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

Annual Report 1993
VOLUME I - IMPLEMENTATION

Prepared by:

Charles F. Willis

S. P. Cramer and Associates, Inc.

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Oregon Department of Fish and Wildlife

Cooperators:

Oregon Department of Fish and Wildlife
S. P. Cramer and Associates, Inc.
Washington Department of Wildlife
Columbia River Inter-Tribal Fish Commission
University of Washington
National Marine Fisheries Service
Pacific States Marine Fisheries Commission
Oregon State University

Prepared for:

U. S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife Division
PO Box 3621
Portland, Oregon 97208-3621

Project Number: 90-077
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EXECUTIVE SUMMARY

by Charles F. Willis

We report our results from the third year of a basinwide program to harvest northern squawfish (*Ptychocheilus oregonensis*) in an effort to reduce mortality due to northern 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 rate of 10-20%, reductions in numbers of larger, older fish resulting in restructuring of their population 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. We also conducted an angling fishery in areas inaccessible to the public at four dams on the mainstem Columbia River and at Ice Harbor Dam on the Snake River. 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 above Bonneville Dam, a sport-reward fishery, and a dam-angling fishery. Low catch of target fish and high cost of implementation resulted in discontinuation of the tribal longline fishery. However, the sport-reward and dam-angling fisheries were continued in 1992 and 1993. In 1992, we investigated the feasibility of implementing a commercial longline fishery in the Columbia River below Bonneville Dam and found that implementation of this fishery was also infeasible.

Although we were unable to implement an effective longline fishery, it was important to the attainment of program objectives to attempt to substantially increase total annual exploitation. Estimates of combined annual exploitation rates resulting from the sport-reward and dam-angling fisheries remained at the low end of our target range of 10-20%. This suggested the need for additional, effective harvest techniques. During 1991 and 1992, we developed and tested a modified (small-sized) Merwin trap net. We found this floating trap net to be very effective at catching northern squawfish at specific sites. Consequently, in 1993 we examined a systemwide fishery using floating trap nets.

Evaluation of the success of test fisheries in achieving our target goal of a 10-20% annual 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 consisted of the Oregon Department of Fish and Wildlife (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, was responsible for coordination and administration of the entire program and subcontracted various tasks and activities to WDW, CRITFC, UW, NMFS, and PSMFC based on expertise each brought to the tasks involved in implementing the program. Objectives of each cooperator related to fishery implementation were as follows.

1. ODFW (Report A): Investigate the feasibility of implementing a large-scale, floating trap-net fishery in the Columbia River downstream from McNary Dam.

2. WDW (Report B): Implement a systemwide (Columbia River below Priest Rapids Dam and Snake River below Hells Canyon Dam) sport-reward fishery.

3. PSMFC (Report C): Process and provide accounting for reward payments to participants in the sport-reward fishery.

4. CRITFC (Report D): Implement a systemwide angling fishery at eight mainstem dams on the Snake and Columbia rivers, and investigate juvenile salmonid consumption by channel catfish caught by dam anglers in the lower Snake River.

5. CRITFC (Report E): Investigate the efficacy of removing northern squawfish near hatchery release sites in the Bonneville pool.

6. CRITFC (Report F): Investigate the presence of northern squawfish concentrations in lower reaches of mainstem Snake River and Columbia River tributaries, and collect information regarding the origin and function of documented concentrations.

7. NMFS (Report G): Investigate differences in juvenile salmon survival associated with releases from Bonneville Hatchery at alternative release locations and following removal of northern squawfish by electrofishing.

Background and rationale for the study can be found in Report A of our 1990 annual report (Vigg et al. 1990). Highlights of results of our work in 1993 by report are as follows.

Report A
Implementation of a Floating Trap-Net Fishery for Northern Squawfish in the Columbia River Downstream from McNary Dam

1. An experimental fishery using floating trap nets (modified Merwin traps) in the Columbia River downstream from McNary Dam was implemented to determine its effectiveness in catching large numbers of northern squawfish throughout this area. Special consideration was given to the potential for, and impact on, incidental catches of adult salmonids.

2. Information from a pre-season site survey was used to select fishing locations most likely to be productive areas for capturing northern squawfish with trap nets.

3. We fished 16 trap nets from June 2 through August 4, 1993. A total of 1,392 sets were made with a mean soak time of 2.9 hours. The total catch was 45,803 fishes of which northern squawfish comprised 23% (10,440 fish).

4. Of the total number of northern squawfish caught, 16% (1,688 fish) were within our target range [greater than 11 inches (275 mm) total length]. The mean catch rate of northern squawfish over 11 inches was 0.3 fish per hour. Bycatch of adult salmonids totaled 2 % of the total catch (1,036 fishes).

5. Operational criteria designed to limit incidental take of salmonids restricted dates and times when, and locations where, we could fish. In addition, lack of crew experience with the gear and limited gear effectiveness in areas of high flow velocity below Bonneville Dam contributed to the low harvest rate for northern squawfish.

6. We did not find the floating trap-net fishery to be feasible (in terms of catch versus cost) for implementation on a large scale. However, use of trap nets within the boat restricted zone at The Dalles Dam cul-de-sac each year has been productive in comparison to catches of northern squawfish by dam anglers at that dam. Other selected sites above Bonneville Dam may also produce effective catches of northern squawfish using trap nets on a limited basis and at a reduced cost. We recommend an evaluation of the use of trap nets on a site-specific basis above Bonneville Dam in 1994.

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

1. Objectives for 1993 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 dynamics of the fishery.

2. The northern squawfish sport-reward fishery was conducted from May 3 through September 12, 1993. Twenty registration stations were located throughout the lower Snake and Columbia rivers.

3. A total of 104,616 northern squawfish 11 inches or longer were caught by 15,106 anglers, which represented 43% of the total number of registered anglers (34,879) that participated in the fishery in 1993. Harvest of northern squawfish decreased 44% over that observed in 1992 and 34% over that observed in 1991, with a decrease

in participation of 60 % and 48 % , respectively. The catch per unit effort (CPUE) of 2.99 fish per angler day in 1993 represented an increase of 21% over the catch rate observed in 1992 and 29% over that observed in 1991.

4. Fork lengths of northern squawfish over 250 mm (11 inches total length) averaged 334.7 mm (S.D. 61.6 mm) in 1993, which represented a statistically significant decrease in mean fork lengths between 1992 and 1993. A statistically significant decrease in mean fork lengths was also observed between 1991 and 1992, suggesting a continuing trend in decreased average size of northern squawfish harvested in the sport-reward fishery each year.

5. A total of 2,100 fishes of species other than northern squawfish were returned to registration stations in 1993, representing 2% of the total catch. In order of their frequency of occurrence, peamouth, smallmouth bass, channel catfish, and walleye composed the majority of non-target fishes caught.

7. The portable computerized data collection unit was significantly faster than manual data entry for use in exit interview information and biological data collection, but it was not significantly faster than manual data entry for use in registering participants. Biological data can be collected approximately twice as fast using the computerized data collection system.

