

The stress value is adequate, but the strain value is less than desired for a initial value and indicates the mediocre condition of the frozen fish. The quality of the fish was most likely due to poor handling of the raw product, and time and temperature abuse before the fish was frozen.

Mince prepared from the frozen fish was divided into four sample lots. One lot was washed, using a similar procedure mentioned in previous reports. This lot was further divided into unmodified washed mince and washed mince mixed with cryoprotectants. An unwashed lot was also divided into samples with and without cryoprotectants.

All samples were placed into 500-g plastic containers, vacuum sealed and frozen at -30° C. These samples were transferred to -20° C frozen storage and sampled at 30, 90, and 150 days by the torsion method. The torsion method uses a twisting module that records stress (related to gel hardness) and strain (related to gel elasticity).

As shown in Appendix Figures F-1 and F-2, the washed sample mixed with cryoprotectants had superior stress and strain values to the other samples and there was little loss texture characteristics during the frozen storage. There was significant loss of strain for the washed mince if cryoprotectants were not added.

There was little change in the oxidative rancidity of either the washed or the unwashed mince over the first three months, as shown in Appendix Figure F-3. There was a slight rise from Month 3 to 5, but not sufficient to reject the product. There was little microbiological change over the frozen shelf-life of the product, as shown in Appendix Figure F-4.

Liquid Fertilizer

Deliveries of approximately 126,000 pounds of northern squawfish to Inland Pacific Fisheries in Payette, Idaho, were processed into fish fertilizer. The process has been previously assessed to be satisfactory, and no new information has been added in 1992. Fertilizer processing is a relatively low valued end use, with previously estimated exvessel prices of **\$.02-\$.05** per pound if fish were marketed.

Minced Food Product

Stoller Fisheries again processed northern **squawfish** into a minced food product in 1992. All squawfish over 9 inches long were processed into mince. The remainder were processed into fish meal. Approximately 15 % , or 12,000 lbs, of northern squawfish delivered were too small to process into mince. The presence of small fish in the mix lowered the total yield.

The quality of fish received by Stoller Fisheries was good. Fish was freshly frozen and well-packaged. Less expensive packaging materials would also be acceptable for food fish shipments. The mince was processed by itself and not mixed with other species.

The best estimate of exvessel level prices for northern squawfish if marketed is between **\$.05/lb** and **\$.15/lb**.

Renderers

The 44,400 pounds of industrial grade northern squawfish delivered to renderers was combined with other protein sources and eventually processed into animal **feed**.

Mink Feed

Surplus industrial grade northern squawfish was collected by the OSU mink farm to use as mink feed. No feeding experiments were supported in 1992.

Seafood Brokers

Northern squawfish delivered to brokers was used to test the possibilities of export markets on the Asian region. Initial results indicate estimates of exvessel prices consistent with domestic use as mince, between **\$.05/lb** and **\$. 15/lb**.

Salmon Habitat Restoration

Assessment of northern squawfish flesh for its suitability in salmon stream enrichment experiments indicates that the fish is acceptable in this use.

Social and Regulatory Issues

Commercial Fishery

The 1992 commercial **longline** fishery operated at such high cost (\$84.87 in direct expenditures per fish removed, at much higher unit cost if administrative costs were accounted for) and low levels of catch that it was discontinued in August 1992. Highly restrictive regulations imposed on this fishery continue to result in low fisherman interest and high monitoring costs. Conflicts with target fishery seasons (salmon) in Zone 6 and a reputation as a low-status “trash” fishery limit the operational possibilities of this fishery in the mode used to date.

Dam Angling Fishery

The dam angling fishery operated without notable conflict in 1992. Some minimal tension between dam anglers and sport-reward fishery participants continues to exist and will likely always exist as sport-reward participants judge higher catches-per-unit-of-effort to be available to them in restricted areas close to the dams. The availability of fish in near-dam areas to dam anglers and not to sport-reward anglers has caused resentment among a small proportion of sport anglers.

Columbia River Inter-Tribal Fish Commission (CRITFC) personnel, who provide management oversight of dam angling crews, noted some very favorable interactions in 1992 between tribal fishery technicians in the Bonneville crew and members of The Dalles Rod and Gun Club who volunteered as anglers. The fishery technicians supervised the volunteer anglers on three fishing periods at the Bonneville Dam.

A further positive outcome of the 1992 dam angling fishery noted by CRITFC personnel was the opportunity for tribal members, many of whom are commercial fishermen, to develop both the skills and acceptance as co-managers of the Columbia River’s fishery resources.

Sport-Reward Fishery

The sport-reward fishery was the largest of the three fisheries in terms of budget, geographic scope, and numbers of people involved. Approximately 37,500 anglers registered to fish for northern squawfish during the 1992 season. Over 15,000 anglers returned their catch for payment and filled out the angler survey. Due primarily to the large numbers of people involved, most of the social and regulatory issues that arise are related to this fishery.

Continuing conflict with other on-water users is evident in this fishery. Angler complaints were received about crowding with other anglers and with commercial fishermen, although few complaints of actual gear damage from conflict with other anglers or commercial fishermen were received. Some complaints were received about speeding boats, and a larger number about jet skiers. Some anglers complained about overcrowding on boat ramps, the size of boat ramps, and the wait time to launch.

Other comments made by anglers often enough to take note include questions about the voucher survey, requests that all northern squawfish be eligible for payment regardless of size, requests that dams be opened to anglers for fishing, comments about the enjoyment received from fishing, comments about the need for more flexible registration systems that would cut down on travel time and use of gas, requests that earnings from the northern program be tax-free, requests for more information on fishing techniques and the biology of northern squawfish, and criticisms of rude creel clerks and Native American commercial fishing.

The sport-reward fishery is also the source of the largest number of enforcement problems. Several issues plagued enforcement personnel throughout the 1992 season. The most important issue has to do with legitimate ownership of northern squawfish and establishing the location of catch. Both parts of this issue relate to establishing the eligibility of a northern squawfish for payment. Northern squawfish must be checked in by a registered angler to be eligible for payment. If northern squawfish can be transferred between anglers, there is no requirement that an angler in possession of northern squawfish at the time of interception by enforcement personnel be registered to fish in the fishery. This makes it extremely difficult for enforcement personnel to determine whether an unregistered angler in possession of northern squawfish caught those fish in eligible waters or from waters outside the system included in the predator control program. The greatest potential for abuse of the northern squawfish payment system lies in the possibility of party fishing for northern squawfish outside the area of the predator control program, with delivery of large numbers of ineligible fish to check stations for payment. Establishing legitimate ownership of northern squawfish and legitimate source of catch are continuing problems for enforcement personnel.

The survey of a sample of non-returning anglers revealed few social or regulatory issues related to their participation in the fishery. For a few of the non-returning anglers, hours of registration site operation or location of the registration site contributed to their failure to return northern squawfish for payment. For the vast majority, however, failure to

catch qualifying northern squawfish was the reason for not returning to the site. Anglers participated at other times in the fishing season, and most planned to participate again in 1993. Conflicts with other anglers or with other river uses were not mentioned as factors in their fishing trips.

For the creel clerks employed in the sport-reward fishery, interaction with the public was seen overall as a positive aspect of their job. Some problems arose with security at isolated registration sites; 19% saw station security as only fair or poor.

Contaminant Tests

Dioxin test results have now been received from the Oregon Department of Environmental Quality. They are presented in the Interim Report (Appendix A). The dioxin test results are also included with results of tests for organic pesticides and heavy metals and presented in Appendix G.

DISCUSSION

Fishery Operations

Commercial Fishery

Operations of the commercial fishery have been discontinued for the foreseeable future. Extremely low catch rates in 1992 and the resulting high costs per fish removed indicate significant problems with achieving cost-effectiveness comparable with the other two removal fisheries.

To date, fears about incidental catch of game or protected species have driven the choices of gear and regulations in the commercial fishery. The overriding incidental species concerns have hindered the development of a commercial fishery through the development of rules that are inconsistent with the operational flexibility required of commercial fisheries.

One way to further explore commercial fishery feasibility would be to redesign the fishery to conform more closely with standard commercial fishery operations. This approach would rely on the active participation of commercial fishermen in the design, implementation, and oversight stages. The 1992 fishery did include an advisory board of fishermen, but this board was not active nor was it a participant in the design of regulations under which the fishery operated. Commercial fishermen experienced in the harvest of "rough fish" work throughout the region and would be available to operate an experimental fishery on a contract basis. Incidental catch concerns would be addressed in this type of fishery through on-board observation and monitoring of fishery operations.

Dam Angling Fishery

Catches of dam angling crews varied widely, leading to similar variations in expenditures per fish removed in this fishery. Compared to the sport-reward fishery, average costs per fish removed were somewhat higher. However, the sport-reward fishery had large levels of administrative costs (costs associated with program operation not specific to a particular site) that were not included in the budget presented. A cost-effectiveness comparison between the sport-reward and dam angling fisheries is **not** possible without a full accounting of costs associated with each program.

The reasons for the wide disparity among catches by crews are not apparent from the data used to prepare this report. It would be useful to know whether crew organization or contracting arrangements affect crew performance in ways that can be modified for the 1993 fishery.

Sport-Reward Fishery

The wide variation in cost per fish removed among sites justifies a reassessment of the number of registration sites and their location for 1993. The base level of operating costs per site suggests efficiencies to be realized through the consolidation of the number of sites and increased streamlining of operations. High administrative costs associated with the large number of registration stations, employment of biologists at sites, and quality control difficulties associated with a large number of individual fishermen result in high costs per squawfish removed from the system.

In general, anglers are satisfied with the reward aspect of the fishery, although there is a minority that requests higher reward payments and questions the existence of commercial or dam fisheries. However, the large numbers of anglers who see the recreation opportunity provided by northern squawfish fishing and the contribution to salmon enhancement as important motivations for their participation indicate that an increase in the reward is not necessary for continued participation. It may even be possible to decrease the reward payment and continue participation at levels high enough to accomplish removal goals. **Midlevel** reward payments (\$2 per fish) were in the original experimental implementation plan, but were never instituted.

Complaints about processing time at stations continue; perhaps angler processing time could be streamlined in 1993 through changes in site operations and biological sampling procedures. More flexible registration procedures would be appreciated by a large segment of the angling Population. The creel clerk survey supported the complaints of some anglers about lengthy processing times, although overall creel clerks were more concerned with poor equipment and needs for improved station security.

The fears about the high numbers of non-returning anglers being related to poor check station location or discouragement with the fishery were not borne out by the survey. The overwhelming reason for not returning to the check station site was failure to catch northern

squawfish on that trip. However, poor catch on one trip did not discourage anglers from either further participation in the 1992 fishery or plans to participate in the 1993 fishery. Check stations were evaluated to be conveniently located by the large majority of anglers surveyed.

Distribution of Catch

Overall, the 1992 food-grade collection network was a success, but many improvements can be made to make a future operation run much more efficiently, collect a greater percentage of food-grade **squawfish**, and cost considerably less. In 1993 and beyond, the handling network will be operated with two major objectives, realizing these objectives will affect all the agencies participating in the removal program: (1) incorporate as much private sector participation possible, and (2) minimize handling and distribution costs.

Handling Recommendations

1. Overall handling must improve; conscientious handling should be considered part of the job.
2. Fish must be iced immediately, the melt-water drained after the fish are chilled, and iced again. Once the fish are chilled to near freezing, the ice will melt at a very slow rate.
3. Ice should be used judiciously; huge amounts of ice were wasted in 1992.
4. Any fish that are cut open or are in obviously poor condition should be separated from other fish at all times.
5. Fish that get dirty should be cleaned before they are iced.
6. Dam anglers should drop their fish directly into coolers with ice. There is no need to kill them.
7. Washington Department of Wildlife technicians should drop fish directly into coolers as they are being counted and should not remove them from the coolers afterwards.
8. During the 1993 field season, OSU will transfer ownership of handling equipment (coolers, freezers, and totes if necessary) to the agencies who use this equipment in the field. In the context of a network operated principally by the private sector, efficiencies will be realized by equipment ownership and accounting that is under each project's control.
9. A 65% to 75% rate of food-grade collection in 1993 is an attainable goal.

Future Handling Network Recommendations

'Experience in 1992 has led to the following recommendations for future set up and operation of the fish handling network.

1. Subcontract local fish processors, meat markets, or cold storage facilities to serve as receiving and packaging locations. These facilities should have enough freezer space to store at least a week's worth of frozen fish (preferably more) and have ice available. Ideally, someone would be present in the evenings to receive the incoming **squawfish** and process them that night. The contracts should include a fixed overhead/labor rate with additional payment based on the volume handled. These contracts could be put out as competitive bids, but it seems that one is lucky to find even one processor in a given area that can satisfy the needs of the program.
2. In as many locations possible, the Washington Department of Wildlife should hire technicians who can work in the field and process fish in the evening. A setup of this type is by far the least expensive handling option available because it greatly reduces redundant labor charges and other "hidden" costs. People who have worked for local processors in the past would be good candidates for these jobs and could train others to grade fish as well. This ideal situation is not available everywhere, but has potential in 1993 for Longview, Clarkston, and Cascade Locks. This system should be pursued as a first option in all locations possible.
3. Subcontract a trucking outfit or fish processor who delivers fish regionally to pick up frozen squawfish from the food-grade collection locations. This task could be put out as a competitive bid in the future. This service would eliminate the need for OSU to pick up fish in a large rental truck.
4. Agencies operating removal fisheries in remote, low volume locations (Snake River dams, John Day Dam, Lyon's Ferry sport-reward site) should become responsible for disposition of their catch. This could be storage in chest freezers and monthly deliveries to a processing location or establishing a rendering pickup system with a local merchant. It is extremely inefficient to contract someone to pick up fish from these locations. This system should also apply to the Merwin Trap fishery unless it begins to yield enough squawfish to justify food-grade handling.
5. Bonneville, The Dalles, and possibly **McNary** dams should deliver their catch daily to a fish processing location (if one is available in the area). The coolers full of iced squawfish would be placed in a lockable drop-box where ice and fresh coolers would be available for the next day. Delivering large totes of ice to the dams is a negotiable issue, but for cost considerations should be avoided if possible. CRITFC should plan on purchasing their own coolers for 1993 because OSU will have no property control over equipment used by dam anglers.

6. Any handling network should be administered by someone who is familiar with both the harvest and handling aspects of the overall program. Private sector fish processors are not familiar with the handling requirements and goals of this fishery, so one must know how the system should operate before negotiating contracts.

After a workable private sector system has been developed, then the question arises as to who should pay for it. It seems that two possible options exist (or some combination of these two).

1. The participating agencies pay for the fish handling services themselves (include the charges in their budgets).
2. A single entity sets up and pays for handling services (the current system). A handling administrator submits a budget to pay for all handling services.

Roth have advantages and disadvantages, but Option 2 probably provides more flexibility in the event of changes in the removal program that seem to be inevitable.

Catch Utilization

OSU Value-Added Product Experiments

The results of this investigation suggest that squawfish could serve as a resource for the production of surimi. Surimi quality is maintained well during the first three months of frozen storage. A good grade of surimi can be made from fish that has been stored in ice up to nine days. This is unusual as Alaska pollock and Pacific whiting undergo significant deterioration after three days of ice storage.

Roe from northern **squawfish** is varied in color and size. It constitutes approximately 12% of the weight of the female **squawfish**. Because of the quality and color characteristics, it would be unlikely that squawfish could be harvested for its roe.

In general, the mince made from frozen squawfish held up well in frozen storage if **cryoprotectants** were used before re-freezing. The initial strain value was lower than mince made from fresh fish and is due to (1) the denaturation of proteins in the native state during frozen storage and (2) the fact that fish were not frozen immediately after capture as indicated by the high K-value. Nonetheless the results are encouraging as they show that frozen **squawfish** can be used as a mince at a later time period. This would simplify the handling and storage of squawfish caught at the dams. Also the production of mince would occur when enough raw material has been stored.

Liquid Fertilizer

This product form is a feasible outlet for supplies of northern **squawfish** on a technical basis, but since estimated prices will be relatively low, fertilizer does not offer the greatest

potential for cost recovery. Fertilizer processing remains a viable alternative for processing industrial-grade fish that have no higher values use.

Minced Food Product

Minced food products continue to be the highest valued use for food-grade northern **squawfish**. The Interim Report (Appendix A) presents a comparative assessment of various end uses of northern **squawfish** compared to their incremental handling costs.

The presence of small fish in the mix represent a loss from minced food processing. According to Stoller Fisheries, experience with other “rough” fish fisheries (carp and suckers) suggests that continued large-scale removals of northern squawfish may actually increase average size of fish.

Contaminant levels (DDT, DDE) in northern squawfish organs are high enough to present problems when northern squawfish is processed alone as fish meal. Mixing with less contaminated species has resulted in meals with acceptable levels.

Renderers

The 44,400 pounds of industrial-grade northern squawfish delivered to renderers was combined with other protein sources and eventually **processed** into animal feed.

Mink Feed

Surplus industrial-grade northern squawfish was collected by the OSU mink farm to use as mink feed. No feeding experiments were supported in 1992.

Seafood Brokers

Northern squawfish delivered to brokers was used to test the possibilities of export markets on the Asian region. Initial results indicate estimates of exvessel prices consistent with domestic use as mince, between **\$.05/lb** and **\$.15/lb**.

Salmon Habitat Restoration

Assessment of northern squawfish flesh for its suitability in salmon stream enrichment experiments indicates that the fish is acceptable in this use.

Utilization Conclusions

We now have two years of consistent estimates of an exvessel price range for northern squawfish of **\$.05-\$.15** per pound in food use, and **\$.02-\$.05** per pound in industrial use. Given this information and the level of interest in utilization of northern squawfish, it is time to consider the design and implementation of a mechanism by which

users can pay for the fish. If **small amounts** of northern squawfish were still provided free of charge to potential users for experimentation, it would benefit the long-term program in terms of maximizing the exposure of northern **squawfish** to all potential users.

Given the successful experience with food-grade processing and the potential for future marketing, it is time to consider an application to the U.S. Food and Drug Administration (FDA) for a market name. Previous inquiries with the FDA indicated that there is no impediment to the assignment of a market name other than to avoid duplication with existing names.

Social and Regulatory Issues

Fisheries

In general, social and regulatory issues associated with the three removal fisheries for northern squawfish are improving as the project matures. The most prominent issues continue to be related to the large numbers of anglers participating in the sport-reward fishery. Large numbers of anglers (over 40,000 registered in 1992) mean more conflicts for space at boat ramps, congestion at check stations, congestion on the water, and conflicts with other river users, such as commercial fishermen and jet skiers. Enforcement of fishery regulations of both the northern squawfish fisheries and other fisheries becomes increasingly difficult as numbers of anglers increase.

Enforcement efforts have been made difficult by the dispersal of registration sites, the large number of anglers possessing northern squawfish, and the difficulties of tracking fish origin. The establishment of clear regulations, consistent between Oregon and Washington, related to the legality of party fishing and fishing license numbers on registration forms are minimum conditions for reasonable oversight by enforcement personnel.

Regulations related to quality of northern squawfish continue to be only marginally enforceable. Without placing the burden of quality evaluation solely on the creel clerk, it is difficult to see how angler contributions to fish quality can increase over current levels. On-site handling of northern squawfish once anglers have delivered the fish still has some unmet potential for improvement.

Continuing comments criticizing Native American commercial fishing on the Columbia River, albeit in small numbers, indicate that there is a public education need associated with this program that has been unaddressed. Comments to the effect that commercial fishing on the river should be banned, that Native Americans should be restricted to the use of poles or **dipnets** only, that Native American fishing should be limited to subsistence use only, or that Native Americans are the cause of the salmon problem, all indicate a basic misunderstanding about Native American fishing rights, their historical place in the river system, and their place in the larger arena of fishery management. For the continued smooth operation of a Northern **Squawfish** Predator Control Program as well as

for fishery management in general, it would be worthwhile to produce some educational materials that clearly describe the realities of resource ownership and treaty rights. Concepts such as rights retained by Native Americans when signing treaties as contrasted to rights **assigned** to Native Americans by non-natives are apparently not understood by a persistent minority of anglers.

Contaminant Tests

Low levels of dioxin contamination in northern squawfish flesh indicate no problems for long-term utilization of this fish. Previous tests for organic and heavy metal contaminants indicate no problem with human consumption. The only contaminant problem posed by northern squawfish is from DDT and DDE levels in organs when squawfish are processed into fish meal without a mix of other species.

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APPENDIX A

Interim Report on Harvest, Handling, Utilization, and Regulation

**INTERIM REPORT ON THE FEASIBILITY OF
HARVEST, HANDLING, UTILIZATION AND REGULATION
OF NORTHERN SQUAWFISH**

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INTERIM REPORT ON THE **FEASIBILITY** OF HARVEST, HANDLING, UTILIZATION AND REGULATION OF NORTHERN SQUAWFISH

INTRODUCTION

This report presents a consolidation and summary of research activities conducted by Oregon State University between 1989 and 1992 on four components of the fishery for not-them squawfish (*Ptychocheilus oregonensis*): harvest, handling, utilization and regulation. The report is a four-year retrospective on how we began, what we did, and what we found out as part of the research project "Development of a System-wide Predator Control Program: **Stepwise** Implementation of a Predation Index, Predator Control Fisheries, and Evaluation Plan in the Columbia River Basin". The report consolidates information contained in annual reports and other project-related information. For purposes of readability the report does not contain citations.

The first section of the report presents a description of the research background: what was known about not-them squawfish and its utilization at the beginning of the project, the factors affecting the approach to utilization, and the constraints within which the harvest, handling, utilization and regulation of northern squawfish operated.

The second section of the report describes the evaluation of methods of northern squawfish removal, handling, utilization and regulation. In this section we describe our research objectives and the process we used to meet those objectives.

The third section of the report presents the results of the evaluation, presenting comparisons between alternate harvest methods, handling methods, utilization methods, and regulatory approaches.

The final section presents recommendations on each of the four research components based on the evaluation of project activities through 1992.

Information on 1992 operations is preliminary. **At the** time of this report writing, all projects are still entering data and making final assessments of the 1992 season.

BACKGROUND

We began our evaluation activities in 1989. Although predation research had been conducted on northern squawfish prior to that time, 1989 was the first year that harvest technology and predation experiments resulted in yields of fish. 1989 was also the beginning of the attempts to implement northern squawfish population control through harvests.

The existence of yields and the potential for large quantities of northern squawfish to be harvested raised the issue of utilization for the first time. The project was faced with the need to dispose of northern squawfish yields. In the crudest terms, the choice was between using the harvested fish or burying them. On the assumption that public stewardship responsibilities dictated that utilization of a natural resource was more responsible than disposal, we proceeded to investigate the feasibility of utilization alternatives. We began with an assessment of what was known about northern squawfish and its utilization.

Underutilization of Northern Squawfish

Northern squawfish **had** long **been** considered a “trash” or “junk” fish. Native **Americans had** traditionally consumed only very small amounts of northern squawfish. Anglers typically killed and threw back and northern squawfish caught incidentally. Commercial fishermen did not land northern squawfish because markets did not exist. With the exception of a few people who canned northern squawfish for home consumption, the fish was not utilized.

A major reason for the lack of utilization of northern **squawfish** was the characteristics of the fish. Although the flesh of northern squawfish was sweet and mild, the fish contained a large number of small barbed bones which made it difficult and time consuming to eat. The appearance of the fish was not a barrier to human consumption.

Another reason for the underutilization of northern squawfish was tradition. Tradition plays an important role in human consumption of fish. Consumer preferences for fish are often the result of practices established over several years. Historical choices made for preferred species will sometimes label a less desirable species as “trash” fish because the preferred species is at levels of abundance capable of filling consumption needs. Species preferences **carry** down through generations and may remain fixed even after abundance levels of the preferred species are no longer equal to all human consumption needs. Once a fish has been labeled “trash”, it is often difficult to overcome that historical perception.

Associated Research

Conversations with fish brokers and other researchers **revealed** that Sacramento blackfish (*Orthodon microlepidotus*), a species with characteristics similar to those of northern squawfish, were sold in California market areas with Asian population concentrations. A research project in progress to assess harvest methods and market potential for Sacramento squawfish (*Ptychocheilus grandis*) had been hindered in the development of markets by dioxin contamination of the fish.

On the basis of these conversations, we determined that outlets for experimentation with northern squawfish as human food would likely be those serving Asian consumers.

Constraints to Northern Squawfish Utilization Experiments

We developed our assessment approach within **the** context of several constraints: legal, biological, health, regulatory, and social.

The legal constraint within which utilization of northern squawfish must be conducted is the Oregon statute which classifies northern **squawfish** as “**food fish**”, and as such prohibits any disposal which constitutes “wanton waste” or “destruction”. Burying of northern squawfish was determined to fall into the wanton waste category.

The biological constraint within which we planned the utilization assessment was a high level of uncertainty about the characteristics of northern squawfish yield. Neither the size nor the stability of yields from the predation control project were known. We knew that concentrations of northern squawfish would be available seasonally due to both spawning aggregations and salmon smolt migration times.

The public health constraint within which we developed was the need to ensure that contaminant levels in northern squawfish were low enough to allow human consumption. The experience with Sacramento squawfish alerted us to the possibility of contamination of northern squawfish in the Columbia River from organic sources, heavy metals, or dioxin.

The major regulatory constraint for the harvesting and utilization of northern squawfish was the need to avoid destructive overlap between the harvest of northern squawfish and other fisheries. **Incidental** catch of closely regulated species were of particular concern.

Social constraints to harvest and utilization consisted of the need to avoid approaches to harvest or handling which caused conflict with **existing** river activities, including recreational and commercial fishing, nonfishing water activities, boat ramp use, enforcement problems, or negative public perceptions.

Project Objectives

One objective of the predator control program was to control predation on juvenile salmonids through the achievement of target levels of northern squawfish removals. In consultation with researchers within the Oregon Department of Fish and Wildlife, we determined that **within** this overall program objective of target removals, the objective of the “feasibility” project would be the following: 1) to assess alternative approaches to harvest, handling, and utilization and to evaluate their relative cost-effectiveness; 2) to evaluate regulatory and social issues related to the control program as a whole 3) to evaluate removal fisheries for social impacts in their contribution to target removal goals.

Evaluation Criteria

To say that an activity is feasible means it is workable, practical, or attainable. One aspect of feasibility, then, is whether an activity is workable within the existing constraints. The assessment of feasibility of various program components is properly done within the context of the overall program goals.

A second aspect of feasibility involves tradeoffs. If a range of alternatives is workable, then choosing among alternatives is a matter of looking at the tradeoffs between alternatives in light of the overall objective.

The least-cost focus of the feasibility project objectives led to the adoption of **cost-effectiveness** as a standard for evaluation of alternatives. It is worth noting why **cost-effectiveness** was chosen as an evaluation criterion rather than cost-benefit analysis since **cost-benefit** analysis more commonly comes to mind in the evaluation of activities.

A cost-benefit analysis requires the quantification of both costs and benefits of a particular activity or project. Inputs to the activity are costs; outputs from the project are benefits. If outputs from the activity are fixed, benefits are fixed. When benefits are fixed and only costs are variable, the appropriate basis for comparison between alternatives is **cost**. The question is: for a given benefit (output), what is the range of costs represented by alternatives?

The predator control project fixes output through its specification of target removal goals for northern squawfish. The goal is not to eradicate northern squawfish through the maximum possible output, but rather to achieve predation control through target removal levels which alter northern squawfish population size and age structure. Because output is fixed, the appropriate evaluation criterion is cost-effectiveness; the minimum cost approach to a given output.

The cost-effectiveness question applies to removal methods, handling methods, and utilization methods. The questions that this project asks are: What are the least-cost alternatives for meeting target goals of fish removal? What are the least-cost alternatives for handling the fish removed? What are the least-cost alternatives for achieving northern squawfish utilization that avoids "wanton waste"?

The above is not to suggest that the only benefits resulting from the conduct of removal fisheries for northern squawfish are biological benefits of predator reduction. Economic benefits associated with harvest, handling, and utilization activities accrue to the economy at large. Economic benefits include the economic impact of expenditures by fishermen, increases in employment, and purchase of support services. Social benefits also accrue, such as an increase in recreational fishing opportunities and an opportunity to participate in salmon enhancement. An assessment of these benefits is included in this report.

Summary of Background

The background knowledge with which we began our assessment of utilization alternatives may be summarized in the following way. Northern squawfish had no general history of harvest or utilization. It was a bony fish with **sweet-tasting** flesh. Oregon state law required that we avoid wasteful or destructive use of the harvest. The size and time flow of northern squawfish yields were unknown. Harvest methods and times must be set to minimize the problem of incidental catch. Harvest, handling and utilization methods must minimize the likelihood of conflict with either activities or enforcement problems.

EVALUATION PROCESS

Building on the background information we acquired, we developed our procedure for evaluation. Given the approach to control populations of northern squawfish through harvest, and the concurrent need to regulate the harvest, handle catch and ensure utilization, the major research task was to assess the alternatives for each fishery component. We evaluated the characteristics of the fish, contaminant levels, removal methods, handling methods, product forms, market potential, regulations, social issues, and enforcement issues.

Fish characteristics

We began with an understanding that northern squawfish was extremely bony. We conducted both sensory and chemical evaluations to determine other species characteristics. We conducted small-scale sensory evaluation tests with consumers and owners of restaurants and markets. Chemical analyses of northern squawfish flesh were conducted by the Oregon Department of Agriculture (ODA), OSU Department of Food Science and Technology, and by private users to assess nutritive composition.

Contaminant levels

We arranged with the Oregon Department of Environmental Quality (DEQ) to include northern squawfish in fish tissue tests they conducted in 1989. Both flesh and organs of Northern squawfish were tested for pesticides (PCB's, chlordane, DDT derivatives) and heavy metals (mercury, aluminum, lead, arsenic). We subcontracted with the DEQ to arrange the testing of samples of northern squawfish for dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF)). The DEQ contracted with the Duluth, Minnesota lab of the Environmental Protection Agency (EPA) to perform the tests.

Removal Methods

We evaluated the three major removal methods - sport angling, **commercial** longlining, and dam angling - on the basis of cost per unit catch, social issues, regulatory issues, handling requirements, and enforcement problems.

Data were collected on the sport-reward fishery through **several means**. **Anglers who registered in the** fishery were surveyed about their fishing time, **fishing** methods, expenditure patterns while fishing, miles traveled to fish, experience fishing, assessment of problems associated with fishing for northern **squawfish**, and views of the northern squawfish program. Anglers were given a questionnaire to fill out with the voucher for payment. Anglers who registered to fish but did not return to the check-out station were surveyed through telephone interviews. Creel clerks who staffed the sport-reward fishery sites were surveyed about fishery operations at the end of the fishing season. Data on catch, effort and expenditures per site were provided by the sport-reward fishery administrators. Information on enforcement issues was obtained through interviews with enforcement personnel.

Data on the commercial fishery **were** collected through four sources. Logbooks recording catch, effort, and expenditures were filled out by fishery participants. Commercial **fishery** observers and commercial fishermen were surveyed about fishery operations. Data on payments per fish and total fishery expenditures were provided by commercial fishery administrators. Information on enforcement issues was obtained through interviews with enforcement personnel.

Data on the dam angling fishery were collected through three sources. Weekly catch and effort reports as well as total **fishery** expenditure reports were provided by the dam **fishery** administrators. A summary of issues related to dam **fishing** operations was also provided by dam fishery administrators. Information on enforcement issues was obtained through interviews with enforcement personnel.

Data on some experimental harvest methods was also collected. Purse seine operations provided data on catch, effort, and expenditures. The same data were provided for the Merwin trap operations.

Handling' Methods

The scope of the fish collection and distribution program has been dependent on two factors: the fish removal program and the end-use program. The evolution of the fish handling system reflects the expansion of the magnitude and geographic scale of the removal fisheries as well as the changing focus of the end-use evaluation. The pickup and distribution system evolved from a cooperative effort between researchers in 1989 to an expanded specialized program involving five employees in 1992.

Large volumes of fish in 1991 and 1992 harvested under a “full-scale” fishery implementation plan required the development of a handling system which was responsive to rapid changes in quantities and location of harvest. Total program harvest increased almost twelve-fold between 1990 and 1991. In addition, attention was paid to the development of a fish grading system which would provide as much food quality fish as possible for utilization-

Data on volume of fish, distances traveled, expenditures and fish quality were collected for each year of fish handling. The costs of the fish handling program were evaluated in four components; administrative/operating costs, on-site costs, off-site costs and coordination costs. These costs are discussed below and summarized in Table 1.

Administrative/operation (**admin/op**) costs include all costs associated with the design, set-up and implementation of a basic fish-handling system which will remove fish from landing site and dispose of them. These costs vary according to both the scale of operation and the configuration of the program. Included in **admin/op** costs are administrative and handling labor, field stations, equipment, vehicles, and service to sites (pick up and delivery). The magnitude of **admin/op** costs in any fishing year is Sensitive to several factors: numbers of harvest sites, geographic dispersion of harvest sites, projections of removals, fish handling setups at harvest sites, and the delineation of ‘responsibility between respective projects. Once these factors are determined at the beginning of a fishing year, total **admin/op** costs remain fixed. Average **admin/op** costs per fish decrease as the numbers of fish landed increase. **Admin/op** costs are not sensitive to a particular end use for the **fish**.

On-site costs include the costs related to the handling and pickup of fish **onsite**. These costs vary according to the setup of operations **onsite** and the quality control system in place. Included in these costs are the design and implementation of a handling system, training materials for on-site employees, interim handling and storage **onsite**, and equipment for quality control. On-site costs are sensitive to the setup **onsite**, the end use of the **fish**, and the degree to which **onsite** employees comply with quality control requirements.

-Off-site costs include all costs incurred away’ from harvest sites related to handling fish for a particular end use. These costs include additional sorting and storage needs, packaging and ultimate transportation to users. Off-site costs are sensitive to the type of end use and to the volume of fish handled, but are only indirectly sensitive (through quality outcomes) to fish handling at harvest sites.

Coordination costs are those costs associated with the administration of a particular handling arrangement. Coordination costs are sensitive to the degree of complexity in removal sources and end uses. They are also sensitive to the effectiveness of preseason planning and the extent to which the responsibilities of all cooperating parties are clearly delineated and enforced.

A sub-objective of the feasibility research project was to develop a plan for the transferral of fish handling responsibilities to the private sector. Components of the private sector plan

must include a description of the supply sources and location, a discussion of quality control issues at harvest sites and during transportation and **handling**, a discussion of transportation and storage logistics, an evaluation of costs under alternative approaches, and recommendations for project contracting conditions which will ensure adequate coordination between private parties and the predator control project.

Product Forms

The development of products which will **utilize** the entire catch and avoid “wanton waste” requires a consideration of product forms which can accommodate both food grade and industrial grade fish. We tested the suitability of northern squawfish for processing into various product forms listed in Table 2. These product forms were tested through a combination of private and public sources. Experiments were conducted by rough fish processors, fish meal producers, bait dealers, fertilizer producers, fish brokers, a mink producer and the Astoria Seafood Laboratory of the Coastal Oregon Experiment Station, Oregon State University. Experimental product forms include fillet, boned mince, mince with binders and cryoprotectants, roe, liquid fertilizer, fish meal, fish oil, animal food and bait.

Data on product form experiments were collected through a combination of forms. The, Astoria Seafood Lab work was summarized in annual reports. Interviews were conducted with market testers to obtain feedback on whole-fish and mince product. Reports on fish **meal** and oil composition were obtained from producers. Market reports on acceptance of privately produced **mince** were provided. The fertilizer producer was interviewed to ascertain costs and price constraints. The results of mink feed trials were reported in a written summary. Bait users and fish brokers were interviewed about product suitability.

Market Potential

Data on costs, prices and market potential of northern squawfish in various product forms were obtained from the end users listed above. Users were asked to provide information on special handling requirements, costs of processing, estimates of raw product prices, and other information about the market in which they sell their product.

We investigated the requirements necessary for the assignment of an alternative name for northern squawfish for the purposes of marketing. We contacted the U.S. Food and Drug Administration (FDA) to determine whether impediments existed in using a market name. We also contacted tribal representatives and other researchers to enquire about alternative traditional names for northern squawfish.

Regulations

Regulations pertaining to existing commercial and sport fisheries in the Columbia River were reviewed for consistency with planned development of fisheries for northern squawfish. Particular attention was paid to restrictions on gear, incidental catch, season timing, and fishing location. In 1990 we began what will be a continuing process of identification of issues specifically related to the regulation of fisheries for northern squawfish. A detailed questionnaire was circulated to state fishery agencies, public utility districts, the Columbia River Inter-Tribal Fish Commission, The U.S. Army Corps of Engineers, FPAC members and CBFWA members. Recipients were asked to identify any issues related to the development of fisheries for northern squawfish which were in conflict with existing regulations or presented potential conflicts- A follow-up survey was made of these same interests in 1991.

Social Issues

We were interested in identifying issues associated with fisheries for northern squawfish which were either costs or benefits associated with the conduct of the fisheries. Social costs include crowding on the water or boat ramps, commercial-sport gear conflicts, coordination difficulties, etc. Benefits include provision of additional recreational fishing opportunities to the angling public. We identified the existence and relative magnitude of social costs through a monitoring procedure established for each fishery. Conflicts and negative external effects of the commercial longline fishery were identified through two means: post-season interviews with commercial fishermen participants and commercial fishery employees. Conflicts and coordination issues were identified for the dam angling fishery through post-season summaries provided by dam fishery administrators and fishery agency observers. Conflicts and other social issues associated with the sport-reward fishery were identified through the angler questionnaires, a survey of nonreturning anglers, and a survey of fishery employees.

Enforcement Issues

Issues related to the enforcement of regulations associated with the commercial longline, dam angling, and sport-reward fisheries were identified through informal surveys of enforcement personnel. Questions were asked about particular problems created by each of the three fisheries and about additional enforcement burden, if any, created by each fishery.

Summary of Evaluation Process

Fish characteristics, contaminant levels, removal methods, handling methods, product forms, market potential, regulations, social issues and enforcement issues were evaluated using a variety of data. Sources of information included laboratory tests, market trials, experimentation by fish processors, participant surveys, employee surveys, enforcement

contacts, published legal and regulatory documents, **agency** surveys, logbooks, private sector **consultation**, and consultation with other researchers-

EVALUATION RESULTS

This section summarizes the results of our evaluations of fish characteristics, contaminant levels, removal methods, handling methods, product form, market potential, regulations, social issues, and enforcement.

Fish Characteristics

Sensory, technical and chemical evaluations conducted on whole, filleted and minced northern squawfish yielded consistent results across evaluating groups; consumers, restaurant owners, retail market owners, processors and **laboratories**.

Sensory evaluations indicate that northern squawfish fillets have a flaky texture, bland to sweet taste, and good appearance. The coloration of the flesh is acceptable, and no objectionable odor exists. **Ease** of handling is acceptable. The large number of barbed bones is a problem for fillet consumption- Deboned mince of northern **squawfish** has a firm texture and a bland taste adaptable to a range of seasonings. Washing is required to remove blood deposits from processing.

Technical evaluations indicate that northern squawfish has superior potential in the production of engineered seafoods from mince. Engineered seafood have advantages over **natural-form** seafoods of increased shelf life in frozen storage and an increased versatility of use. A key factor in a species' suitability as an engineered product is its ability of the mince to form a gel. Northern squawfish was found to have superior gel strength lasting over a longer period than most ocean-caught fish. Northern squawfish also has demonstrated good shelf life with the addition of cryoprotectants.

Chemical evaluations for protein, ash, fat and fatty acids indicate the following: protein content is roughly **18%**, a level between levels for carp (17%) and **yellow perch** (19%). Ash content is approximately, **1.4%**, a level similar to carp and exceeding yellow perch. Total fat content is low, roughly **.6%** as compared to yellow perch at **.9%**. Fatty acids are in general below levels in carp and yellow perch. Northern squawfish is a low-fat, moderately high protein fish. **In** minced form, both protein and ash proportions decline with successive washings.

Contaminant Levels

Contaminant tests performed by the Oregon DEQ and the EPA indicate that northern

squawfish is suitable for human consumption without advisories.

Tests for pesticide contamination (**PCB's, chlordane, DDT derivatives**) indicate that all pesticide levels in northern **squawfish** sampled are below FDA action levels .

Tests for heavy **metal contamination** (mercury, aluminum, lead, arsenic) indicate that all heavy metal levels in sampled northern squawfish are below FDA action levels.

Tests for dioxin contamination (**TCDD and TCDF**) indicate **all** samples with detectable concentrations of TCDD (10 of 15 samples) were below FDA action levels of **25 ppt.** and above EPA guideline levels of **.07 ppt.** TCDD concentrations are similar to other resident fish in the Columbia River system. Neither the FDA or EPA have adopted criteria to establish action levels of TCDF at this time. However, TCDF is considered to be approximately **one-tenth** as toxic as TCDD.

The Washington Department of Health has reviewed data from the Columbia River and has determined that a fish consumption advisory for the general population is not warranted at this time. The Oregon Health Division has reviewed TCDD data for fish from the Columbia River and has not issued a fish consumption advisory.

Removal Methods

The **three** major removal methods - the commercial **longline** fishery, dam angling fishery, and sport-reward fishery vary widely in types of operation, costs of operation, administration, oversight, and quantities of **fish** removed. Contributions of each removal fishery to total catch in 1990, 1991, and 1992 are summarized in Table 3.

Commercial longline fishery:' In the three years of its operation the commercial **longline** fishery has contributed little to overall removal goals (Table 3). Landed catch has been **low** and costs high relative to the other two fisheries. The fishery has been plagued by low levels of participation and low catch per unit effort since its inception. Expenditures in the commercial **longline** fishery per fish removed have been very high.

Commercial fishermen have been interviewed to document their perspective on problems with fishery operation. Their assessment of problems includes difficulties with preordained **fishing** hours, seasons, rules on employment of gear, and what is seen as invasive oversight by **onboard** observers.

Observers who worked on commercial fishery vessels were interviewed in 1992. Their summary of fishery operations notes problems in excessive paperwork and equipment problems, and some problems related to low levels of fishermen participation, such as overstaffing and fishermen resentment of the level of observer coverage.

Remuneration systems in the commercial fishery have included a monthly stipend in 1990, a per-fish payment without stipend in 1991, and a combined stipend/per-fish payment in 1992. Remuneration approaches have been revised each year in response to 'feedback from participating fishermen. Levels of compensation appear to have been set at levels high enough to cover normal operating costs.