8. To obtain additional catch information, we contacted by phone 1,744 (8.8%) out of 19,758 anglers who did not return to exit the sport-reward fishery from stations where they had registered to participate (i.e., non-returning anglers). Sixty-five percent of non-returning anglers reported returning all fish caught to the water unharmed. Ten percent of these anglers reported killing nongame fish and returning fish to the water, and 15% kept fish to eat. Non-returning anglers caught an estimated 2,968 northern squawfish 11 inches or longer in total length. An estimated 19% of these fish were returned to the water unharmed. Only 54% of non-returning anglers failed to exit the fishery through a registration station because they had not caught northern squawfish. Twenty-one percent reported that they did not have enough northern squawfish to make the return to a station worthwhile, and an additional 21% caught only northern squawfish less than 11 inches in total length. Some additional northern squawfish were harvested within the remaining 4% of non-returning anglers contacted who gave their fish away or otherwise disposed of them. A recall bias study (calling returning anglers for whom information was known) indicated that average responses to questions were accurate. Marked differences were observed between estimates of bycatch based on returning angler data alone and estimates based on information obtained via the phone survey. This may be due to a lack of willingness on the part of returning anglers to be detained for questioning following a long fishing day.

9. We recommend that the 1994 sport-reward fishery start in early May and extend through mid-September. Registration stations should be operated with one shift per day extending from 1 p.m. to 9 p.m., seven days per week. Self registration during

periods when stations are closed should continue. Fourteen registration stations should be operated throughout the area in which the fishery was implemented during 1991 through 1993, with the elimination of six stations to accommodate budget reductions and the relocation of one other station to more efficiently accommodate angler use. Use of computerized registration should be discontinued. A streamlined phone survey of non-returning anglers should continue to provide information regarding total catch of target and non-target fishes. An aggressive public relations program should be implemented to increase awareness of, participation in, and efficiency of the sport-reward fishery.

Report C
Northern Squawfish Sport-Reward Payments

1. During 1993, a total of $303,897 was paid to anglers for 101,299 northern squawfish harvested in the sport-reward fishery.

2. Payment activity for the sport-reward fishery was highest during June and July, accounting for about 63% of total dollars paid.

3. The average catch of northern squawfish per voucher ranged from 6.5 fish in May to 9.3 fish in June and July. The mean catch was 8.2 northern squawfish per voucher.

4. Voucher processing proceeded smoothly with checks being cut and mailed to the angler within l-5 days after receipt of the voucher.

5. Vouchers that had missing or incomplete information were returned to anglers for completion causing delay in payment. A total of 646 vouchers were returned. Anglers returned 505 of the vouchers with the information needed for processing.

6. The number of vouchers that were not processed totaled 141 with a combined potential reward of $1,194. There were a variety of reasons for vouchers not being processed. Examples that commonly occurred included failure to complete the required questionnaire and submission of the voucher beyond the deadline for payment.

Report D
Controlled Angling for Northern Squawfish at Selected Dams on the Columbia and Snake Rivers and Diet Analysis of Incidentally Caught Channel Catfish

1. Dam angling at eight dams on the lower Snake and Columbia rivers during 1993 resulted in 16,949 northern squawfish being caught during an l&week season.

2. Total effort and northern squawfish catch decreased 39% and 42 % , respectively, compared to 1992 figures. Overall catch per angler hour was unchanged compared to the 1992 catch rate of 1.7 northern squawfish per hour fished.

3. Effort at Snake River dams decreased 79% since 1991 because of continuing low catch rates (0.5 fish per hour) of northern squawfish. The catch rates of northern squawfish in 1993 at Columbia River dams increased at Bonneville Dam (from 2.7 to 2.9 fish per hour) and John Day Dam (from 1.2 to 2.2 fish per hour) while decreasing at The Dalles Dam (from 3.0 to 1.4 fish per hour) and McNary Dam (from 2.9 to 1.9 fish per hour) compared to 1992 catch rates.

4. Incidental species caught as compared to the total catch decreased slightly from 5.8 % in 1992 to 5.5% in 1993. Contributions to bycatch of bass (*Micropterus* spp.) increased from 1.0% in 1992 to 2.1% in 1993, which partially offset a decrease in the percentage of catfish (*Ictalurus* spp.) caught from 3.7% in 1992 to 2.0% in 1993. Three juvenile and three adult salmonids (*Oncorhynchus* spp.) were caught in 1993, and all except one of the juveniles were released in good condition.

Report E
Removal of Predacious Northern Squawfish Found Near Hatchery Release Sites in Bonneville Pool: An Analysis of Changes in Catch Rates and Diet Associated with the Release of Hatchery-Reared Juvenile Sahnonids

1. Three areas in the Bonneville pool where hatchery-reared juvenile salmonids are released were targeted for investigating distribution and predation activities of northern squawfish. Catch rates of northern squawfish increased significantly after hatchery releases at all three locations.

2. A total of 1,772 northern squawfish were caught from mid-March through mid-May 1993 in 394.4 hours of netting at all locations, yielding a seasonal catch rate of 4.5 fish per hour. Of the total northern squawfish catch, 88.5% were within the target range of 11 inches (275 mm) or larger in total length.

4. Northern squawfish caught after salmonid releases had a significantly higher frequency of occurrence and mean number of juvenile salmonids in their gut compared to fish caught before releases.

5. Consumption indices, used as a relative measure of consumption rates, were also higher at each location after juvenile salmonid releases. Our data suggest that northern squawfish respond numerically and functionally to releases of hatchery-reared juvenile salmonids.

Report F
Investigation of Northern Squawfish Concentrations in Tributaries to the Mainstem Columbia, Snake and Clearwater Rivers

1. Five tributaries along the mainstem Columbia, Snake and Clearwater rivers were examined for northern squawfish concentrations to determine if northern squawfish commonly migrate from mainstem reservoirs into free-flowing tributaries to spawn.

2. A total of 1,686 northern squawfish were captured from May 11 to July 25, 1993, with 1,541 (91%) captured in an upstream migration trap at Threemile Falls Dam on the Umatilla River. None of the fish captured at Threemile Falls Dam bore tags or marks indicating that they originated from mainstem Columbia River areas where northern squawfish were marked and released.

3. The majority (58%) of northern squawfish trapped at Threemile Falls Dam were caught during a one-week period following an increase in the average weekly water temperature from 15° Celsius to 18°C and a decrease in the average weekly flow from 1,705 cubic feet per second (cfs) to 419 cfs. These fish may have originated from the mainstem Columbia River as part of a spawning migration ascending the Umatilla River. Alternatively, they may have (1) been an aggregation of resident fish attempting to reascend the river after having been washed downstream of the dam by high spring flows, (2) aggregated either from the mainstem Columbia or from within the Umatilla River in response to increased prey abundance below Threemile Falls Dam, or (3) aggregated below the dam to escape unsuitable environmental conditions above the dam or in the mainstem Columbia River. Concentrations of northern squawfish are observed at Threemile Falls Dam each year. Future work should attempt to document the origin of these fish.