The combined sources of information suggest that the fishery has suffered from the perception of low status, competition with other fishing activities available to commercial fishermen, and rigid constraints imposed on fishery operations, but not necessarily from inadequate compensation for participating fishermen-

Dam angling fishery: The dam angling fishery expanded its operation by 33% between 1990 and 1991, from 6 to 8 dams. The number of dams in this fishery remained fixed between 1991 and 1992. In contrast, sport-reward fishery increased the number of check-in stations by 375% between 1990 and 1991, and by 33% between 1991 and 1992. The dam angling fishery share of total removals has declined over the time period in part due to the increase in the sport-reward fishery and in part due to a decrease in dam landings in 1992 (Table 3).

Various assessment of dam angling operations indicate that coordination, safety and security issues related to **fishing** off the dams have been or continue to be resolved. The dam fishery has had duties of removal and assisting in biological evaluation which at times have worked against each other. Coordination with other projects continues to improve.

Personnel in the dam angling fishery continue to have occasional difficulties with public perceptions that anglers are unfairly catching "sport" fish. Public education efforts could be directed at this problem.

Sport-reward fishery: In the three years of its operation, the sport reward fishery has continually expanded the scale of its operation, from 4 sites in 1990 to 15 sites (+375%) in 1991 to 20 sites (+33%) in 1992. In 1992 the sport-reward fishery operated 20 check-in sites over a 300 mile area of the Columbia and Snake Rivers.

Both absolute numbers of removals as well as the proportion of total removals accounted for by the sport-reward fishery has increased as the fishery has expanded (Table 3).

As it has grown, the sport-reward fishery has attracted an larger and more diverse population of anglers from a wider geographic area. Some sites routinely attract single-day fishermen traveling less than 40 miles to fish, while others attract fishermen traveling 100 or more miles who spend three days fishing.

A relatively high (59% in 1992) percentage of anglers who register to fish for northern squawfish do not return to the station to check in fish. Anglers who did not return to the site spent about two-thirds of their fishing time targeting northern squawfish. The major reason for anglers not returning has been the lack of qualifying catch of northern squawfish. The

second most important reason is that anglers returned after hours when the check station was closed. However, these anglers were not permanently disaffected with the northern squawfish program. Almost 90% of those surveyed said they expected to participate in the sport-reward fishery again. The most important reasons these anglers gave for participation in the northern squawfish program were recreation and the opportunity to earn money. Participation in salmon enhancement was also important to many.

Operations of the sport-reward fishery were assessed in a survey of creel clerk supervisors in 1991. Check-in procedures, operating hours, the data collection process, data forms, and staffing levels tended to be evaluated as effective by the majority of clerk supervisors. The majority evaluated equipment at sites to be inadequate. The assessment of 1992 operations is in progress.

Handling Methods

Handling methods employed during the feasibility project have increased in complexity as the project changed. In 1990, with total removals of 16,900 fish, the handling system was comprised of a single employee, one truck, some uninsulated totes and a few chest freezers. The rapid expansion of the removal program in 1991 required a focus on the rudiments of handling large volumes of fish. The handling system expanded to four employees, four trucks, insulated and uninsulated totes, and numerous chest freezers. Quality control considerations were sacrificed to the more pressing need to dispose of an almost twelve-fold increase in quantities landed. By 1992 a system was in place for handling large volumes of fish, and more attention could be placed on system design for quality control. The handling system consisted of five employees, three trucks, several fish processors, and numerous coolers. In 1992 30% of all fish handled were food grade; of the sites which were targeted for food grade, 37% food grade resulted.

Property control of both fish and equipment has surfaced as an increasingly important issue as the scale of program operation has increased. A significant number (120) of portable coolers were lost from the project in 1992. Discrepancies between numbers of fish caught by removal projects and the number of fish handled suggest that a certain number of northern squawfish may be "recycling" through the system, perhaps being caught in a removal fishery then checked into the sport-reward fishery for payment. We are continuing to look for other sources of discrepancies.

Table 4 lists rough estimates of handling cost by component: admin/op, on-site, off-site, and coordination costs. These estimates were derived on the basis of best knowledge to date of handling requirements and associated charges associated with particular end uses. Cost estimates are presented to illustrate the relative magnitude of cost components and the changes in those costs as the end-use mix changes. We discuss three end uses which cover the quality spectrum and which have accounted for the majority of fish utilization to date. These end uses comprise two grades of fish; industrial and food. Rendering represents the

lowest quality industrial use, fertilizer a higher quality industrial use, and food the highest quality food use.

Admin/op costs are fixed per season once the scale and scope of the program is established. Late planning and changes program operation combined with uncertainty about actual levels of removals have required administration and operation planning for northern squawfish handling to proceed on a “worst-case” basis, resulting in fixed costs per season which are higher than the minimum required. Although total **admin/op** costs are fixed once a season begins, average **admin/op** costs per fish decreases as -the volume of fish handled increases. For the volume of fish handled in 1992, **admin/op** costs are estimated to range between **\$.40** and **\$.45** per pound.

On-site costs vary within season according to the efficiency of on-site handling and the end use for which the fish are being handled. **Our** best estimate of the range of costs added to basic **admin/op** costs as a consequence of handling for a particular end use are: rendering **\$.08** per pound; fertilizer **\$. 10** per pound; and food **\$. 12** per pound.

Off-site costs also vary within season according to the volume of fish handled and the end use for which they are being handled. Our best estimates of the range of off-site costs added to basic **admin/op** costs and to on-site costs are: rendering **\$.08** per pound; fertilizer **\$.12** per pound; food **\$.16** per pound.

Total variable costs associated with particular end use are the sum of on-site and off-site costs. For rendering these costs are **\$. 16** per pound, for fertilizer **\$.22** per pound, and for food **\$.28** per pound.

Coordination costs are time costs associated with the amount of planning, the delineation of responsibilities between projects, **and** the complexity of end uses. These costs are unquantified here; they may be low, medium or high in any given season depending on the effectiveness of the preseason planning, the predictability of operations, and the communication between projects .

As noted, each of the three types of end uses is associated with variable costs in addition to the fixed administrative/operating costs to dispose of a volume of fish. The costs vary according to the handling required for a particular end use either on-site or off-site. The three **end** uses also vary in the degree to which they offer the possibility of cost-recovery through the sale of northern squawfish. Table 5 presents a summary of estimated \$ per pound recoverable on a per pound basis. Per pound prices will vary according to market conditions at the time of sale; table values are based on a range of estimates provided to this project by experimental users in 1991.

Rendering is the least-cost alternative if no cost recovery is possible. Rendering is considered as the baseline against which other alternatives are compared. The existence of food and fertilizer markets makes cost-recovery possible through the sale of fish. Food use offers the

potential for greatest cost-recovery, at our best current estimate of \$. 10 - \$. 15 per pound, followed by fertilizer, at our **best current** estimate of \$.02 - \$.05 per pound. Under current conditions, rendering involves a processing charge and offers no potential for cost recovery through sale of raw product to renderers.

Depending on the price at which northern squawfish is sold, the opportunity exists to recover from 33% to 83% of fertilizer cost margin over the rendering baseline. From 83% to 125% of the food cost margin over baseline can be recovered. High quality fish sold for food use pays for the extra cost of handling once exvessel price reaches \$.12 per pound. At \$.15 per pound, high quality fish more than pays for the extra handling required.

We present an example of the effect of different end uses on variable handling costs in Table 6. We look at the variable costs (on-site + off-site) costs of handling 300,000 pounds of northern squawfish for four combinations of uses: A. all rendered; B. 50% rendered/50% fertilizer; C. 50% rendered/50% food; D. 50% fertilizer/50% food. Fertilizer is evaluated at its minimum and maximum estimated prices (\$.02, \$.05). Food is also evaluated at its minimum and maximum prices (\$. 10, \$.15).

All combinations of uses are compared to the “baseline” rendering costs. We look at two separate cases: variable costs associated with end uses when there is no cost-recovery, and variable costs associated with end uses when cost-recovery occurs. There are other possible combinations involving different shares and more than two uses, but these four combinations are sufficient to illustrate the effect of end uses and cost-recovery on costs of handling.

All cost comparisons are conducted in terms of variable costs associated with different end uses. Fixed costs of administration and operation are assumed to be constant regardless of end use, as are coordination costs.

Case 1 in Table 6 involves no sale of fish and results in no cost recovery. Variable cost differences between the different end uses are a function of differences in handling requirements on-site and off-site. If all 300,000 pounds of fish are rendered (Alternative A), variable costs are \$48,000. If half the fish are used as fertilizer **and** half rendered (Alternative B), an additional \$9,000 over the baseline is incurred for a total variable cost of \$57,000. This is a 19% increase over baseline variable costs.

If half the fish are directed at a food use instead of fertilizer (Alternative C), variable costs are an additional \$18,000 over baseline rendering costs, an increase of 38%. Dividing the fish between fertilizer and food uses (Alternative D) is the most expensive alternative without cost recovery. Alternative D incurs an additional \$27,000 (56%) over the rendering baseline for a total variable cost of \$75,000.

Food and fertilizer uses add to handling costs because they require more exacting handling than rendering. However, food and fertilizer uses offer a market potential that rendering does not. Case 2 includes cost recovery realized through the sale of northern **squawfish** for food

(\$.05-\$.10) and fertilizer (\$.02-\$.05) uses.

If all fish are rendered (Alternative A), no cost recovery occurs. If fish are divided between rendering and fertilizer uses, \$3,000 is realized in cost recovery if fish are sold at \$.02 per pound; \$7,500 in cost recovery if fish are sold at \$.05 per pound. At a price of \$.02, variable handling costs are 12.5% more than the rendering baseline. At \$.05 per pound, variable handling costs are 3.1% more than baseline rendering costs.

If fish are divided between rendering and food (Alternative C), a cost recovery of \$15,000 is realized if fish are sold at \$.10 per pound; \$22,500 if sold at \$.15 per pound. Variable costs of the rendering/food combination are 6.3% above the rendering baseline if the food price is \$.10 per pound; and 9.4% lower than the rendering baseline if the food price is \$.15 per pound.

The fertilizer/food combination (Alternative D) realizes a cost recovery of \$18,000 if sold at the low end of both price ranges (\$.02;\$.10), an 18.7% increase over the rendering baseline. At the high end of the price range (\$.05; \$.15) the cost savings is \$30,000, a 6.3% decrease from the price of the rendering baseline.

For the 300,000 pounds handled, at the costs and prices given, the most cost-effective combination is Alternative C, the rendering/food combination. Cost recovery allows the direction of fish at these end uses to proceed at costs which are lower than the baseline costs of rendering.

Aside from the baseline rendering (Alternative A) we did not consider single-use end uses of all fertilizer or all food. In practical terms, given the types and dispersion of removal fisheries encompassed by the northern squawfish program, we will continue to receive a range of grades of fish. This eliminates the possibility of an all-food-grade choice. Directing all fish to fertilizer is possible, but this entails disposing of food grade fish at less than their maximum value. A combination of uses which capitalizes on different grades will offer the greatest potential for cost recovery and therefore be more cost-effective than a single use.

Product Forms

Experiments on various product forms were designed to address the workability aspect of feasibility. We were interested in testing a range of products to determine the technical practicality of using northern squawfish in each one. Of the several product forms tested, Table 7 summarizes the characteristics and feasibility of each according to tests performed to date. Feasibility is assessed on the basis of technical aspects of processing and producer/consumer responses to product form. The cost-effective component of utilization is addressed in the “discussions” section.

Processing yields were calculated for both headed and gutted and mince product forms. Headed and gutted yields from round fish ranged from 46 to 54%. Minced yields from round

fish ranged from 304%. Yields range according to the size of the fish and the compatibility between fish size and shape and processing equipment.

Rendering: Northern squawfish have been rendered and combined with other fish and animal byproducts to product animal feed. Northern squawfish are suitable for this use.

Liquid fertilizer: Northern squawfish was found acceptable in the production of liquid fertilizer when used in combination with carp to enhance oil content. The production process requires fish free of contamination from sand.

Whole fish as food: Whole fish were found to have acceptable appearance, odor, texture and taste, but unacceptably large numbers of bones.

Fillets: Fillets were judged to have good taste, color and texture, but are unacceptable unless deboned.

Mince: Mince is found to have good appearance and color, bland taste, firm texture, good shelf life, superior gel strength, and is versatile in different final products. Mince requires washing for appearance and a binder to improve mixing. Shelf life is improved with the addition of cryoprotectants.

Sutimi: Northern squawfish has a long shelf life on ice and prepares a firm mince suitable for surimi. Variable supply and low volumes limit its use in this product form, but combination with other species may be possible. Accumulation of northern squawfish in frozen storage until sufficient quantities are available for surimi processing is also possible.

Roe: Variable color and size of northern squawfish roe renders it unacceptable for food consumption.

Mink food: Feeding trials indicate an acceptable nutrient content of northern squawfish in mink diet.

Bait: Northern squawfish were acceptable forms of crawfish and crab bait, although due to the low oil content are not as desirable as other bait sources. Northern squawfish was successfully used as grizzly bear bait for a tagging experiment in Northern Idaho.

Fish meal: Northern squawfish were found to be an acceptable ingredient in fresh water fish meal production, but unacceptable (based on a single trial) as an ingredient in marine fish meal.

Export product: Northern squawfish have been experimented with in 1992 as an export product. Results from these trials are not yet available.

Market Potential

The results of the evaluations of market potential of the product forms listed above are presented in this section. Market potential is evaluated on the basis of supply (quantity, quality, and cost of supply in each form) and demand (quantity demanded in this form, area of demand, seasonality of demand). Results are summarized in Table 8.

For many product forms, product attributes are not a constraint to marketability. The key issue in marketability is the match of quantity demanded with the timing, quality and quantity of product supplied. Northern squawfish is an input to production in several end uses, e.g. mince, meal or fertilizer. The quantity demanded of 'northern squawfish is therefore influenced by not only the price and attributes of northern squawfish, but also by the price and attributes of substitute raw products available to processors. Market potential of northern squawfish depends critically on its ability to compare favorably on a price basis with these substitutes.

Rendering: Renderers will process northern squawfish for a fee. The fish can then be combined with other fish and animal byproducts to product animal feed. Because rendering requires an additional expenditure, it offers a disposal alternative rather than market potential.

Liquid fertilizer: Industrial grade northern squawfish is easily supplied for processing into liquid fertilizer. Demand for northern squawfish in fertilizer processing exists. The potential of **cost-recovery** through this end use depends on the continued operation of use of northern squawfish.

Whole fish as food: The unacceptably large numbers of bones in northern squawfish preclude any market potential in this form, unless an export market develops.

Fillets: The same problems with bones as indicated for whole fish limit market potential to deboned forms of fillets.

Mince: Mince has several positive qualities, has received good market acceptance, has the interest of an established producer, and has good market potential.

Surimi: Mince has good properties for surimi. Market potential in this area will depend on experimentation with other species in combination and on the general availability of supply of established surimi species.

Roe: Poor color and size attributes indicate little market potential.

Mink food: Trials indicate an acceptability of northern squawfish in mink diet. However, the industry is small and there is no indication of commercial interest in northern squawfish as feed.

Bait: Northern squawfish was an acceptable but not premium bait for crawfish and crab. Quantity demanded is limited, with expected price at around \$.15 per pound. Demand would strengthen if substitutes were less available, but quantity would still be limited.

Fish meal: Acceptability of northern squawfish in fresh water fish meal production indicate some market potential, mostly as a byproduct of mince production.

Export product: Market potential for whole fish as exports with other fresh water species is still unknown-

Regulations

The survey of Columbia River authorities identified a number of issues related to the regulation of the sport-reward fishery. These issues were addressed through various actions.

Incidental catch in northern squawfish fisheries, particularly of salmon and steelhead, was perhaps the most pressing issue-facing the regulation of northern squawfish activities. The predator control program has responded to this concern through the development of a weekly reporting system on incidental catch throughout the fishing season.

A second issue raised was the need to include enforcement personnel of the Columbia River Inter-Tribal Fish Commission in the review of plans for any fishery which will operate in Zone 6. All fisheries activities affect the ability of enforcement personnel to carry out their responsibilities- This problem has been addressed on a system-wide scale with program and enforcement personnel participating in a post-season enforcement meeting. The purpose of the meeting is to incorporate enforcement evaluation into the next season's planning.

A need was identified for the State of Washington to reclassify northern squawfish as foodfish and require a license for its capture. Reclassification is a necessary precondition to the operation of a commercial fishery on northern squawfish. To date, reclassification has not taken place.

The need to develop regulations associated with the development of commercial fisheries for northern squawfish was also identified as a need. To date, commercial fishing for northern squawfish has been addressed on a year-to-year basis without long term planning for the type of fishery operations or the interaction of a commercial fishery for northern squawfish with fisheries for other species.

Monetary compensation for sport anglers was raised as a potential problem but has not proven to be a hindrance to sport-reward fishery operations in Oregon, Washington, or Idaho.

The use of "in-lieu" sites by the angling public has continued to be allowed by treaty tribes.

Safety and security issues on the dams were the final issue raised in the survey. To date, pre-season plans have been submitted and preseason meetings conducted with personnel of the U.S. Army Corps of Engineers. Corps personnel are satisfied with this process and with the safety procedures in place.

Social Issues

Program staff, fisheries employees, anglers, enforcement personnel and the general public all have had input to the definition of issues related to the conduct of the predator control program. Matters of inter-project cooperation create possibilities for conflict as well as possibilities for mutual benefit. In general, inter-project *cooperation* has been good and improves as the project matures.

Commercial Fishery: A major issue in the commercial fishery is differences in cultures between fisheries agencies and commercial fishermen. There is a **conflict** between bureaucratic requirements for paperwork and monitoring and the operating styles of commercial fishermen. An “agency” fishery emphasizes predictability, control, record **keeping**, and monitoring. A commercial fishery usually places a premium on variability in schedule, innovation, and independence. Commercial fishing is often the most efficient method of fishery removal but to capture that efficiency it requires flexibility to innovate and develop new techniques.

Commercial fisheries for northern squawfish have also been handicapped by being defined as “low status” and unknown. Individual uncertainty about personal association with the **fishery**, uncertainty about yields, and the existence of established fishing alternatives create an environment of reluctant participation.

Also at issue are conflicts between commercial fishermen in Zone 6 and recreational anglers. Gear conflicts have been recorded as has an expression of resentment on the part of some sport-reward anglers about commercial fishermen catching fish **which** are perceived to be the property of anglers. This is a minority view but one that has been well vocalized.

Some commercial fishery observers noted the positive interactions they had with commercial fishermen. Observers indicated that they valued the opportunity to interact with someone from another culture and to learn about cultural practices and historical fishing practices on the Columbia River.

Dam Angling: Anglers working on dams have experienced some of the same verbal assaults by sport-anglers as have commercial fishermen working in Zone 6. The conflict appears to be over perceptions of “rights” to catch fish in the sport-reward program, perceptions of unfair access to sites not available to sport anglers, and perceptions that dam catches will result in lower catch per unit effort in the sport fishery.

There has also been positive interaction between anglers on dams and the general public. Dam anglers have often served as a source of information on Native American culture as well as on the predator control program.

The location of the dam angling fishery requires that extra safety and security precautions are part of the dam angling fishery. Safety and security systems require close cooperation with Corps of Engineer personnel. This cooperation has been effective.

Coordination difficulties between fish removals and biological workups which were present earlier in the program have been resolved through changes in operations.

Sport-Reward Fishery: Issues related to the operations of sport-reward sites are the most common identified by anglers. One issue related to the operating hours of sport-reward sites. Of the surveyed anglers not returning to sites in 1991, 15% did not return because the site was closed. Some indicate a need for a streamlined check-in and check-out process and less onerous reporting requirements at the end of the fishing day. A common objection is to the minimum 11" size for payment.

Conflicts exist at some boat ramps about crowding and disrepair. On-water conflicts exist between anglers and other water users due to crowding. Some anglers object to the existence of legitimate commercial fishing activities, perceiving river fish to be "their" fish.

A major benefit of the sport reward fishery is its provision of additional recreational opportunities for anglers. Anglers are appreciative of the opportunity to recover some costs of fishing for a species which does not offer benefits of other recreational species (e.g. trophies or food).

Another benefit expressed by anglers is the opportunity to participate in salmon enhancement activities. Anglers have also expressed active interest in the utilization of northern squawfish. Working against this perception of positive benefits from program participation is the "killer squawfish" image promoted in program literature. The purpose of the predator control program is to mitigate imbalances in an ecological system where some species are harvested and others are not, and in doing so to achieve higher levels of smolt survival. These goals offer the opportunity for public education about biological communities and their interdependencies. 'Portraying one species as a "killer fish" rather than simply as a species well-adapted to the still-water environments created by reservoirs sabotages any opportunity for general public education in this area.

Enforcement Issues

The primary enforcement issues associated with the northern squawfish predator control program arise out of the introduction of new and unique fisheries into a heavily used system.

One issue relates to the monitoring responsibilities of enforcement personnel. 'Angler fishing for northern squawfish falls within the purview of Oregon Department of Fish and Wildlife enforcement because a license is required to fish. Angler fishing does not fall directly within the purview of either Washington Department of Wildlife or Washington Department of Fisheries enforcement since it is classified as neither a game nor a food fish, and a license is not required to catch it. Northern squawfish falls into a grey area of no defined enforcement authority, and represents an increased enforcement burden on existing enforcement personnel. In the fall of 1992 a meeting which includes enforcement representatives of the Columbia Inter-Tribal Fish Commission, the Washington Department of Wildlife, the Washington Department of Fisheries, and the Oregon Department of Fish and Wildlife will be held to begin the design of a coordinated enforcement program for northern squawfish.

A second enforcement issue relates to the reward payment for northern squawfish in the sport fishery. At an average of 2 lbs. per fish, a \$3 per fish payment equals \$1.50 per pound, a price which exceeds the exvessel price of most fish. The size of the reward payment is high enough to create incentives to land large numbers of fish from sources outside the system, creating a monitoring and enforcement burden to the program. The reward payment also creates an incentive for program personnel to "recycle" caught fish through the system for payment. This problem has been addressed through tail clipping of all fish taken in removal fisheries. Discrepancies between data on total catch versus total numbers of fish handled suggest that despite the tail clipping system the problem continues to exist. We are pursuing all possible explanations for the discrepancies in numbers of fish caught and fish handled.

A third enforcement problem concerns property loss. This is a new problem in 1992 which is just beginning to be addressed.

Summary of Evaluation Results

Both sensory and technical characteristics of northern squawfish make it suitable for a variety of uses. The large number of bones in the fish make mince products most appropriate for human consumption. Levels of contaminants are not high enough to pose a risk to humans. Northern squawfish are suitable in a range of product forms. The greatest market potential exists for food, fertilizer, and meal. Of the three major removal methods, the commercial **longline** fishery has had the greatest difficulties in organization, participation, and levels of catch. The sport-reward fishery and dam angling fishery are generally comparable in terms of costs per fish removed. Relative cost effectiveness between the two is heavily influenced by changes in catch-per-unit-effort. Some conflicts remain in the operation of the dam angling and sport-reward fisheries. These conflicts are primarily with a minority of the public participants who object to crowding and to multiple fisheries for northern squawfish. Handling costs are sensitive to program organization as well as to the types of end uses. A comparison of handling costs for different end-use combinations indicates that the food/rendering or food/fertilizer combinations are the most cost-effective. Regulations for experimental commercial fisheries still need to be developed. A reclassification of northern

squawfish as food fish in Washington would allow commercial fisheries to proceed on commercial fisheries in that state. Enforcement responsibilities remain to be clearly defined. Plans to prevent further illegal recycling of northern squawfish and further property loss need to be developed.

DISCUSSION AND RECOMMENDATIONS

Removal Methods

The breakdown of expenditure data into time proportions for removal, administration, and biological evaluation is still incomplete for all removal fisheries. Rough estimates on 1991 expenditure data indicate that a wide disparity exists between costs per fish removed in the commercial fishery and in the other two fisheries.

The commercial fishery estimate of around \$180 per fish removed is high because the fixed costs of design implementation and administration were averaged over very small numbers of fish removed. If catch rates had been higher, average cost per fish removed would fall. In evaluating the commercial fishery, the appropriate questions are concerning reasons why catch rates were so low. As indicated above, participation rates were low and enthusiasm of those participating was lacking.

Commercial fisheries as previously structured are not cost-effective. There is little opportunity for cost recovery with these fisheries given a structure that specifies gear, times of operation, methods of operation, requires significant levels of paperwork and observation which is considered intrusive by fishermen. However, this conclusion does not necessarily apply to all commercial fisheries. Commercial fisheries do offer potential for efficient removals of northern squawfish if allowed to operate on a flexible experimental basis.

Once adjusted for total administration and oversight costs and for time spent in activities not directly related to removals (e.g. biological evaluation), dam angling and sport-reward fisheries are likely to be within \$2-3 of each other in average expenditure per fish removed, at approximately \$14-\$17. The two fisheries have developed to be complementary rather than substitute activities, covering different areas of the river and targeting different concentrations of northern squawfish. Catch-per-unit-effort is higher in the dam fishery but total catches are higher in the sport-reward fishery.

Of the three alternatives available, the commercial fishery as it has been structured is not cost-effective in meeting program goals. Based on the preliminary analysis of expenditures applied to removals, the combination of dam angling and sport-reward fisheries is the most cost-effective alternative. It should be noted that to say that the dam-sport combination is relatively cost-effective is not the same thing as saying the two fisheries operate at minimum

cost.

Recommendations:

1. Discontinue commercial fisheries as previously structured.
2. Experiment with new commercial fisheries on a pilot fishery basis in consultation with an experienced "rough fish" fisherman. Ensure observer coverage to monitor incidental catch.
3. Continue sport-reward and dam angling fisheries as complementary operations. Establish operating goals of minimizing cost of fish removed for these projects. Explore approaches to decreasing administration costs of each fishery. Clearly define removal, handling, and evaluation responsibilities.
4. Continue fishery monitoring on a smaller-scale. Reduce the information requirement from anglers. Monitor catch, effort and financial performance. Monitor conflicts and coordination problems.

Handling Methods

Costs of handling northern squawfish are sensitive to the degree of coordination and task sharing which exists between removal fisheries. and handling operations.

Because the program is dispersed over a large geographic area, logistical planning has a significant influence on handling costs. Vehicle rental, road miles, and travel time account for a large part of the fish handling budget. An efficient program-wide transportation system significantly reduces basic administrative/operations costs.

The locations of field stations relative to receiving and processing locations also affects handling costs. The greater the distance between field stations and processing locations, the higher are **the** operating costs. The location of the 1992 WDW field office for the Longview sport-reward area at the processing facility represented an ideal situation.

The distribution of fish handling responsibilities among projects also affects overall handling costs. Efficiency gains will be realized to the extent that on-site handling is supervised and performed on each project. The "internalization" of handling costs will affect cost savings.

Cost-recovery through sale is dependent on an effective quality control program. A key to good quality control is good design and effective reinforcement. On-site supervision of quality requirements is much less costly than external supervision.

The further incorporation of the private sector into the fish handling program requires the clear delineation of responsibilities and predictability in program operations. A contract to handle fish will not be amenable to ad *hoc* changes in operations-

Recommendations:

1. Stabilize the overall predator control program at some level which allows smooth planning and transitions from one season to the next.
2. Minimize the costs of fish handling for the entire predator control project, rather than for individual projects. Internalize as many fish handling responsibilities to each project as possible.
3. Develop fish handling plans for sport-reward sites and for dams which will minimize handling costs to the project as a whole without compromising removal goals. Explicitly account for portions of budgets dedicated to fish handling so they will not be counted as removal costs.
4. Implement a permanent quality control system with incentives to comply.

Product Form

A wide array of product forms has been tested. The list is not exhaustive but the variety is sufficiently extensive to provide adequate information to interested commercial users on the product potential for northern squawfish. The process of experimentation itself has brought northern **squawfish** to the attention of fish processors and fish brokers and created interest in utilization.

In the interest of minimizing total program costs, attention should now shift to ensuring some cost recovery for the northern squawfish catch. Questions regarding purchase of northern squawfish have been directed at the OSU project by private sector representatives. The main hindrance to date in recovering costs through purchase of not-them squawfish has been the absence of a mechanism to transfer payments from the private sector to the predator control program or to an appropriate public entity.

A major question any private sector representative will have is the quantity and quality of northern squawfish which will be available in a given season.

Recommendations:

1. Discontinue experimentation with different product forms.

2. Distribute information on products tested and test results in report format to any interested private party.
3. Develop a contracting mechanism to implement private sector payments for northern squawfish whether for food or industrial uses. Set a goal of maximum cost recovery to the predator control program.
4. Develop an incremental program of private bidding for access to the not-them squawfish yield.
5. Develop long term program goals on yields and scale of operation. Stability in yields will enhance involvement of the private sector as purchasers of northern squawfish.
6. Conduct baseline monitoring of utilization contracts.

Market Potential

The greatest market potential for northern squawfish is in mince, fish meal (as a byproduct of mince) and fertilizer. These uses have accounted for the bulk of fish utilized to date and offer the potential to absorb large volumes of fish in the future. Export of northern squawfish as food fish along with other underutilized species remains a possibility but only a theoretical one at this point in time.

The evaluation of market potential has generated enough information for reasonable decisions to be made regarding the disposition of northern squawfish. Under current cost and price conditions, the most cost-effective alternative for utilization is the food/rendering or food/fertilizer combination. The food/rendering combination has the slightly lower cost of the two but has the disadvantage of requiring weekly deliveries of fresh fish to renderers. The food/fertilizer combination entails slightly higher costs, but has the advantage of allowing frozen fish to accumulate in storage for large-volume deliveries. The exact combination for maximizing the recovery of costs and thereby minimizing total costs of handling will depend on the quality of fish removed and handled, the costs of handling and prices of sale in a given year.

Recommendations:

1. Discontinue further experiments in market potential of northern squawfish. Disseminate the information acquired to date in booklet format to all interested private sector parties.
 2. Maximize the amount of cost recovery to the northern squawfish program by directing northern squawfish to the food/rendering combination or
-

food/fertilizer combination.

3. Sell northern squawfish to private sector interests through contract.
4. Maintain flexibility to provide small experimental quantities of northern squawfish to fish brokers.
5. Build quality-control requirements into all removal projects.
6. Conduct baseline monitoring of market transactions, quality control, and coordination between removal fisheries and end uses.

Regulations

Safety, enforcement, site-access, and incidental cost issues have all been addressed. A remaining area still unaddressed is the classification of northern squawfish as food fish in the state of Washington in order to allow commercial harvesting. Another area related to Washington regulations is the lack of licensing requirements for fishing for northern squawfish, which increases the difficulty of monitoring.

Perhaps the most pressing unaddressed area with regard to regulation is the lack of a system of regulations which would encourage experimental commercial fisheries for northern squawfish and protect against incidental catch concerns. The regulations under which the experimental commercial fishery were promulgated in 1990- 1992 prevented the flexibility needed by commercial fishermen to operate successfully.

Recommendations:

1. Reclassify northern squawfish as food fish in the State of Washington.
 2. Require a license for recreational capture of northern squawfish in the State of Washington.
 3. Develop a proposal for experimental commercial fisheries both in Zone 6 and in the lower river which are consistent with incidental catch concerns and other regulation needs.
 4. Open commercial fishing opportunities for experiment on a least-cost basis.
-

Social Issues

Interproject cooperation continues. to improve. The monitoring of social factors through interviews with sport anglers, dam anglers, and other project personnel is an effective mechanism for staying on top of program-wide issues which need to be addressed.

There are two major issues which need to be addressed immediately. The first is the negative perception that a vocal minority of sport-reward anglers and the general public have of the commercial fisheries in Zone 6 and the angling off the dams. There is ample evidence to suggest that some people perceive Native American fishermen to be intruders as commercial fishermen on the water and as anglers on dams, catching fish which “belong” to the sport-reward fishery.

Although these comments are expressed by a minority, they are expressed often enough to indicate a problem in perception that should be addressed. Public education about the predator control fishery and the role played by the dam fishery could address part of the problem. It would also be useful to create public educational materials that address the system-wide problems on the Columbia River with enough historical perspective to increase awareness of Native American rights.

The second issue is the “killer squawfish” representation in program literature. This term has been adopted by many anglers who use it in their survey forms to express why they are participating in the program. The imagery of a killer not only does not promote public awareness of the program’s goals, it hinders awareness by diverting attention from the idea of bringing a system into balance to the idea of a “bad” species.

Recommendations:

1. Develop public education materials which present the activities of the predator control program in the context of problems facing the river as a whole. Use the opportunity to educate the public more broadly on Columbia River issues.
 2. Develop public education materials which portray the historical role of Native Americans in the Columbia River system and raise levels of consciousness about treaty rights.
 3. Discontinue the “killer squawfish” terminology.
 4. Direct program public education materials toward the “ecosystem balance” approach which emphasizes the positive aspects of harvesting a population to bring a multispecies community into balance.
 5. Continue to monitor social interactions within and between removal fisheries and the program as a whole.
-

Enforcement Issues

Preventing payment for unauthorized fish, property control, and a clear definition of enforcement responsibilities continue to be the major enforcement issues facing the predator control program.

The question of enforcement responsibilities is being addressed through meetings between enforcement personnel and program personnel. The incorporation of enforcement representatives into the design of fishery operation plans should ensure fishery operations which are easier to monitor.

The question of payments for unauthorized fish is a more difficult one. Illegal fish can come from either outside or inside the program. Fish from outside sources **fall** within the purview of enforcement personnel. Fish from inside the project that are being “recycled” through the system pose a more difficult enforcement problem.

Property control is another issue which needs to be addressed before the next season. Better inventory control systems, better monitoring, and strong sanctions imposed on program personnel will be required to prevent program losses of property.

Recommendations:

1. Continue active coordination between enforcement and implementation personnel in the design of plans for removal fisheries.
 2. Design a roving “spot-check” program for all removal fisheries to monitor for tail clipped fish.
 3. Design a cooperative property control program which involves all project administration. Agree on sanctions to be imposed and procedures to be used for the program as a whole.
-

TABLES

Table 1. Components of handling costs for the northern squawfish predator control program.

Cost Component	Type	Sensitive to:
Admin/Op	fixed per season	# harvest sites dispersion of harvest sites projected removals on-site setup delineation of responsibility
On-Site	variable	on-site handling end use quality control compliance
Off-Site	variable	off-site handling end use volume of fish
Coordination	variable	preseason planning complexity of program complexity of end uses delineation of responsibility

Table 2. Product forms for northern squawfish tested, 1989-1992.

User	Apprx. Lbs. N. Squawfish	Product Form
Multiple-use processor	154,265	liquid fertilizer
Renderer	134,000	mixed fish/animal meal for feed
Rough fish processor	130,000	fish mince fish meal, oil
Mink Grower	9,500	mink feed
Seafood Lab	2,200	frozen mince, surimi, roe
Fish meal processor	2,000	fish meal
Restaurants & Markets	1,986	whole; fillet
Restaurants & Markets	60	frozen boxed mince
Bait crab crawfish bear	1,500	whole; cut
Fish brokers (export)	600	whole frozen

Table 3. Removals by fishery and percent of total program removals, 1990-1993.

Fishery	1990 # Removed' (%)	1991 # Removed (%)	1992 # Removed (%)
Commercial longline	1,400 (8)	1,100 (.5)	1,880 (.1)
Dam angling	11,000 (65)	40,000 (20)	27,500 (13)
Sport- reward	<u>4,500</u> (27)	<u>158,000</u> (79)	<u>184,000</u> (87)
Total	16,900	199,100	213,380.

Table 4. Estimates of cost per pound of different components of northern squawfish handling system.

Cost Component	Cost Per Pound Handled
Admin/Op	. Fixed per Season (ave. cost/lb. declines as total lbs. increase) \$.40 - \$.45 for 1992
On-Site	
rendering	\$.08
fertilizer	.10
food	.12
Off-Site	
rendering	.08
fertilizer	.12
food	.16
Coordination	
rendering	variable with
fertilizer	extent of pre-season
food	planning, contracts, delineation of responsibilities

Table 5. Total variable costs (on-site + off-site) per pound and cost recovery per pound for three end uses of northern squawfish.

End Use	On-Site+Off-Site Cost per Pound	Cost Margin over Rendering	Cost-Recovery per Pound	% Cost Margin over Baseline which is Recoverable
Rendering	\$.16	\$ 0	\$0	0%
Fertilizer	\$.22	\$.06	\$.02 - .05	33-83%
Food	\$.28	\$.12	\$.10 - .15	83- 125%

Table 6. Estimated variable costs of handling 300,000 pounds of northern squawfish for different end uses.

End Use	Variable Cost	\$ Change from Baseline	% Change from Baseline
Case 1: No cost-recovery			
A. All Rendered (baseline)	\$48,000	---	---
B . Render/Fen (.5/.5)	\$57,000	+ \$9,000	+ 19%
C. Render/Food (.5/.5)	\$66,000	+ \$18,000	+ 38%
D. Fert./Food (.5/.5)	\$75,000	+ \$27,000	+ 56%
Case 2: Cost-recovery			
A. All Rendered (baseline)	\$48,000	---	---
<u>Cost-recovery: 0</u>			
B . Render/Fert. (.5/.5)			
fert. @ \$.02/lb.	\$54,000	+ \$6,000	+ 12.5%
fert. @ \$.05/lb.	\$49,500	+ \$1,500	+ 3.1%
<u>Cost-recovery: \$3,000 @ .02/lb.; \$7,500 @ \$.05/lb.</u>			
C. Render/Food (.5/.5)			
food@\$.10/lb.	\$51,000	+ \$3,000	+ 6.3%
food@\$.15/lb.	\$43,500	- \$4,500	- 9.4%
<u>Cost-recovery: \$ 15,000 @ \$.10/lb.; \$22,500 @ \$.15/lb.</u>			
D. Fert./Food (.5/.5)			
(fert. @ \$.02/ food@\$.10)	\$57,000	+ \$9,000	+ 18.7%
(fert. @ .05/ food@\$.10)	\$45,000	- \$3,000	- 6.3%
<u>Cost-recovery: \$18,000 (\$.02; \$.10); \$30,000 (.05; \$.15)</u>			

Table 7. Characteristics and feasibility of various product forms tested for northern squawfish.

Product Form	Characteristics	Feasible
Round (human use)	good size good appearance good taste large # bones	no
Fillets	good appearance good texture good taste large # bones	no
Mince	firm texture bland taste needs binder versatile use	yes
Roe	variable size variable color med. firm texture	no
surimi	good shelf life good mince quality firm texture	yes
Fertilizer	liquid combine with carp acceptable quality requires clean fish	yes
Fish Meal	nutritive comp. of carp substitute for carp flesh and entrails	yes
Fish Oil	combine with other fish use byproducts	yes
Bait	cut pieces acceptable not first quality	under some conditions
Export market	whole round	unknown

Table 8. Summary of market characteristics and market potential of northern squawfish product forms.

Product	Market Characteristics	Market Potential
Round (human use)	good availability minimal processing low to no demand	poor
Fillets	machine processing demand unknown quality good	unknown
Mince	steady supply versatile product	good
Roe	poor availability low demand	poor
Surimi	seasonal supply variable quantity quality good	unknown
Fertilizer	seasonal supply variable quantity quantity demanded unknown	good
Fish meal	byproduct of mince	good
Fish oil	byproduct of mince	unknown
Bait	not premium quality substitutes available	poor
Export market	unknown	unknown

APPENDIX B

Commercial Longline Fishery

Appendix Table B-1. Agency expenditures by category in the 1992 commercial longline fishery for northern squawfish, preliminary date.

Expenditure category	Total ODFW expenditure
Salaries/wages	\$47,805
Fringe benefits	11,785
Supplies	939
Operation & maintenance	6,603
Bait	7,105
Payment for squawfish	4,020
Travel	11,941
Overhead	<u>23,527</u>
TOTAL	\$113,725

APPENDIX C

Dam Angling Fishery Expenditures

Appendix Table C- 1. Agency total expenditures and expenditure per fish removed for the 1992 dam angling fishery, by fishing crew.

Fishing Crew	Total Expenditure (components explained in text)	Total Catch	Expenditure Per Fish Removed
Bonneville	\$92,220	3,356	\$27.48
The Dalles	90,877	6,692	13.58
John Day	79,444	3,422	23.22
McNary	96,020	6,960	13.80
Ice Harbor	12,352	186	66.41
Lower Monumental	65,737	6 1 8	106.37
L.Goose/L. Granite	262,509	3,537	74.22
Mobile Crew	78,276	2,997	26.12
Volunteer Angling	<u>2,835</u>	<u>100</u>	<u>28.35</u>
Total	\$780,270	27,868	\$28.00

Appendix Table C-2. Crew-specific expenditures, total catch, and expenditure per fish removed for the 1992 dam angling fishery.

Fishing Crew	Crew Expenditures (components explained in text)	Total Catch	Crew Expenditure Per Fish Removed
Bonneville	\$67,020	3,356	\$19.97
The Dalles	59,377	6,692	8.87
John Day	54,244	3,422	15.85
McNary	72,920	6,960	10.48
Ice Harbor	6,052	186	32.54
Lower Monumental	38,437	618	62.60
L. Goose/L. Granite	226,809	3,537	64.12
Mobile Crew	44,676	2,997	14.91
Volunteer Angling	<u>2,100</u>	<u>100</u>	7.35
Total	\$570,270	27,868	\$20.46

APPENDIX D
Sport-Reward Fishery

SPORT REWARD VOUCHER

LAST NAME																								
FIRST NAME															M. I.									
STREET																								
CITY															STATE					ZIP				
MD			DAY			YR			DOCUMENT #				SOCIAL SECURITY #											
NUMBER OF QUALIFYING SQUAWFISH:				VOUCHER #:																				

NUMBER OF QUALIFYING SQUAWFISH (print):

SIGNATURES:

CREEL CLERK

ANGLER
(Signed in Presence of Creel Clerk)

Keep record of voucher #. Please send completed voucher as soon as possible. Voucher void after 10/15/92.

Appendix Figure D- 1. Sport-reward fishery survey form.