5. Sampling efforts in the Palouse, Tucannon, and Potlatch rivers, and Lapwai Creek were less successful at locating northern squawfish concentrations. High spring flows may have reduced capture gear efficiency and previously reported concentrations of fish may not have occurred in 1993. Other studies have shown that concentrations of northern squawfish at specific locations are often variable among years. Removal of northern squawfish in prior years may also have reduced the number of fish available for migration into these tributary areas.

Report G
Effectiveness of Predator Removal for Protecting Juvenile Fall Chinook Salmon Released from Bonneville Hatchery

1. Subyearling chinook salmon from Bonneville Hatchery released into the midstream Columbia River prior to electrofishing efforts 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 may be affected by the dispersal rate of study fish from the area of release. Faster dispersal may result from higher discharge below Bonneville Dam by affecting hydraulic conditions at the mouth of Tanner Creek. Degree of smoltification may also affect dispersal rate.

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. It appears that the number and size of northern squawfish in the study area have declined over the study period, perhaps as a result of harvest under the northern squawfish management program, and that this general decline in population abundance contributed to the effectiveness of localized predator removal at Bonneville Hatchery in 1993. Electrofishing to remove northern squawfish from the migration route of juvenile salmon released from Bonneville Hatchery appeared to eliminate the survival difference between mainstem Columbia River and Tanner Creek release groups under the conditions that existed in 1993.

REPORT A

Implementation of a Floating Trap-Net Fishery for Northern Squawfish in the Columbia River Downstream from McNary Dam

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ABSTRACT

Modified Merwin trap nets were tested by an experimental fishery in the Columbia River downstream from McNary Dam to determine their effectiveness in selectively harvesting northern squawfish (*Ptychocheilus oregonensis*) over 11 inches in total length. The fishery was evaluated for its potential to supplement exploitation rates of the sport-reward and dam-angling fisheries to achieve the objectives of the northern squawfish management program. Special consideration was given to the potential for, and impact on, incidental catches of adult salmonids (*Oncorhynchus* spp.) listed as threatened and endangered under the Endangered Species Act (ESA).

Preseason site and data surveys identified suitable fishing locations where physical parameters are favorable to trap-net deployment and northern squawfish habitat was present. A total of 16 floating trap nets were operated from June 2 through August 4, 1993. We made 1,392 sets with a mean soak time of 2.9 hours. The total catch was 45,803 fishes including 10,440 (23 % of the total catch) northern squawfish of which 1,688 (4% of the total catch) were large (greater than 11 inches in total length). Mean catch rate was 0.3 large northern squawfish per hour of soak time. Nearly all incidentally captured fishes were released alive and in good condition. Bycatch of adult salmonids totaled 1,036 fishes (2% of the total catch).

Operational criteria, designed to limit incidental take of salmonids, restricted the fishing time, dates, and locations. In addition, lack of prior operating experience with the gear type and limited gear effectiveness in high velocities found in the free-flowing river below Bonneville Dam contributed to the low harvest rate for northern squawfish. We determined that a large scale floating trap-net fishery outside the boat restricted zones (BRZs) of hydropower projects would not significantly improve the exploitation rate of northern squawfish either above or below Bonneville Dam. However, we recommended that floating trap-net testing be continued on a limited basis at selected sites in the reservoirs above Bonneville Dam where deployment conditions are more favorable to trap-net success. We showed that there is minimal impact, injury, or delay to adult and juvenile salmon from trapnetting, provided that trap nets are maintained faithfully and routinely, and fished when water temperatures are less than 68° Fahrenheit. Consequently, trap nets could be fished in BRZ areas in June and July, with very little effect on salmonids, but with much higher northern squawfish catch rates than we averaged in the present study.

INTRODUCTION

Since 1990, various northern squawfish fisheries have been implemented and evaluated in the Columbia River Basin (Nigro 1990; Willis and Nigro 1991; Willis and Nigro 1992). Angling fisheries (sport-reward fishery and controlled angling at selected hydropower projects) have been implemented annually. In addition, longline gear was tested for applicability to commercial harvest (Mathews et al. 1989; Mathews and Iverson 1990; Vigg et al. 1990; Mallette and Willis 1991; Mathews et al. 1991; Mallette et al. 1992). Longlining resulted in low northern squawfish catch rates, unacceptable high levels of bycatch, and logistical difficulties.

Although absolute catches were highest from implemented angling fisheries, the exploitation rate was still lower than would be likely to significantly reduce northern squawfish predation on salmonids. Consequently, we tested a large-scale floating trap-net fishery to hopefully improve the harvest level above the low end of the 10-20% target exploitation rate. We based our decision to conduct this study on the promising results from limited testing of a modified Merwin trap net by Mathews et al. (1991, 1992a, 1992b) and Lynch (1993). The objectives of the present study were to (1) transfer floating trap-net technology from the University of Washington to ODFW staff and other trap-net operators, (2) refine floating trap-net applications and develop a procedure to acquire quantities of floating trap nets, and (3) stepwise implement a floating trap-net fishery in three reaches of the Columbia and Snake rivers.

METHODS

From December 15, 1992, to February 3, 1993, we conducted a preseason trap-net site survey in the Columbia and Snake rivers (Iverson and Mahoney 1993) to identify the most suitable locations for floating trap-net deployment. Over 200 locations were evaluated for accessibility, trap-net setting qualities, and estimated northern squawfish catch potential. Physical characteristics and northern squawfish habitat requirements were recorded, summarized, and graded for each site.

We compiled available data regarding river contour, substrate, velocity, clarity, and temperature, as well as data regarding northern squawfish abundance and habitat requirements from various regional resource management agencies (data survey). This information was used to confirm and supplement the results of the site survey.

We worked with regional fisheries management agencies to develop an implementation strategy and operational criteria for trap-net deployment in the Columbia and Snake rivers. Uncertainties related to bycatch rates of, and potential impact on, salmonid stocks listed as threatened or endangered under the ESA precluded agreement on criteria for fishery implementation in the Snake River or in boat restricted zones (BRZs) at hydropower projects in the Columbia River. The fishery's objectives were revised to reflect the shift of fishing effort to the remaining midreservoir and free-flowing Columbia River reaches as follows.

We proposed to (1) contract with a single private sector entity to operate a maximum of eight floating trap nets in the free-flowing river reach below Bonneville Dam (Reach I) and (2) contract with four treaty tribes and/or CRITFC to operate a maximum of eight floating trap nets in the river reach from McNary Dam downstream to Bonneville Dam (Reach II). Fishing effort in Reach I was scheduled to start on May 17 and gradually increase over time. Fishing effort in Reach II was scheduled to start June 1. Fishing operations in both reaches were scheduled to cease September 24.