**ANNUAL QUESTIONS: TO BE ANSWERED
ONLY ONCE PER FISHING YEAR**

A1. HAVE YOU FILLED OUT THIS SECTION IN 1992?
1. YES 2. NO

IF NO, PLEASE ANSWER BELOW
IF YES, THANK YOU. NO NEED TO FILL OUT AGAIN

A2. How many fishing trips do you usually make per year?
1. 0 5. 16-20
2. 1-5 6. 21-25
3. 6-10 7. >25
4. 11-15

A3. Of these trips, number in this general location:
1. 0 5. 16-20
2. 1-s 6. 21-25
3. 6-10 7. >25
4. 11-15

A4. Years you have been a sport fisherman:
1. <1 3. 6-7
2. 1-3 4. 8-9
3. 4-s 5. 10 or more

AS. Did you fish in the squawfish control program last year?
1. YES
2. NO

A6. State of residence:
1. OREGON
2. WASHINGTON
3. IDAHO
4. OTHER (please specify): _____

A7. Age:
1. 14-M 5. 51-60
2. 21-30 6. 61-70
3. 31-40 7. >70
4. 41-50

A8. Education:
1. GRADE SCHOOL 5. COLLEGE
2. HIGH SCHOOL DEGREE
3. SOME COLLEGE 6. GRADUATE
4. VOC. OR TECH. DEGREE
OR COMMUN. COLL.

A8. How did you hear about the squawfish control program?
1. NEWSPAPER
2. RADIO
3. TV
4. WORD OF MOUTH
5. STATE FISHERY AGENCY
6. OTHER (please specify)

A9. How important are the following factors in your participation in the squawfish control program?

A. PAYMENT FOR SQUAWFISH

1. Very important
2. Of some importance
3. Not important

B. RECREATION OPPORTUNITY

1. Very important
2. Of some importance
3. Not important

C. COVERING EXPENSES FOR OTHER TARGET SPECIES

1. Very important
2. Of some importance
3. Not important

D. PARTICIPATING IN SALMON ENHANCEMENT PROGRAM

1. Very important
2. Of some importance
3. Not important

A10. COMMENTS:

VOUCHER #:

**PLEASE RETURN TO BACK SIDE OF FORM FOR
QUESTIONS ABOUT THIS FISHING TRIP**

TRIP QUESTIONS: TO BE ANSWERED EVERY TRIP. Members of a single household fishing and submitting voucher together: Main angler in household answer questions for entire household. Members of separate households fishing individually or together, submitting separate vouchers: Each registered angler should answer questions for him/herself. (If group expenditures made for #7,8,9, enter amount of your individual expenditure only.)

PLEASE FILL IN OR CIRCLE THE APPROPRIATE ANSWER

- | | |
|--|---|
| <p>T1. Number of anglers in your party:
PEOPLE</p> <p>T2. Number of hours spent fishing for
squawfish: HRS PER PERSON</p> <p>T3. Miles traveled (one way) to fish at this
reservoir:
1. <20 4. 60-79
2. 20-39 5. 80-99
3. 40-59 6. 100 or more</p> <p>T4. If staying away from home, number of
days you stayed in the area this trip:
1. <1 5. 4
2. 1 6. 5
3. 2 7. >5
4. 3</p> <p>T5. Primary reason for this trip: (circle only
one)
1. SQUAWFISH
2. OTHER FISH
3. COMBINATION OF OTHER FISH/
SQUAWFISH
4. NONFISHING ACTIVITY
5. OTHER (please specify)</p> <p>T6. If you stayed overnight, type of
accommodation:
1. MOTEL
2. STATE PARK
3. NATIONAL PARK CAMPGROUND
4. PRIVATE CAMPGROUND
5. FRIEND OR RELATIVE
6. OTHER (please specify)
_____</p> | <p>T7. Approximate amount spent on this trip to
purchase:
<u>FOOD</u>
1. RESTAURANTS: \$ _____
2. GROCERY STORE: \$ _____
<u>OTHER</u>
3. ACCOMMODATIONS: \$ _____
3. GAS: \$ _____
4. FISHING SUPPLIES: \$ _____
5. BAIT: \$ _____
6. OTHER (please specify): _____
_____</p> <p>T8. Primary fishing method you/(your party)
used: (circle only one)
1. BOAT, ANCHORED
2. BOAT, DRIFTING
3. BOAT, TROLLING
4. SHORE
5. ANGLING, SURFACE
6. ANGLING, BOTTOM
7. OTHER (please specify): _____</p> <p>T9. Primary bait or tackle you&our party)
used: (circle only one)
1. WORMS
2. CUT FISH BAIT
3. SPINNERS
4. SPOONS
5. FLATFISH
6. SURFACE PLUGS
7. HOOK AND LINE WITH 1 HOOK
8. HOOK AND LINE WITH >1 HOOK
9. OTHER (please specify): _____</p> <p>T10. Approximate purchase price of primary
tackle used:
_____</p> <p>T11. Any problems encountered while fishing:
ON BOAT RAMP OR WATER (please
specify): _____

_____</p> |
|--|---|

**Telephone Questionnaire for Non-returning Anglers
'Northern Squawfish Sport-Reward Fishery 1992**

Angler Name: _____ Interviewer Name: _____ Date: _____

Our records show that you registered to fish for northern squawfish at _____ (location) on _____ (date) but did not return to the site to register your catch. We would like to ask you a few follow-up questions about your fishing experience to help us identify any areas of needed improvement in our program.

1. How many hours did you fish for northern squawfish that day? _____ HRS.

2. How many hours did you fish for other species that day? H R S .

3. What was your primary target species? _____

Other target species? _____

4. Did you catch any northern squawfish?

Y E S NO _____

If yes: Number <11" _____ Number >11" _____

6. While you were fishing for northern squawfish did you catch any other species?

YES _____ NO _____

Species

Number

Appendix Figure D-2. Sport-reward fishery non-returning angler survey form.

7. While you were fishing for species (other than squawfish) what did **you** catch?

Species

Number

8. What fishing method(s) did you use to fish for northern squawfish?

9. Reason for not returning to site:

10. How important are the following factors in terms of their importance to you in participating in the squawfish fishery?

A. Payment for squawfish

1. Very important
2. Somewhat important
3. Not important

B. Recreational opportunity

1. Very important
2. Somewhat important
3. Not important

C. Opportunity to cover expenses while targeting game species

1. Very important
2. Somewhat important
3. Not important

D. Participating in salmon enhancement

1. Very important
2. Somewhat important
3. Not important

11. Did you return any squawfish for payment in 1992? YES___ NO-
If yes: # squawfish returned: _____
12. Were the 1992 **check** stations conveniently located for you? YES___ NO__
If no: what new locations would you propose? _____
13. How many fishing trips do you typically make per year (all locations)? _____
14. Of these fishing trips, number in this general location: _____
15. How many additional fishing trips do you typically make per year to participate in the squawfish program?

16. Do you plan to fish in the 1993 sport-reward fishery for northern squawfish?
Y E___S NO _____.
Reason:_____

Thank you for your time.

**Telephone Questionnaire for Creel Clerk Evaluation
of the 1992 Sport-Reward Fishery**

Interview date: _____

We would like your help in evaluating the operation and conduct of the sport-reward fishery this summer. Your answers will be confidential. Information from this survey will be reported in **summary form** only. Individual respondents will not be identified.

1. Please tell us how **many** complaints in the following categories you heard from anglers.

	Many	Some	Few	None	NA
<u>Boat Ramps</u>					
overcrowding on boat ramps	---	---	---	---	---
size of boat ramps	---	---	---	---	---
time waiting to launch	---	---	---	---	---
other (specify)					

<u>Fishing</u>					
crowding with other anglers		---	---	---	---
crowding with commercial fishermen	---	---	---	---	---
gear damage from crowding with anglers	---	---	---	---	---
gear damage from crowding with comm. fishr.	---	---	---	---	---
boats passing too fast	---		---	---	---
jet skiers	---		---	---	---
water skiers	---		---	---	---
litter in water	---		---	---	---
litter on banks	---		---	---	---
other (specify)					

<u>Registration and Check-In</u>					
registration processing time	---	---	---	---	---
registration processing paperwork	---	---	---	---	---
problems with other anglers	---	---	---	---	---
check-in time	---	---	---	---	---
check-in paperwork	---	---	---	---	---
fish quality requirements	---	---	---	---	---
other (specify)					

Appendix Figure D-3. Sport-reward fishery creel clerk survey form.

2. We would like your evaluation of several parts of the sport-reward fishery operation, and any recommendations you have for change.

a. operating hours: good ___ fair ___ poor -

recommendations: _____

b. registration process: good ___ fair ___ poor ___

recommendations: _____

c. fish check-in process: good - fair - poor ___

recommendations: _____

d. data forms: good - fair - poor ___

recommendations: _____

e. data collection process: good ___ fair ___ poor ___

recommendations: _____

f. staffing ___ fair ___ poor ___

recommendations: _____

g. equipment: good ___ fair ___ poor ___

recommendations: _____

h. interaction with public: good ___ fair ___ poor ___

recommendations: _____

i. station security: good ___ fair p_o_o_r ___

recommendations: _____

j. other recommendations:

3. Did you or your crew hear any complaints about the sport-reward fishery **from** townspeople near your site? **YES** ___ **NO** ___

If yes, please specify:

4. Did you or your crew hear compliments about the operation of the sport-reward fishery? YES ___ NO ___ If **yes**, please specify:

THANK YOU FOR YOUR HELP.

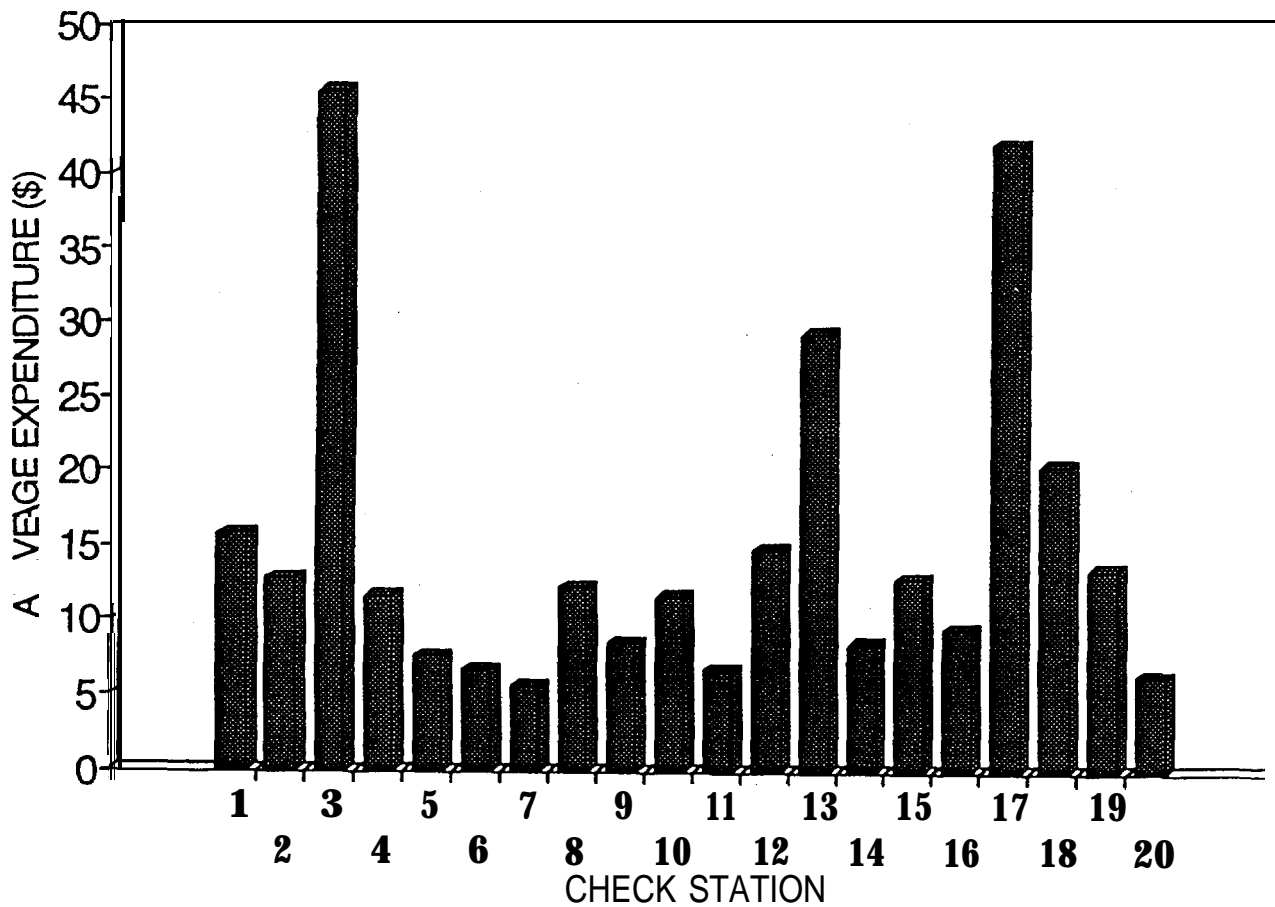
Appendix Table D-1. Sport-reward fishery **check** station codes, 1992.

Check Station	Code
Willow Grove	1
Kalama Marina	2
St. Helens	3
Vancouver	4
M. James Gleason	5
Hamilton Island	6
Covert's Landing	7
Cascade Locks	8
Bingen	9
Dalles	10
LePage Park	11
Maryhill State Park	12
Plymouth	13
Columbia Point	14
Ringold	15
Hood Park	16
Windust Park	17
Lyons Ferry State Park	18
Boyer Park	19
Green Belt	20

Appendix Table D-2. Agency total expenditures and expenditure per fish removed for sport-reward fishery by check station, station-specific expenditures only.

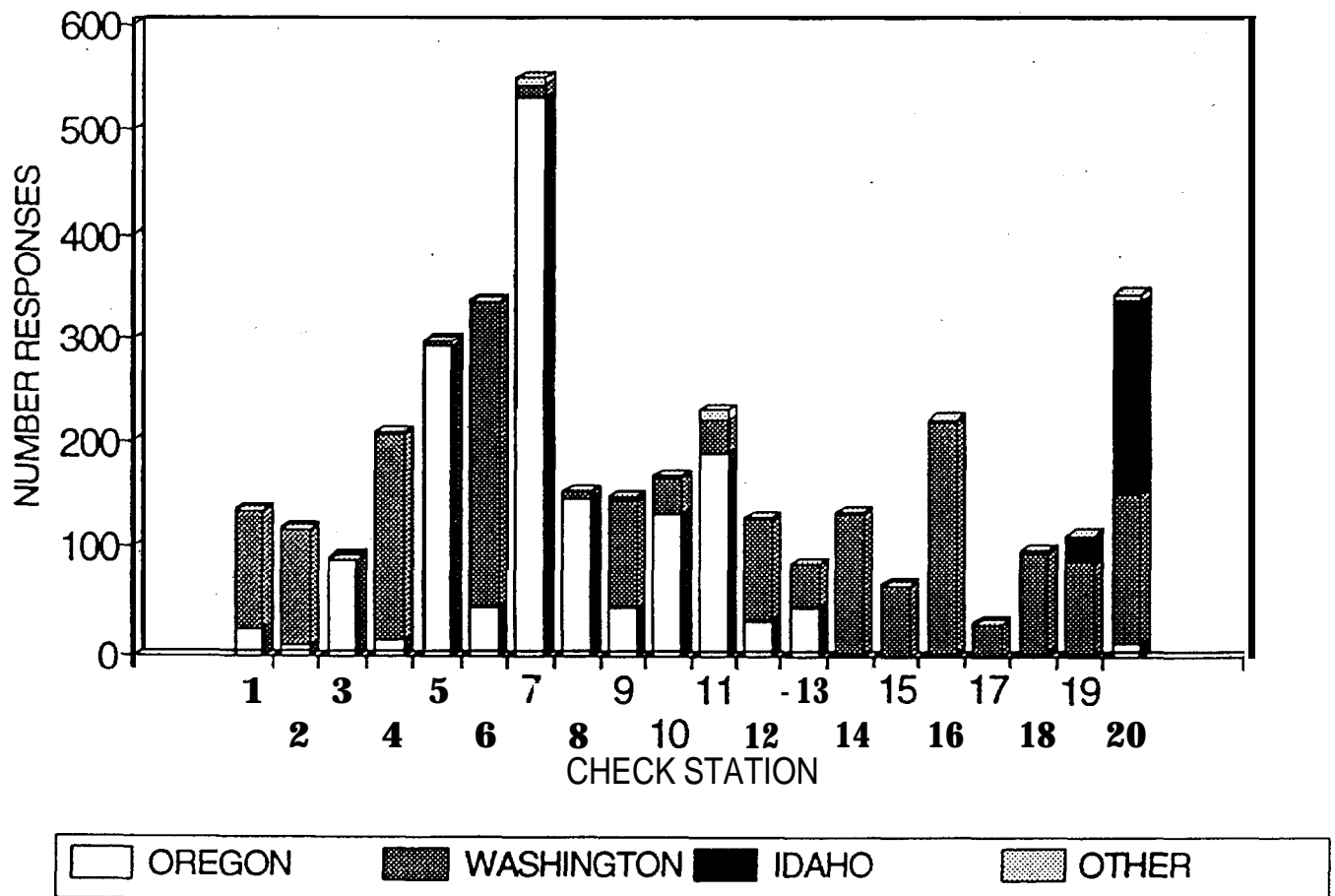
Check Station	Total Expenditure (including payment per fish)	Total Catch	Expenditure Per Fish Removed
Willow Grove	\$89,665	5,677	\$15.79
Kalama Marina	88,203	6,659	13.25
St. Helens	73,469	1,609	45.66
Vancouver	101,224	8,655	11.70
M. James Gleason	116,822	15,351	7.61
Hamilton Island	113,632	17,039	6.67
Covert's Landing	135,017	23,836	5.66
Cascade Locks	83,512	6,779	12.32
Bingen	90,550	10,575	8.56
Dalles	78,535	6,705	11.71
LePage Park	79,031	16,896	4.68
Maryhill State Park	75,823	5,072	14.95
Plymouth	71,961	2,454	29.32
Columbia Point	93,265	11,030	8.46
Ringold	65,962	5,103	12.93
Hood Park	85,498	9,037	9.46
Windust Park	61,821	1,464	42.23
Lyons Ferry State Park	63,692	3,113	20.46
Boyer Park	79,583	5,850	13.60
Green Belt	<u>136,840</u>	<u>21,382</u>	<u>6.40</u>
TOTAL	\$1,784,105	184,286	\$9.68

AVERAGE EXPENDITURE PER FISH REMOVED
SPORT-REWARD CHECK STATIONS 1-20, 1992



Appendix Figure D-4. Average agency expenditure per fish removed.

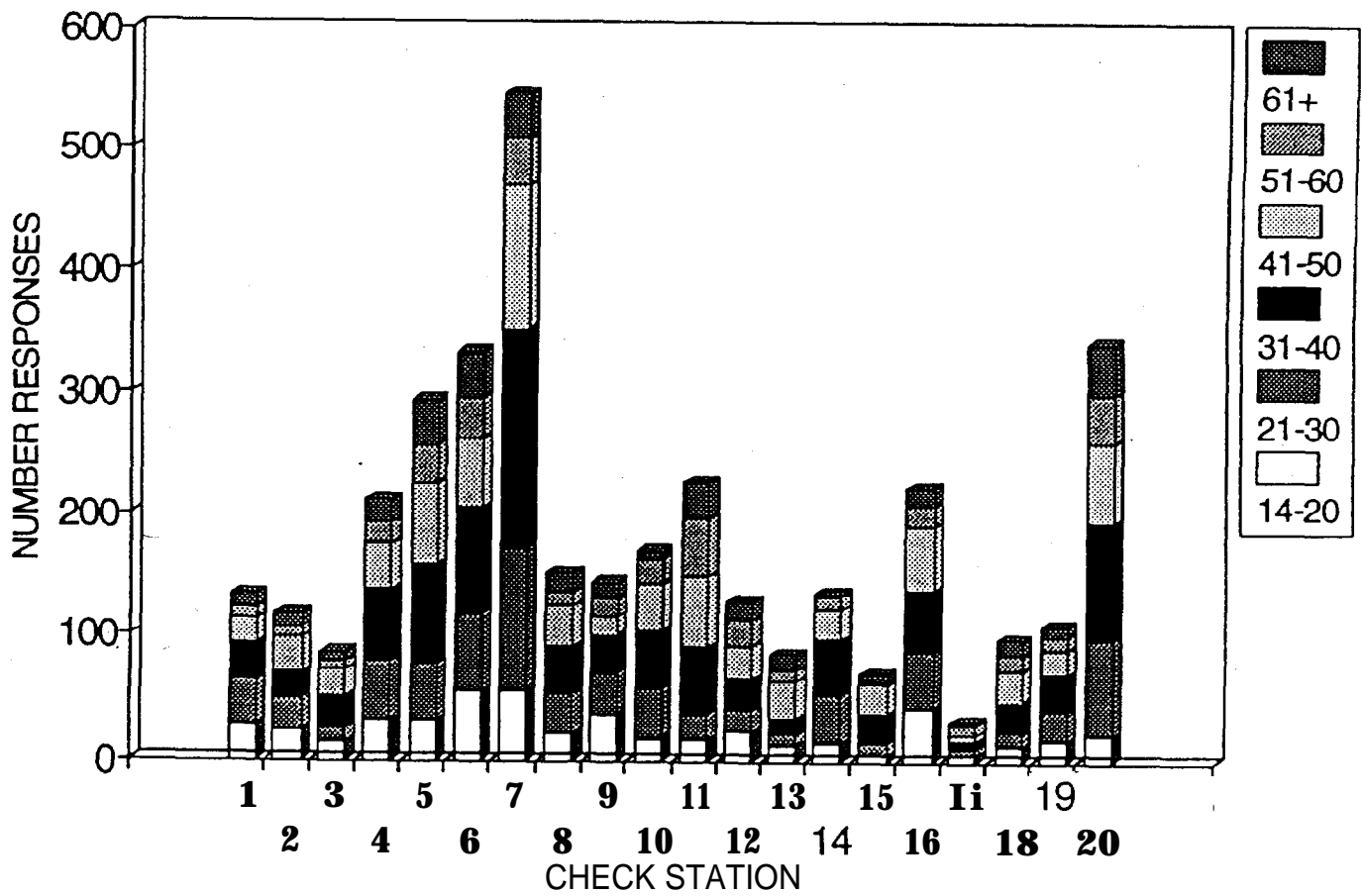
STATE OF RESIDENCE OF SPORT ANGLERS ANGLER ANSWERS BY CHECK STATION, 1992



Appendix Figure D-5. State of residence of sport anglers.

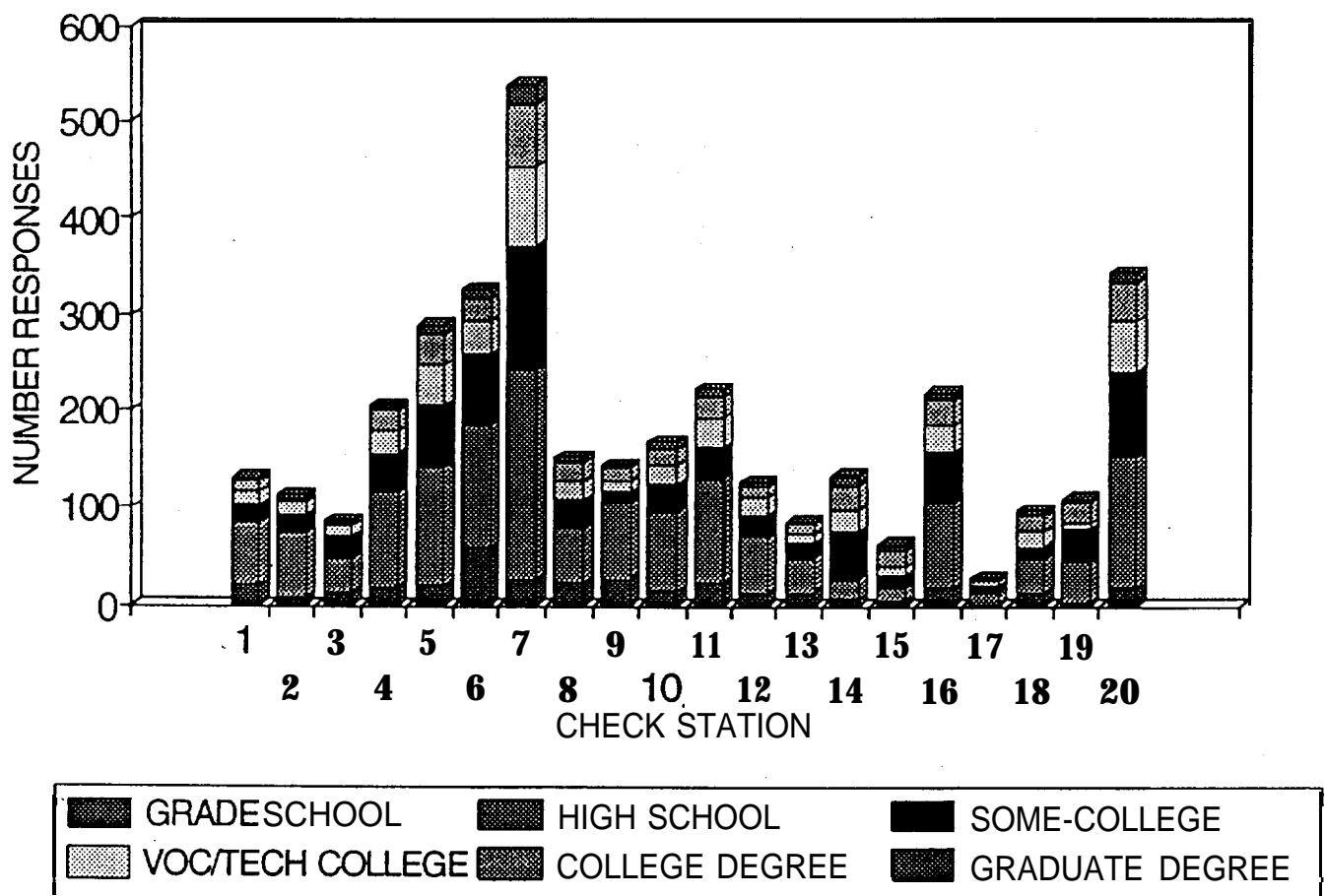
AGE OF SPORT ANGLERS

ANGLER ANSWERS BY CHECK STATION, 1992



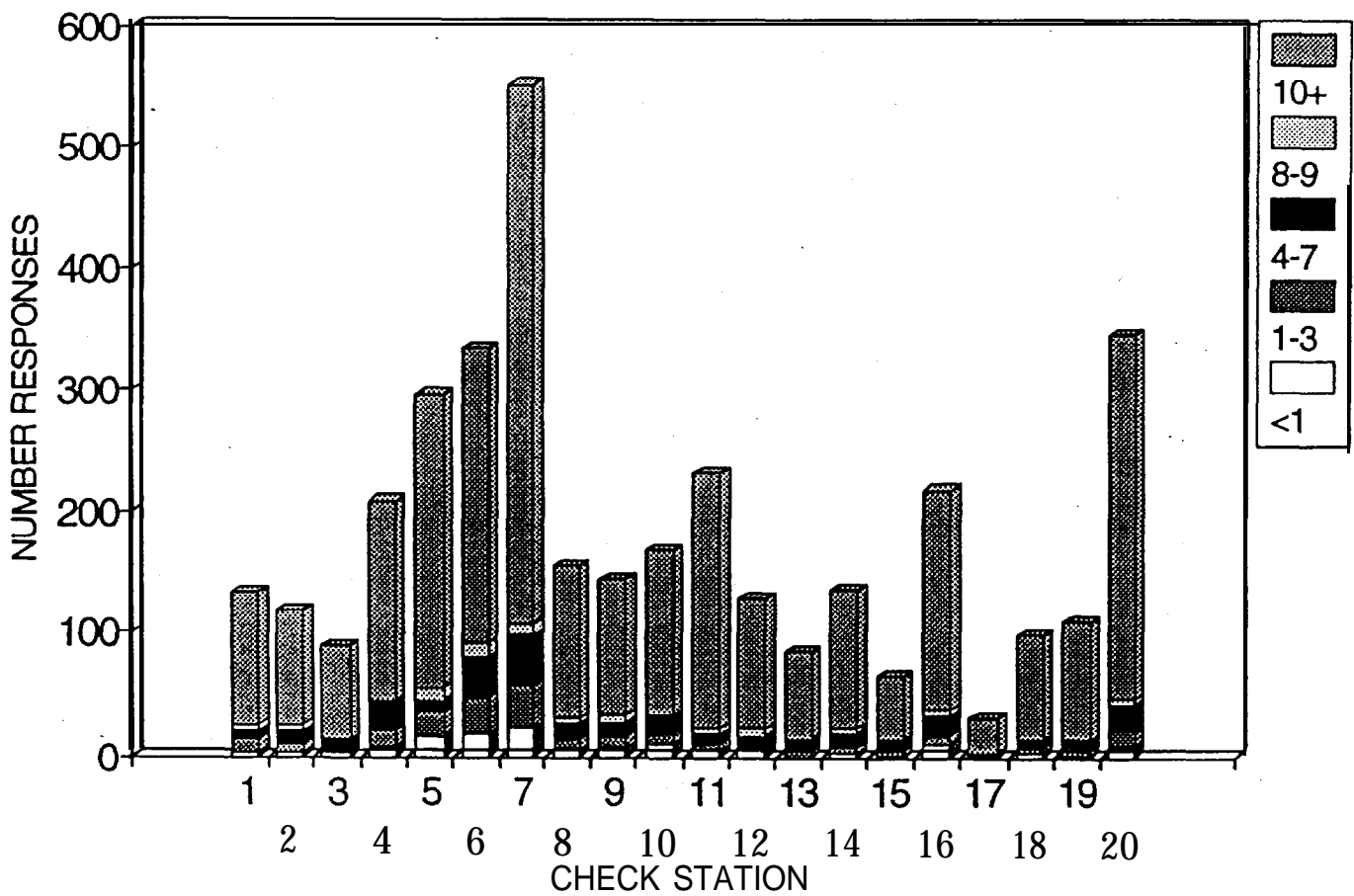
Appendix Figure D-6. Age of sport anglers.

EDUCATION LEVELS OF SPORT ANGLERS ANGLER ANSWERS BY CHECK STATION, 1992



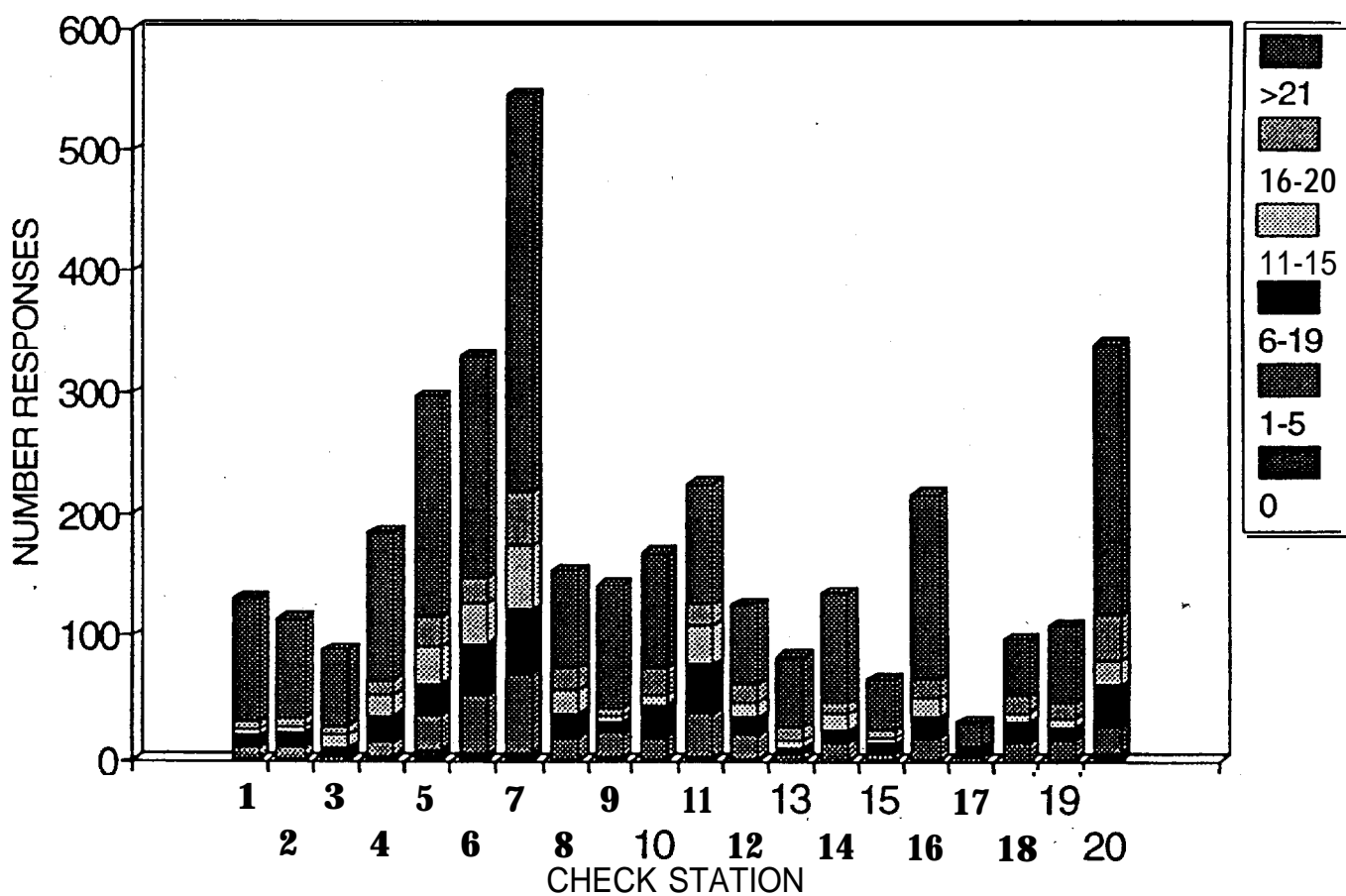
Appendix Figure D-7. Education levels of sport anglers.

N. YEARS YOU HAVE FISHED?
 ANGLER ANSWERS BY CHECK STATION, 1992



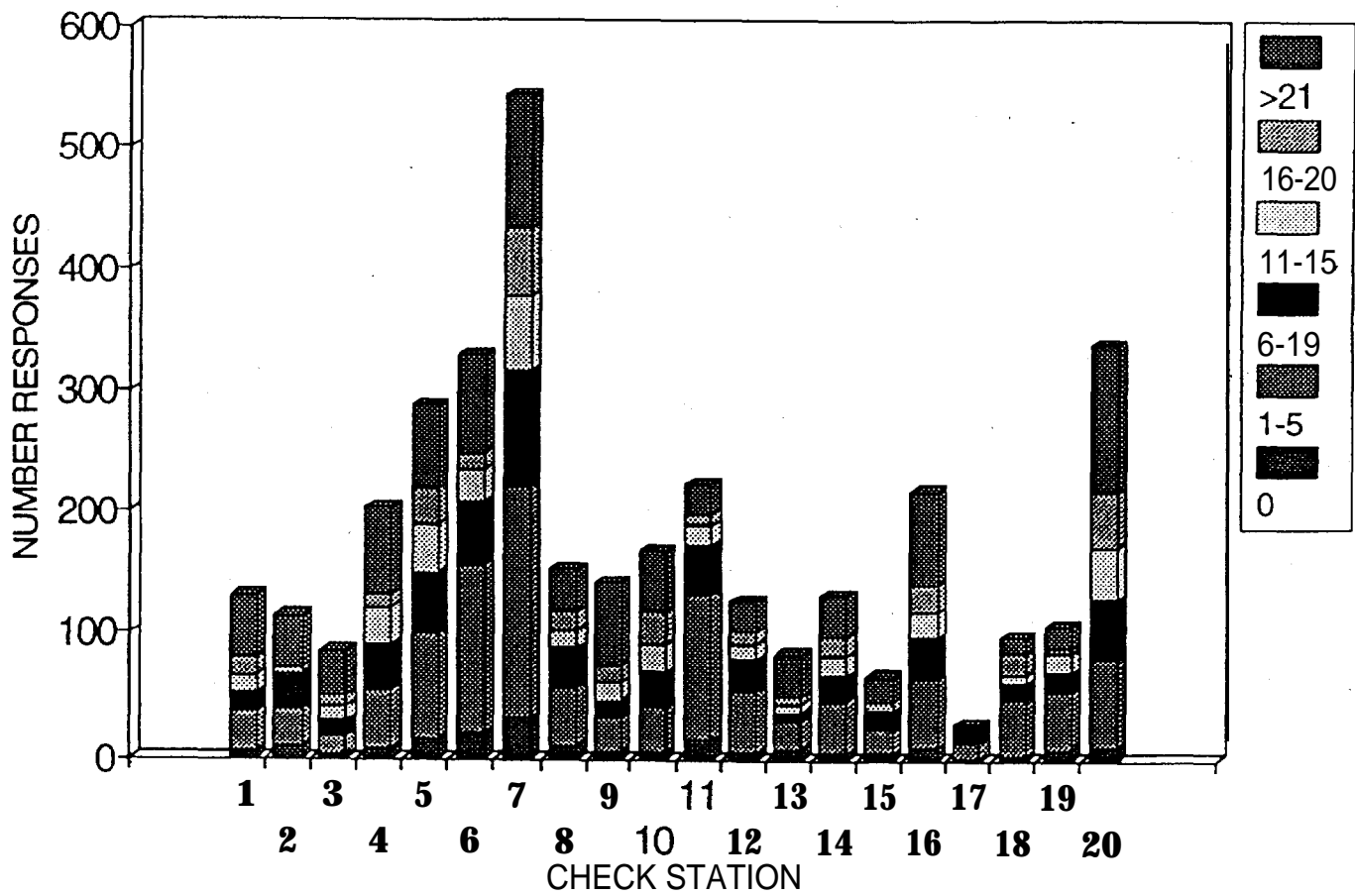
Appendix Figure D-8. Number of years sport anglers have fished.

N. FISHING TRIPS YOU MAKE PER YEAR?
 ANGLER ANSWERS BY CHECK STATION, 1992



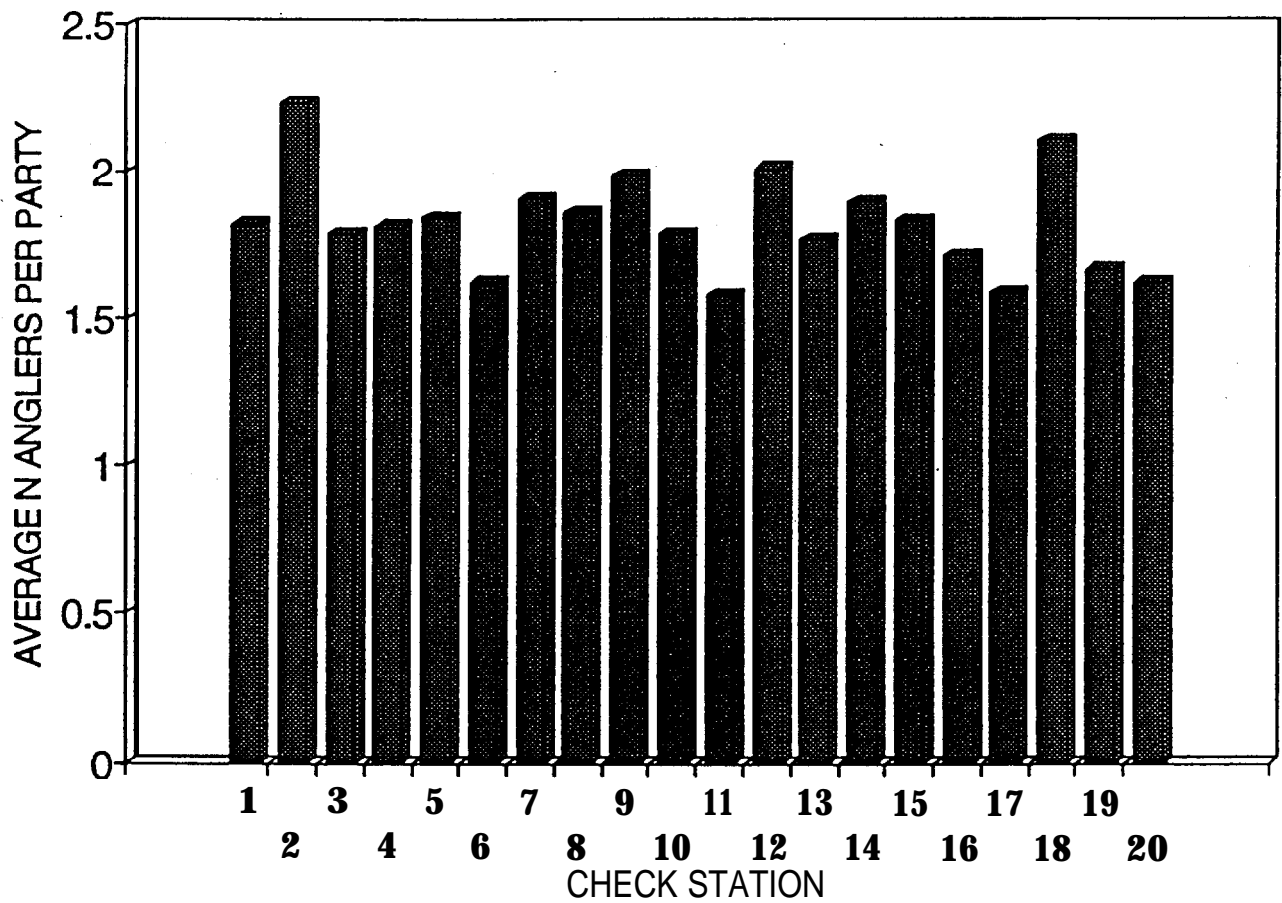
Appendix Figure D-9. Number of sport fishing trips made by anglers per year.

N. TRIPS PER YEAR TO THIS LOCATION?
 ANGLER ANSWERS BY CHECK STATION, 1992



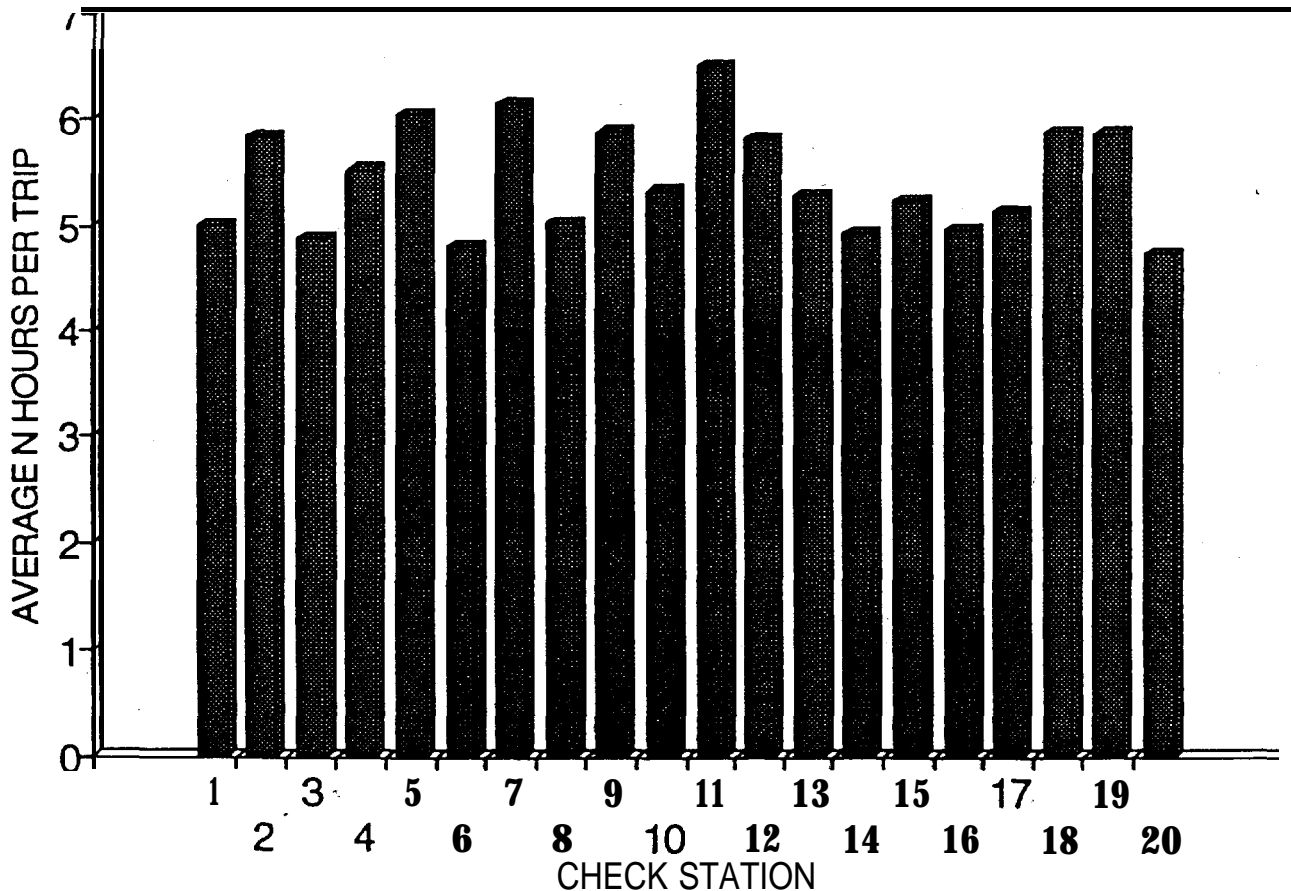
Appendix Figure D-10. Number of sport fishing trips to check station location.

AVERAGE NUMBER OF ANGLERS IN PARTY
SPORT-REWARD CHECK STATIONS 1-20,1992



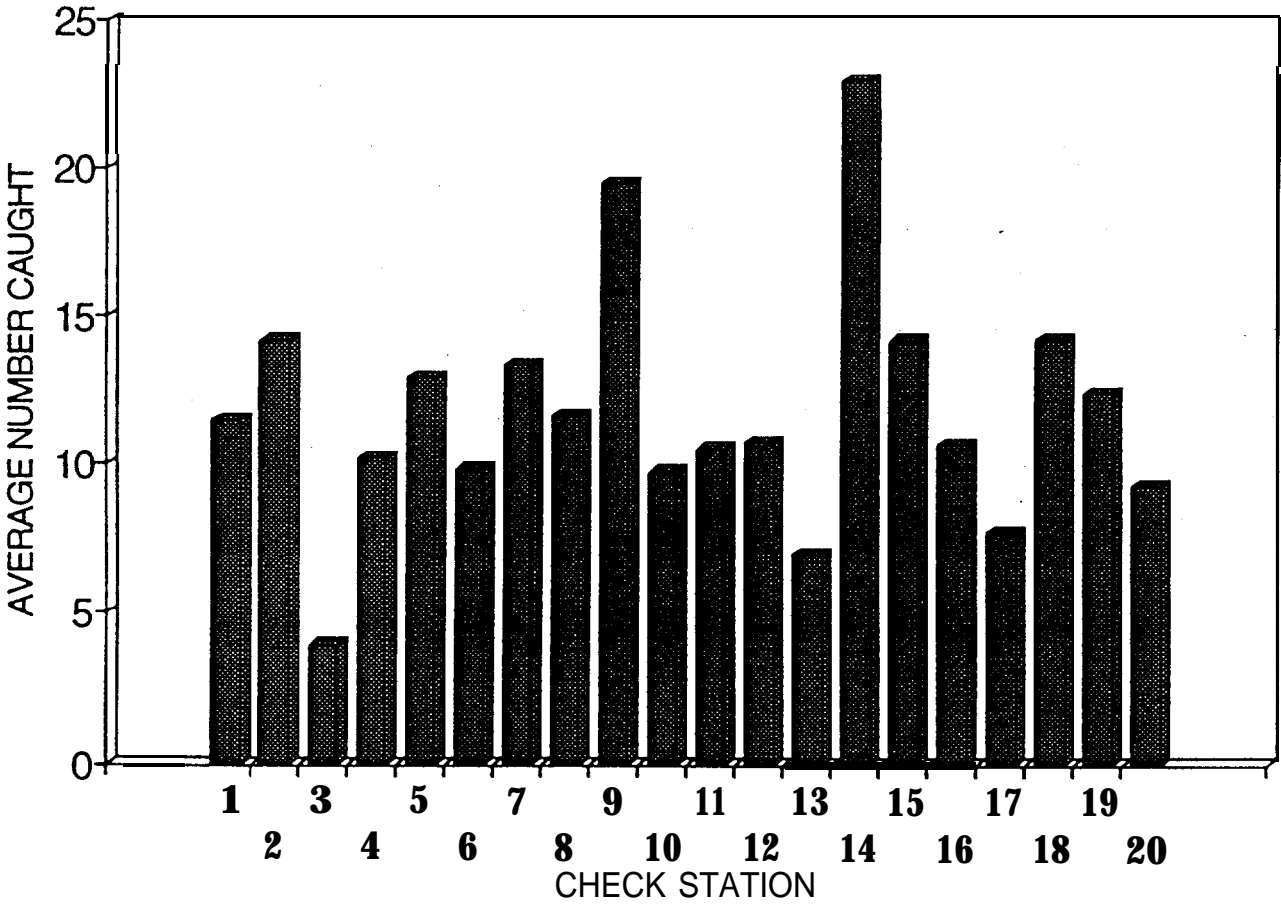
Appendix Figure D-1 1. Average number of sport anglers in party.

AVERAGE NUMBER OF HOURS SPENT FISHING
SPORT-REWARD CHECK STATIONS 1-20, 1992



Appendix Figure D-12. Average number of hours spent fishing.

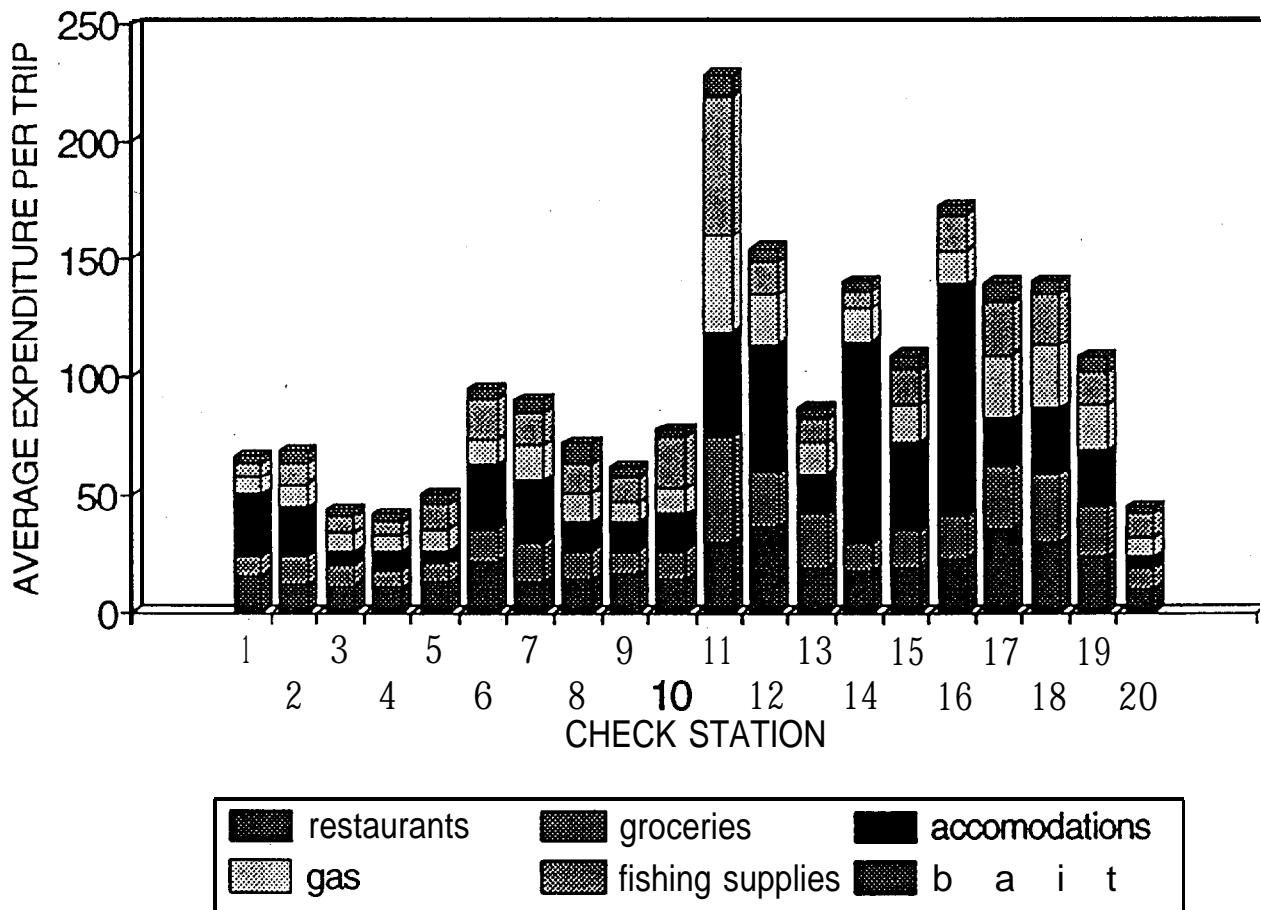
NUMBER OF N.SQUAWFISH CAUGHT PER TRIP
SPORT-REWARD CHECK STATIONS 1-20, 1992



Appendix Figure D- 13. Number of northern squawfish caught per trip.

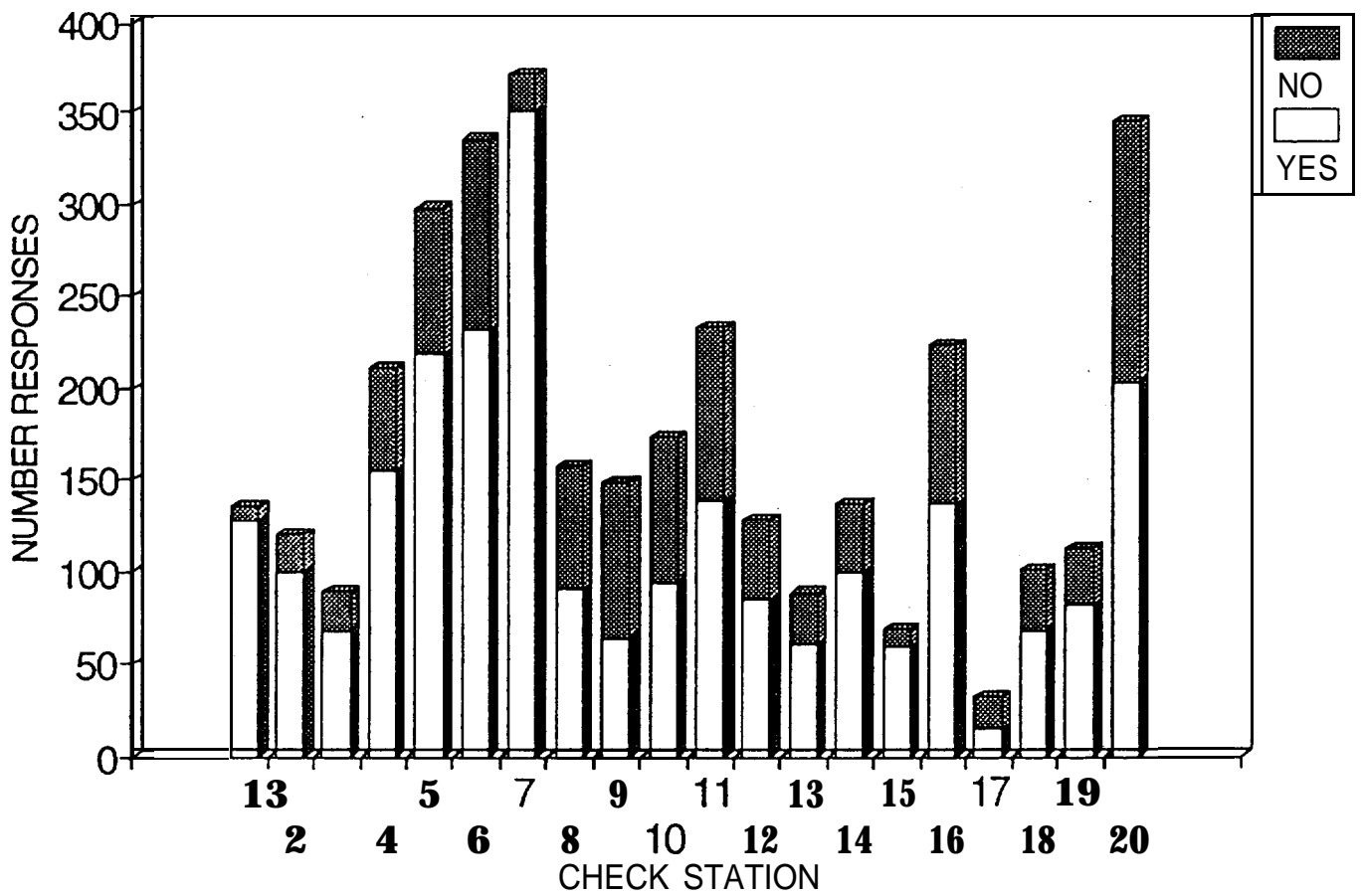
ANGLER EXPENDITURES BY CATEGORIES

SPORT-REWARD CHECK STATIONS 1-20,1992



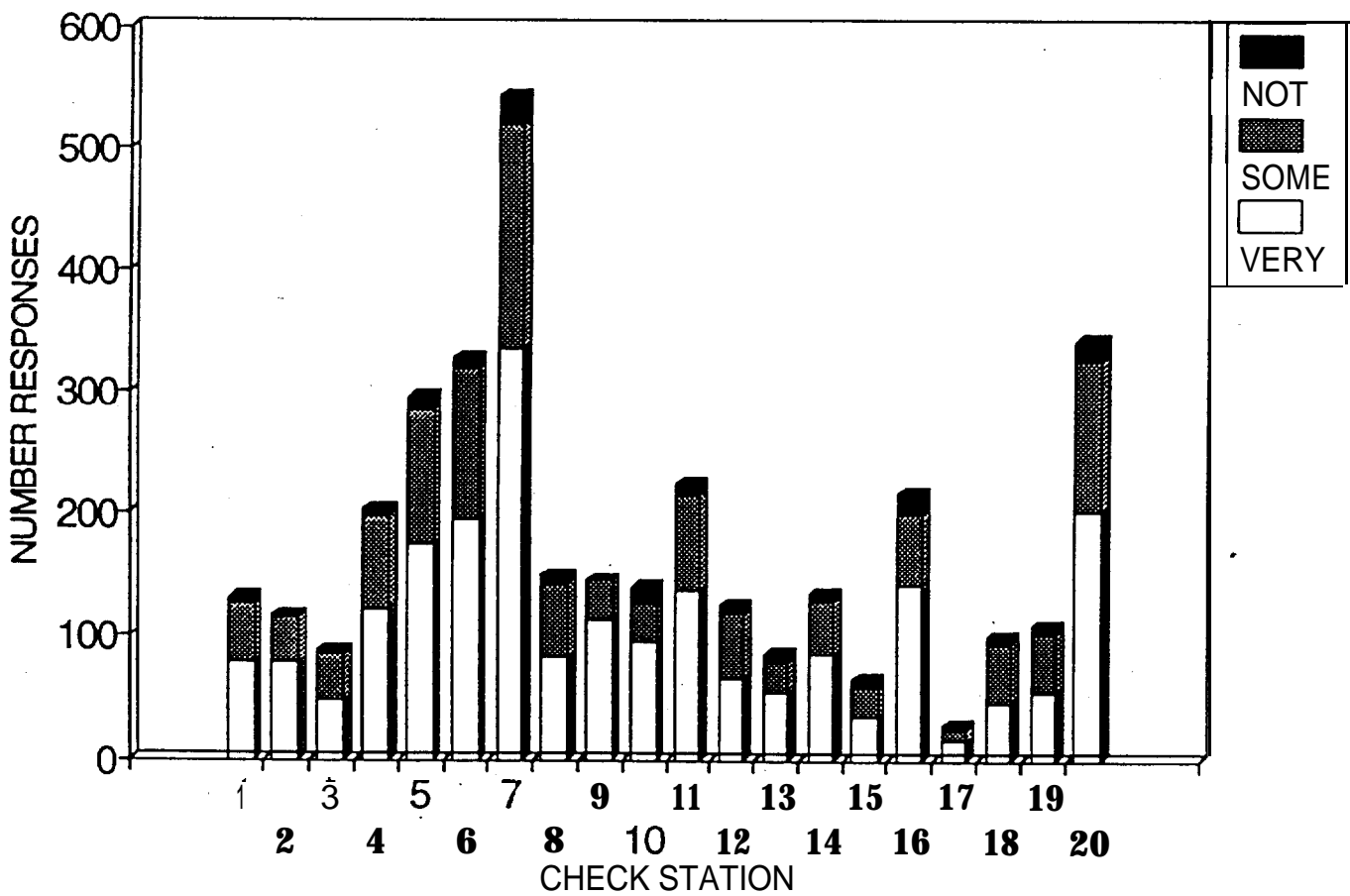
Appendix Figure D-14. Angler expenditures by category.

DID YOU FISH FOR SQUAWFISH IN 1991? ANGLER ANSWERS BY CHECK STATION, 1992



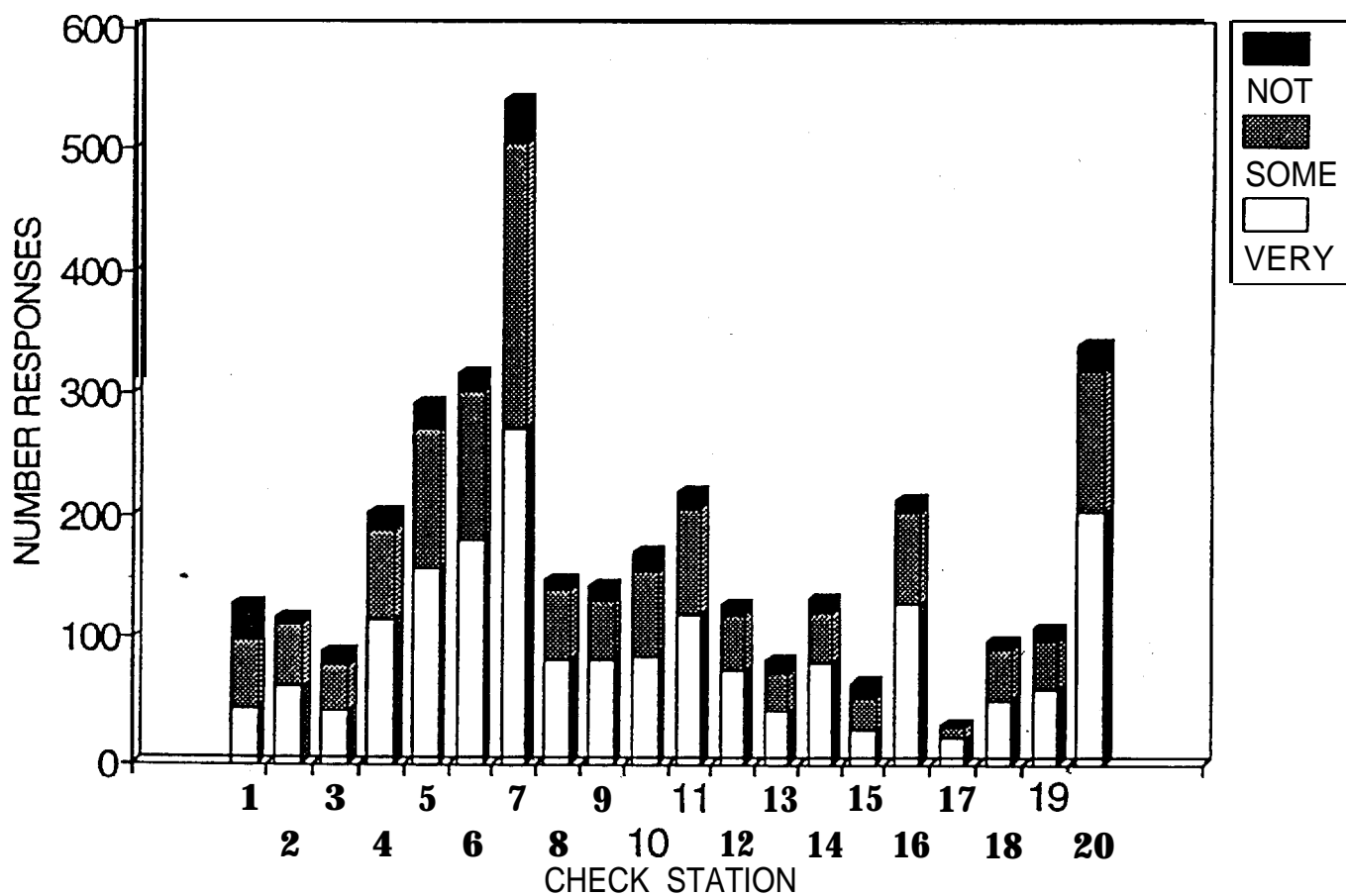
Appendix Figure D-15. Previous participation in the northern squawfish fishery.

HOW IMPORTANT IS PAYMENT FOR SQUAWFISH? ANGLER ANSWERS BY CHECK STATION, 1992



Appendix Figure D-16. Importance of payment for squawfish to anglers.

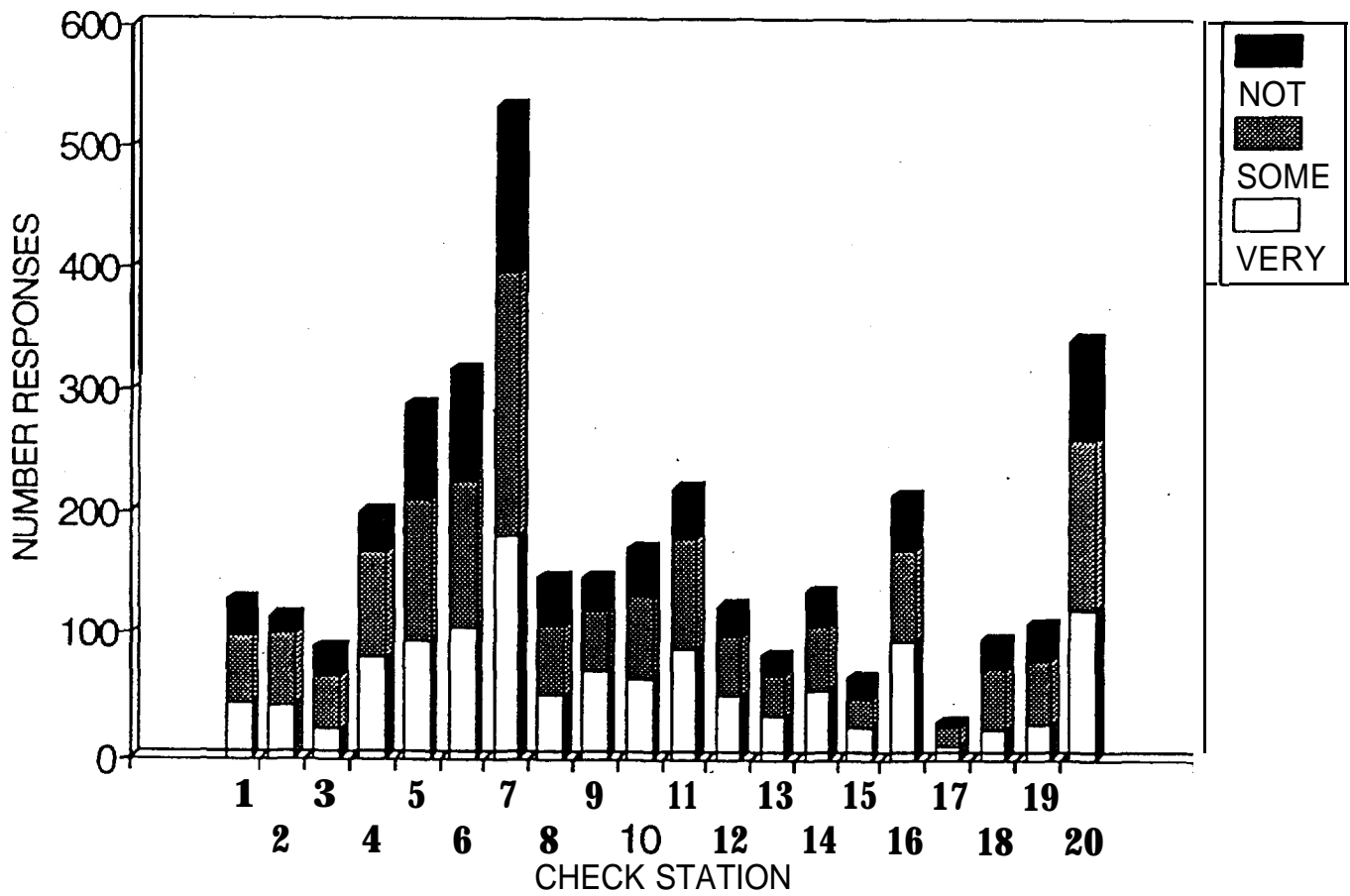
IMPORTANCE OF A RECREATION OPPORTUNITY ANGLER ANSWERS BY CHECK STATION, 1992



Appendix-Figure D-17. Importance of the recreational fishing opportunity to anglers.

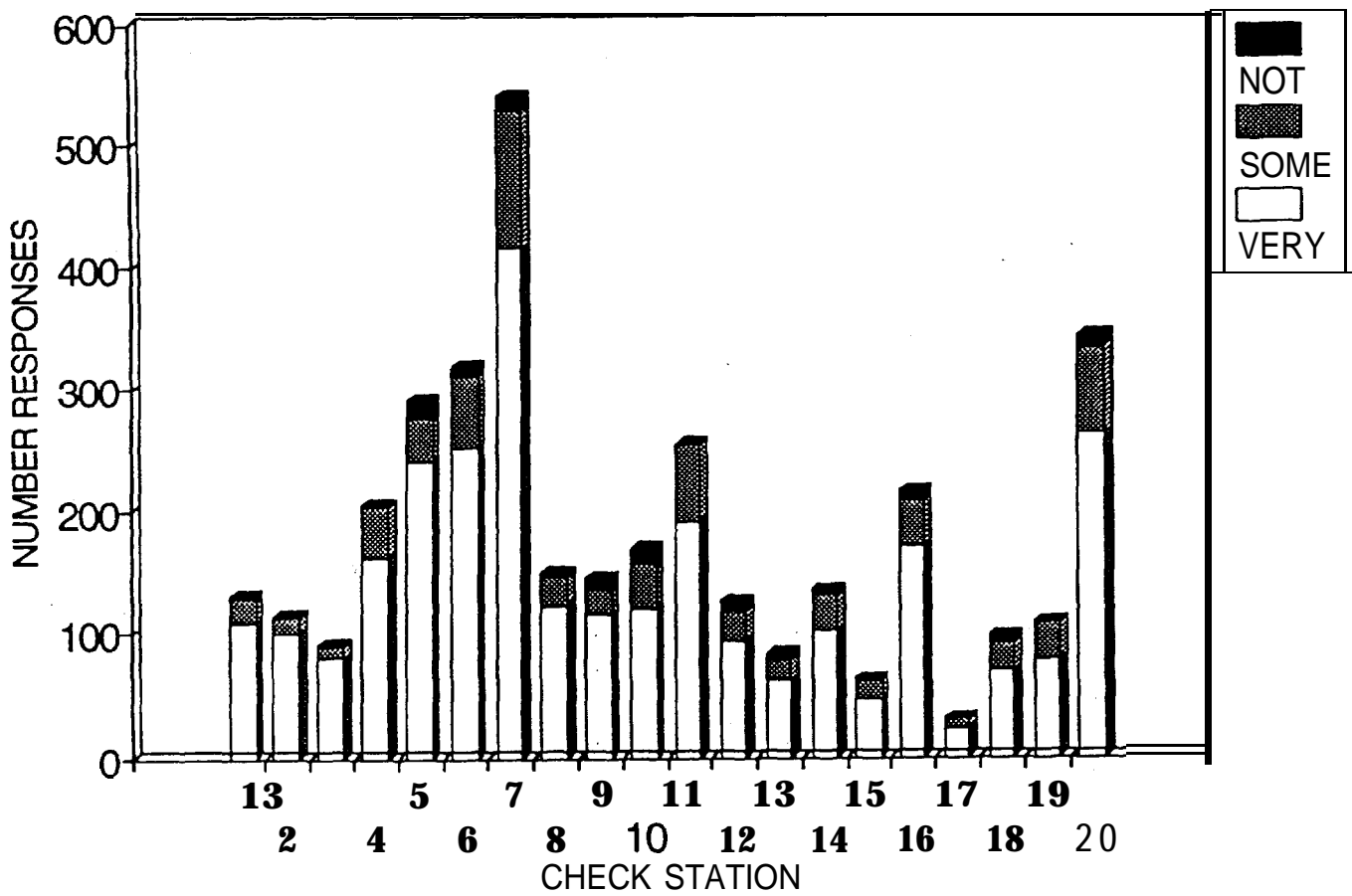
IMPORTANCE OF COVERING FISHING EXPENSES

ANGLER ANSWERS BY CHECK STATION, 1992



Appendix Figure D-18. Importance of covering fishing expenses to anglers.

IMPORTANCE OF SALMON ENHANCEMENT ANGLER ANSWERS BY CHECK STATION, 1992



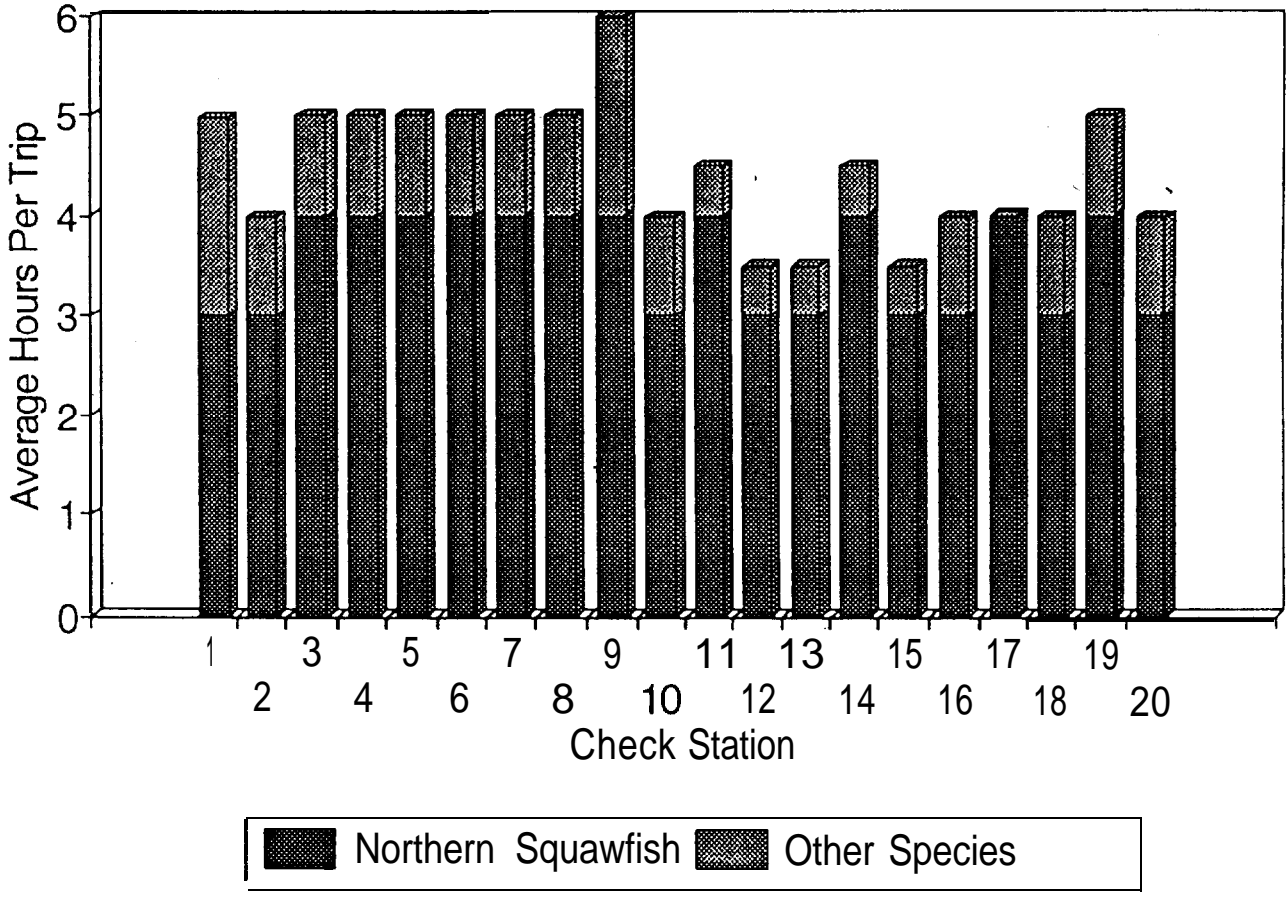
Appendix Figure D-19. Importance of salmon enhancement to anglers.

Appendix Table D-3. Number of responses from each site, 1992 non-returning angler survey.

Check Station	N Responses
Willow Grove	23
Kalama Marina	21
St. Helens	22
Vancouver	41
M. James Gleason	45
Hamilton Island	44
Covert's Landing	50
Cascade Locks	23
Bingen	23
Dalles	26
LePage Park	25
Maryhill State Park	27
Plymouth	22
Columbia Point	14
Ringold	8
Hood Park	37
Windust Park	7
Lyons Ferry State Park	18
Boyer Park	17
Green Belt	67

AVERAGE NUMBER OF HOURS SPENT FISHING

NON-RETURNING ANGLERS 1992



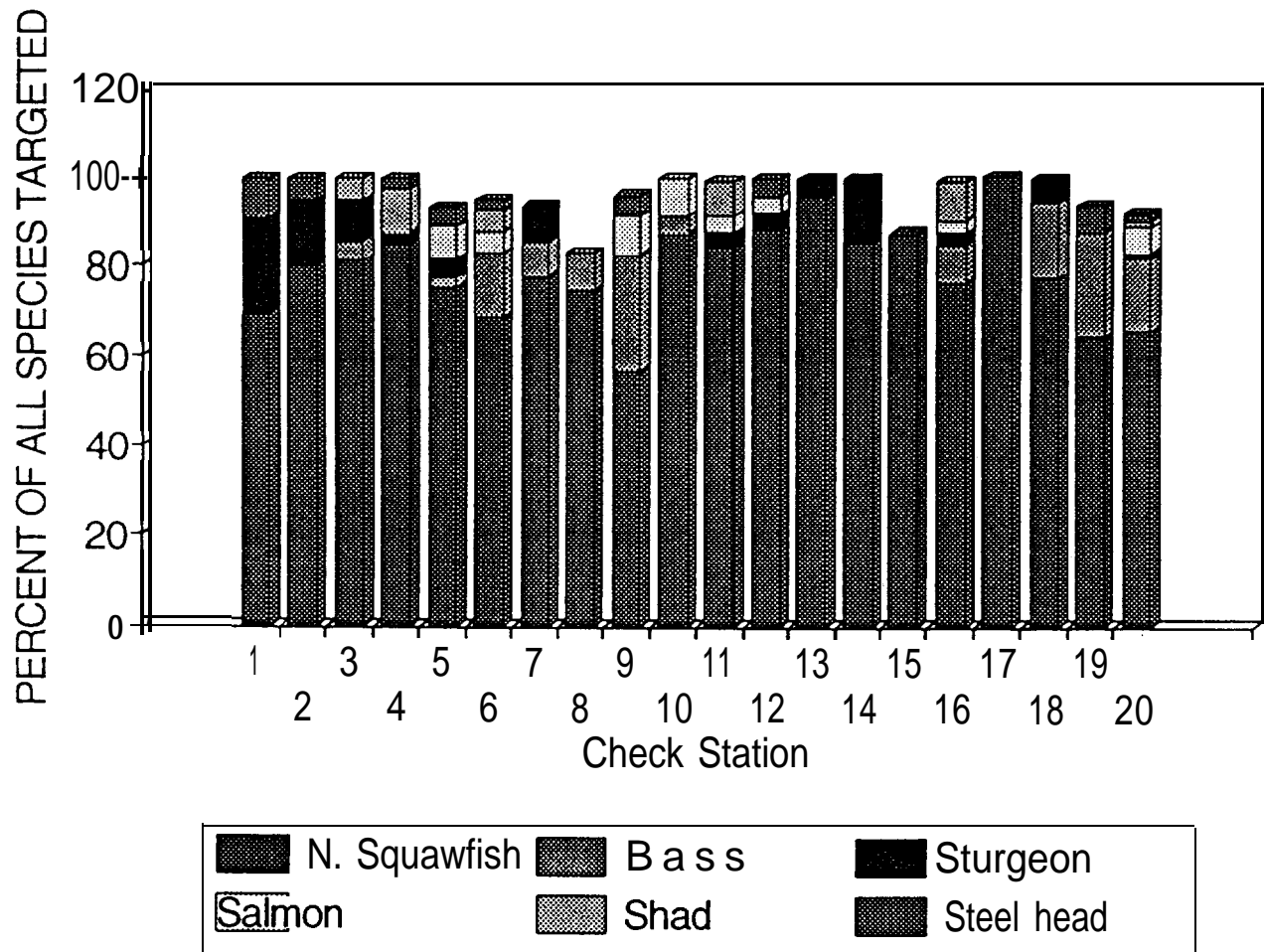
Appendix Figure D-20. Average number of hours spent fishing for northern squawfish and other species, non-returning anglers.

Appendix Table D-4. Percent of non-returning anglers who caught northern squawfish and percent of northern squawfish caught which qualified for payment.

Check Station	% Catching N. Squawfish	% Catch > 11"
All Sites Combined	26.1	10.9
Willow Grove	26.1	10.0
Kalama Marina	33.3	5.9
St. Helens.	45.5	3.5
Vancouver	41.5	7.7
M. James Gleason	26.7	16.0
Hamilton Island	4.6	100.0
Covert's Landing	20.0	9.7
Cascade Locks	17.4	55.6
Bingen	17.4	50.0
Dalles	19.2	18.8
LePage Park	48.0	-1.9
Maryhill State Park	36.0	0
Plymouth	27.3	0
Columbia Point	21.4	0
Ringold	62.5	0
Hood Park	37.8	4.0
Windust Park	28.6	0
Lyons Ferry State Park	22.2	0
Boyer Park	5.9	100.0
Green Belt	14.9	30.8

TARGET SPECIES OF NONRETURNING ANGLERS

SPORT-REWARD CHECK STATIONS 1-20, 1992



Appendix Figure D-21. Primary target species of non-returning anglers.

Appendix Table D-5. Frequency of incidental catch while fishing for northern squawfish, non-returning anglers.

Check Station	% Catching Non-Squawfish Species
All Sites Combined	26.1
Willow Grove	39.1
Kalama Marina	40.0
St. Helens	45.5
Vancouver	31.7
M. James Gleason	35.6
Hamilton Island	38.6
Covert's Landing	30.0
Cascade Locks	60.9
Bingen	47.8
Dalles	46.2
LePage Park	40.0
Maryhill State Park	40.7
Plymouth	22.7
Columbia Point	14.3
Ringold	75.0
Hood Park	35.1
Windust Park	14.3
Lyons Ferry State Park	27.8
Boyer Park	23.5
Green Belt	44.8

Appendix Table D-6. Species composition of **incidental** catch, non-returning anglers.