We developed operational criteria for acceptable levels of cumulative salmonid bycatch, handling procedures for incidentally captured adult salmonids, and trap-net relocation. We reviewed spatial and temporal distribution and size of historic and projected 1993 salmonid runs and salmonid bycatch data for previous trap-net studies and provided related recommendations to regional fisheries managers. The subsequently formulated biological opinion and adopted operational criteria for fishery implementation are summarized in Appendix A-l. Additionally, we developed criteria for trap-net relocation based on performance. Adequately deployed trap nets were scheduled to be relocated to a different site if less than 30 northern squawfish were caught per trap-net day.

We modified and refined the design of the floating trap-net unit to improve catch efficiency and mobility. Design modifications were realized through the construction of a prototype trap net and trailer. Deployment of floating trap nets of the modified design proved to decrease the labor intensity of gear assembly and increased trap-net mobility greatly. Specifications for net frames, travel trailers, and nets are summarized in Appendix A-2. ODFW contracted with Fish tec, Environmental Fishery Service, to acquire quantities of trap-net units prior to fishery implementation. We prepared for limited deployment of alternative, sunken Pennsylvania (Lake Erie) style trap nets if sufficient quantities of floating trap nets were unavailable at the start of the fishery.

We conducted trap-net seminars and workshops for participating fishing crews prior to the start of the fishing season.

Solicited contracts for inseason trap-net operations were modified significantly to accommodate the limiting time schedule. For Reach I, fishing and moving crews were staffed with ODFW employees. In terms of trap-net operations, private sector involvement was limited to supervisory functions related to trap-net relocation and maintenance. Only three contracts were completed for operations of two trap nets each in Reach II. Tribal contractors encountered staff shortages and equipment downtime to varying degrees. One tribal crew experienced significant effort loss due to a malfunctioning vessel that could not be replaced inseason. A proportion of the effort loss was compensated by the formation of a third ODFW fishing crew that operated trap nets in Bonneville Reservoir. However, the overall effort loss in Reach II was significant. The discrepancy of trap-net effort among river reaches above and below Bonneville Dam was addressed **inseason** by transferring one fishing crew and five floating trap nets from Reach I to Reach II during the last week of July. All trap-net activities ceased immediately following gear translocation based on fishery non-compliance with prescribed operational criteria (excessive water surface temperature).

The study area in the lower Columbia River was divided into six transections as follows:

Area	From	Upstream To
1	West End Puget Island (RM[1] 38)	Bachelor Point (RM 92)
2	Bachelor Point (RM 92)	Bonneville Dam (RM 145)
3	Bonneville Dam (RM 145)	The Dalles Dam (RM 191)
4	The Dalles Dam (RM 191)	John Day Dam (RM 217)
5	John Day Dam (RM 217)	Six Mile Canyon (RM 260)
6	Six Mile Canyon (RM 260)	McNary Dam (RM 293)

[1] Standard river mile.

The fishery was implemented seven days per week from June 1 through August 4. On this, date water surface temperatures exceeded 68° F (see Operational Criteria, Appendix A-l). Three ODFW and three tribal fishing crews (each staffed with two shifts and three or more persons per shift) fished a total of 16 trap nets. One trap-net relocation and maintenance (moving) crew (staffed with two shifts and three persons per shift) assisted with trap-net operations in Areas 1 and 2.

Fishing crews recorded data regarding location (river mile and site description), soak time (the cumulative amount of time that the net was open), water depth, temperature, and clarity, distance from the net entrance to shoreline, and catch (species, life stage, condition, and disposition) for each set (Appendix A-3, Appendix Figures A-3.1 and A-3.2). Fishing crews collected subsample fork length data on the northern squawfish catch. Non-target fish including northern squawfish of less than 11 inches in total length were quickly released. We clipped the **caudal** fins of all harvested northern squawfish, transported them to local field stations, and stored them in freezers until collection by Oregon State University personnel.

The moving crew recorded trap-net relocations on a form (Appendix A-3, Appendix Figure A-3.3). In addition, most crews used cellular phones to frequently update catch information and net location status.

Data forms were transmitted daily from various field offices to the main project office in Clackamas for electronic data entry, verification, and summary. Weekly preliminary catch summaries (Weekly Field Activity Reports) were generated on Mondays for the previous week. Weeks are defined as starting on Mondays (except Week 1, which started on Tuesday, June 1) and ending on Sundays (except Week 10, which ended on Wednesday, August 4).

To ensure compliance with operational criteria, we monitored current salmonid run size data as they were made available.

I

RESULTS

Effort

Sixteen floating trap-net units were used by six fishing crews (CTUIR, CTWSRO, NPT, ODFW-A, ODFW-B, and ODFW-C) from June 1 through August 4. Numbers of nets used per fishing crew varied from 0 to 5 depending on logistical constraints, availability, and distance between trap-net locations that were fished simultaneously. Table A-l shows maximum numbers of trap nets deployed by crew and area. All but CTWSRO and NPT crews fished in one area only.

Fishing crews made a total number of 1,392 sets. Appendix A-4, Appendix Table A-4.1 demonstrates numbers of sets by area and week. Values for Area 1 and Week 1 include effort of two sets made on June 2 where sunken Pennsylvania trap nets were used in lieu of sufficient numbers of available floating trap nets. Also included are three floating trap-net sets that were accidently made just above the BRZ area of the McNary Dam forebay (Area 7).

The number of sets per week increased steadily over time from 91 (Week 2) to 258 (Week 9). Effort was focused on the lower sampling areas with the majority of sets (853, or 61%) made in Areas 1 and 2. The cumulative number of lower sampling area sets increases to 1,073 or 77%, if Area 3 is included. Appendix A-4, Appendix Table A-4.2 shows numbers of sets made by crew, area, and week. Fishing crews averaged 31.5 sets per week, (excluding Weeks 1 and 10) and ranged from 11 (CTWSRO crew) to 53.8 (ODFW-B crew) sets per week.

Table A- 1. Maximum number of floating trap nets deployed by crew and area.

Area	No. of trap nets	Fishing crew	Dates From	To
1	4	ODFW-A	Jun. 02	Jul. 28
2	3	ODFW-B	Jun. 01	Aug. 04
3	2[1]	CTWSRO[2]	Jun. 12	Aug. 04
	3	ODFW-C	Jul. 07	Aug. 04
4	2[1]	CTWSRO	Jun. 03	Jun. 05
	2[3]	NPT		
5	2[3]	NPT		
6	2[3]	NPT		
	2	CTUIR	Jun. 29	Aug. 04

[1] Identical trap nets.
[2] Trap nets were fished by CIWSRO crew through July 04 and permanently transferred to the ODFW-C crew on July 26.
[3] Identical trap nets.

Total soak time was 4,051 hours with a mean soak time of 2.91 hours per set (Appendix A-4, Appendix Table A-4.1). For each area, mean soak time per set ranged from 2.57 (STD = 1.99) in Area 2 to 3.44 (STD = 2.6 1) in Area 4. Figure A-l illustrates increasing cumulative soaking hours over time from 197 (Week 2) to 793 (Week 9) hours as was expected with increasing effort (numbers of sets).