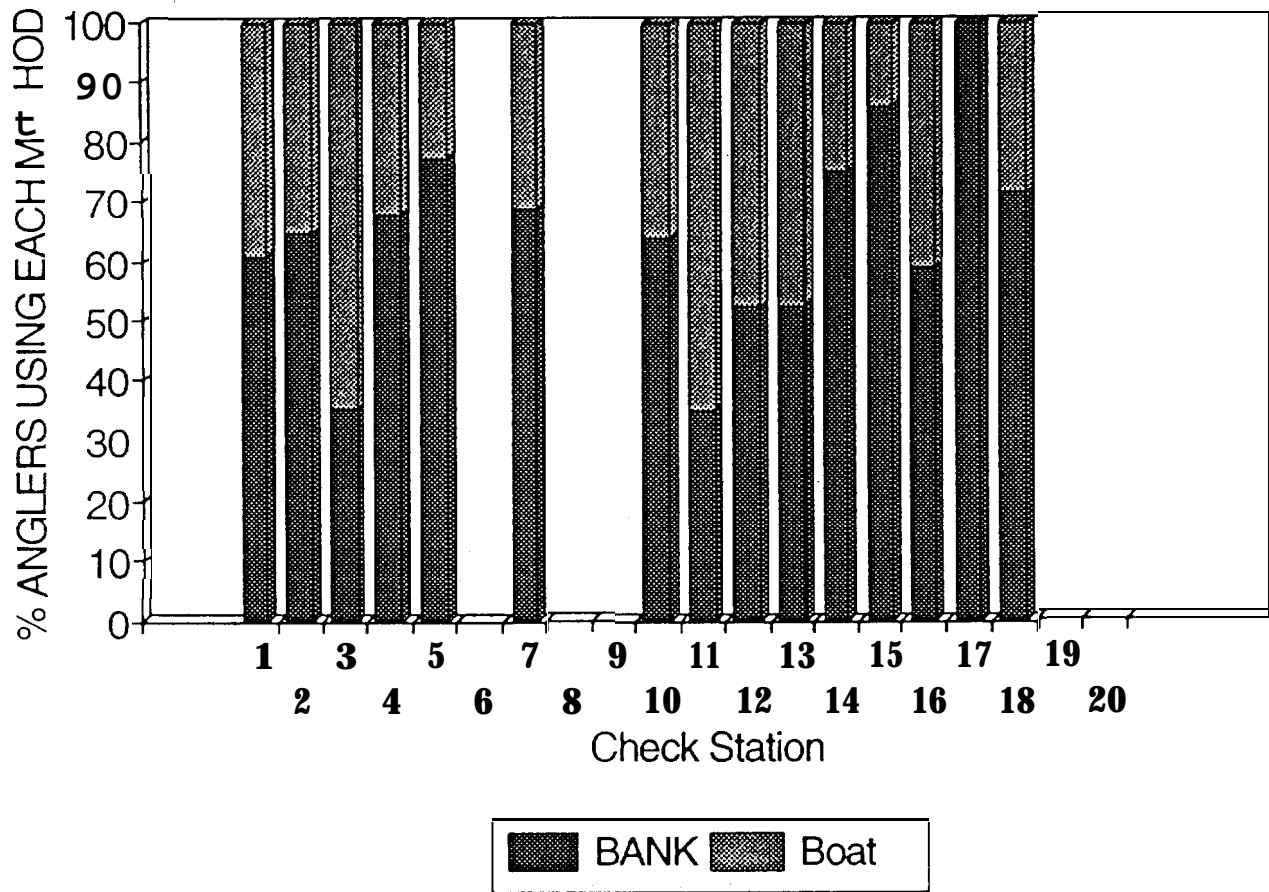
Species	N Caught at All Sites
Sturgeon	45
Trout	18
Steelhead	9
Perch	59
Shad	41
Carp	52
Bullhead	11
Suckers	18
Flounder	13
Bass	239
Peamouth	23
Catfish	109
Chub	10
Salmon	29

Appendix Table D-7. Target species caught in combination with northern squawfish trips, non-returning angler survey, all sites.

Species	Number Caught
Bass	86
Shad	73
Catfish	30
Sturgeon	19
Salmon	15
S tealhead	8
Trout	6
Chub	6
Suckers	5
Carp	2

FISHING METHODS, NONRETURNING ANGLERS

SPORT-REWARD CHECK STATIONS I-20, 1992

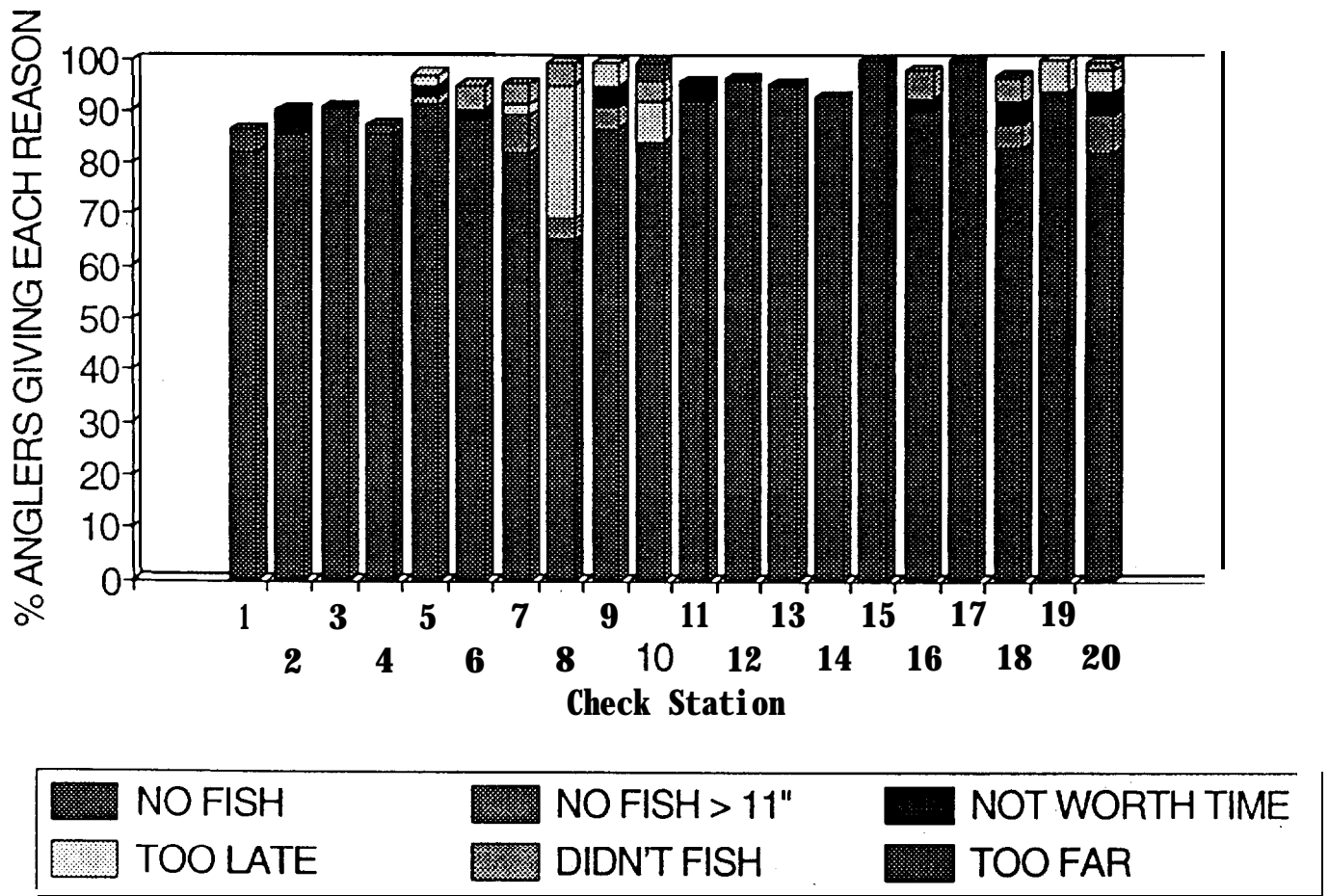


Appendix Figure D-22. Fishing methods used by non-returning anglers.

Appendix Table D-8. Bait and tackle used by non-returning anglers, all sites.

Bait or Tackle	% Non-Returning Anglers Using
Nightcrawlers	43.2
Lures	14.4
Jigs	6.0
Plugs	5.0
Grubs	5.0
Chicken Skin	3.6
Spinners	3.0
Liver	2.3
Shrimp	2.3
Plastics	2.3
Smelt	.9

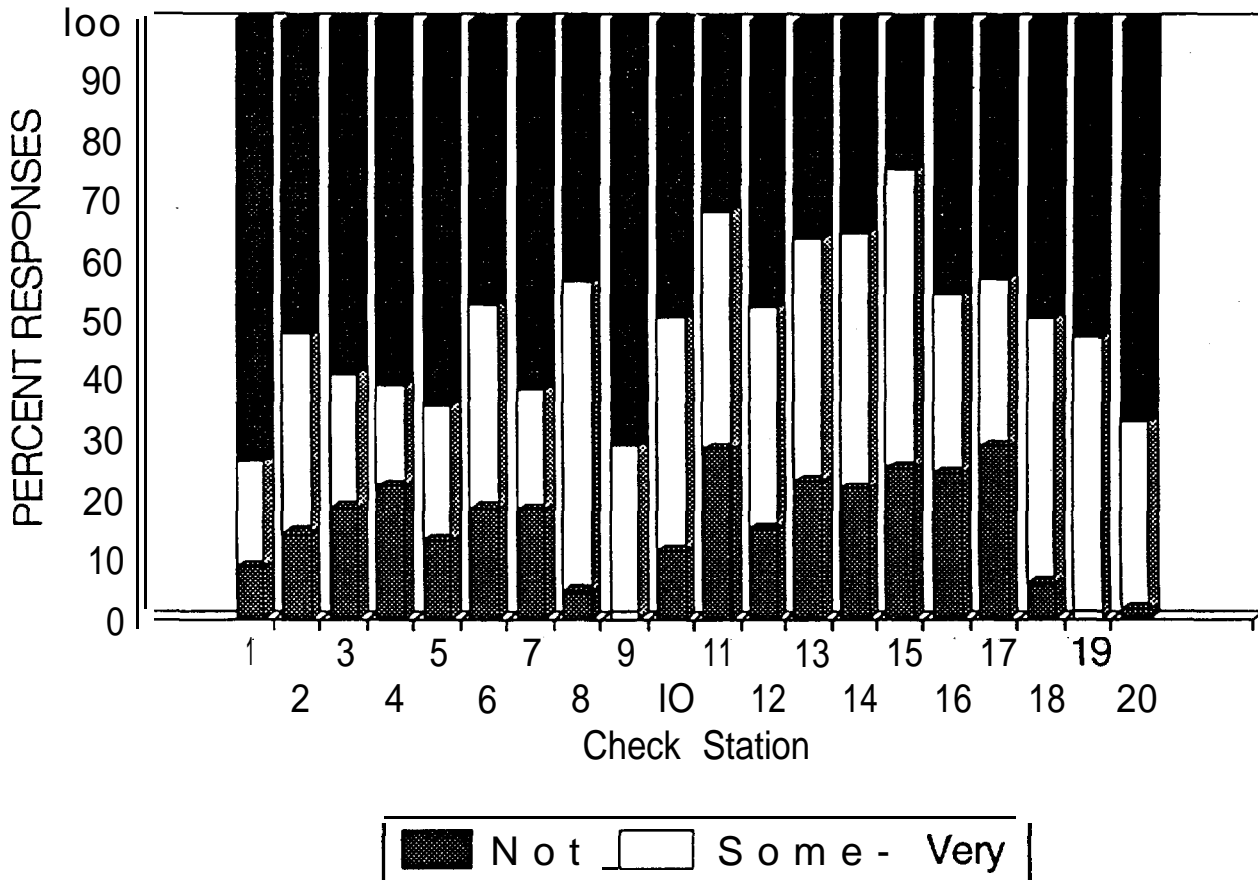
REASONS FOR NOT RETURNING TO CHECK-IN NON-RETURNING ANGLERS 1992



Appendix Figure D-23. Angler reasons for not returning to the registration site.

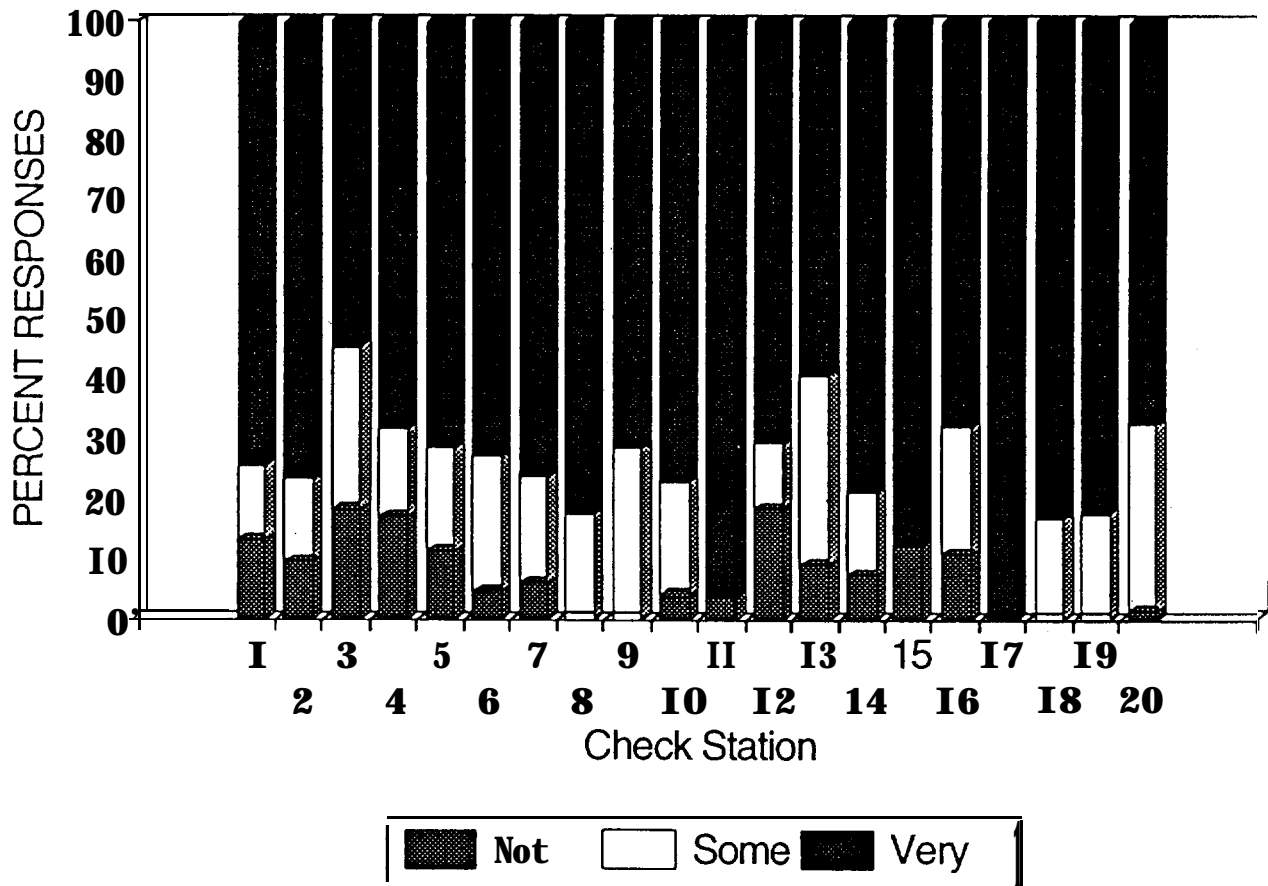
IMPORTANCE OF PAYMENT FOR SQUAWFISH

NON-RETURNING ANGLERS 1992



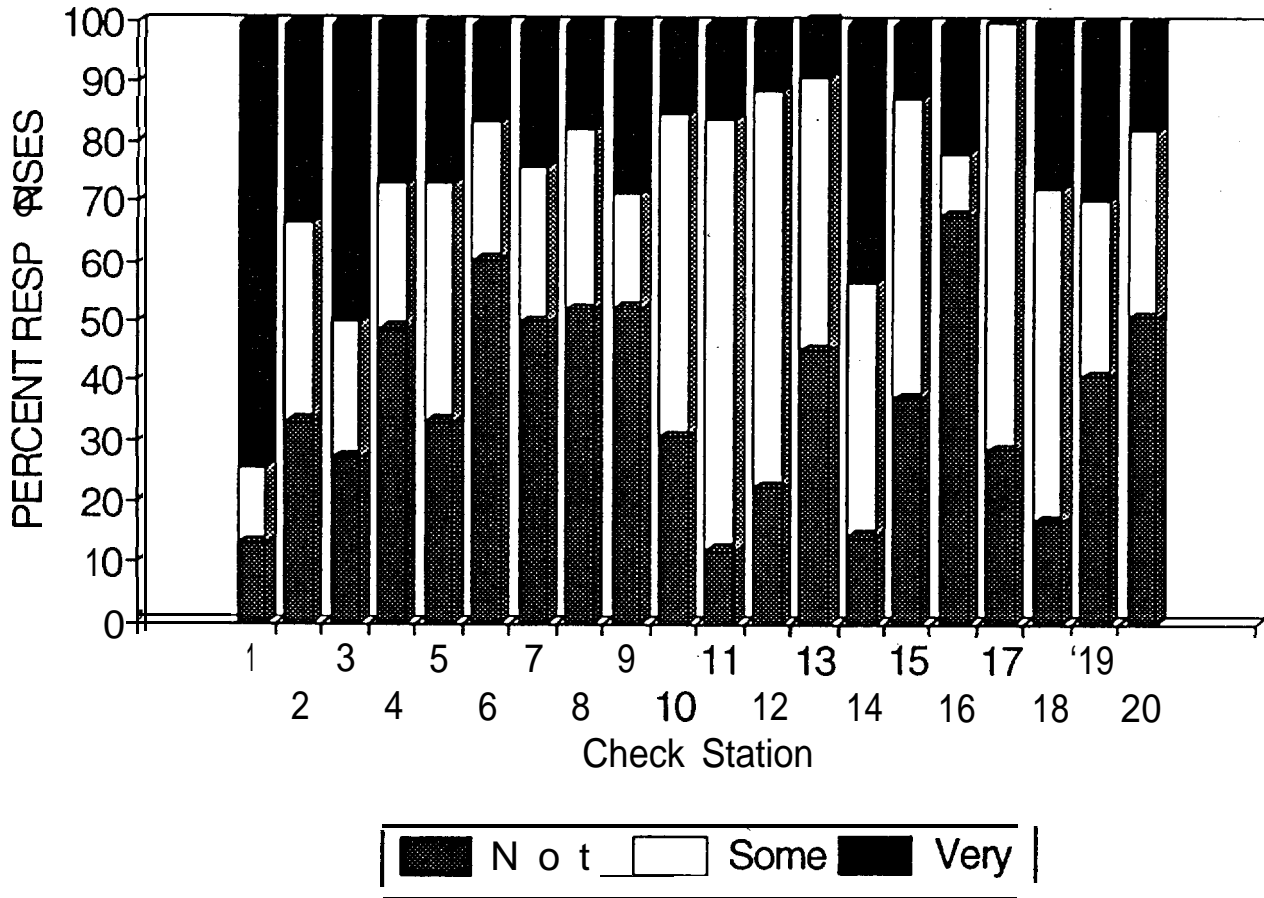
Appendix Figure D-24. Importance of payment for northern squawfish to participation in the sport-reward fishery, non-returning anglers.

IMPORTANCE OF A RECREATION OPPORTUNITY NON-RETURNING AGLERS 1992



Appendix Figure D-25. Importance of recreation to participation in the sport-reward fishery, non-returning anglers.

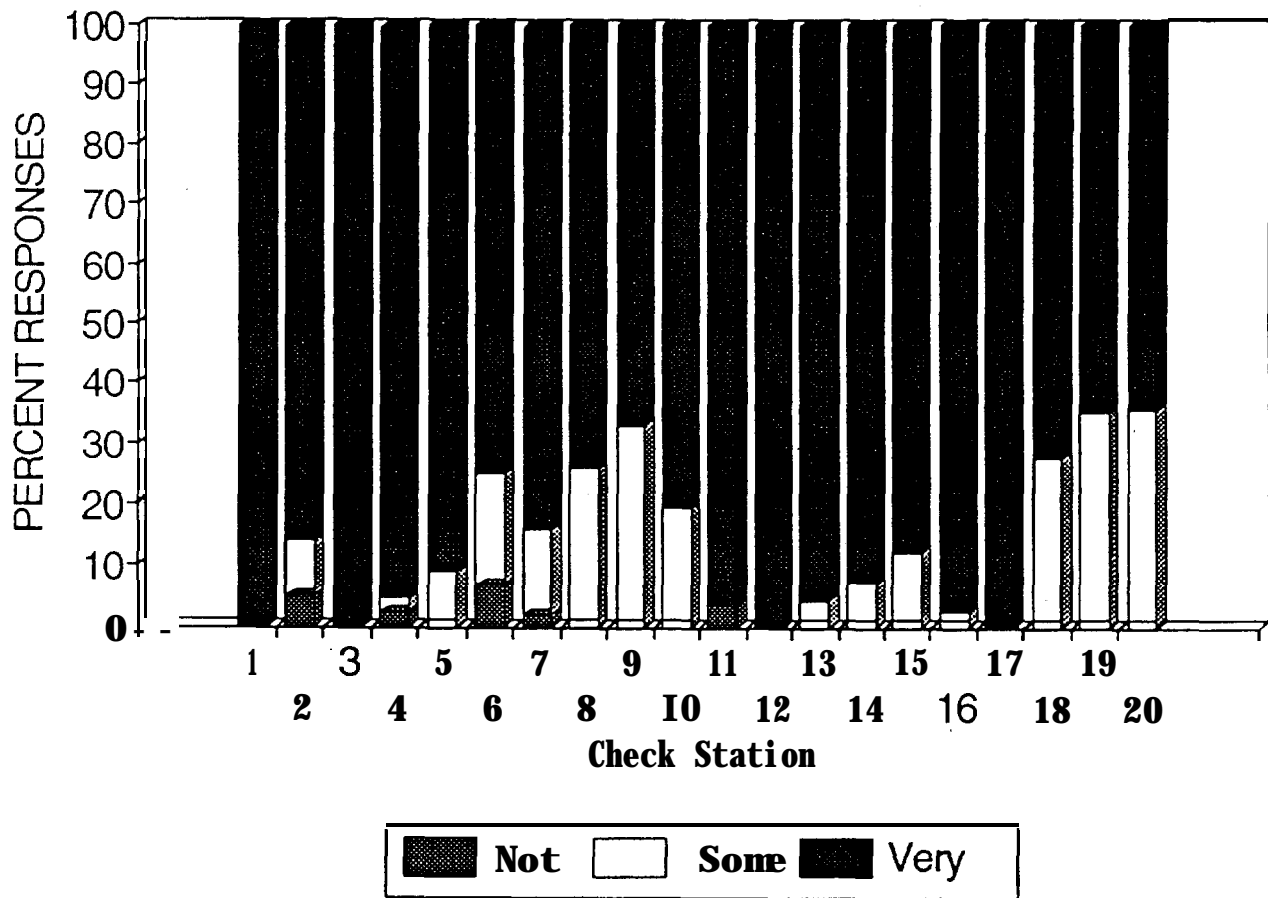
IMPORTANCE OF COVERING EXPENSES NON-RETURNING ANGLERS 1992



Appendix Figure D-26. Importance of the opportunity to cover fishing expenses to participation in the sport-reward fishery, non-returning anglers.

IMPORTANCE OF SALMON ENHANCEMENT

NON-RETURNING ANGLERS 1992



Appendix Figure D-27. Importance of contributing to salmon enhancement to participation in the northern squawfish fishery, non-returning anglers.

Appendix Table D-9. Percent of non-returning anglers who returned northern squawfish for payment at least once in 1992 and average number returned.

Site Returned	% Returning Fish	% Not Returning Fish	Ave. #
All Sites Combined	48.0	52.0	1
Willow Grove	56.5	43.5	38
Kalama Marina	57.1	42.9	69
St. Helens	40.9	59.1	72
Vancouver	41.5	58.5	207
M. James Gleason	48.9	51.1	127
Hamilton Island	52.3	47.7	91
Covert's Landing	54.0	46.0	145
Cascade Locks	40.9	59.1	226
Bingen	56.5	43.5	21
Dalles	53.9	46.1	90
LePage Park	44.0	56.0	31
Maryhill State Park	59.3	40.7	7
Plymouth	31.8	68.2	62
Columbia Point	61.5	38.5	120
Ringold	25.0	75.0	21
Hood Park	64.9	35.1	34
Windust Park	42.9	57.1	44
Lyons Ferry State Park	55.6	44.4	12
Boyer Park	29.4	70.6	221
Green Belt	31.3	68.7	
	54		

Appendix Table D-10. Average number of fishing trips taken by non-returning anglers each year.

Site Trips Squawfish	Ave. N Trips Per Year	Ave. N Trips This Location	Ave. N Additional for Northern
All Sites Combined	34	9	
Willow Grove	54	43	7
Kalama Marina	67	46	9
St. Helens	66	56	7
Vancouver	53	39	11
M. James Gleason	47	37	10
Hamilton Island	53	25	6
Covert's Landing	45	34	12
Cascade Locks	50	36	11
Bingen	29	17	6
Dalles	59	31	8
LePage Park	44	21	6
Maryhill State Park	39	25	8
Plymouth	47	29	7
Columbia Point	65	28	11
Ringold	61	50	23
Hood Park	56	50	22
Windust Park	56	44	24
Lyons Ferry State Park	41	24	7
Boyer Park	52	33	11
Green Belt	48	31	4

Appendix Table D-1 1. Non-returning angler assessment of check station convenience.

Site	% Anglers Judging Sites Convenient	% Anglers Judging Sites Inconvenient
All Sites Combined	89.3	10.7
Willow Grove	78.3	21.7
Kalama Marina	90.5	9 . 5
St. Helens	77.3	22 . 7
Vancouver	87.8	12.2
M. James Gleason	84.4	15.6
Hamilton Island	95.5	4.5
Covert's Landing	92.0	8.0
Cascade Locks	95.7	4.3
Bingen	91.3	8.7
Dalles	96.2	3.8
LePage Park	92.0	8.0
Maryhill State Park	70.4	29.6
Plymouth	86.4	13.6
Columbia Point	85.7	14 . 3
Ringold	100.	0
Hood Park	97.3	2.7
Windust Park	85.7	14.3
Lyons Ferry State Park	83.3	16.7
Boyer Park	94.1	5.9
Green Belt	95.5	4.5

Appendix Table D-12. Percent of non-returning anglers who plan to fish for northern squawfish in 1993.

Site	% Yes	% No	Most Frequently Cited Reason For Majority Answer
All Sites Combined	92.8	7.2	money
Willow Grove	95.7	4.4	money
Kalama Marina	95.2	4.8	money
St. Helens	90.9	9.1	money
Vancouver	92.7	7.3	recreation
M. James Gleason	95.6	4.4	money
Hamilton Island	95.5	4.5	money
Covert's Landing	92.0	8.0	money
Cascade Locks	91.3	8.7	money
Bingen	95.7	4.3	money
Dalles	96.2	3.8	recreation
LePage Park	84.0	16.0	recreation
Maryhill State Park	92.6	7.4	recreation
Plymouth	86.4	13.7	recreation
Columbia Point	100.	0	recreation
Ringold	100.	0	money
Hood Park	97.3	2.7	money
Windust Park	87.5	12.5	money
Lyons Ferry State Park	100.	0	recreation
Boyer Park	88.2	11.8	salmon enhancement
Green Belt	13.4	86.8	not worth it

Appendix Table D- 13. Creel clerk evaluation of the 1992 sport-reward program (N=21).

Program Component	Good (%)	Fair (%)	Poor (%)	NA (%)
Operating Hours	90.5	9.5	0	0
Registration Process	85.7	14.3	0	0
Check-in Process	76.2	0	0	19.1
Data Forms	71.4	19.1	9.5	0
Data Collection	90.5	9.5	0	0
Staffing	85.7	14.3	0	0
Equipment	61.9	33.3	4.8	0
Station Security	81.0	4.8	14.2	

Appendix Table D-14. Frequency of angler complaints about various aspects of the sport-reward fishery, as reported by creel clerks (**N=21**; % creel clerks having received the complaint).

Type of Complaint	Many	Some	Few	None	NA
Boat Ramps					
overcrowding	0	4.8	19.5	66.7	9.5
size	4.8	0	33.3	52.4	9.5
wait time to launch	0	4.8	19.0	67.0	9.5
Fishing.					
angler crowding	0	4.8	19.1	76.2	0
commer. fisherman crowding	0	4.8	4.8	90.5	0
gear damage from anglers	0	0	4.8	90.5	4.8
gear damage from commer.	0	0	9.5	85.7	4.8
speeding boats	0	4.8	23.8	61.9	9.5
jet skiers	4.8	9.5	42.9	42.9	0
water skiers	0	9.5	33.3	57.1	0
litter in water	9.5	14.3	28.6	47.6	0
litter on banks	9.5	9.5	47.6	33.3	0
Registration/Check-In					
registration time	14.3	4.8	52.4	28.6	0
registration paperwork	4.8	4.8	33.3	57.1	0
other anglers	0	4.8	33.3	57.1	0
check-in time	9.5	4.8	38.1	4.8	0
check-in paperwork	9.5	0	14.3	4.8	71.4
fish quality requirements	14.3	9.5	19.1	52.4	4.8

APPENDIX E

Handling and Distribution of Northern Squawfish

Appendix Table E-1. Northern **squawfish** handling and distribution budget summary through October 1992.

Category	Item	Total Cost
Service Contracts:	Processors	
	Rendering	
	Cold Storage	
	Trucking	
	Rentals	
	<u>Subtotal</u>	
Personnel:	4 Technicians	
	Tech/administrator	
	Per diem	
	<u>Subtotal</u>	
Vehicles:	30,000 lb.	11,500
	Pickups	12,500
	<u>Subtotal</u>	24,000
Equipment:	Coolers	24,800
	Miscellaneous	3,000
	<u>Subtotal</u>	<u>27,800</u>
	TOTAL	\$294,500

Appendix Figure E-1. Transfer of handling and distribution responsibilities.

TRANSFER OF OREGON STATE UNIVERSITY NORTHERN SQUAWFISH HANDLING AND TRANSPORTATION RESPONSIBILITIES TO THE PRIVATE SECTOR

Jon Pampush
December 2, 1991

History of the Northern Squawfish Collection and Transportation Network

In 1990, the Columbia River Northern Squawfish Predator Control Program was implemented on a scale that was expected to begin removing large numbers of northern squawfish. **As** part of the economic evaluation of the program, Oregon State University became responsible for developing a system for collecting and identifying end-users for the harvested squawfish. The 1990 removal program was essentially a pilot scale effort with most activity restricted to the **McNary Pool**. The collection and transportation system was also small scale; one employee, a few chest freezers, and a two-ton pickup truck.

Harvested squawfish were bagged by Oregon Department of Fish and Wildlife technicians and frozen in chest freezers provided by OSU. As needed the OSU employee emptied the freezers and delivered the frozen fish to a cold storage facility. Most of the **40,000** lbs. of squawfish harvested that year were converted to liquid fertilizer by Inland Pacific Fisheries in Payette, Idaho. A small quantity of food-grade squawfish was processed by the Astoria Seafood Laboratory and test-marketed in the Portland area.

In 1991 the removal program was expanded considerably creating the need for an expanded handling network. Two hundred and fifty thousand pounds of northern squawfish was harvested, most of which was converted to animal feed **by** a rendering facility in Portland. Inland Pacific Fisheries received about **50,000** lbs. The 1991 handling and transportation system was intended to be an expanded version of the 1990 system, but the unexpected large volume of squawfish that was harvested in May and June of 1991 required modification of the handling program during the height of the harvest period.

Inland Pacific Fisheries was unable to process the squawfish during the field season causing a rapid accumulation of frozen squawfish in cold storage. Fearing huge cold storage charges, running out of tote space, and the prospect of no one processing the fish in the near future, the decision was made to have the **remaining** 1991 catch (July through September) disposed of at a rendering facility in Portland. At this point of the 1992 season, there was no large volume food-grade market for the harvested squawfish.

To date, the most **significant** market prospect for northern squawfish was identified in July of 1991. Larry Stoller of **Stoller Fisheries** in Spirit Lake, Iowa ran a series of processing and marketing tests and determined that northern squawfish is an excellent source of fish flesh for his principal product "**gefilte fish**" (kosher minced fish). From this point on Stoller has been interested in marketing whatever quantities of food-grade northern squawfish that becomes available and has **served** as a handling and transportation consultant.

In 1992, the handling and transportation **system** was designed to accommodate the collection of food-grade northern squawfish. OSU contracted the services of five fish processors to receive, package, and **freeze** food-grade squawfish and handle the remaining industrial-grade that would later be processed by Inland Pacific Fisheries. Stoller Fisheries received about 90,000 lbs. of food-grade squawfish during the summer of 1992, Inland Pacific Fisheries received about 145,000 lbs. for fertilizer production, and about 73,000 lbs. was rendered.

Issues Related to the Transfer of Handling Responsibilities to the Private Sector

Throughout the development of the Northern Squawfish Predator Control Program there has been a desire among the participating agencies to transfer as much of the fish handling and transportation responsibilities as possible **to the private sector**. However, many features of the removal program have made immediate transfer of these responsibilities to the private sector difficult if not impossible for the following reasons:

1. The removal program has expanded (geographically and level of harvest) every year since its inception in 1990. Complete privatization of the handling phase cannot occur **until** the removal program stabilizes and yields become predictable from year to year.
2. Each year, new information about end-uses becomes available. Accommodating the Stoller food-grade market required a drastic modification of the 1991 handling program. Should the removal program continue long **term** and produce predictable yields, someone may become interested in processing the harvest locally. Local processing would create the need for further modification of the existing food-grade handling program.
3. There is disagreement about how much the agencies conducting the removal fisheries **should be** responsible for handling fish. Some have expressed the view that the agencies should do virtually no handling (**even** in the field) and others have felt that considerable agency handling is necessary to operate a efficient, cost-minimizing program.

4. Because the program involves several agencies conducting different fisheries with unpredictable results, it has been necessary for OSU (up to this point) to maintain considerable direct handling responsibilities to accommodate the “unknowns.”

The above mentioned problems must be resolved before a long term private sector operated handling program can be implemented. In 1993, every effort should be made to design and accommodate a handling program that will be functional, efficient, and cost-minimizing.

Current Private Sector Participation in the Handling Program

In 1992, OSU sub-contracted five private fish processors and a trucking outfit with the intention of collecting large volumes of food-grade squawfish for processing by Stoller Fisheries. Sport reward technicians and OSU employees delivered iced squawfish in coolers to the processors where they were graded, boxed and frozen. Squawfish in poor condition were **frozen** in totes for later conversion to organic fertilizer by Inland Pacific Fisheries. In some locations, it was not practical to collect food-grade squawfish and squawfish from these locations were either converted to fertilizer or rendered. For the most part the system was successful and produced 90,000 lbs. of food-grade squawfish.

About 75% of OSU's 1992 handling and transportation budget was paid to private sector sub-contractors for services related to handling squawfish. The 1992 season should be considered a successful transition year.

The following is a description of the 1992 fish processor/food-grade collection system:

* OSU purchased handling equipment from 1990 - 1992 including chest freezers, insulated and non-insulated commercial fishing totes, and coolers. This equipment was distributed to participating agencies and sub-contractors.

* OSU sub-contracted five fish processors who received, packaged and froze the squaw-fish harvested by the sport reward and dam angling fisheries. The fish processors were at these locations:

<u>Location</u>	<u>Processor Name</u>
Longview, WA	Tri-River Smelt
Portland, OR	Point Adams Packing Company
Cascade Locks, OR	Bonneville Fisheries
The Dalles, OR	Kingfish Trading Company
Richland, WA	Wellsian Cold Storage,

* Sport reward technicians who **operated** in areas serviced by a fish processor delivered their catch daily to these locations and here they were restocked with fresh coolers and ice for the next day. OSU employees picked up full coolers from Bonneville, The Dalles, and McNary Dams and delivered them to nearby processors.

* For logistical and cost reasons, low volume and distant harvest locations (John Day Dam, Snake River dams, Snake River sport reward area) were not **serviced** by fish processors. The **squawfish** from these areas were either frozen in chest freezers and collected by OSU employees or were delivered by WDW technicians to a subcontractor who made arrangements for a rendering pick-up.

* OSU sub-contracted Americold Cold Storage in Wallula, WA; Americold in Nampa, ID; and Pacific Cold Storage in Portland. These facilities stored frozen squawfish and served as the pick-up locations for shipment to end-users.

* OSU rented a 30,000 lb truck for delivering equipment to processors (coolers and totes), picking up frozen fish from remote locations, and transferring frozen fish from processors to cold storage facilities.

* OSU sub-contracted May Trucking in Portland to handle deliveries to Inland Pacific Fisheries in Payette, Idaho.

* Stoller picked up boxed fish from the cold storage facilities for delivery to the Spirit Lake, Iowa processing facility.

* OSU currently rents warehouse space from Intermountain Industrial Supply for storing equipment.

Overall, the 1992 season went fairly well demonstrating that this type of arrangement best accommodates the participating agencies and the collection of whole, **frozen**, boxed food-grade squawfish. For 1993, a few basic changes in the program should increase efficiency, increase food-grade yield, and reduce costs. In 1992 the removal program harvested about 292,300 pounds of northern squawfish. Of that total, OSU **attempted** to collect food-grade from 214,500 pounds.

The following is a breakdown of the food-grade squawfish handling system for the 1992 season:

Total Volume Harvested in 1992..... **292,300** lbs
Total Volume Handled by Food-Grade System.....214,500 lbs

Food-Grade Handling System Analysis:

<u>End-Use</u>	<u>Volume (lbs)</u>	<u>% Total</u>
Food-Grade	91,030	42.4
Non Food-Grade	123,470	57.6

A 42% rate of food-grade collection for the **1992** pilot season should be considered a success, but in the future **65%-75%** food-grade should be attainable. This could be accomplished by improving angler and agency handling as well as modifications in the overall handling program.

End-Use Alternatives

Identifying end-uses for the squawfish and developing a system that can accommodate these products is an issue that needs discussion. OSU has identified three, possibly four, entities that can utilize the volume of squawfish that is expected to be harvested in 1993. Other groups are currently test-marketing squawfish, but for now only the following are known to be capable of processing large volumes of squawfish:

1. Stoller Fisheries - Spirit Lake, Iowa. Stoller **fisheries** has processed about 130,000 lbs of Columbia River northern squawfish (food-grade and fishmeal). Stoller's principal product is **gefilte** fish, a pickled kosher product. Of the three major consumers of the **squawfish** harvested by the removal program, Stoller has shown the most interest among them and has paid for much of the end-use transportation costs. Stoller has served as a fish handling consultant during the 1991 and 1992 seasons.
-

2. Inland Pacific Fisheries - Pavette, Idaho. Inland **Pacific Fisheries** processes liquid organic fertilizer. **IPF has been receiving frozen squawfish free** of charge for three seasons. **IPF tends to process squawfish in the fall** after the field season **is over and is a questionable long-term participant**

3. Darling/Delaware Rendering - Portland, Oregon. Darling/Delaware produces animal feed from animal byproducts. This outfit is essentially a disposal service and they charge up to **\$50/ton** to handle the squawfish. The rendering option has been considered a last resort in the past.

4. Global Feed Consortium - Bellingham, Washington. Global Feed is a **fishmeal/fertilizer** manufacturer and a **recent** end-use development with promising prospects. Global Feed may be able to process the industrial-grade squawfish at a considerable savings compared to Darling/Delaware. Global **Feed** uses a mobile processing unit that may be ideal for accommodating the squawfish handling program. This unit can save on transportation costs and Global feed does not charge a disposal fee.

An analysis of the cost effectiveness of accommodating each of these end-users revealed little difference between them (see OSU 1992 Interim Report). In 1993 OSU will again set up a food-grade collection system intended to produce whole frozen squawfish for Stoller Fisheries and other interested parties who can utilize whole frozen squawfish. The fate of the industrial-grade fish is unknown at this point (hopefully the **industrial-grade** will be a relatively small volume in 1993).

Recommendations for Future Handling Programs and Incorporation of the Private Sector

The following points concerning the characteristics of private **sector fish** handling and transportation systems should be considered before recommendations for further private sector involvement in the squawfish program are discussed:

1. Private sector fish processors design handling and processing systems around fisheries that are market driven and include features such as non-payment for low quality **fish** and non-participation when it is no longer profitable. The squawfish removal program clearly does not operate under these conditions.

2. The purpose of the squawfish program is to remove **squawfish** - not to create a profitable commercial fishery. Any end-use or handling program is a byproduct of the primary goal of removing squawfish and will never operate at the cost **efficiency** of a true commercial fishery. The best one can do is to design a handling system that is the least expensive within the context of the program objectives.

3. The sport angling public must be accommodated because they represent the “commercial fishermen” of the squawfish removal program. Private fish processors are unfamiliar with this concept since they operate systems designed to turn a profit - not accommodate “inefficient” fisherman.

4. It would be unwise to entirely transfer the administration of the squawfish handling program to a fish processor who intends to operate the program in a way that is familiar to him/her. The result would probably be a program that is quite efficient but short on accommodating the participating agencies and the public. The squawfish handling program should be set up and overseen by an administrator who is familiar with both the removal and the handling phases of the overall program.

With the above introductory points in mind, a description of the best long term private sector squawfish handling scenario follows, The principal goal of **OSU's** future handling program is to collect as much food-grade squawfish possible.at the least **cost**. To accomplish the goal of minimizing handling costs, much of the fish handling responsibilities should be distributed among all program participants.

Uncertainties about the availability and cost of facilities and services prevent a detailed specification of the 1993 handling plan. Furthermore, there is still some questions about the extent to which the agencies are willing to contribute to fish handling.

Recommended general characteristics of future food-grade northern squawfish handling programs:

* Contract local fish processors, meat markets, or cold storage facilities to serve as receiving and packaging areas. These facilities should have enough **freezer** space to store at least a weeks worth **Of** frozen fish (preferably more). Ideally, **someone** would be present in the evenings to receive the incoming squawfiih and process them that night. In the future these contracts could probably be put out for competitive bid, but it seems that one is fortunate to **find** even *one* qualified contractor in a given area anyway.

* In as many locations possible, Washington Department of Wildlife should hire technicians who can work in the field and process fish in the evening. A setup of this type is by far the least expensive handling option available because it greatly reduces redundant labor charges and other “hidden” costs. People who have worked for local processors in the past would be good candidates for these jobs and could train others to grade fish as well. This ideal situation is not available everywhere but has potential in 1993 for Long-view, Clarkston, Pullman, and Cascade Locks. This system should be pursued as a first option in all locations.

* Contract a fish processor who trucks fish regionally to pick up frozen squawfish from the food-grade collection locations. Point **Adams** Packing Company in Portland travels weekly to all of the food-grade squawfish receiving and storage **locations**. This task could be put out as a competitive bid in the future. This service would eliminate the need for OSU to pick up fish in an expensive-to-operate rental truck.