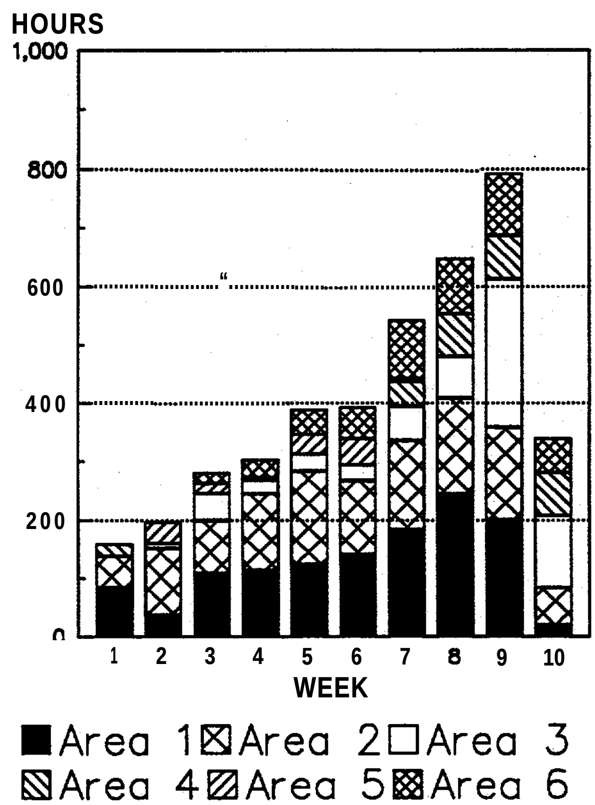

Figure A-l. Effort in Hours by Week and Area

Appendix A-4, Appendix Table A-4.2 shows cumulative soak times by crew, area, and week. Crews averaged 89.76 hours per week (excluding Weeks 1 and 10) with a range from 26.91 (CTWSRO crew) to 144.24 (ODFW-A crew). Appendix A-5, Appendix Figure A-5.1 lists cumulative soak time by area and fishing crew. The CTWSRO crew expended the least amount of effort (3% of the total soak time). Effort expended by CTUIR, NPT, and ODFW-C crews was comparable (11%, 11% , and 13 % , respectively) and ODFW crews B and A expended the most effort (30% and 31% , respectively).

The ODFW-A crew made fewer sets (27% -of 1,392) with a higher mean soak time (114% of 2.91) per set. The ODFW-B crew made more sets (34% of 1,392) with a lower mean soak time (88% of 2.91) per set (Appendix A-4, Table A-4.1). Resulting net differences in numbers of sets made and mean soak times per set for ODFW-A and ODFW-B crews are 25 % and 29%, respectively.

Catch

A total of 45,803 fishes were caught. Appendix A-4, Appendix Table A-4.3 lists total catch by family and species. Cyprinids (minnows) comprised 74.6% of the total catch, salmonids 5.5%, and centrarchids (sunfishes) 5.3%.

Northern Squawfish Catch

Northern squawfish comprised 22.8% (10,440 fish) of the total catch. Most of the northern squawfish caught (8,752 fish, or 83.8% of the northern squawfish catch) were fish smaller than 11 inches in total length. Figure A-2 illustrates northern squawfish catch by area and size class.

Figure A-3 shows northern squawfish catch by week. Catch increased steadily over time for both size classes and averaged 196 large and 987 small fish per week (excluding Weeks 1 and 10).

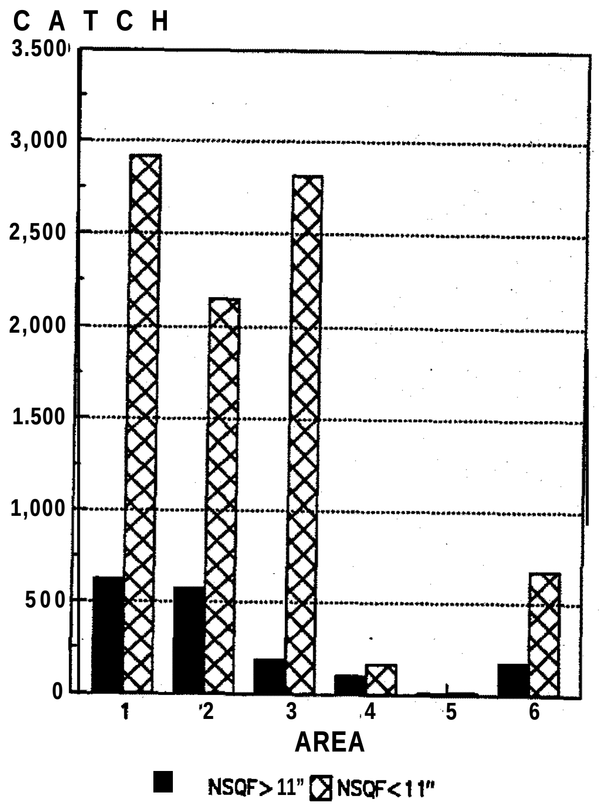

Figure A-2. Northern squawfish catch by area and size class.

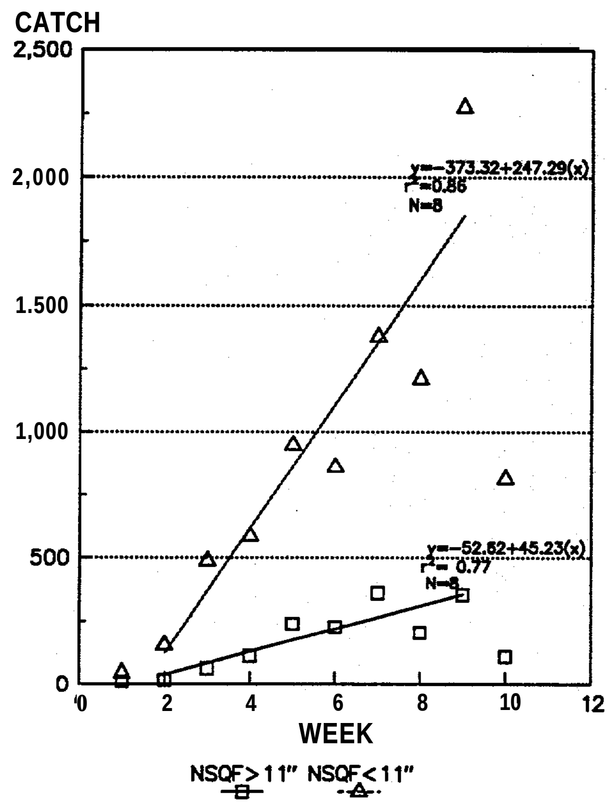

Figure A-3. Northern squawfish catch by week and size class.