* In distant, unproductive harvest locations (Snake River Dams, John Day Dam, Lyon’s Ferry Sport Reward site) set up a system where **the** agencies operating in these areas are responsible for disposition of their catch. This could be storage in chest freezers with occasional deliveries to a processing location or establishing a rendering pickup system with a local merchant. OSU can make pre-season arrangements for drop-off locations but does not intend to visit these **areas during** the season. In 1993 OSU will make permanent ‘the transfer of chest freezers (and totes if necessary) to the agencies operating in these areas. This situation should apply to the Merwin Trap fishery as well unless it begins to yield enough squawfish to justify food-grade handling.

* Bonneville, The Dalles, and possibly **McNary** Dams should deliver their catch daily to a fish processing location. The coolers full of iced **squawfish** would be **placed** in a lockable drop-box where ice and fresh coolers would be available for the next day. Delivering large totes of ice to the dams is a negotiable issue but for cost considerations should be avoided if possible. Columbia River Intertribal Fish Commission should plan on purchasing their own coolers for 1993 because OSU will have no property control over equipment used by dam anglers.

Budgeting Options for Future Handling Programs

After a workable **private** sector system has been developed then the question arises as to who should pay for it. There are two reasonable scenarios (or some combination of the two):

1. **The** agencies pay for the fish handling services themselves (include the **charges** in their budgets).
2. A single entity sets up and **pays** for handling services (the current system). A handling administrator submits a budget to pay for all handling services.

Both of these options have advantages and disadvantages, but option 2. probably provides more flexibility in the event of the inevitable changes associated with the removal program.

Conclusion

In summary, further transfer of squawfish handling responsibilities to the private sector with the intention of reducing costs and increasing food-grade production is possible. TO accomplish this goal the harvesting agencies must assume more individual handling responsibility as well as some of the associated costs.

For as long as a handling program exists, it is necessary that it be administered by someone who **is** familiar with both the harvest and handling aspects of the program. This would insure a set-up that is accommodating to the program's principal goal - removing northern **squawfish**. Private fish processors are not familiar with this type of fishery because they operate programs that deal with fewer fish harvesters and contain price incentives for quality control.

Quality control will continue to be an important element of the fish handling problem. Agency supervisors must **be** prepared to take action against employees who handle fish poorly. Without interagency cooperation and an overall perception that fish handling is an important part of the job, then any type of handling program will be a failure.

APPENDIX F
Catch Utilization

Appendix Table F-1. Yield of flesh from squawfish surimi processing'

Samples	Percent of round weight (%)					Mean±S.D.
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	
Round fish	100.0	100.0	100.0	100.0	100.0	100.0±0.0
Planked	42.8	39.6	37.7	40.8	35.1	39.2±2.6
Minced flesh	26.4	31.4	24.2	29.2	26.3	27.5±2.5
Washed flesh	17.4	20.0	15.3	1a.5	15.3	17.3±1.8
Refined	16.0	19.8	14.0	17.1	14.2	16.2±2.1
Surimi	17.9	21.6	16.2	1a.5	15.5	17.9±2.1

¹ Surimi sample were processed with 2 wash cycles at **1:3** mince:water ratio.

Appendix Table F-2. Mean composition (% wet wt) of flesh derived from surimi processing^{a,b}

Samples	Moisture	Protein'	Lipid	Ash
Deboned	77.94±0.07^c	17.91f0.50	3.23±0.01	1.22f0.02
Flesh, first wash	79.23±0.02	17.73f0.24	2.58f0.05	0.65f0.01
Flesh, second wash	78.74f0.05	18.86f0.08	2.51f0.04	0.61f0.05
Flesh, third wash	80.48±0.08	17.38f0.33	1.96f0.04	0.50f0.01
Refined, second wash	79.48f0.07	18.54f0.05'	1.78f0.03	0.48f0.01
Refined, third wash	80.32±0.09	17.98f0.22	1.61f0.04	0.42±0.01
Surimi, second wash	72.10f0.05	17.54±0.10	1.96±0.03	0.80f0.02
Surimi, third wash	72.95f0.06	16.90f0.12	1.21f0.02	0.83f0.01

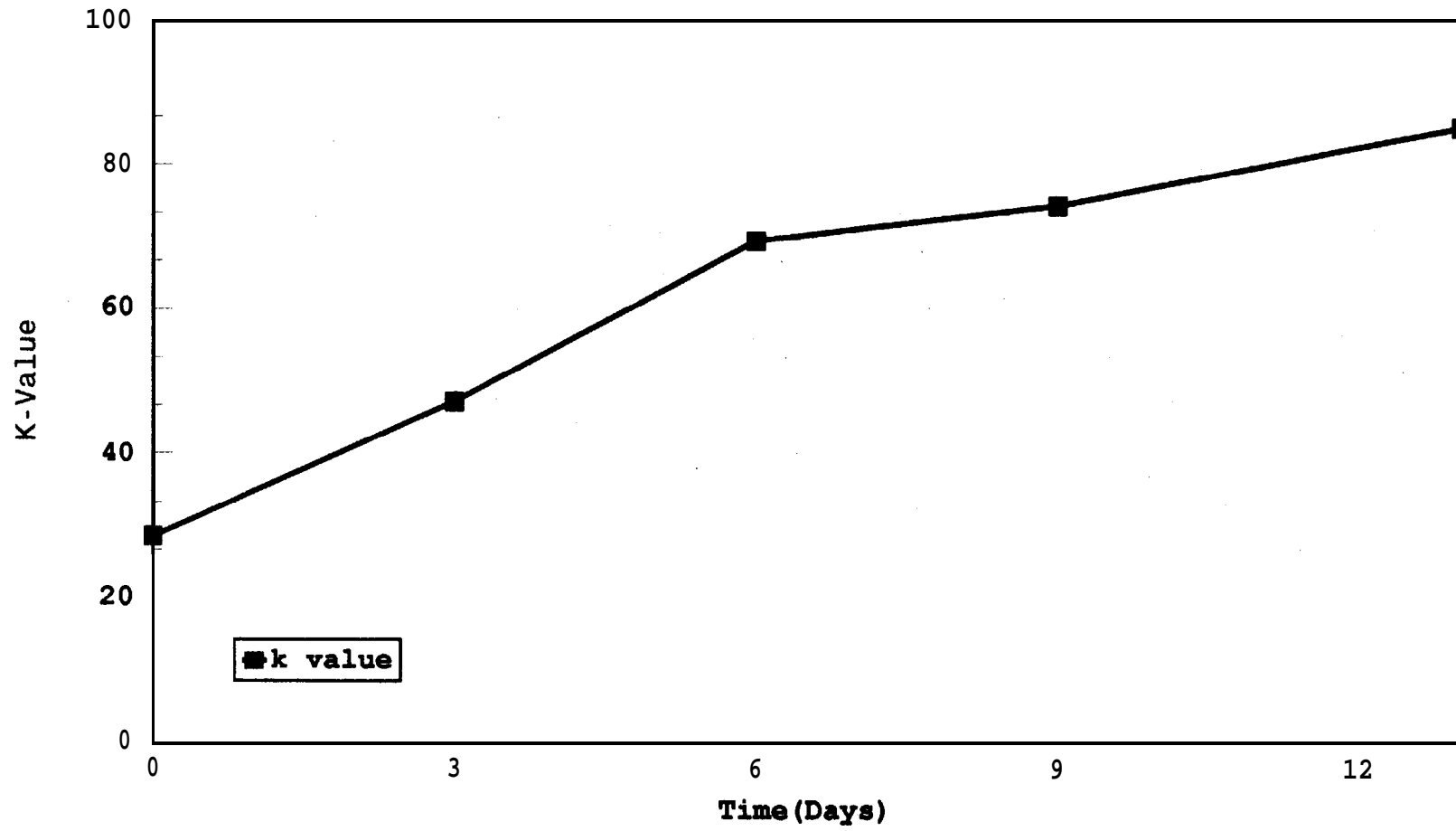
^a **Samples** were determined in triplicate.

^b **Surimi** was composed of washed and refined mince mixed with 4% sucrose, 4% sorbitol and 0.3% polyphosphates as cryoprotectants.

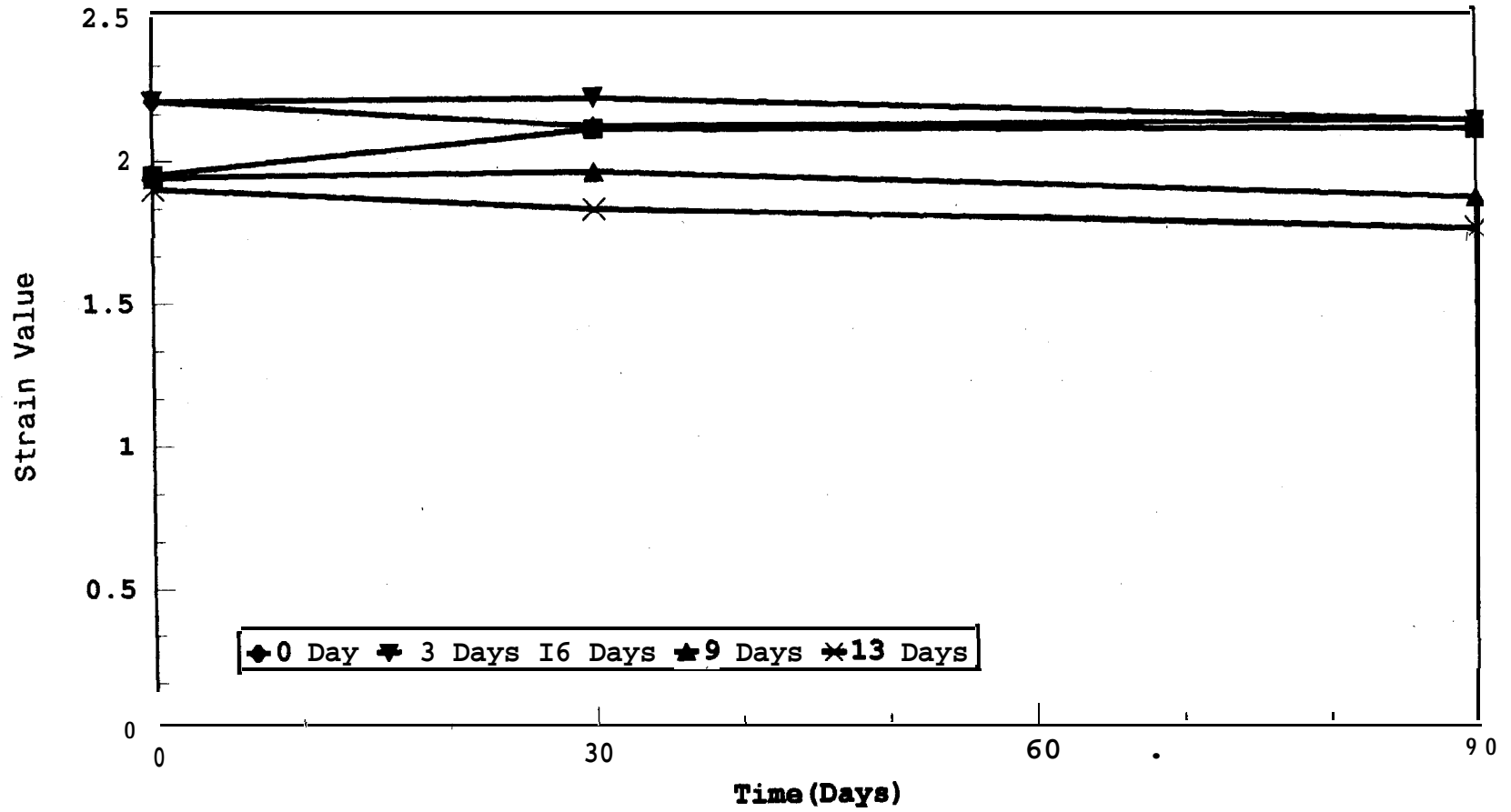
^c **Mean ± S.D.**

Appendix Table F-3. CIE color values of cooked gels from squawfish surimi held in frozen storage.

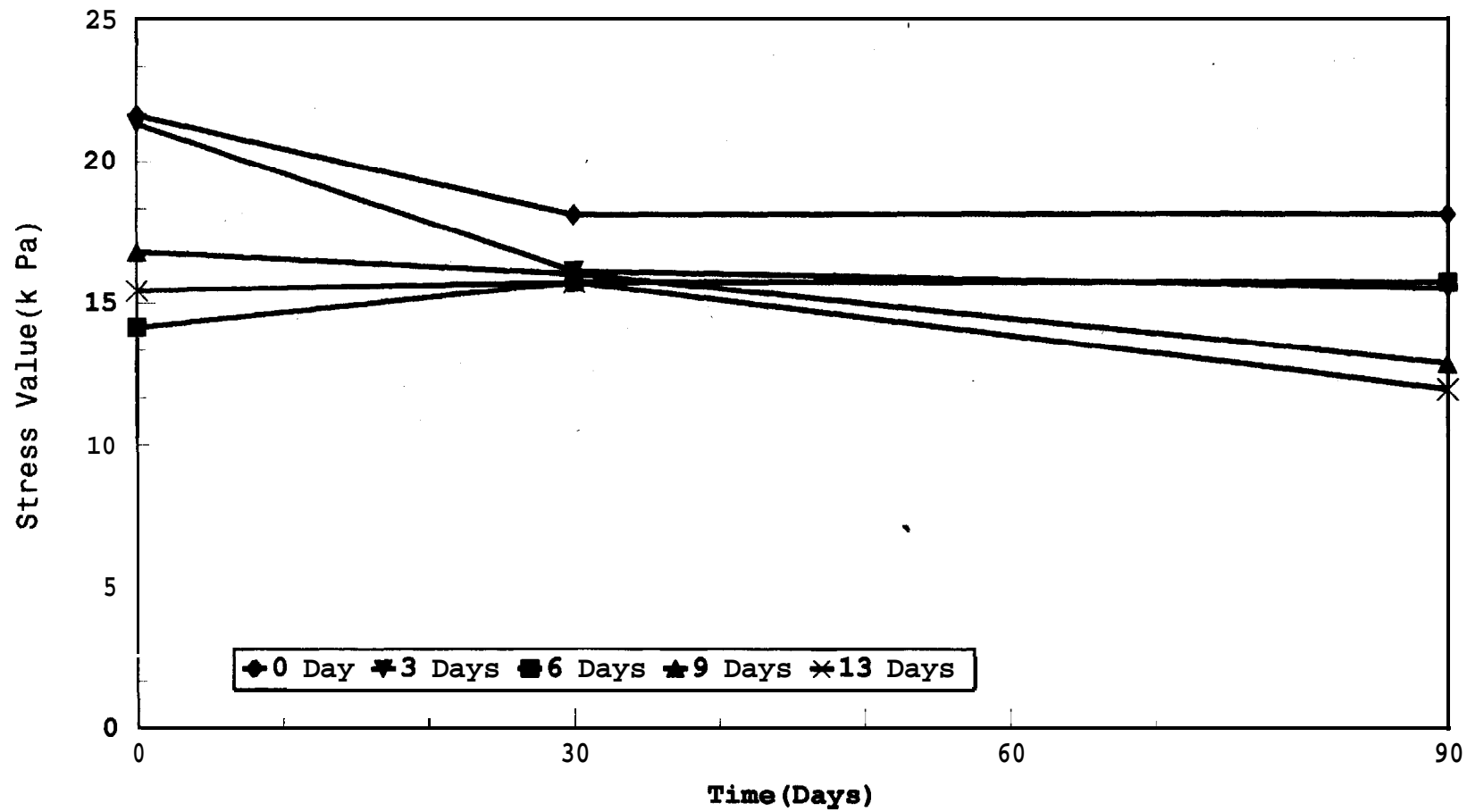
Storage Days	L*	a*	b*	whiteness
0	81.25	-3.51	7.90	79.35
30	81.37	-3.48	8.38	79.28
90	82.01	-3.20	8.85	79.75



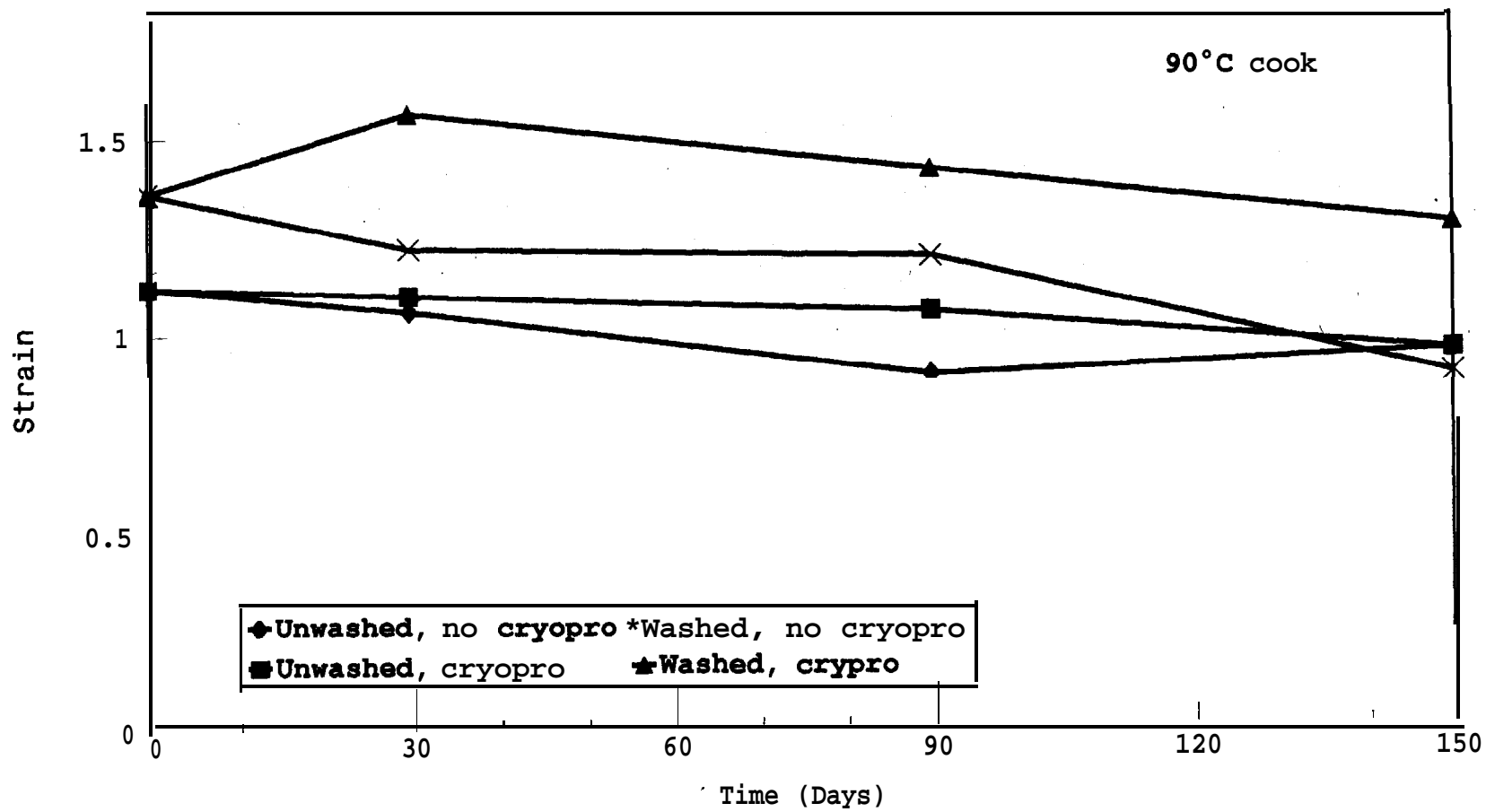
Appendix Figure F-1. Freshness of northern squawfish during ice storage.



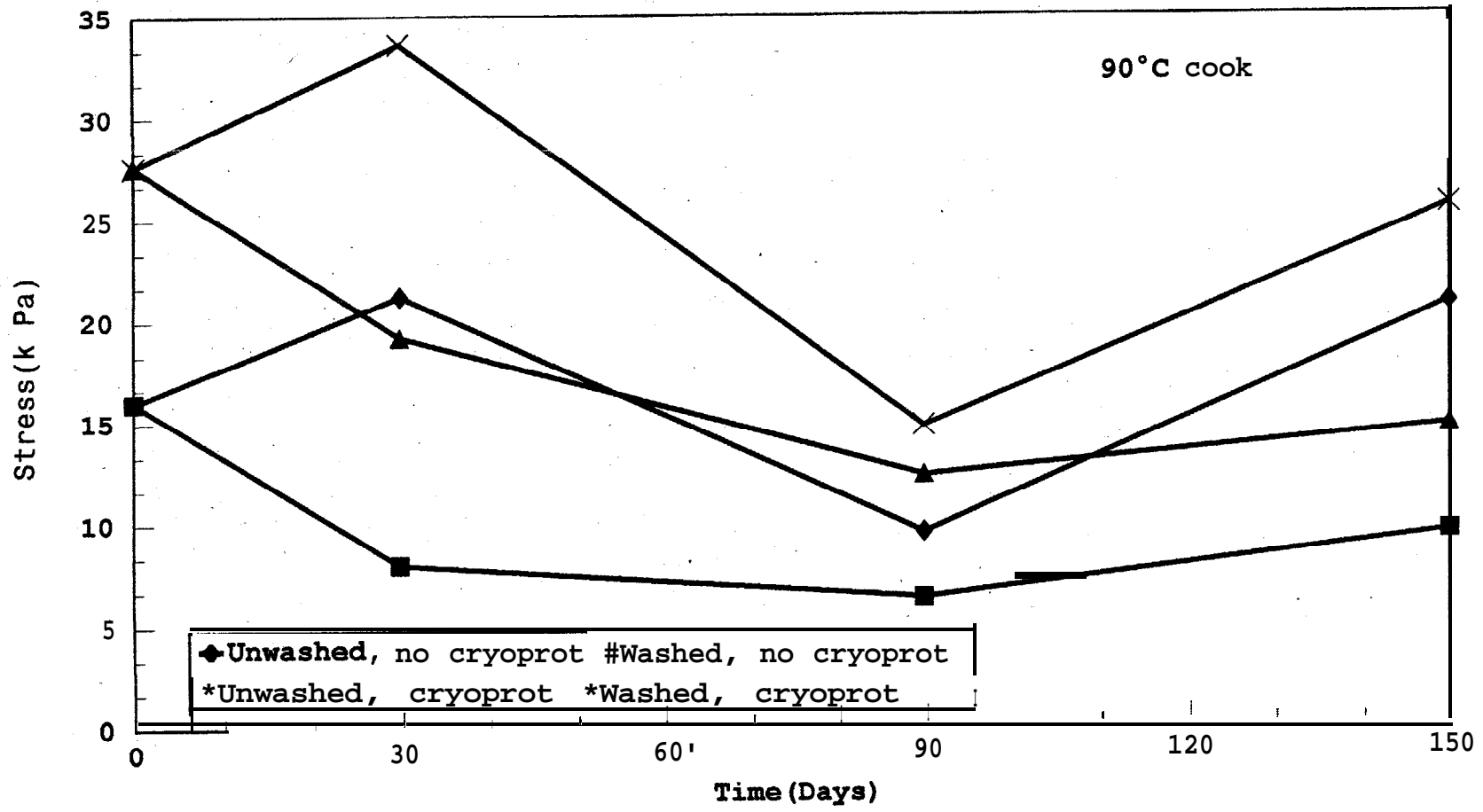
Appendix Figure F-2. Change in strain value of squawfish surimi during frozen storage.



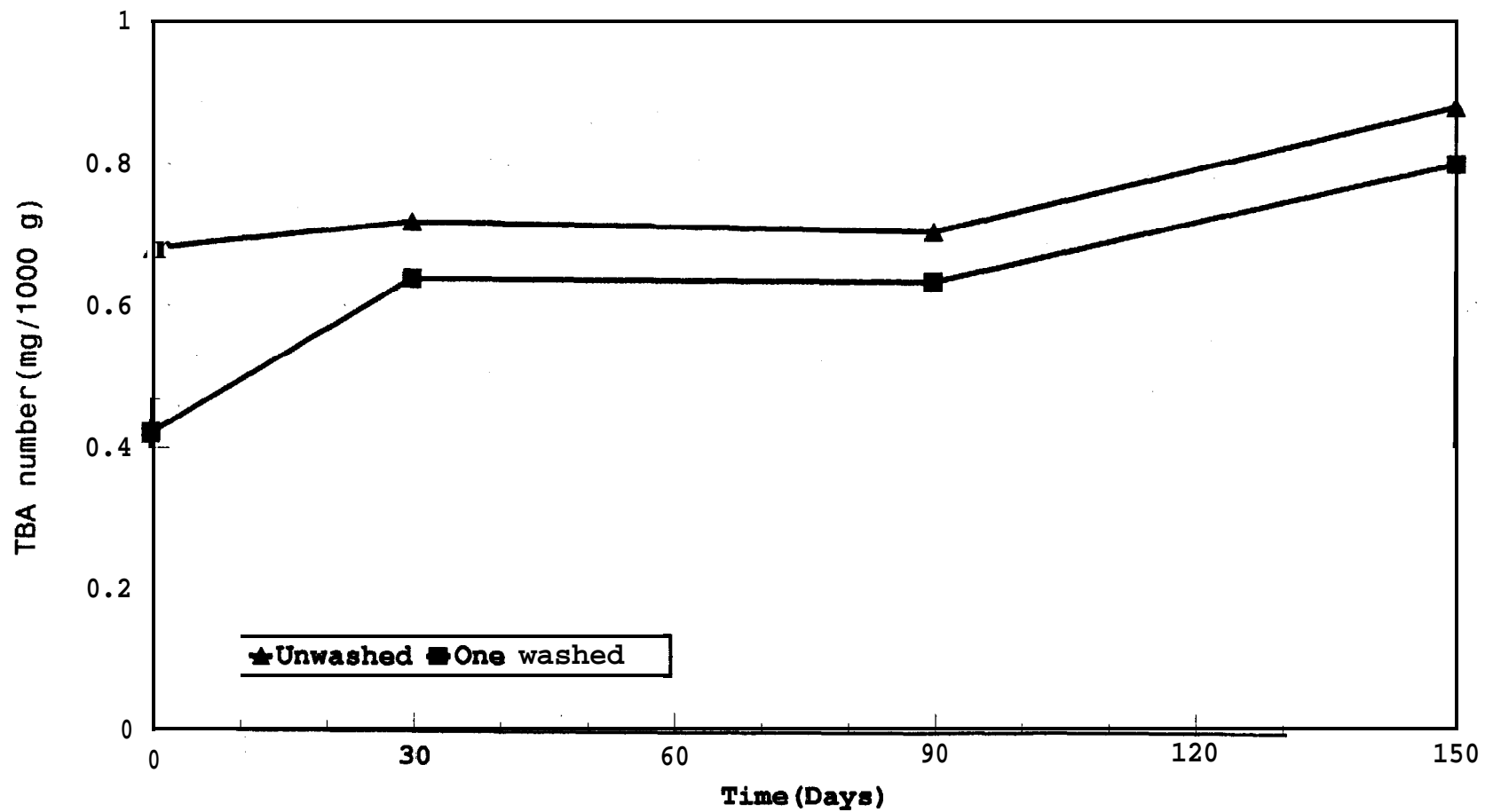
Appendix Figure F-3. Change in stress value of **squawfish surimi** during frozen storage.



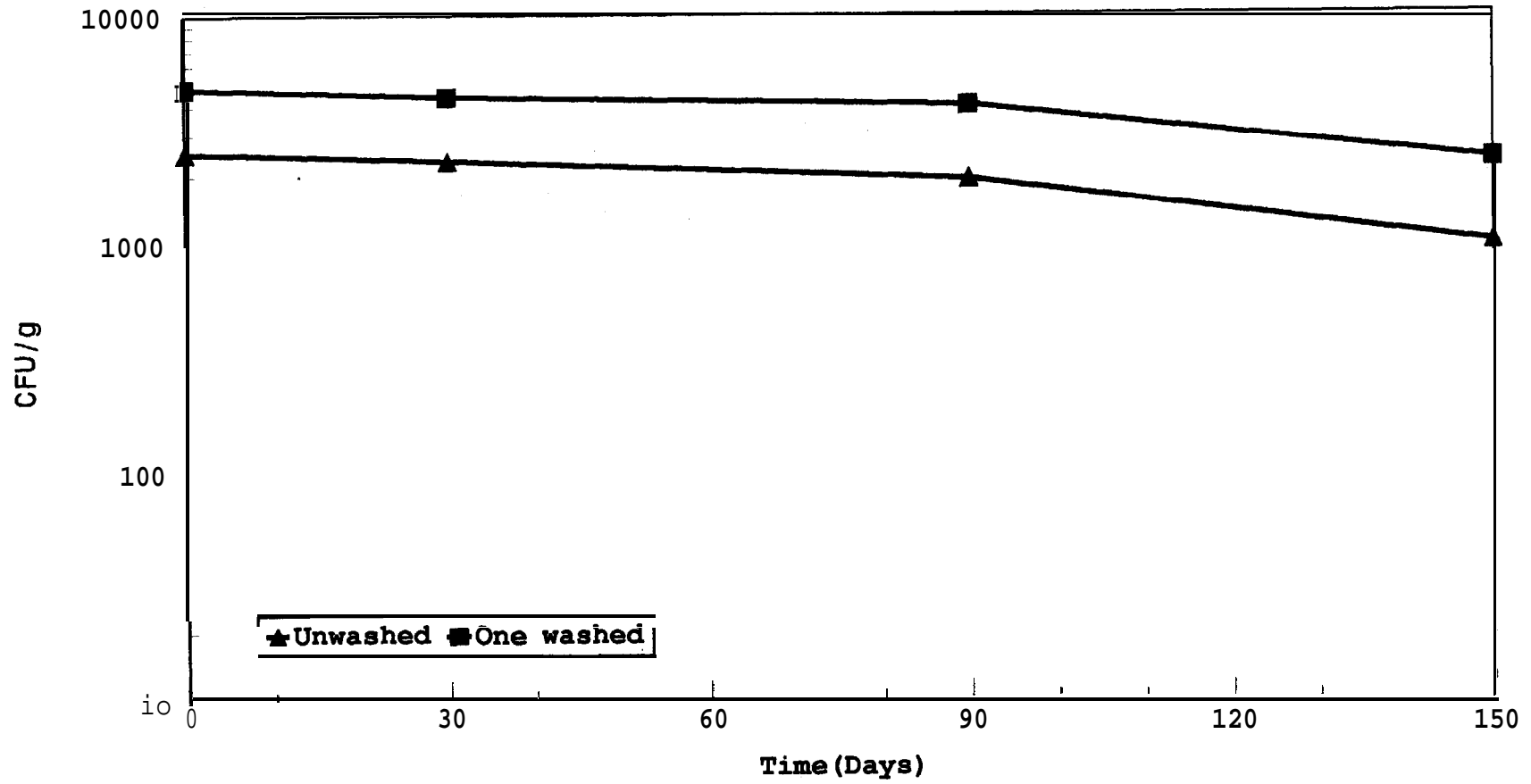
Appendix Figure F-4. Frozen squawfish mince effect of storage time on strain value.



Appendix Figure F-5. Frozen squawfish mince effect of storage time on stress value.



Appendix Figure F-6. Changes in TBA values frozen squawfish mince.



Appendix Figure F-7. Changes in total plate count frozen squawfiah mince.

Appendix Table F-4. Evaluation of color, texture, size and weight of **squawfish** roe.

W H O L E F I S H Q U A L I T Y = S C O R E O F 0-5 (5 H I G H E S T) : C O M B I N A T I O N O F O D O R , E Y E A P P E A R A N C E ,
T E X T U R E , S K I N C O L O R , & B L E M I S H E S .

F I L L E T Q U A L I T Y = S C O R E 0-5 (5 H I G H E S T) : C O M B I N A T I O N O F O D O R , C O L O R , T E X T U R E & B L E M I S H E S .

R O E A P P E A R A N C E = S C O R E 0-5 (5 H I G H E S T) : C O M B I N A T I O N O F C O L O R , B L E M I S H E S , B L O O D , I N T A C T
S K E I N , & O V E R A L L A P P E A R A N C E .

R O E T E X T = S C O R E 5 (0 = M U S H Y & 5 = V E R Y F I R M) .

R O E S I Z E = S C O R E 0-5 (S M A L L G L A S S B E A D [2.5mm] = 1 & L A R G E B E A D [6.5mmD [6.5mm = 5)

D A T E : 5/29/92 Squawfish

FISH LENGTH	FISH WEIGHT	W H O L E F I S H QUALITY	F I L L E T QUALITY	Roe Appearance Color/comments	Roe Appearance score	Roe TEXTURE	Roe SIZE	Roe WEIGHT
12	4471	4	4	4A male no Roe	-	-	-	-
16.51	10401	3	3	4A male no Roe	-	-	-	-
16	8121	3	3	3A male no Roe	-	-	-	-
15	7201	5	5	4A male no Roe	-	-	-	-
12.51	4331	5	5	5A male no Roe	-	-	-	-
11.51	3261	5	5	5A male no Roe	-	-	-	-
16	11451	5	5	5A male no Roe	-	-	-	-
13	4061	5	5	5A male no Roe	-	-	-	-
13	4001	5	5	4I Gray	0	-	0	61
15	8031	5	5	5I Gray	3	4	0	871
15	8901	5	5	5I gray green	3	4	0	871
17	13011	5	5	5I gray green	3	4	.5	1421
18.01	11991	5	5	5I Lt gray/loose eggs	2	3	.5	1531
20.01	21921	4	4	5I Lt green olive	3	4	.5	3081
17.01	12731	5	5	5I Lt green olive	3	4	.2	1721
17.01	12901	5	5	2I Lt green olive	3	4	.3	1861
15.51	7551	5	5	4I Lt green olive	4	4	1	901
19	21451	5	5	4I Lt green olive	4	4	1	2851
16	11351	5	5	5I Lt green olive	4	4	0	1551
16.51	12481	5	5	5I Lt green olive	4	4	1	2131
18	10801	4	4	4I Lt green olive	4	3	1	931
13	5781	4	4	4I Lt green olive	4	3	1	701
16	11401	4	4	4I Lt green olive	4	4	0	1651
16	10851	4	4	5I Lt green olive	3	4	.2	1031
13.51	5421	4	4	5I Lt grn olive/loose eggs	2.5	4	.2	401
17.01	12021	5	5	5I Med. Brown	3.5	4	.5	1541
15.71	7211	5	5	5I Med. Brown/loose eggs	3	4	.5	611
12	3601	4	4	4I medium Brown	4	4	0	251
14.51	6001	5	5	4I medium Brown	4	4	1	751
15	7501	4	4	4I Medium Brown	4	3	0	491
13	4731	4	4	5I Medium Brown	3	3	.2	361

Total Number of fish sampled 31
Number male of fish sampled 8
Number female of fish sampled 23

Average length of all fish 15.33 inches
Average length of male fish 14.06 inches
Average length of female fish 15.77

Average weight of all fish 919.06 grams
Average weight of male fish 666.12 grams
Average weight of female fish 1007.04 grams

Average weight roe 119.78 grams

APPENDIX G
Contaminant Tests

Evaluation of Tests for Dioxin Contamination
of Columbia *River* Northern Squawfish

Gene Foster
Oregon Department of Environmental Quality
Water Quality Division
Portland, Oregon

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October 1992

Evaluation of Tests for Dioxin Contamination
of Columbia River Northern Squawfish

Note: This report was submitted to OSU in October 1992. The report is a summary of toxicity evaluations performed by the Environmental Protection Agency Laboratory in Duluth, Minnesota on samples of northern **squawfish**. Samples were collected at 9 sites in the Columbia River in 1991.

Analysis is performed for both **2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)** and **2,3,7,8-tetrachlorodibenzofuran (TCDF)**. Results are given in terms of TCDD only. Neither **the** Food and Drug Administration nor the Environmental Protection Agency have adopted criteria action levels for **TCDF**. However, TCDF is considered to be approximately one-tenth as toxic as TCDD.

Introduction

Squawfish samples were collected from nine stations, eight on the Columbia River and one on the Columbia Slough. These samples were analyzed for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF). Samples were composites of at least five individuals. Whole body samples were collected at all stations. In addition, at six of the stations steak samples were prepared from the whole body samples. Samples were collected by either electrofishing or netting. Samples were placed on ice and shipped to the DEQ laboratory where they were frozen. Samples were shipped on ice to the USEPA/ERL Duluth Laboratory for analysis.

Squawfish whole body samples were collected at the following locations:

- CR 1: River Mile³⁸ near Tenasillahe Island *
- CR 2: River Mile⁶⁰ near Longview *
- CR 3: River Mile⁸⁴ near St. Helens *
- CR 4: River Mile¹⁰³ at Oregon Slough *
- CR 5: River Mile¹⁸⁵ at The Dalles *
- CR 6: River Mile²⁰⁰ at Miller Island
- CR 7: River Mile²²⁰ near the mouth of the John Day River
- CR 9: River Mile³⁰⁰ upstream of McNary Dam
- CS 1: River Mile/ on the Columbia Slough * .

* = Steak and whole body samples collected at this station.

Results

A total of fifteen samples were analyzed for TCDD and TCDF. TCDD was detected in eleven samples and ranged from 0.4 to 3.9 ng/kg-wet weight (ppt) and had a median of 2.5 ppt for detected values. TCDF was detected in all samples and ranged from 1.5 to 35.5 ppt and had a median value of 17.4 ppt.

Ten samples were collected and analyzed downstream of Bonneville Dam TCDD was detected in seven of the samples and ranged from 0.4 to 3.9 ppt with a median for detected values of 2.5 ppt. TCDF was detected in all ten samples and ranged from 1.5 to 35.5 ppt with a median of 13.45 ppt. There were five samples collected and analyzed from upstream of Bonneville Dam TCDD was detected in four of the samples and ranged from 1.3 to 3.6 ppt with a medina for detected values of 2.7 ppt. TCDF was detected in all five samples and ranged from 16.2 to 34.9 ppt with a median of 22.7 ppt.

Steak samples were collected at six stations. TCDD was detected in three samples and ranged from 0.40 to 1.20 ppt with a median for detected values of 1.00 ppt. TCDF was detected in the six steak samples and ranged from 1.50 to 17.40 ppt with a median of 12.55 ppt.

Discussion

The squawfish TCDD concentrations are similar to those found in other resident fish from the Columbia River system (DEQ files 1992). Squawfish samples collected downstream of The Dalles Dam had higher concentrations of TCDD than

carp collected from the same areas. Squawfish collected upstream of The Dalles Dam had lower concentrations of TCDD than carp collected from the same areas.

The FDA TCDD guideline concentration (developed in the Great Lakes) for the consumption of fish is 25 ppt. The USEPA reference level derived from the USEPA water quality criteria at a 1×10^{-6} cancer risk level is 0.07 ppt. All samples collected from the Columbia River and Columbia Slough were below the FDA guideline concentration of 25 ppt. All samples with detectable concentrations of TCDD were above the USEPA reference level of 0.07 ppt.

The Washington Department of Health has reviewed data from the upper Columbia River and has determined that a fish consumption advisory for the general population is not warranted at this time. The Oregon Health Division has reviewed TCDD data for fish from the Columbia River and has not issued a fish consumption advisory. The issue of safe consumption of fish collected from the Columbia River may be addressed by the Columbia River Bi-State Study in the next year or two.