Catch per unit of effort (CPUE) increased over time for northern squawfish of both size classes (Figure A-4). Appendix A-5, Appendix Figure A-5.2 shows CPUE by area. CPUE for large northern squawfish averaged at 0.3 fish per hour (or 0.9 fish per set) with lowest catch rates occurring in Area 5 and highest in Area 1. Area 3 yielded highest overall northern squawfish CPUE (4.68 fish per hour), approximately twice as high as Areas 1 or 2. Appendix A-5, Appendix Figure A-5.3 shows CPUE by fishing crew. Again, CPUE for overall northern squawfish catch is high for fishing crew ODFW-C, which operated strictly in Area 3. The CTUIR crew achieved highest catch rates (0.38 fish per hour) for large northern squawfish, approximately four times as high as the average.

Fork lengths were taken randomly from 1,105 fish, 10.6% of the catch. Mean fork length for all northern squawfish sampled was 244 mm (SDE = 83.26). Mean fork length for large northern squawfish (492 fish) was 318 mm (SDE = 63.32) ranging from 295 mm in Area 3 (N=16) and Area 6 (N=28) to 358 mm in Area 5 (N= 11). Mean fork length for small northern squawfish (613 fish) was 185 mm (SDE = 36.72). Appendix A-5, Appendix Figure A-5.4 illustrates related fork length frequency. Most frequent (80%) were fish measuring from 130 mm to 310 mm in fork length.

Salmonid Bycatch

Salmonid bycatch comprised 5.5 % (2,5 16 fishes) of the total catch and was classified by species and life stage (Figure A-5). Life stage was not recorded for one salmonid caught in Area 5 during Week 3. Adult and jack salmonid bycatch comprised 41.2% (1,036 fishes) of the overall salmonid bycatch. From the returning adult salmonids (including jacks) that were identified by species, 63% (653 fish) were steelhead (*Oncorhynchus mykiss*) and 30.8% (319 fish) were sockeye salmon (*Oncorhynchus nerka*). The majority of juvenile salmonids (94.7%, or 1,400 fishes) were not identified by species.

Figure A-6 shows salmonid bycatch by area and life stage. Most salmonids (79.2% of 2,515 fishes) as well as the majority of the adults (80.6% of 1,036 fishes) were captured in Areas 1 and 2.

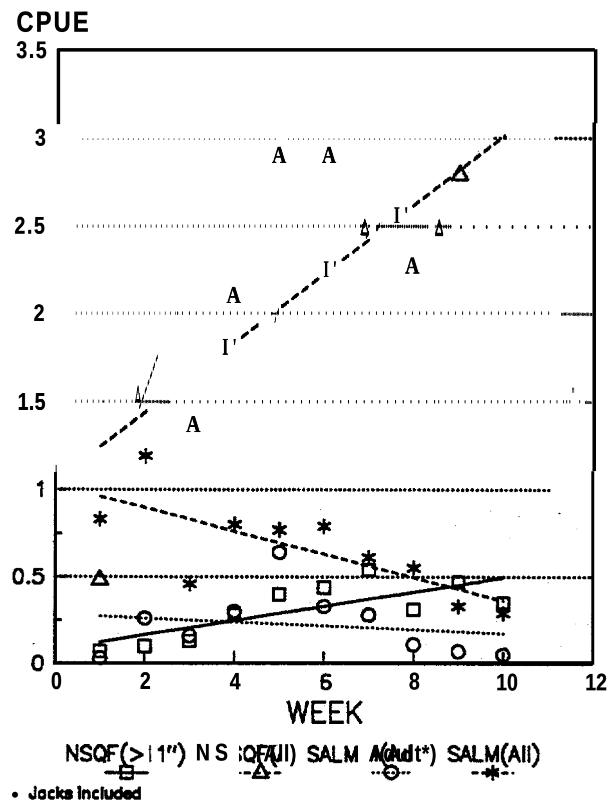

Figure A-4. Catch per unit of effort (CPUE) for northern squawfish and salmonids by week.

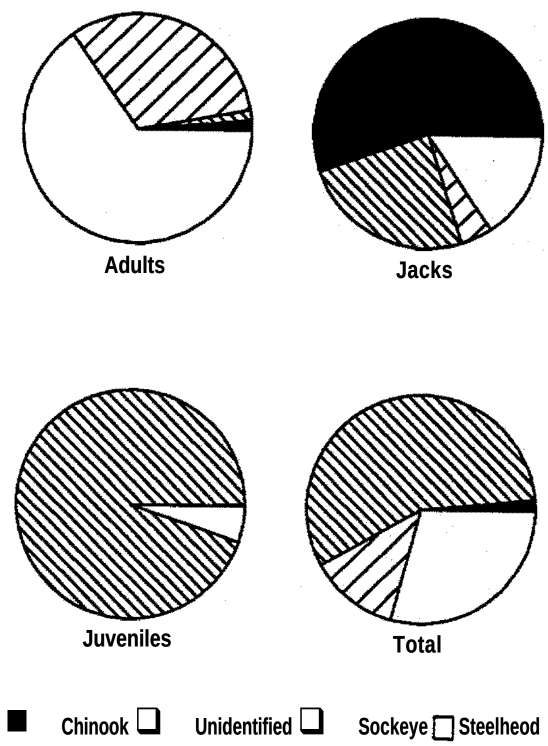

Figure A-5. **Salmonid bycatch** by species and life stage.

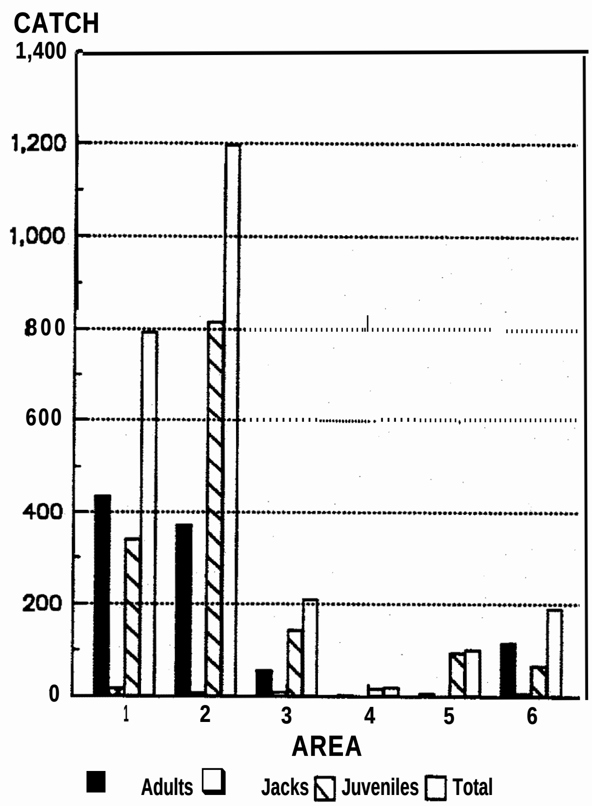

Figure A-6. **Salmonid bycatch** by area and life stage.

Bycatch per unit of effort (CPUE) decreased over time (Figure A-4). Appendix A-5, Appendix Figure A-5.2 shows CPUE by area. CPUE for adult salmonids (including jacks) averaged at 0.15 fishes per hour (or 0.5 fishes per set) with lowest catch rates occurring in Area 4 and highest in Area 1. Area 2 yielded highest overall **salmonid bycatch CPUE** of 0.98 fishes per hour, followed by Area 5 (0.72 fishes per hour). Appendix A-5, Appendix Figure A-5.3 shows CPUE by fishing crew. Again, CPUE for overall **salmonid bycatch** is high for fishing crew ODFW-B, which operated strictly in Area 2. CTUIR and ODFW-A fishing crews accounted for the highest **bycatch** rates (0.37 fishes per hour) for adults and jacks, approximately twice the average.

Appendix A-5, Appendix Figures A-5.5 and A-5.6 illustrate release conditions for adult (including jacks) and juvenile **salmonids** by species. Most fish (93.6%, or 2,354 fishes) were released in good condition and only 0.5% (12 juveniles) were not expected to survive or were dead. Measurable gear and handling impact on incidentally captured salmonids was negligible.

DISCUSSION AND CONCLUSIONS

Success in trapnetting northern squawfish, particularly large (> 11 inches in total length) individuals, was less during this study than anticipated from previous results using Merwin trap nets on the Columbia River and elsewhere. In the past, floating trap nets have worked well, particularly when fished on known or probable concentrations of adult northern squawfish during the spawning season (June and July), -when their upstream migrating proclivities make them susceptible to such gear. The reasons for the relative lack of success during 1993 are complex and not solely a reflection of the technical inadequacies of this gear. However, the 1993 project did serve to emphasize not only the specific circumstances under which floating trap nets may not be very successful, but also the physical limitations and handling problems associated with such gear.

The circumstances contributing to the relatively low overall catch rates can be categorized as (1) administrative or logistical, and (2) technical.

The major administrative and logistical problems encountered during the current project were as follows:

1. Delay in starting date.
2. Compacting of time for gear construction and acquisition.
3. Insufficient site-specific background.
4. Vessel breakdowns.

5. ESA constraints on times and locations of operation.

6. Insufficient communication among the various participants (ODFW, Tribes, UW, Fish tec).

The major technical difficulties included:

1. Inadequate design for use in swift currents.

2. Relative immobility of gear.

3. Need for constant maintenance.

4. Requirement of active migration of fish to be effective.

Discussion follows on each of these points.

Delays in completing contract negotiations resulted in a delayed starting date for the fishery. Concerns had to be resolved regarding (1) the scope of the fishery, (2) the potential for impact on adult salmonids in terms of delayed migration and stress, (3) the spatial distribution of fishing activities conducted by ODFW versus tribal employees, (4) the extent of private sector involvement, and (5) implementation cost. Thus, even though field work was scheduled to start in early June, in fact it was several weeks into the season before a full-scale evaluation effort was launched. In past years, June has been one of the best months for trapnetting large northern squawfish, probably because it is the major month of migratory activity associated with spawning.

The delays in start-up caused reduction in time periods allocated for contracting, manufacture, and delivery of gear. In turn, this caused fewer and less cost-effective choices and a lack of opportunities to allow for preseason adjustments.

The site survey was conducted in early winter under very cold, icy, and windy weather conditions. Subsequently, most of the described site-specific conditions were not representative for the actual fishing season. Most of the information collected and evaluated in the data survey was not specific to sites for trap nets, but rather specific to a broader area. Therefore, the contributions of these surveys to the development of criteria for trap-net site selection were limited. Ideally, the site survey would have been done during months of anticipated operation.

Most of the people hired to operate the trap nets had no prior experience with such gear or similar gear. Some had minimal or no small-boat handling or maintenance experience. Short workshops prior to operation were helpful, but experience is the only really effective way to learn the use of this gear, and it may take a full season to develop an optimally trained crew. Inseason technical support and cooperation reached satisfactory levels, resulting in harvest technology being eventually transferred successfully from UW to

ODFW and tribal staffs. However, by the time most project employees were well trained, optimal times for trapnetting northern squawfish had passed.

Minor vessel breakdowns were encountered, and in one instance a major loss in test effort occurred because of a malfunctioning vessel that could not be repaired or replaced in a timely manner. Such breakdowns in vessels are not a direct reflection on efficiency of the trap-net gear, itself. However, vessels are an integral part of a mobile trap-net operation; trap nets should be readily movable from unproductive sites to potentially better ones. Without smooth-running, efficient work boats, such mobility is lost. Any marine operation relying on vessels can expect a certain level of mechanical problems. The best way to minimize such difficulties is with the acquisition of adequate vessels and with crews experienced in vessel maintenance and repair.

Perhaps the greatest single factor in the relatively low northern squawfish catch rates in 1993 was the ESA constraint on fishing the BRZ areas below the dams. Most previous research on both trapnetting and the distribution and behavior of northern squawfish has shown that northern squawfish concentrations are far higher in BRZ areas than elsewhere, particularly in the summer. Such concentrations are due to two factors. First, northern squawfish innately tend to move upstream to spawn. Since they now encounter dams and probably have limited (although some) proclivity to ascend ladders, their numbers tend to build up immediately below dams during the spawning season. Second, as is only too well known, northern squawfish actively seek salmonids in their diets; consequently, outmigrating smolts weakened in the spillway or turbine in their exodus past the dams create feeding concentrations below the dams. Therefore, trap-net sites within the eliminated BRZ areas, including those in the Snake River reaches, could have greatly contributed to the harvest rate of large northern squawfish (Mathews et al. 1991, 1992a, and 1992b; Iverson and Mahoney 1993).

An unfortunate by-product of the project's late start was a lack of understanding of roles and responsibilities among participants. This created some significant gaps in making decisions about such items as where to place trap nets and when to move them from unproductive sites to alternative sites. It is common sense strategy when testing new fishing gear or exploring new grounds to be as mobile and flexible as possible. In retrospect, we did not achieve an optimal level of flexibility. Ideally, we should have fished more sites with less time on average per site. Improved and refined strategies are needed to coordinate prescribed trap-net relocations more effectively.

The present floating trap net is not adaptable to the high water velocities and tidal influences found in the free-flowing reaches below Bonneville Dam. Even moderate currents pushed the trap-net lead and heart out of shape, and currents created anchoring and debris problems. These problems were anticipated, and prior to this project, funding for developing and testing alternative trap nets specifically designed for swifter currents had been requested. However, since such funding requests were not met, we were left with the less than satisfactory alternative of testing the present trap-net design below Bonneville Dam to see if or how it might be successfully deployed in current. Gear effectiveness under these conditions could be improved by further design modifications and alternative deployment schedules.