Columbia River 1990
 Fish Tissue Summary: TCDDs/TCDFs

Station #	Species	Sample Type	2,3,7,8 TCDD	2,3,7,8 TCDF	TEC	% Lipid
CR #1	carp	wb	2.36 u	4.10		9.85
	D carp	wb	2.25 u	3.61 u		9.37
	carp	st	1.20	3.20		7.36
	sqwfsh	wb	3.00	22.80		6.81
	sqwfsh	st	1.20	12.30		4.72
	cryfsh	wb		u 2.3		
CR #2	carp	wb	1.84 u	5.00		7.47
	carp	st	0.87 u	2.60		4.52
	sqwfsh	wb	2.50	27.20		7.63
	sqwfsh	st	1.34 u	12.80		4.44
	cryfsh	wb	0.3	2.7		
CR #3	carp	wb	1.18 u	2.90		7.20
	carp	st	0.40	2.00		5.10
	sqwfsh	wq	3.90	35.50		6.30
	sqwfsh	st	1.00	14.10		3.00
	cryfsh	wb		u 1.4		
CR #4	carp	wb	1.63 u	2.20		7.40
	carp	st	0.80	2.80		5.40
	sqwfsh	wb	2.50	22.00		5.70
	sqwfsh	st	0.40	8.70		2.60
	cryfsh	wb		u 1.3		
CR #5	carp	wb	2.20	6.90		12.40
	carp	st	1.50	6.10		9.20
	sqwfsh	wb	3.60	34.90		7.20
	sqwfsh	st	2.30 u	17.40		3.00
CR #6	carp	wb	4.30	16.70		19.11
	carp	st	5.60	14.80		13.10
	sqwfsh	wb	2.60	34.10		8.60
CR #7	carp	wb	7.70	6.40		8.84
	carp	st	4.80	4.90		7.50
	sqwfsh	wb	1.30	16.20		2.92
CR #8	carp	wb	4.70	15.10		14.90
	carp	st	4.80	11.00		10.30

Columbia River 1990

Fish Tissue Summary: TCDDs/TCDFs

Station #	Species	Sample Type	2,3,7,8 TCDD	2,3,7,8 TCDF	TEC	% Lipid
CR #9	carp	wb	5.00	15.00		12.29
	carp	st	5.60	15.50		9.70
	sqfsh	wb	2.80	22.70		3.74
cs #1	carp	wb	1.55 u	1.10		7.43
	carp	st	1.80 u	0.90		4.10
	sqwfsh	wb	1.09 u	3.30		5.04
	sqfsh	st	1.20 u	1.50		2.00
	crfsh	wb		0.5		

sqfsh = squawfish

crfsh = crayfish

wb = whole body

st = steak

u = not detected at concentration indicated

2,3,7,8 TCDD = 2,3,7,8-Tetrachlorodibenzo-p-dioxin

2,3,7,8-TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TEC = toxic Equivalency Concentration

Columbia River 1990
Tissue Summary Results: All Stations

TCDD, TCDF, & PCBs

Units = pg/g (ng/kg) or part per trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC	
								Non Carcinogenic	NYS/DEC Carcinogenic
TCDD	41	25	0.3	2.6	7.7	0.07	2s	3	2.3
TCDF	41	40	0.5	6.65	35.5				
3,3',4,4' TeCBP	20	20	90	217	909	2464.8	2000000	110000	
2,3,3',4,4' PeCBP	20	20	1724	4289	21162	2464.8	2000000	110000	
3,3',4,4',5 PeCBP	20	19	45	88	232	2464.8	2000000	110000	
<i>Units = ng/g (ug/kg) or parts per billion</i>									
Monochloro	20	2	8.86	20.6	32.33	2464.8	2000000	110000	
Dichloro	20	12	0.25	1.59	5.23	2464.8	2000000	110000	
Trichloro	20	20	0.69	9.89	25.81	2464.8	2000000	110000	
Tetrachloro	20	20	13.43	40.09	105.28	2464.8	2000000	110000	
Pentachloro	20	20	41.84	95.19	229.08	2464.8	2000000	110000	
Hexachloro	20	20	79.62	218.87	360.47	2464.8	2000000	110000	
Heptachloro	20	20	69.56	143.65	306.02	2464.8	2000000	110000	
Octachloro	20	20	10.6	34.44	68.42	2464.8	2000000	110000	
Nonachloro	20	20	0.93	5.01	10.34	2464.8	2000000	110000	
Decachloro	20	20	0.24	0.73	1.47	2464.8	2000000	110000	
Total PCBs	20	20	371.68	593.01	1153.2s	2464.8	2000000	110000	

TCDD = 2,3,7,8-Tetrachlorodibenzo-p-dioxin

TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl

PeCBP = Pentachlorobiphenyl

HxCBP = Hexachlorobiphenyl

Columbia River 1990
Tissue Summary Results: Squawfish

TCDD, TCDF, & Pas

units = *pg/g (ng/kg)* or part per trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC Yal Carcinogenic	NYS/DEC Carcinogenic
TCDD	1s	11	0.4	2.5	3.9	0.07	2s	3	2.3
TCDF	15	15	1.5	17.4	35.5				
3,3',4,4' TeCBP	9	9	121	381	909	2464.8	2000000	110000	
2,3,3',4,4' PeCBP	9	9	2119	11896	21162	2464.8	2000000	110000	
3,3',4,4',5 PeCBP	9	9	68	138	232	2464.8	2000000	110000	
<i>units = ng/g (ng/kg) or parts per trillion</i>									
Monochloro	9	1		8.86		2464.8	2000000	110000	
Dichloro	9	5	0.2s	1.42	2.19	2464.8	2000000	110000	
Trichloro	9	9	0.69	9.17	20.44	2464.8	2000000	110000	
Tetrachloro	9	9	13.43	46.13	105.28	2464.8	2000000	110000	
Pentachloro	9	9	69.11	102.06	229.08	2464.8	2000000	110000	
Hexachloro	9	9	139.75	232.12	360.47	2464.8	2000000	110000	
Heptachloro	9	9	69.26	162.82	306.02	2464.8	2000000	110000	
Octachloro	9	9	10.6	29.53	68.42	2464.8	2000000	110000	
Nonachloro	9	9	0.93	3.09	10.34	2464.8	2000000	110000	
Decachloro	9	9	0.24	0.47	0.93	2464.8	2000000	110000	
Total PCBs	9	9	371.68	711.65	1153.25	2464.8	2000000	110000	

TCDD = 2,3,7,8-Tetrachlorodibenzo-p-dioxin

TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl

PeCBP = Pentachlorobiphenyl

HxCBP = Hexachlorobiphenyl

Columbia River 1990

Tissue Summary Results: Carp

TCDD, TCDF, & PCBs

Units = pg/g (ng/kg) or part per trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC Non Carcinogenic	NYS/DEC Carcinogenic
TCDD	21	13	0.4	4.7	7.7	0.07	125	3	2.3
TCDF	21	20	0.9	4.5	16.7				
3,3',4,4' TeCBP	11	11	77	163	453	2464.8	2000000	110000	
2,3,3',4,4' PeCBP	11	11	1724	3935	128%	2464.8	2000000	110000	
3,3',4,4',5 PeCBP	11	10	45	68	205	2464.8	2000000	110000	
<i>Units = ng/g (ug/kg) or parts per billion</i>									
Monochloro	11	1		32.33		2464.8	2000000	110000	
Dichloro	11	7	0.54	1.59	1.23	2464.8	2000000	110000	
Trichloro	11	11	1.35	11.29	25.81	2464.8	2000000	110000	
Tetrachloro	11	11	17.04	39.06	66.72	2464.8	2000000	110000	
Pentachloro	11	11	41.84	90.48	191.46	2464.8	2000000	110000	
Hexachloro	11	11	79.62	210.03	355.11	2464.8	2000000	110000	
Heptachloro	11	11	87.95	132.18	222.3	2464.8	2000000	110000	
Octachloro	11	11	24.81	34.82	48.69	2464.8	2000000	110000	
Nonachloro	11	11	2.71	5.45	6.96	2464.8	2000000	110000	
Decachloro	11	11	0.49	1.14	1.47	2464.8	2000000	110000	
Total PCBs	11	11	417.28	554.87	930.5	64.8	2000000	110000	

TCDD = 2,3,7,8-Tetrachlorodibenzo-p-dioxin

TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl

PeCBP = Pentachlorobiphenyl

HxCBP = Hexachlorobiphenyl

Columbia River 1990

Tissue Summary Results: Crayfish

Tam; **TCDF, & PCBs**

Units = pg/g (ng/kg) or part per trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC Non Carcinogenic	NYS/DEC Carcinogenic
TCDD	5	1		0.3		0.07	25	3	2.3
TCDF	5	5	0.5	1.4	2.7				

TCDD = 2,3,7,8- Tetrachlorodibenzo-p-dioxin

TCDF = 2,3,7,8-Tetrachlorodibenzofuran

Columbia River 1990

Tissue Summary Results: Squawfish - Downstream of Bonneville Dam

TCDD, TCDF, & PCBs

Units = pg/g (ng/kg) or part per trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC Non Carcinogenic	NYS/DEC Carcinogenic
TCDD	10	7	0.4	2.5	3.9	0.07	2s	3	2.3
TCDF	10	10	1.5	13.45	35.5				
3,3',4,4' TeCBP	5	5	381	593	909	2464.8	2000000	110000	
2,3,3',4,4' PeCBP	5	5	2783	15649	21162	2464.8	2000000	110000	
3,3',4,4',5 PeCBP	5	5	138	172	232	2464.8	2000000	110000	

Units = ng/g (ug/kg) or parts per billion

Monochloro	5	1		8.86		2.465	2000	110
Dichloro	5	4	0.57	1.7	2.19	2.465	2000	110
Trichloro	5	5	9.17	15.51	20.44	2.465	2000	110
Tetrachloro	5	5	46.13	72.66	105.28	2.465	2000	110
Pentachloro	5	5	69.11	107.37	229.08	2.465	2000	110
Hexachloro	5	5	162.01	182.0	360.47	2.465	2000	110
Heptachloro	5	5	69.26	168.88	306.02	2.465	2000	110
Octachloro	5	5	10.6	34.15	54.44	2.465	2000	110
Nonachloro	5	5	0.93	4.08	7.48	2.465	2000	110
Decachloro	5	5	0.24	0.58	0.93	2.465	2000	110
Total PCBs	5	5	424.91	2.23	1153.25	2.465	2000	110

TCDD = 2,3,7,8-Tetrachlorodibenzo-p-dioxin

TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl

PeCBP = Pentachlorobiphenyl

HxCBP = Hexachlorobiphenyl

Median values calculated from detected values

Columbia River 1990

Tissue Summary Results: Squawfish - Upstream of Bonneville Dam

TCDD, TCDF, & PCBs

Units = pg/g (ng/kg) or part per trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC	
								Non Carcinogenic	NYS/DEC Carcinogenic
TCDD	5	4	1.3	2.7	3.6	0.07	2s	3	2.3
TCDF	5	5	16.2	22.7	34.9				
3,3',4,4' TeCBP	4	4	121	190	294	2464.8	2000000	110000	
2,3,3',4,4' PeCBP	4	4	2119	4289	11896	2464.6	2000000	110000	
3,3',4,4',5 PeCBP	4	4	68	a0	133	2464.8	2000000	110000	

Units = ng/g (ug/kg) or parts per billion

Monochloro	4	0				2.465	2000	110		
Dichloro	4	1		0.25		2.465	2000	110		
Trichloro	4	4	0.69	2.87	7.04	2.4665	2000	110		
Tetrachloro	4	4	13.43	17.48	39.71	2.465	2000	110		
Pentachloro	4	4	87.68	99.05	153.59	2.465	2000	110		
Hexachloro	4	4	139.75	232.92	240.64	2.465	2000	110		
Heptachloro	4	4	71.79	122.25	200.45	2.46s	2000	110		
Octachloro	4	4	14.71	21.96	6a.42	2.465	2000	110		
Nonachloro	4	4	1.63	2.16	10.34	2.465	2000	1	1	0
Decachloro	4	4	0.32'	0.42	0.79	2.46s	2000	110		
Total PCBs	4	4	371.68	518.14	765.98	2.46s	2000	110		

TCDD = 2,3,7,8-Tetrachlorodibenzo-p-dioxin

TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl

PeCBP = Pentachlorobiphenyl

HxCBP = Hexachlorobiphenyl

Median values calculated from detected values

Appendix Table G-1. FDA foodstuff action levels for selected contaminants.

FDA Foodstuff Action Level (ppm)	
Chlorinated Pesticides and PCBs	
alpha-BHC	0.3
beta-BHC	0.3 ^a
Lindane	0.5^b
Heptachlor	0.3
Heptachlor epoxide	0.3
Aldrin	0.3 ^c
Dieldrin	
p,p' DDE	5.0
p,p' DDD	5.0
p,p' DDT	5.0
p,p' Methoxychlor	5.0
Chlordane	0.3
PCB Group 1	2.0
PCB Group 2	2 . 0
PCB Group 3	2.0
PCB Group 4	2.0
PCB Group 5	2.0
Heavy Metals	
Mercury	1.0
Arsenic	^d
Cadmium	d
Chromium	^d
Copper	^d
Lead	^d
Z i n c	^d

^a Level established for rabbit meat. No level established for fish.

^b Level established for eggs. No level established for fish.

^c Level established for sum of Dieldrin and Aldrin values.

^d No FDA action level established.

Appendix Table G-2. Results of tests for organic contaminants in northern squawfish.

DEPARTMENT OF **ENVIRONMENTAL** QUALITY LABORATORIES
Analytical Records Report PAGE- 1 of .

PRELIMINARY report, results are NOT conclusive. Printed by

CASE NAME: **890371** JOHN DAY RESERVOIR
SUBMITTER: **Vigg, Steve**
FUND CODE: **3250 205J(S)**- Nonpoint Source

<u>ITEM #</u>	<u>RESULT</u>	<u>UNITS</u>	<u>TEST</u>
---------------	---------------	--------------	-------------

. 001 **Small Fish, Edible** portion
05/03/89

ATTACHed Chlorinated Pesticides in Tissues, Fish Tissue

. 002 **Large Fish, Edible** portion
05/03/89

ATTACHed Chlorinated Pesticides in Tissues, Fish Tissue

003 **Small Fish, Liver**
05/03/89

ATTACHed Chlorinated Pesticides in Tissues, Fish Tissue

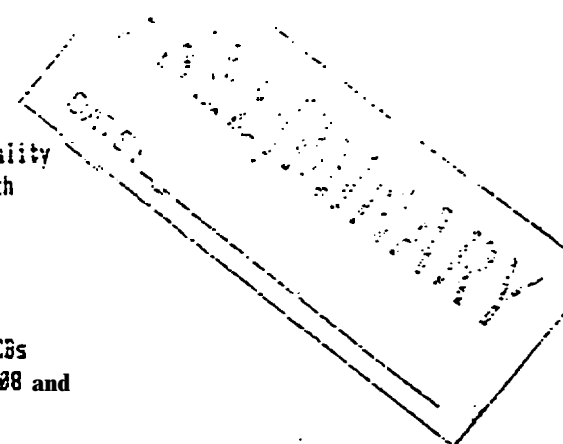
004 **Large Fish, Liver**
05/03/89

ATTACHed Chlorinated Pesticides In Tissues, Fish Tissue

RECEIVED
JUN 16 1989

Water Quality Division
Dept. of Environmental Quality

Department of Environmental Quality
 Laboratories and Applied Research
 Organic Section



GC
 CHLORINATED PESTICIDES AND PCSs
 Complies with EPA NPDES Method 608 and
 RCRA Method 8080

Date: 1 June 1989

Lab #: 898371

Sample: 1-FISH

Iter #: I *SSD*

Concentration µG/KG	Parameter	CAS Registry Number	A
<0.003	alpha-SHC	313846	
(0.003	beta-SHC	319857	
<0.003	Lindane	58899	
<0.003	Heptachlor	76448	
<0.003	Aldrin	289802	
<0.003	Heptachlor epoxide	1824573	
<0.003	p,p' DDE	72559	
<0.003	Endrin	72298	
<0.003	p,p' DDD	72548	
<0.003	p,p' DDT	50293	
<0.003	p,p' Methoxychlor	72435	
0.011	Dieldrin	60571	
<0.003	Chlordane	57749	
(0.012	PCB Group 1	11184282	
<0.006	PCB Group 2	11141165	
<0.003	PCB Group 3	53469219	
<0.003	PCB Group 4	11897691	
<0.003	PCB Group 5	11096625	
ND	Total PCB		

PCB Group 1 includes PCB 1221 and is calculated as 1221.

PCB Group 2 includes PCB 1232 and is calculated as 1232.

PCB Group 3 includes PCB'S 1016, 1242 and 1248 and is calculated as 1242.

PCB Group 4 includes PCB 1294 and is calculated as 1254.

PCB Group 5 includes PCB'S 1268 and 1262 and is calculated as 1264.

ND No PCB's observed above indicated detection limit.

Department of Environmental Quality
 Laboratories and Applied Research
 Organic Section

DATE: _____

PRELIMINARY

GC

CHLORINATED PESTICIDES AND Peas
 Complies with DA NPDES Method 608 and
 RCRA Method 8080

Date: 1 June 1989

Lab #: 830371

Sample: E-FISH
 Item #: 2

590

Amount MG/KG	Parameter	CAS Registry Number
<0.003	alpha-BHC	319846
<0.003	beta-BHC	319857
<0.003	Lindane	58899
<0.003	Heptachlor	76448
<0.003	Aldrin	309002
<0.003	Heptachlor epoxide	1024573
0.073	p,p' DDE	72557
<0.003	Endrin	72248
0.007	p,p' DDD	72548
<0.003	p,p' DDT	50293
<0.003	p,p' Methoxychlor	72435
<0.003	Dieldrin	60571
<0.003	Chlordane	57749
<0.012	PCB Group 1	11104282
<0.006	PCB Group 2	11141165
<0.003	PCB Group 3	53449219
0.113	PCB Group 4	11097691
8.641	PCB Group 5	11096825
0.154	Total PCB	

PCB Group 1 includes PCB 1221 and is calculated as 1221.
 PCB Group 2 includes PCB 1232 and is calculated as 1232.
 PCB Group 3 includes PCB'S 1216, 1242 and 1248 and is
 calculated as 1242.
 PCB Group 4 includes PCB 1254 and is calculated as 1254.
 PCB Group 5 includes PCB'S 1268 and 1252 and is calculated
 as 1266.

NO No PCB's observed above indicated detection limit.

Department of Environmental Quality
 Laboratories and Applied Research
 Organic Section

PRELIMINARY
 DATE: _____

6C
 CHLORINATED PESTICIDES AND PC%
 Complies with EPA NPDES Method 808 and
 RCRA Method 8080

Date: 1 June 1989

Lab #: 890371
 Sample: REDFISH
 Item #: 3

550

Amount MG/KG	Parameter	CAS Registry Number
<0.003	alpha-BHC	319846
<0.003	beta-BHC	319957
<0.003	Lindane	58899
<0.003	Heptachlor	76448
0.03	Aldrin	309662
<0.003	Heptachlor epoxide	1024573
0.785	p,p' DDE	72559
<0.003	Endrin	72248
4.248	p,p' DDD	72548
<0.003	p,p' DDT	50293
0.004	p,p' Methoxychlor	72435
0.037	Dieldrin	60571
<0.003	Chlordane	57749
<0.012	PCB Group 1	11104282
<0.006	PCB Group 2	11141165
(0.003	PCB Group 3	53449219
<0.003	PCB Group 4	11597691
<0.003	PCB Group 5	11096825
ND	Total PCB	

PCB Group 1 includes PCB 1221 and is calculated as 1221.
 PCB Group 2 includes PCB 1232 and is calculated as 1232.
 PCB Group 3 includes PCB'S 1016, 1242 and 1248 and is
 calculated as 1242.
 PCB Group 4 includes PCB 1254 and is calculated as 1254.
 PCB Group 5 includes PCB's 1260 and 1252 and is calculated
 as 1268.

ND No PCB's observed above indicated detection limit.

Department of Environmental Quality
 Laboratories and Applied Research
 Organic Section

PRELIMINARY
 DATE: _____

6C
 CHLORINATED PESTICIDES AND PCSs
 Complies with EPA NPDES Method 508 and
 RCRA Method 8082

Date: 1 June 1989

Lab #: 891371
 Sample: BLUFISH
 Item #: 4

SSD

Amount MG/KG	Parameter	CAS Registry Number
<0.003	alpha-3HC	319841
<0.003	beta-3HC	319857
<0.003	Lindane	56399
a.33	Heptachlor	76448
<0.003	Aldrin	309802
<0.003	Heptachlor epoxide	1024573
3.13	p,p' ODE	72557
a.74	Endrin	72288
0.99	p,p' DDD	72548
<0.003	p,p' DDT	50293
<0.003	p,p' Methoxychlor	72435
<0.003	Dieldrin	60571
<0.003	Chlordane	57749
<0.012	PCB Group 1	11104222
<0.006	PCB Group 2	11141165
<0.003	PCB Group 3	53469219
<0.003	PCB Group 4	11097691
<0.003	PCB Group 5	11096625
ND	Total PCB	

PCB Group 1 includes PCB 1221 and is calculated as 1221.
 PCB Group 2 includes PCB 1232 and is calculated as 1232.
 PCB Group 3 includes PCB'S 1016, 1242 and 1248 and is
 calculated as 1242.
 PCB Group 4 includes PCB 1224 and is calculated as 1254.
 PCB Group 5 includes PCB'S -1266 and 1262 and is calculated
 as 1260.

MD No PCB's observed above indicated detection limit.

PRELIMINARY
DATE: _____ * *

FATS / LIPIDS

LAB #	ID #	FISH TYPE	ppm *	* *
890371-3250	1-Fish	Squawfish	12555	1.256
	2-Fish	Squawfish	5180	0.518

* wet method
(wet weight basis)

Appendix Table G-3. Results of tests for heavy metal contaminants in northern squawfish.

WEDNESDAY OCTOBER 4th, 1989

CASE NAME: 830371 JOHN DAY RESERVOIR
 SUBMITTER: Gates, Richard F. COLLECTOR: Vigg, Steve
 FUND CODE: 3250 205J(G)- Nonpoint Source

ITEM #	RESULT	UNITS	TEST
001	Small Fish, Edible portion 05/03/89		
	0.98	mg/Kg dry	Wtrcury, Fish Tissue
	(0.15	mg/Kg dry	Arsenic, Fish Tissut
	00.04	mg/Kg dry	Cadmium, Fish Tissue
	(0.15	mg/Kg dry	Chromium, Fish Tissue
	1.4	mg/Kg dry	Copper, Fish Tissue
	(0.15	mg/Kg dry	Lead, Fish Tissue
	23.3	%	% SOLIDS, Fish Tissue
	22	mg/Kg dry	Zinc, Fish Tissut
	ATTACHED		Chlorinated Pesticides in Tissues, Fish Tissue
002	Large Fish, Edible portion 05/03/89		
	3.20	mg/Kg dry	Mercury, Fish Tissut
	(0.15	mg/Kg dry	Arsenic, Fish Tissue
	(0.04	mg/Kg dry	Cadmium, Fish Tissue
	(0.15	mg/Kg dry	Chromium, Fish Tissue
	1.2	mg/Kg dry	Copper, Fish Tissue
	(0.15	mg/Kg dry	Lead, Fish Tissut
	23.0	%	% SOLIDS, Fish Tissue
	19	mg/Kg dry	Zinc, Fish Tissue
	ATTACHED		Chlorinated Pesticides in Tissues, Fish Tissue
003	Small Fish, Liver 05/03/89		
	ATTACHED		Chlorinated Pesticides in Tissuts, Fish Tissue
004	Large Fish, Liver 05/03/89		
	ATTACHED		Chlorinated Pesticides in Tissues, Fish Tissue

REPORT I

Columbia River Ecosystem Model (CREM): Modeling Approach for Evaluation of Control of Northern Squawfish Populations Using Fisheries Exploitation

Prepared by

**Dr. L.J. (Sam) Bledsoe, PJ.
Amy L. Bleich
Helen Rudd**

**Center for Excellence in
Space, Earth and Life Sciences
-Computer Sciences Corporation
Lanham, Maryland**

1992 Annual Report

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INTRODUCTION

This report provides an estimate of the current season juvenile **salmonid** mortality changes resulting from 1992 predator fisheries and an estimate of the future effect of such fisheries based on a variety of predator population dynamics assumptions. This report also includes the description of EZ-CREM, a user interface to the Columbia River Ecosystem Model (CREM) developed to allow biologists to analyze data with CREM.

The objectives of this contract included tasks intended to result in:

1. Revised seasonal, reservoir specific projections of juvenile **salmonid** mortality in response to the predator fishery control program.
2. A user interface for version of the computer model to be used **by** the researchers and the project managers.
3. Long-term systemwide projections of **salmonid** mortality.

To meet Objectives 1 and 3 of the contract, the following numerical studies were performed:

1. Effect of Predation on Apparent Reservoir Residence Time in Tagging Studies of Juvenile Salmonids.

In the absence of predators, the **salmonid** residence time could be calculated simply by averaging the arrival times for the distribution of salmon downstream. In reality, however, predation could affect the shape of that distribution. It was necessary to validate the observed residence times of the salmonids in the model with experimental tagging studies. This could be done by comparing the empirical data to the simulated residence times obtained by varying the predation rates in a representative reservoir. The rationale for performing this study was the need to quantitatively determine the effect of predation on the average **salmonid** residence time.

2. Study of **Salmonid** Mortality Sensitivity to Various Simulation Parameters.

To provide the fisheries management with accurate projections of the juvenile **salmonid** mortality in response to predation, it is necessary to be aware of the sensitivity of mortality to various assumptions used by CREM with respect to the forcing function parameters. Important parameters are the catchability coefficients, maximum temperature effect, velocity threshold, spawning effect, and flow-dependent residence time parameters.

The “Methods” section describes in detail the methods and the relevant mathematical equations used in all the modeling and simulation studies. This section also provides information on the sources of the observed data and explains various assumptions made with respect to predator population sizes, model parameters, etc. The section entitled “Results” presents the results of various numerical studies and projections in the appropriate tabular and/or graphical form. The “Discussion” section presents analyses of the numerical data, comparison between the simulation and the empirical results, and possibilities in model improvement. The appendix to the report contains the EZ-CREM User’s Guide.

OBJECTIVES

1. Provide estimates of predation-related juvenile **salmonid** mortality for Columbia and Snake River projects based on the most recent research data, and revised estimates of salmonids mortality in response to existing and proposed predator control measures and other management actions.
2. Develop a user interface for versions of CREM to allow researchers and project managers to operate the model to investigate the consequences of management alternatives in the system. Implement a system of menus and graphic output modules for a PC based version of CREM 2.1.
3. Provide estimates of the probable long-term consequences of the present and possible alternative predator control programs on squawfish and **salmonid** mortality.

METHODS

Effect of Predation on Apparent Reservoir Residence Time in Simulated Tagging Studies of Juvenile Salmonids

In the Columbia River Ecosystem Model (CREM; Bledsoe et al. 1990), downstream progress of juvenile salmonids is determined using a mean residence time (rt) measured in days. This residence time characterizes *only* the movement of the salmonids and is used along with other factors to determine the time of arrival at the downstream dam.

It is important to determine the effects of predation on the apparent residence time of subyearling chinook salmon through simulated tagging experiments. The results can be used to estimate the extent to which predation biases the residence time determined by tagging experiments.

CREM Version 2.1 (described in detail in Bledsoe et al. 1992) was used to model the passage of juvenile salmonids through the John Day Reservoir. **Salmonid** residence times were determined with reference to baseline conditions of predator density and river flow. Rather than the constant residence time described in Bledsoe et al. (1990), these simulations assumed that residence time is inversely proportional to river flow. The computation of residence time takes the form:

$$rt(i,j) = prt2(i,j)*area(j)/Fl + prt1(i,j)$$

where:

rt(i,j) = residence time of **salmonid** group i in region j,
prt2(i,j) = flow-dependant residence time parameter of salmonids group i in region j,
area(j) = area of region j,
Fl = daily river flow into reservoir, and
prt1(i,j) = flow-independent residence time parameter of **salmonid** group i in region j.

In a normal simulation, one of the two parameters, prt1 and **prt2**, will be set to zero and the other will be non-zero depending upon flow-independent (**prt1** > 0, **prt2** = 0) or flow-dependent (**prt1** = 0, **prt2** > 0) residence times. For flow-dependent rt's, if the value of **prt2** is set to the mean of depth for a reservoir region, the residence time will be approximately equal to the neutrally buoyant particle travel time in the region. If fish are hypothesized to move more slowly than water travel by a factor $X1 < 1$, the prt 2 should be increased by a factor $1/X1$.

Chinook subyearling migrants have been shown to lag river flow by a factor of 1./2.5. Table 1 gives values of **prt2** for subyearling chinook 0 and other stocks; prt 1 is set uniformly to zero for the residence time exercise. **Prt2** values are set to mean reservoir depths for non-chinook 0 species ("other") and 2.5 times greater for chinook 0s.

Table 1. Values of the residence time parameter prt2 for subyearling chinook 0 and other stock. Prt1 is set to 0.

		i (Salmonid Group)		
		1 (Ch 0)	2 (Others)	3 (Tagged)
j (Region)	1 (Tailrace)	20.0	8.0	20.0
	2 (Mid-bay)	56.5	22.6	56.5
	3 (Forebay)	91.0	36.4	91.0

The baseline for predator densities in the reservoir regions was based on estimates proportional to the 1991 electroshock predator density indices as described in Bledsoe et al. 1992. The baseline river flow came from 1957 flow data, which was used to represent a typical case of seasonal river flow.

In the simulated tagging experiments, three **salmonid** groups pass into John Day reservoir:

1. Subyearling chinook, representing observed 1990 passages.
2. All other salmonids, representing observed 1990 passages.
3. "Tagged" subyearling chinook, released at intervals of 20 days throughout the season.

The first two groups produce prey densities appropriate to the observed passages in the 1990 season, allowing for the appropriate density-dependent predator response. The third, tagged, group is small relative to the other two. Each release of the tagged group into the reservoir is compared to the arrival of that group at the downstream dam to determine average residence time.

The average residence time of subyearling chinook from a release is determined as follows:

$$RT_i = \frac{\sum_{t=0}^{19} n_{it}t}{\sum_{t=0}^{19} n_{it}}$$

where:

- RT_i** = the average residence time of the **ith** release,
- n_{it}** = the number of tagged fish arriving at the downstream reservoir on day t after release i, and
- t = number of days since the last release.

Each tagged release simulation is performed twice. The first assumes that predators are present in numbers estimated for that season. The second assumes that only 1% of the estimated numbers are present to determine the predator effect on apparent residence time. The simulations were performed for different river flow rates with release staggered at intervals of 20 days throughout the season. To confirm that the tagged group was small

enough to avoid perturbing the residence times, the studies were repeated with tagged groups of varying sizes.

The two studies simulate the release of 100 tagged fish on each release day. The first case assumes the baseline river flow, and the second case assumes that the flow rate is **50 %** of baseline. In addition, each of these studies includes a simulation with predator density of 200% of the baseline.

Long-Term Systemwide Salmonid Mortality Projections

CREM (Version 2.1) was first used to project long-term (1990 through 1995) juvenile **salmonid** mortalities due to predation by northern **squawfish** in 1990 (Bledsoe et al. 1992). Those estimates were based for all years on 1990 values of the driving functions (passage numbers, fishing effort). Only three of the lower Columbia River reservoirs were included in that study -- John Day, The Dalles and Bonneville.

The updated study performed this year provided the projections of **salmonid** mortality due to predation in the extended Columbia-Snake River system, which included the eight reservoirs listed below. The estimates of total annual mortalities were calculated for each of the years 1992 through 2000, based on the latest available information, e.g. 1992 predator removal and electroshock data.

The catch from the following fisheries was included in the calculation of the projections: Oregon and federal electroshock, sport fishing, and dam angling. Commercial fishing in 1992 took place only below Bonneville Dam (outside of the region covered by the LONGCREM simulator), and therefore was not included in the calculations.

The LONGCREM model was used to project **salmonid** mortality from 1992 to 2000. The model currently incorporated in LONGCREM covers the Snake and lower Columbia River systems by successive execution of CREM (Version 2.1) for each year in the following reservoirs: Little Goose, Lower Monumental, Ice Harbor, **McNary**, John Day, The Dalles, and Bonneville. To provide more complete data for the future predator control analyses, the **salmonid** mortality projections were produced using two predator population regrowth scenarios:

- a) assuming no regrowth of the predator population numbers (i.e., births equal natural mortality), and
- b) assuming 10% annual predator population regrowth.

Both scenarios were **modelled** with the same fishing effort and the same catchabilities. The predicted mortalities are presented in the “Results” section of this report.

Study of Mortality Sensitivity to Various Model Parameters

One of the main objectives of this project has been accurate prediction of **salmonid** mortality for future years. While the CREM parameters have been carefully chosen based on fishery efforts, biological facts, observed data, etc., it was necessary to determine how a change in any of the parameters that are central to the simulation could affect the predicted **salmonid** mortality. Some parameters could be more sensitive than others to large- or **small**-scale perturbations. If such parameters were discovered, they could be further optimized by the LONGCREM (see **Bledsoe** et al. 1992).

First, LONGCREM was executed with the standard parameter values, using the 1991 predator catch and the, **salmonid** passage data. The mortality for Snake River chinook subyearlings was calculated to be 95% at the estuary. Then several parameters were singled out for the mortality sensitivity study, parameters determining flow-dependent residence time, maximum temperature effect, spawning effect, predator catchability coefficients, and velocity threshold.

For each of these parameters LONGCREM was executed twice, at the 200% parameter value and at 50% parameter value, while the other parameters remained' intact at their standard values. Chinook mortality was noted after each simulation. The degree of perturbation (%) of a given tested parameter was the same for all the reservoirs, while the actual parameter values were reservoir-specific. The change in mortality with respect to parameter perturbation is displayed in the form of a "tornado" diagram in the "Results" section of this report.

EZ-CREM Package: Menu-driven User Interface to CREM

The Columbia River Ecosystem Model (CREM) affords the user extensive control over a wide range of model parameters and driving functions that are read from several input files. The simulation model is optimized for use by experienced computer programmers and simulation experts rather than the average fishery scientist. For the purposes of fisheries management, most of the conditions of simulations require little modification. However, number and format of the input files makes it awkward to work with the subset of conditions that managers or field biologists might want to modify.

To provide these users with a more effective management tool for projections of **salmonid** mortality and predator removal, the CREM (Version 2.1) software was modified and bundled with utility programs into the EZ-CREM package. The package was designed to be executed on any IBM AT personal computer or compatible. It allows for a "user-friendly" way to interact with the CREM model. This package consists of the following parts.

1. An overall driver that provides a menu to control the other programs in the package.

2. Three menu-driven utilities that modify existing CREM input files and produce new ones to suit user requirements. Specifically, the utilities modify the predator removal effort file, the control parameters file, and the model parameters file. The menus allow the user to select groups of parameters to examine and modify without reference to the format of the files that contain them.
3. A modified version of the CREM program that allows the user to change the distribution of predators in the reservoir and the projected effectiveness of different gear types, which are used for predator removal in different areas of the reservoir.
4. An output module in which selected CREM output information is displayed at **user-**specified intervals during the simulation execution.

When invoke, EZ-CREM allows the user to specify a simulation parameter file, or to continue with the default file. After reading all parameters and data for forcing functions, EZ-CREM allows the user to display and modify selected parameters before beginning the simulation.

As the simulation proceeds, intermediate output of predator population and of cumulative **salmonid** mortality is displayed on the screen at each output time-step. The output of the final time-step at the end of the execution remains on the screen and can be printed using the “print screen” key on the keyboard.

The EZ-CREM package is enhanced by adding initial parameter display/modification panels and by streamlining the output displays, either through more detailed tabular output or through graphical displays at the end of the simulation.

Utilities were developed that allow the user to modify the information in the input files that drive the model. Rather than install all the utilities in the EZ-CREM program itself, making the program large and the menus complex, development concentrated on a package of programs to accompany EZ-CREM that can be used to modify input files before EZ-CREM is invoked. In this way, EZ-CREM is a modular package that can be easily updated as new or modified scientific mechanisms are added to the original ecosystem model. These utilities will allow the EZ-CREM user to access and modify the contents of the simulation parameters **and** the CREM parameter file. In both cases, the utilities allow the user to specify the file for input and output, and select groups of parameters from a main menu. The parameters for a selected group appear on submenu panels for modification.

The utilities were integrated with EZ-CREM into an “umbrella” menu system that can be enhanced to accommodate new capabilities as needed to allow EZ-CREM to be used by field biologists to perform **inseason** analysis of to-date squawfish mortalities and adjust effort levels to meet management targets. An EZ-CREM user’s guide is provided in Appendix A.

RESULTS

Simulated Tagging Study

In each table of results, average residence time and total number to tagged salmonids arriving at the downstream dam are reported for each simulated release. Note that differences tabulated in all cases are between the simulation with 100% baseline predation and the simulation with 1% of baseline predation.

Table 2. Long-term projected **salmonid** mortality due to predation (no regrowth in predator population assumed); Study 1 - baseline flow, 100 tagged fish/release.

Flow Rate: 100%		Size of each release: 100 fish						
Julian date of Release		111	131	151	171	191	211	231
		Average Residence Time (days)						
Predator Pop.	200%	9.0	7.8	7.8	8.0	7.8	9.1	6.5
	100%	9.0	7.8	7.9	8.4	8.8	8.5	6.5
	1%	9.1	7.9	8.0	8.7	9.3	9.3	6.3
	Diff.	-0.1	-0.1	-0.1	-0.3	-0.5	-0.8	-0.2
		Total Arriving at Downstream Dam from Release						
Predator Pop.	200%	68	88	79	48	33	26	21
	100%	73	92	84	61	53	40	26
	1%	77	96	90	75	76	78	53
	Diff.	-4	-4	-6	-14	-23	-38	-27

Table 3. Long-term projected **salmonid** mortality due to predation (10% yearly regrowth in predator population assumed); 50 % baseline flow, 100 tagged fish/release

Flow Rate: 50%		Size of each release: 100 fish						
Julian date of Release		111	131	151	171	191	211	231
		Average Residence Time (days)						
Predator Pop.	200%	10.8	9.0	8.8	8.6	8.2	8.9	6.7
	100%	10.8	9.1	8.8	9.0	9.2	8.8	5.9
	1%	10.9	9.2	9.0	9.2	9.7	9.6	6.1
	Diff.	-.1	-.1	-.2	-.2	-.5	-.8	-.2
		Total Arriving at Downstream Dam from Release						
Predator Pop.	200%	43	66	62	35	22	10	8
	100%	46	72	69	47	40	30	14
	1%	49	79	78	61	61	63	41
	Diff.	-3	-7	-9	-14	-21	-33	-27

Long-Term Mortality Projections

The annual mortality results for the juvenile salmonids were obtained from a series of LONGCREM simulations for the nine subsequent years, each assuming no regrowth of the predator population numbers (i.e., births equal natural mortality) and a continuation of the same fishing efforts with the same catchabilities. These predicted mortalities are shown in Table 4. The **salmonid** mortalities due to the predation model with 10% annual population regrowth are shown in Table 5. The following notation is used in both tables: **ch0s** - Snake River chinook subyearlings; **ch0c** - Columbia River chinook subyearlings; **other** - all other salmonids species: **coho**, sockeye, chinook yearlings, steelhead.

Table 4. Tagged release simulation results - baseline flow, 100 tagged fish/release (Study 1). Projected **salmonid** mortality (%) due to predation (no regrowth in predator population assumes).

		1992	1994	1996	1998	2000
Little Goose	ch0s	45.08	26.10	13.77	6.96	3.56
	ch0c					
	other					
Lower Monumental	ch0s	55.74	45.25	33.76	24.02	16.86
	ch0c					
	other					
Ice Harbor	ch0s	38.71	33.79	28.73	24.13	20.05
	ch0c					
	other					
McNary	ch0s	49.93	26.09	14.35	10.50	9.81
	ch0c					
	other					
John Day	ch0s	57.91	45.86	39.51	41.10	42.45
	ch0c	46.95	29.82	18.35	16.20	15.39
	other	2.25	0.96	0.24	0.10	0.05
The Dalles	ch0s	13.69	8.21	6.64	6.44	12.86
	ch0c	12.86	5.62	2.90	2.07	2.25
	other	0.70	0.16	0.03	0.00	0.00
Bonneville	ch0s	33.58	19.11	15.14	14.97	15.11
	ch0c	28.96	12.72	6.49	5.10	4.83
	other	1.60	0.35	0.07	0.02	0.00
Total % Mortality	ch0s	98.20	92.04	83.30	77.51	75.39
	ch0c	68.34	42.23	25.90	22.16	21.32
	other	4.63	1.46	0.34	0.12	0.07

Table 5. Tagged release simulation results - 50% baseline flow, 100 tagged fish/release (Study 2). Projected **salmonid** mortality (%) due to predation (10% yearly regrowth in predator population assumed).

		1992	1994	1996	1998	2000
Little Goose	ch0s	45.08	30.04	16.35	9.77	5.76
	ch0c					
	other					
Lower Monumental	ch0s	55.74	49.87	43.14	36.01	29.44
	ch0c					
	other					
Ice Harbor	ch0s	38.71	37.18	35.45	33.20	34.84
	ch0c					
	other					
McNary	ch0s	49.93	28.46	16.35	10.53	3.18
	ch0c					
	other					
John Day	ch0s	57.91	47.08	42.29	40.60	40.69
	ch0c	46.95	32.72	24.06	19.48	17.15
	other	2.25	0.96	0.24	0.10	0.05
The Dalles	ch0s	13.69	8.15	6.14	5.90	13.30
	ch0c	12.86	6.18	3.08	2.13	2.97
	other	0.70	0.16	0.04	0.01	0.02
Bonneville	ch0s	33.58	19.58	14.16	13.58	13.58
	ch0c	28.96	13.98	6.88	5.11	4.71
	other	1.60	0.34	0.07	0.02	0.01
Total % Mortality	ch0s	98.20	93.84	88.06	83.33	81.36
	ch0c	68.34	45.74	31.50	25.26	23.44
	other	4.63	1.46	0.35	0.12	0.07

DISCUSSION

Conclusions of the Tagging, Study

In Study 1, using 100% of the baseline flow rate, the reduction of the predator population by 99% produced an increase in residence times ranging from no change to less than one day. The typical baseline river flow data used in this study is shown in Figure 1. The variation in the increase during the season follows the passage curve of the untagged chinook **subyearlings**. (see Figure 2) and appears to be an effect of prey density. To determine average residence time, each release of the tagged group into the reservoir is compared to the arrival of that group at the downstream dam (see Figure 3).

In Study 2, using 50% of the baseline flow rate, the difference in residence times with and without predators ranges from no change to a **7/10** of a day increase.

The effect on survival of the tagged fish is more pronounced. In Study 1, the tagged release of Day 2 11 had an 64% survival rate under 100% predation and 92 % under 1% predation. In Study 2, the respective survival rates for that day are 53% and 83%. The effects of predation on prey survival are magnified by lower rates of flow. This result is expected, since the migration speed is **proportional** to the flow rate; less flow results in longer periods of exposure to predation.

These results indicate that predators produce a negligible increase in the observed mean residence times of **salmonid** prey passing through the reservoir. The difference increases with increasing prey density **and/or** with decreasing flow, but remain negligible relative to the expected variability in passage time and subsequent mortality in the real system. This result implies that measures of residence time, such as Miller and Sims (1984), can be taken as direct measures of **salmonid** migration rates with no significant bias due to the high predation rates occurring in the reservoir. The size of the bias induced by predation in apparent residence times is less than 10% even in cases of low flow (50%) or normal and high predation (200% of normal). Since the variability in residence times in actual tagging experiments varied from five to over 100 days, the bias induced by predation can be regarded as negligible relative to this natural variability.

Flow Through McNary Dam - 1957

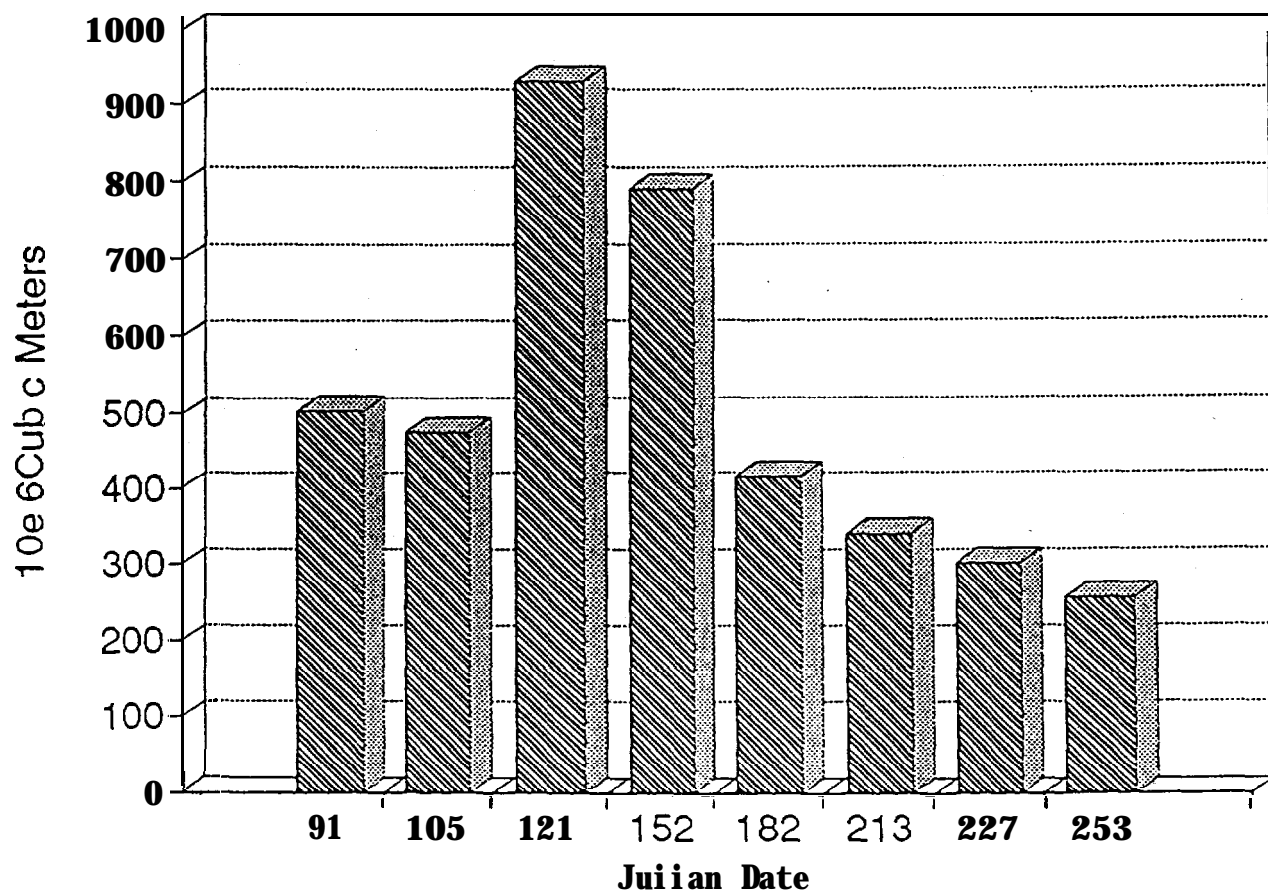


Figure 1. Flow through McNary Dam -1957.

McNary Passage by Julian Day Tagged Release Simulation

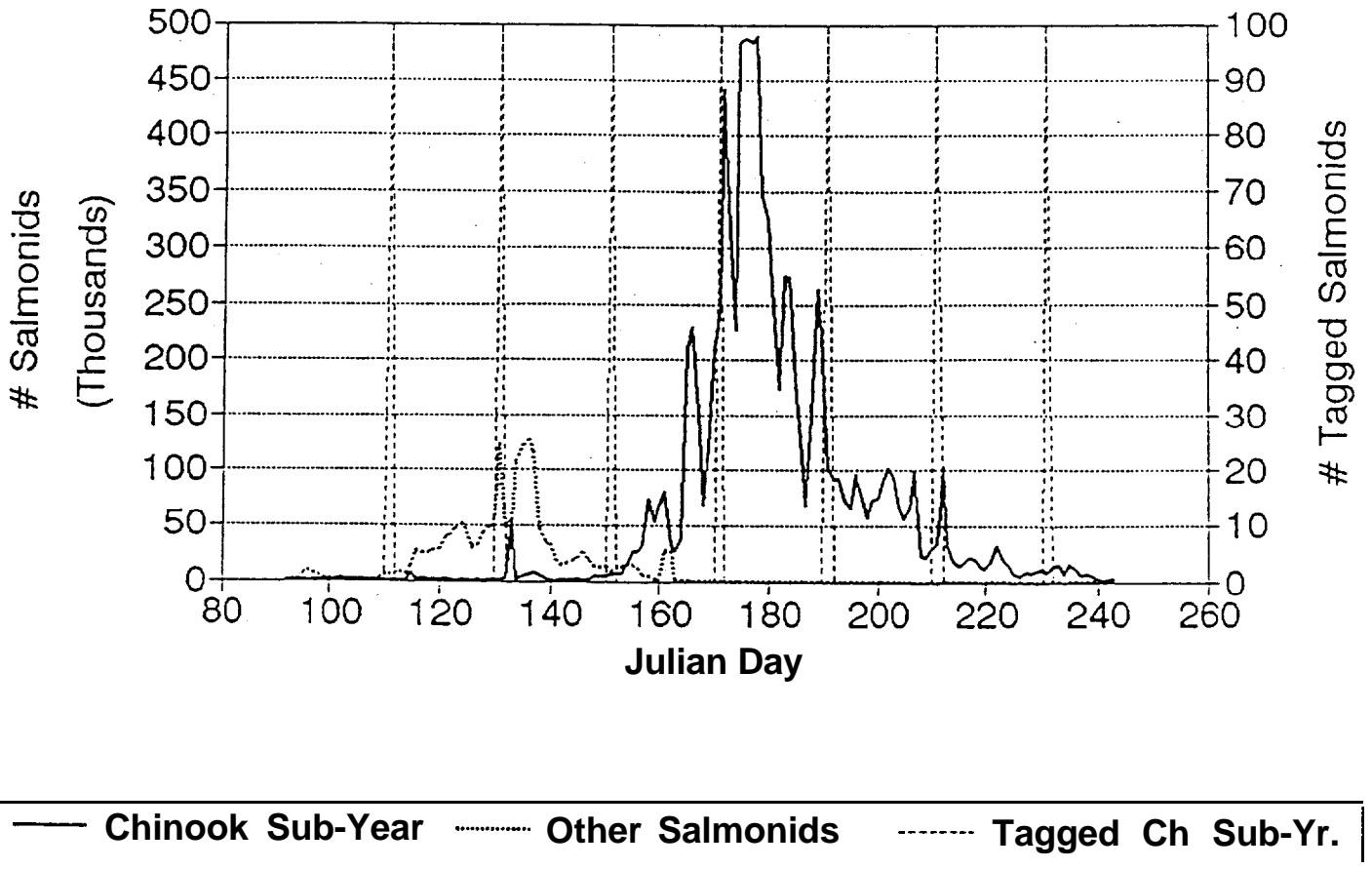


Figure 2. McNary passage by Julian Day - Tagged Release Simulation.

Tagged Release & Downstream Arrival

McNary Releases and John Day Arrivals

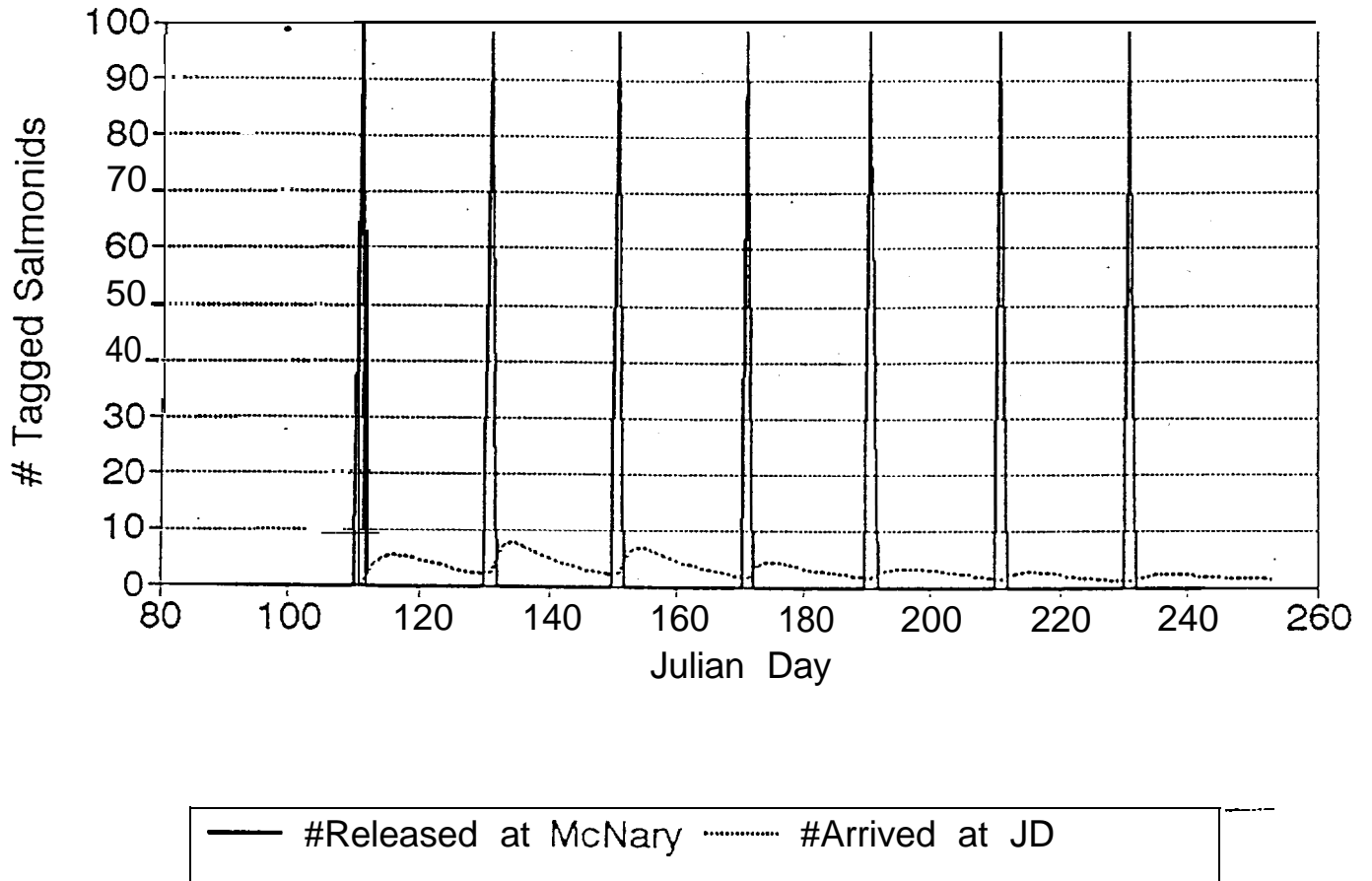


Figure 3. Tagged release and downstream arrival - McNary releases and John Day arrivals.

Long-Term Salmonid Mortality Projections

The results of the long-term mortality projections from Tables 4 and 5 are plotted in Figures 4 and 5, respectively. They clearly demonstrate the gradual decreasing of the 1992-2000 mortalities for Columbia and Snake River chinook **O**s for both predator populations regrowth models described earlier. The projected mortalities of the other **salmonid** stock are also shown in the figures.

These results are to be expected in light of the current effort to control the predator population by various means (assuming these efforts continue at least at the current level). The higher total **salmonid** mortality in the case of the 10% predator population regrowth model compared to the no-regrowth one was not surprising either, since the increase in predator population would result in higher **salmonid** mortality in the absence of the proportionally increased predator catch.

The difference between predation mortality for Snake or Columbia River subyearling chinook and other **salmonid** groups appears very large. To understand this difference, consider only the mortality that occurs in a single reservoir, John Day, during a single year, 1992.

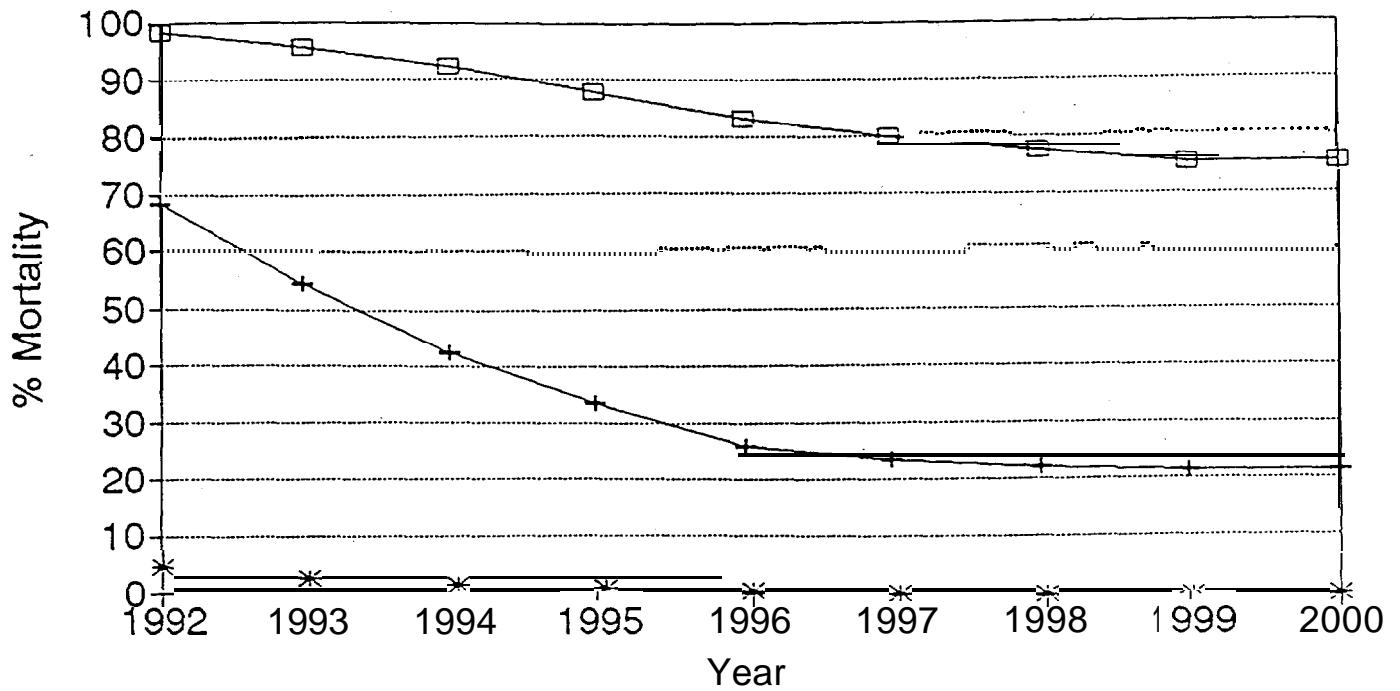
Figure 6 shows the passage time series for three **salmonid** groups, Snake River and Columbia River subyearlings and other **salmonid** groups (non-chinook species and yearling chinook). Also show are the water temperature and river flow time series. Table 6, below, shows the total mortality experienced by these three **salmonid** groups for 1992 in John Day Reservoir.

Table 6. Predation mortality (percent) predicted by CREM for three **salmonid** groups in John Day Reservoir during 1992. A) Normal daily passage into the reservoir; B) Artificial uniform daily passage into the reservoir, for test purposes (see text).

Group	Snake River chinook O s	Columbia River chinook O s	Other Salmonids
a) Predation Mortality	49.1	41.8	2.2
b) Predation Mortality (uniform passage)	31.0	31.0	16.7

Salmonid Mortality Projections

0% Predator Regrowth



—□— Snake River Ch0 —+— Columbia River Ch0 —*— Other Species

Figure 4. Salmonid mortality projections - 0% predator regrowth

Salmonid Mortality Projections 10% Predator Regrowth

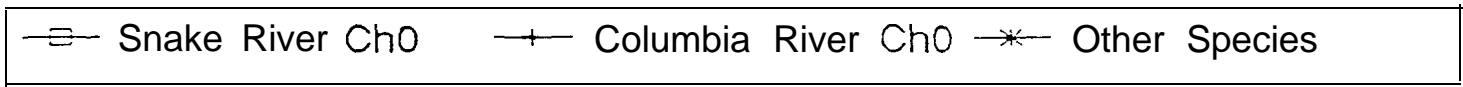
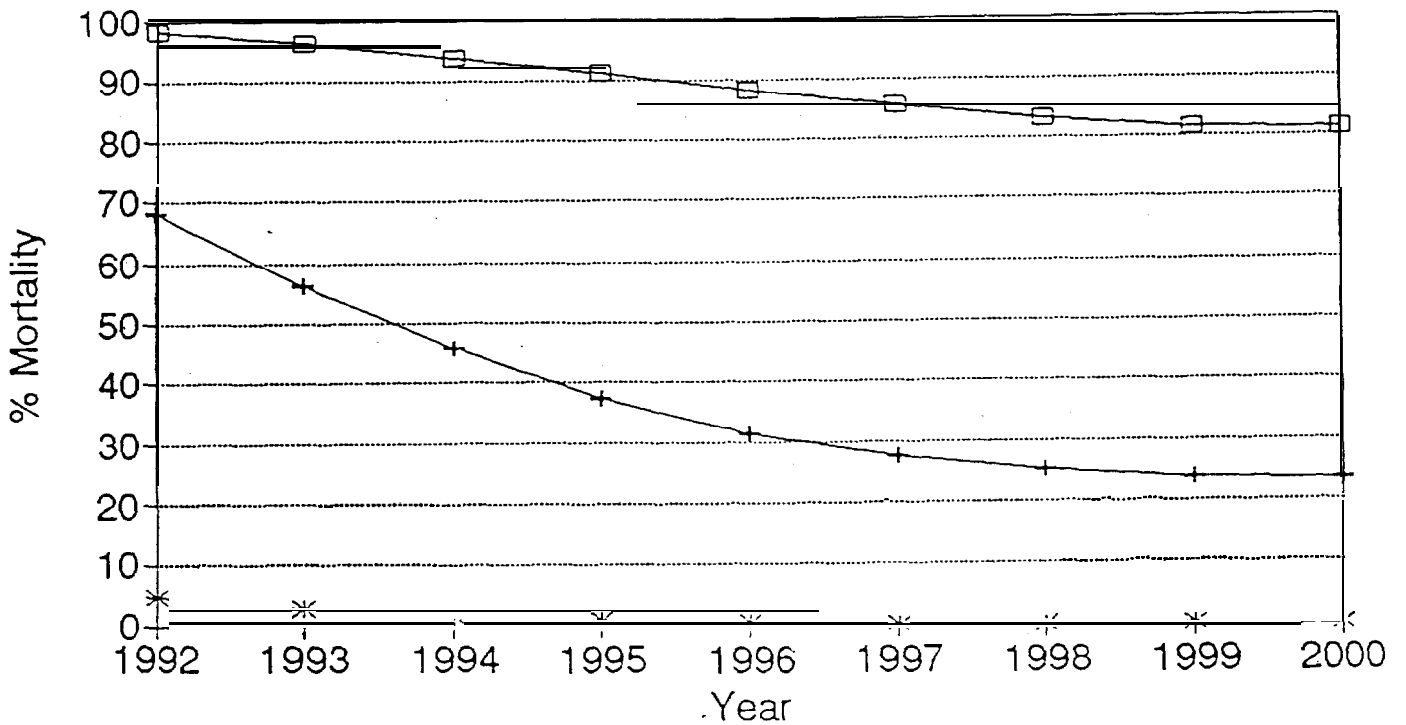


Figure 5. Salmonid mortality projections - 10% predator regrowth.

John Day Predation Environmental functions

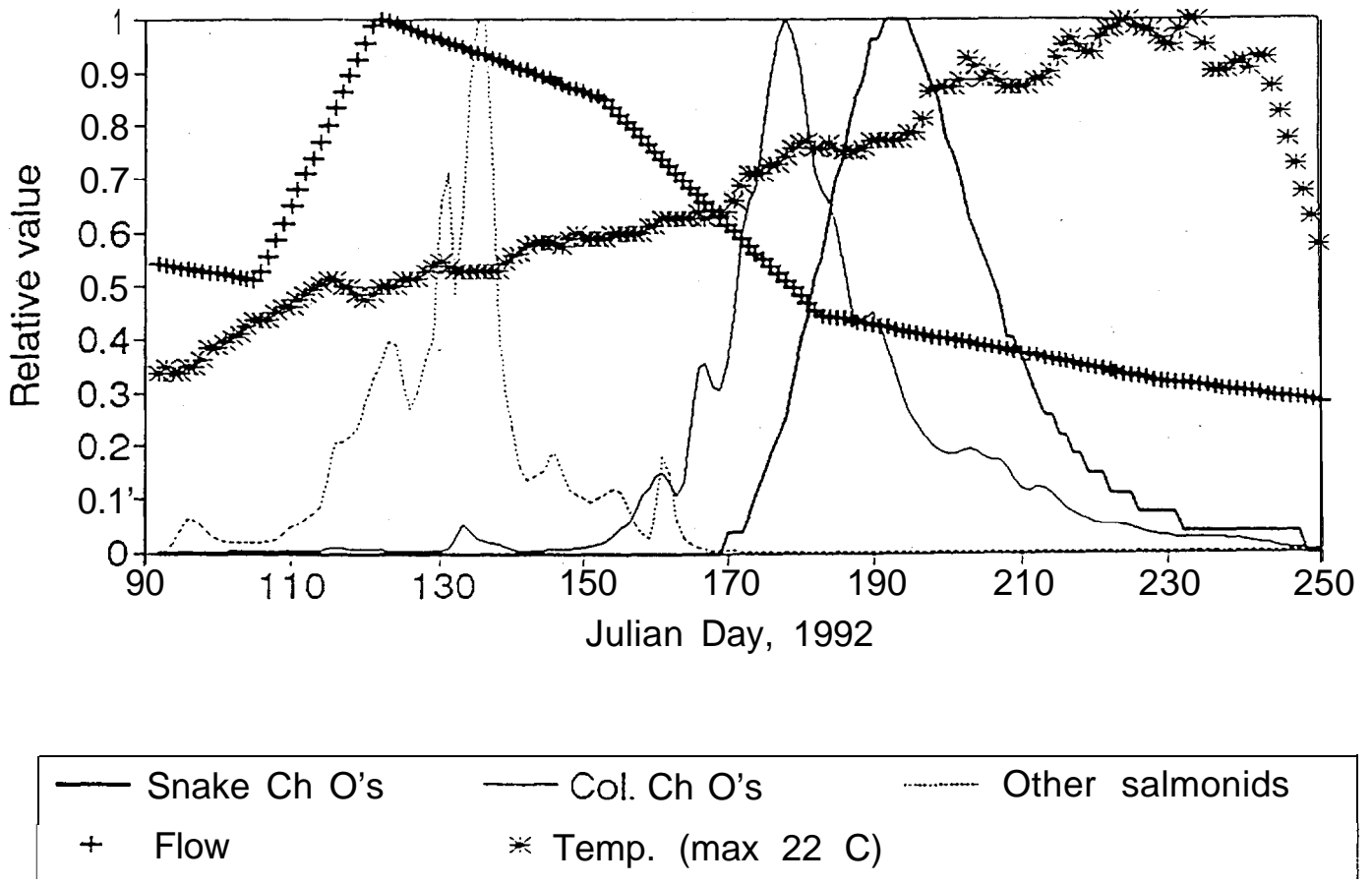


Figure 6. John Day predation - Environmental functions.

Snake and Columbia subyearlings both experience nearly 50% mortality, according to Table 5, however other salmonids experience only 2% mortality. Subyearling mortality is about 22 times as great. There are two differences in the simulated conditions under which these two groups experience predation pressure. The first is that the subyearlings travel more slowly through the reservoir by a factor of 2.5 than the other groups, which migrate in proportion to water velocity. This makes them subject to predation pressure for about 2.5 times as long as the others. The second difference is in the timing of the passage into the reservoir. As can be seen in Figure 6, subyearlings migrate predominantly during the latter part of the year whereas other groups migrate earlier in the season. There are also differences in the sizes of the groups, which result in differences in **salmonid** densities in the reservoir and, consequently, predation rate due to the non-linear functional curve. However, it is possible to explain the mortality difference solely in terms of the passage duration and seasonal timing differences.

The effect of passage duration would make an obvious difference in mortality, but only on the order of magnitude of the size of the timing difference, about 2.5 times. To investigate the effect of seasonal timing of the migration runs, a simulation was performed in which passage into the reservoir was replaced with a uniform rate of entry during the simulated season, Julian Day 92 through 253. The total number of fish passing into the reservoir was the same for the test simulation as for the normal simulation. However, in the test simulation, the number of fish per day that enter the reservoir was constant for each group.

Figure 7 graphs the time series of cumulative predation mortality for the normal and the test simulation. Under conditions of uniform daily passage, the subyearling mortality is reduced to about 60% to 75% of the mortality under the actual passage histogram. However, for the other **salmonid** groups, predation increases by a factor of about 7.6. The test simulation under conditions of uniform daily passage eliminates the variability in the mortality graphs that is due to varying **salmonid** densities and leaves only the effect of time in the season to vary the rate of mortality. Figure 7 shows that the uniform passage mortality curve rises much more rapidly late in the season. Figure 6 shows that this is the time when flow is lowest and, therefore, passage time, which is inversely proportional to flow, is longest, causing greater mortality due to time of exposure to predators. Figure 6 also shows that temperature is much higher, peaking at 22° C. Temperature also causes much faster rates of predation, according to U.S. Fish and Wildlife Service research results. In the Columbia River Ecosystem Model, predation increases due to temperature alone by a factor of more than 3 from Day 134, when “other” salmonids are at peak passage rate (water temperature 12° C), to Day 190, when Snake River subyearlings are at peak passage (water temperature 17° C).

The combined effect of all factors results in about a factor of 18 increase in mortality:

Inherently slower passage (2.5) X
Higher temperatures (3.1) X
Lower late season flows (2.2) = 17.6

Effect of Passage Timing Normal vs. Uniform Passage

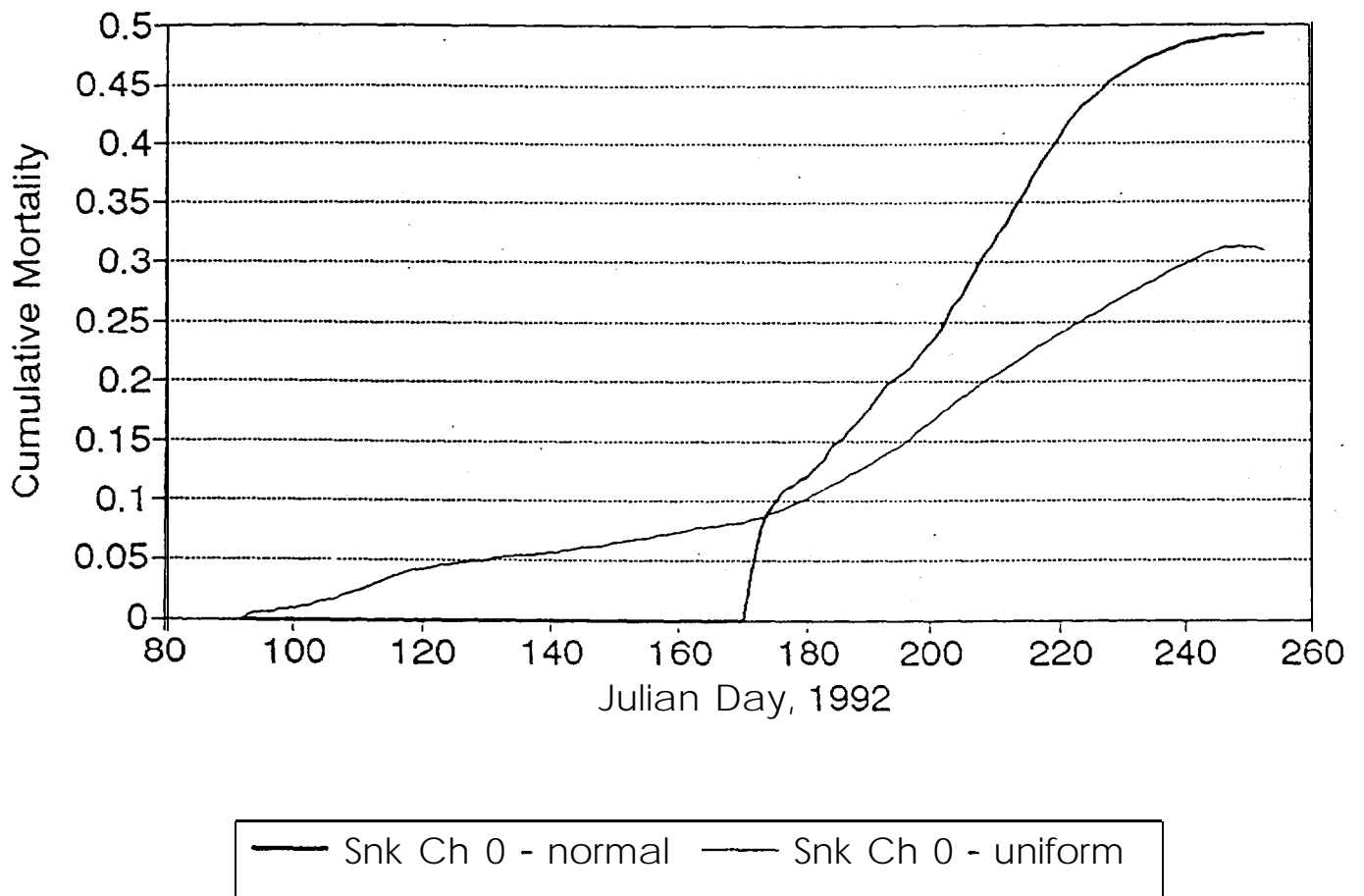


Figure 7. Effect of passage timing - Normal vs. Uniform passage into John Day reservoir.

Subyearling mortality was about 22 times higher than the other species. However, the remaining $22/17.6 = 1.25$ factor that is unaccounted for above can be explained in terms of the non-linear increase in per capita consumption rate of predators with increase in prey density. Prey density is between six and 10 times higher during the late season when the Snake River subyearlings are migrating than during the early season when other groups are in the reservoir (Figure 8). The functional response curve increase from about 0.5 for low prey densities to a maximum of 4.0 prey per **squawfish** for these prey density increases.

Conclusions of the Mortality Sensitivity Study

The “tornado” diagram shown in Figure 9 displays the results of a study of Columbia River system **salmonid** mortality sensitivity to certain parameters used by **LONGCREM**, using Snake River chinook subyearlings as an example.

The baseline mortality was estimated at 95% with all the modeling parameters at their standard values. According to this diagram, **salmonid** mortality is most sensitive to the changes in the flow-dependent resident time parameter, **prt2**. When that parameter value was doubled, the **salmonid** mortality at the end of the simulated river system increased by 5 % . At half the standard parameter value, **salmonid** mortality dropped by 25 % . Other parameters were demonstrated to have less of an influence on the mortality -- parameters responsible for the maximum water temperature effect and the spawning effect. The **salmonid** mortality showed no apparent sensitivity to other tested parameters, the catchability coefficients, and the velocity threshold.

This study led to the conclusion that the presently used parameters are sufficiently accurate for our simulation studies and there is no need for their additional optimization.

Prey in mid-reservoir cf. predation rate

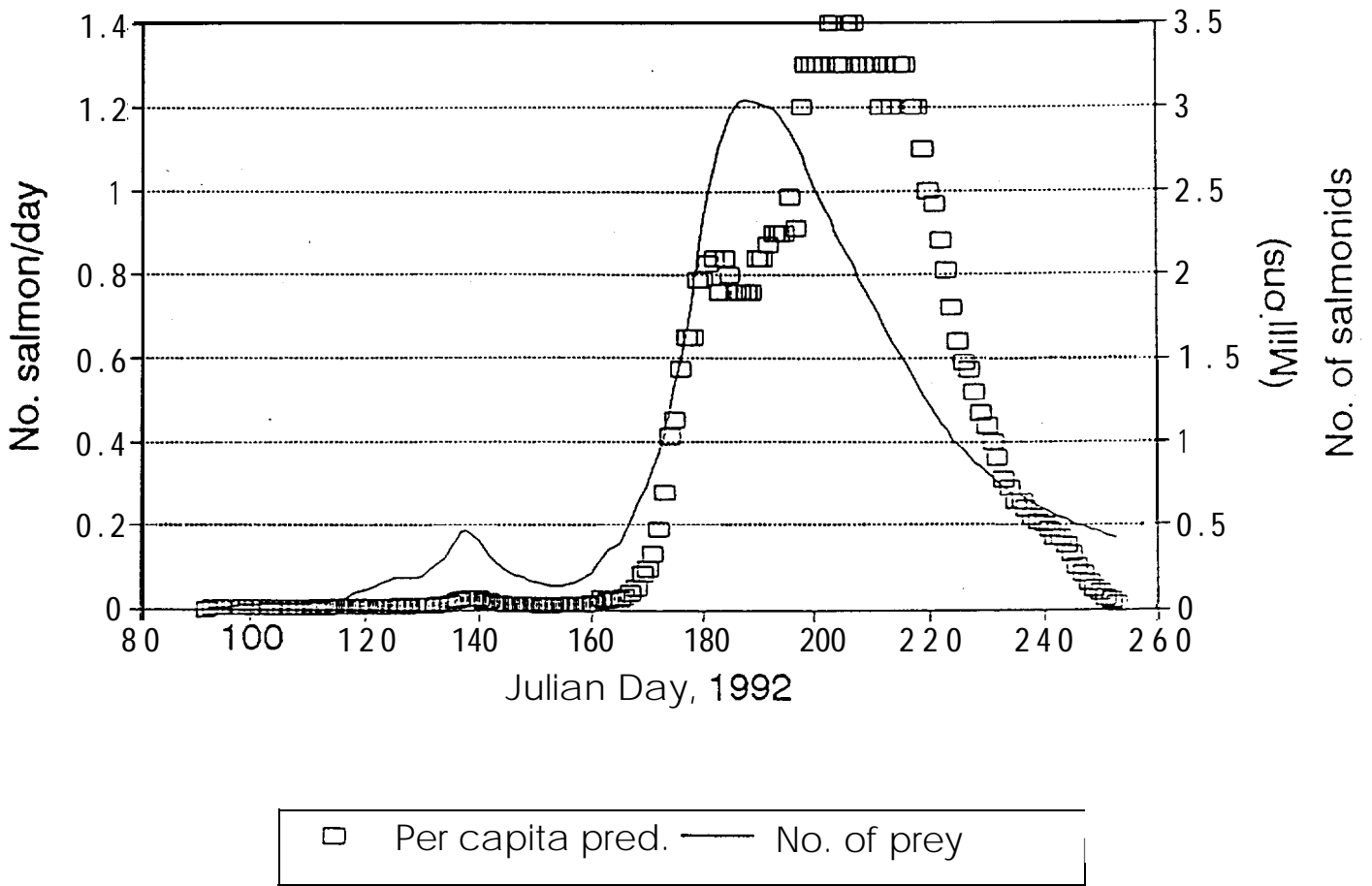
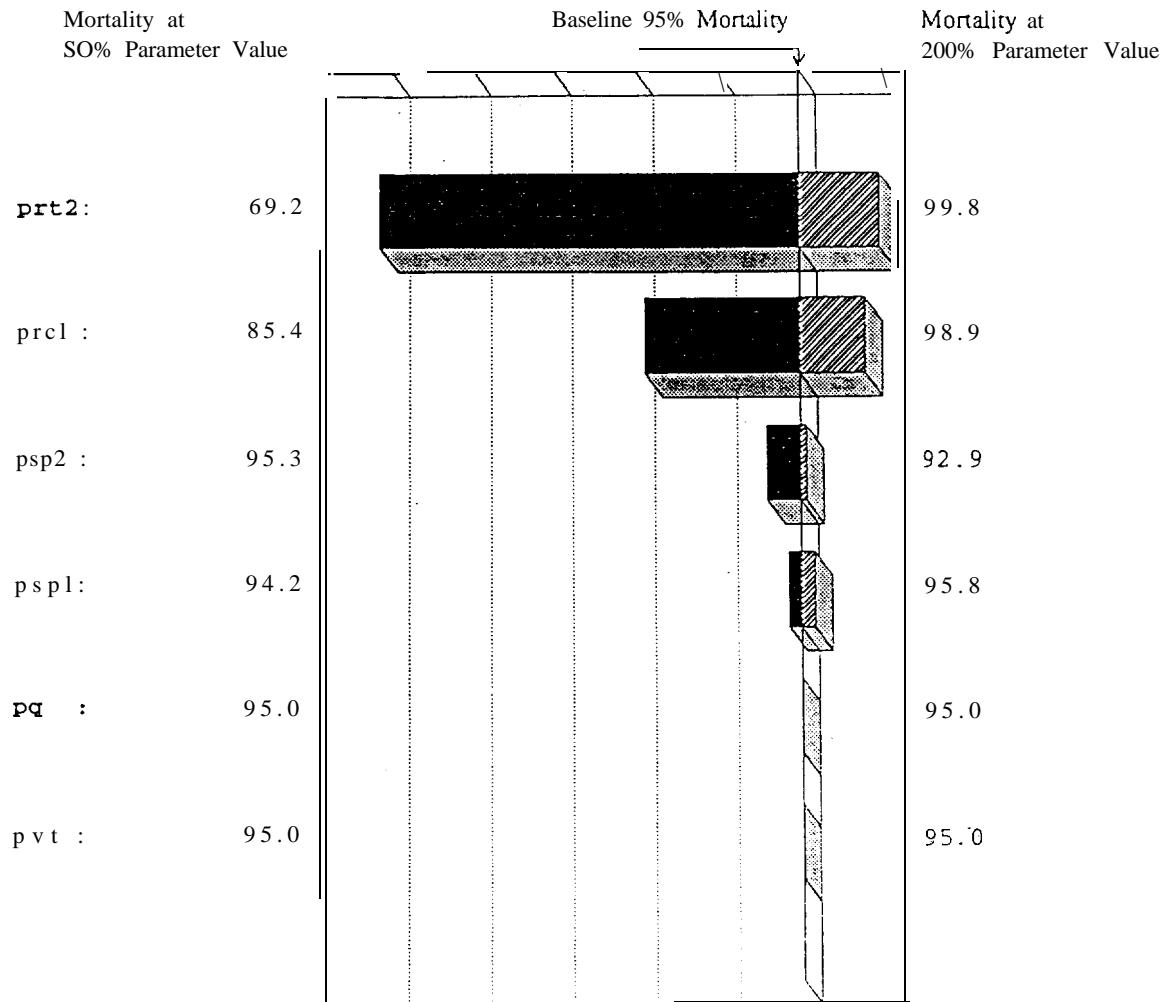


Figure 8. Prey in John Day Mid-Reservoir cf. Predation rate

Salmonid Mortality Sensitivity Analysis U s i n g C R E M



PARAMETERS:

- | | |
|------------|-------------------------------|
| prt2 | flow-dependent residence time |
| prcl | - maximum temperature effect |
| psp1, psp2 | - spawning effect |
| pq | catchability coefficient |
| pvt | - velocity threshold |

Figure 9. Salmonid mortality sensitivity analysis using CREM.

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- Miller, D.R., and C.W. Sims. 1984. Effects of flow on the migratory behavior and survival of juvenile fall and summer chinook salmon in John Day Reservoir. Annual Report (Contract **DE-A179-83BP39645**) to the Bonneville Power Administration, Portland, Oregon.

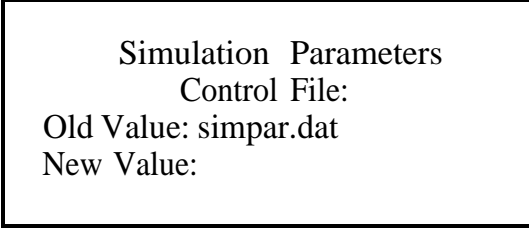
APPENDIX A

EZ-CREM User's Guide

The EZ-CREM utility is executed by entering EZ-CREM from the directory in which the program is located. The example presented below uses 1990 data for the John Day Reservoir.

Once **in EZ-CREM**, the **ENTER** key is used to confirm a user choice. Pressing the **ESCAPE** key at any time will return the user to the previous menu.

The first panel to appear is shown in Figure A1. Using the arrow keys, the user may choose a different simulation parameter file, or allow it to use the default.



```
Simulation Parameters
Control File:
Old Value: simpar.dat
New Value:
```

Figure A1.

The driving menu will now appear on the screen (Figure A2). The user may opt to change parameters, continue and immediately execute the program with the default parameters, or to quit EZ-CREM.



```
Change Parameter
Continue
Quit
```

Figure A2.

Choosing the CHANGE PARAMETERS option brings up a new menu (Figure A3).

Predator Dist.
Catchability Coeffs.

Figure A3.

Pressing the ESCAPE key at this time will return the user to the previous menu. The CONTINUE option immediately begins execution of CREM, displaying tabular output for each time step, as in Figure A4:

Julian Day: 253.0

Predator Distribution by Area

	Trailrace	Mid-Res.	Forebay	Total
Initial Catch	2798	.8107E+05	898.9	.8477E+05
Current Catch	2464	.7114E+05	799.2	.7441E+05
US Elec.	243.5	13.50	53.04	310.1
%Exp. Rate	8.703	.1665E-01	5.900	.3658
Or Elec.	61.76	12.98	35.30	110.0
%Exp. Rate	2.207	.1601E-01	3.928	.1298
Commercial	611.7	822.9	.0000	1435
%Exp. Rate	21.86	1.015	.0000	1.692
Sport	1548	1.031	3070	4619
%Exp. Rate	55.32	.1272E-02	341.5	5.449
Dam Ang	3863	.0000	30.71	3893
%Exp. Rate	138.0	.0000	3.416	4.593
Total	6328	850.4	3189	.1037E+05
%Exp. Rate	226.1	1.049	354.8	12.23

Figure A4.

Upon selecting PREDATOR DIST, the user may use the arrow keys to choose any of the three parameters in the box, followed by pressing ENTER. The selection in Figure A5 will appear on the screen to allow the user to make a change.

	Predator Distribution Percent by Area			Total
	Tailrace	Mid-Res.	Forebay	
Squawfish	3.300	95.60	1.060	99.96

<p>Old Value: 1.060 New Value:</p>
--

Figure A5.

Pressing ENTER returns the updated value if entered. Pressing the ESCAPE key will return the user to the Figure 'A3 menu. The other option in this menu, CATCHABILITY COEFFS, will bring up the table shown in Figure A6, and any changes can be made in the same manner as described above.

	Catchability Coefficients				
	Tailrace	Mid-Res.	Forebay	unused	unused
us Es	4430	67.90	2510	.0000	.0000
ODFW ES	1410	85.40	2260	.0000	.0000
Commercial	1550	419.0	.0000	.0000	.0000
Sport	211.0	1.520	2210	.0000	.0000
Dam Ang.	3960	.0000	263.0	.0000	.0000

<p>Old Value: 4430 New Value:</p>

Figure A6.

Once all changes are implemented, the user may ESCAPE back through the previous menus to the driving menu (Figure A2) and execute the program.