The present design, even though it is more mobile than Merwin trap nets, is still a relatively cumbersome, unfamiliar piece of gear, compared with gill nets, longlines, or seines. It takes several people, an efficient work skiff, a launching ramp, and two or three hours to set or pull a net. When crews get short-handed or overworked, a natural outcome is that trap nets may not be moved often enough in response to the ever-changing distribution and behavior of the fish. Furthermore, the gear requires regular and dependable maintenance. Web and lead should often be cleaned of algae, particularly as temperatures increase.

Finally, this is a passive gear (i.e., catch rates are directly dependent upon fish movements). The best time to use such gear is during June and early July when spawning northern squawfish have a natural tendency to move upstream. The peak of such activity may have been passed by the time the crews gained sufficient experience.

Effort levels were adequate in Areas 1 and 2 (downstream from Bonneville Dam), but only moderate to low in Areas 3 through 6. Catch composition resembled results of earlier mobile Merwin trap-net studies (Mathews et al. 1992a) with respect to northern squawfish catch and combined bycatch of other cyprinids and centrarchids. The ratio of large to small northern squawfish decreased substantially compared to 1992 data, possibly as a result of sampling site characteristics (moderate to poor habitat for piscivorous northern squawfish). Contrary to this year's implementation, fishing locations in 1992 included BRZ areas at hydropower projects where 49.4% of the effort and 74.6% of the northern squawfish catch occurred. Salmonid bycatch was lower than 1992 results as was expected as a probable cumulative effect of the elimination of sampling sites within BRZ areas and generally smaller salmonid run sizes.

The floating trap nets as deployed in this study had a relatively high cost per fish, Thus, this method is impractical to pursue on a large scale throughout the reservoirs or below Bonneville Dam, particularly given the level of constraints imposed to achieve standards set for incidental salmonid catches. However, we showed in this study (as has been previously demonstrated) that handling stress and delays on adult and juvenile salmon from trap nets is minimal, either absolutely or relative to other standard fishing or sampling methods such as gillnetting, electrofishing, or seining. Therefore, considering the high trapnetting success rate in BRZ areas of previous studies, we recommend that limited further test efforts with trap nets should continue, especially above Bonneville Dam. And specifically, state and federal agencies and tribes should continue to review the concept of BRZ-specific deployment of trap nets in June and July.

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APPENDIX A-1

Operational Criteria

Operational Criteria Applicable to the Floating Trap-net Fishery for Northern Squawfish in the Columbia and Snake Rivers.

__In:__ Biological opinion under Section 7 of the Endangered Species Act (ESA) on operation of the Federal Columbia River Power System (FCRPS) through January 31, 1994. 1993. National Marine Fisheries Service (NMFS). Washington D.C.

(1) Bonneville Power Administration (BPA) shall not operate Merwin trap nets or conduct any type of trapnetting in the Snake River in 1993.

(2) BPA shall not operate trap nets in the Columbia River when water temperatures exceed 68° Fahrenheit.

(3) BPA shall not hold adult or juvenile salmonids longer than 3 hours during the period of May 31 through September 30.

(4) BPA shall not operate trap nets within 500 feet of any fishway entrance.

(5) Between May 31 and September 30, if water temperatures are below 68" Fahrenheit, only nighttime fishing (from one hour after sunset until one hour before sunrise) will be conducted. However, if *Oncorhynchus nerka* are present at Bonneville Dam prior to May 31, then only nighttime fishing will be allowed, beginning on the date of first detection.

(6) BPA shall not conduct Merwin trapnetting in dam boat restricted zones (BRZ's) from May 31 through September 30.

(7) If, during three-hour periods (between May 31 and September 30), any one of the following criteria occurs, trap-net operation at the affected site will cease.

(a) Salmonid to northern squawfish ration exceeds 1: 1.

(b) Salmonid catch rates exceed 20 per three hours of trap-net effort.

(c) Density criteria for fish held in the trap net exceed 2.0 pounds per cubic foot of water with a water temperature of 50°F when adult salmonids are present. For each degree of water temperature below or above 50°F, the poundage can be increased or decreased 5%, respectively (Senn et al. 1984).

(8) Outside of the May 31 through September 30 period, four-hour maximum holding times will be followed except:

(a) If any of the above criteria are met (7.a-b), maximum holding-time will not exceed three hours; or

(b) If any of the above criteria (7.a-b) are met during a three-hour period, fishing at the affected site will cease.

(9) BPA shall cease all trapnetting operations if cumulative incidental catch of salmonids exceeds cumulative catch criteria developed by the Oregon Department of Fish and Wildlife (February 10, 1993, memorandum from R. Boyce, ODFW, to Fish Passage Advisory Committee).

(10) The criteria for resuming trapnetting at a given site following cessation (according to Section X.B.7.a.7) will be based on re-initiation of consultation with NMFS.

(11) The criteria for resuming trapnetting following a period of cessation (according to Section X.B.7.a.9) will be based on salmonid ladder counts and smolt collection data. Fishing will only resume when NMFS determines that such data indicate that salmonid abundance has dropped below the threshold levels that triggered cessation of trapnetting.

(12) Adult salmonids and other incidental species, when possible, will be released over the cork line or through a net opening designed for release. However, if the operator judges dipnetting to be less harmful, soft-meshed shallow dip nets will be used. Since fishing will not occur at temperatures above 68 Degrees Fahrenheit, and holding times will be short, it is reasonable that in the absence of a better method, occasional dipnetting should be allowed to minimize release stress.

(13) BPA shall conduct additional investigation of alternative release methods for incidentally caught adult salmonids.

APPENDIX A-2

Gear Specifications

Floating Trap-Net Frame

The frame consists of five basic sections. The two pontoons are identical, making them interchangeable. Each pontoon is approximately 24 feet long, 24 inches wide, and 20 inches tall. The pontoons are constructed from .125-inch 5052 alloy aluminum, break-formed to eliminate as many welded seams as possible. Each pontoon has a watertight subdeck that is also made of individual watertight compartments, each having an inspection-access plate. Tie-down loops are provided on each side of the pontoons for attaching the trap net and bumper floats. Each pontoon has eight lo-inch welded aluminumcleats placed as per prints. Reinforced towing eyes are welded on both ends of each pontoon. The pontoons are equipped with two single speed sailboat winches placed on reinforced pads on each end of the pontoons. Sockets for removable handrails are placed on the outboard side of each pontoon. Eight removable deck boards, constructed of .75-inch marine grade plyboard, allow access to the storage area above the watertight deck. These deck boards form the walking deck of the pontoons. The watertight deck and the walking deck are painted with non-skid paint.

Three cross-deck walkways connect the two pontoons. Each walkway is 14 feet long and identical, making them interchangeable. The walkways are also break-formed from .125-inch 5052 aluminum. The walkways are attached to the pontoons with quick-connect pins made from one-inch stainless steel shafting. The walking surfaces are painted with the same non-skid material as the pontoons.

Floating Trap-Net Trailer

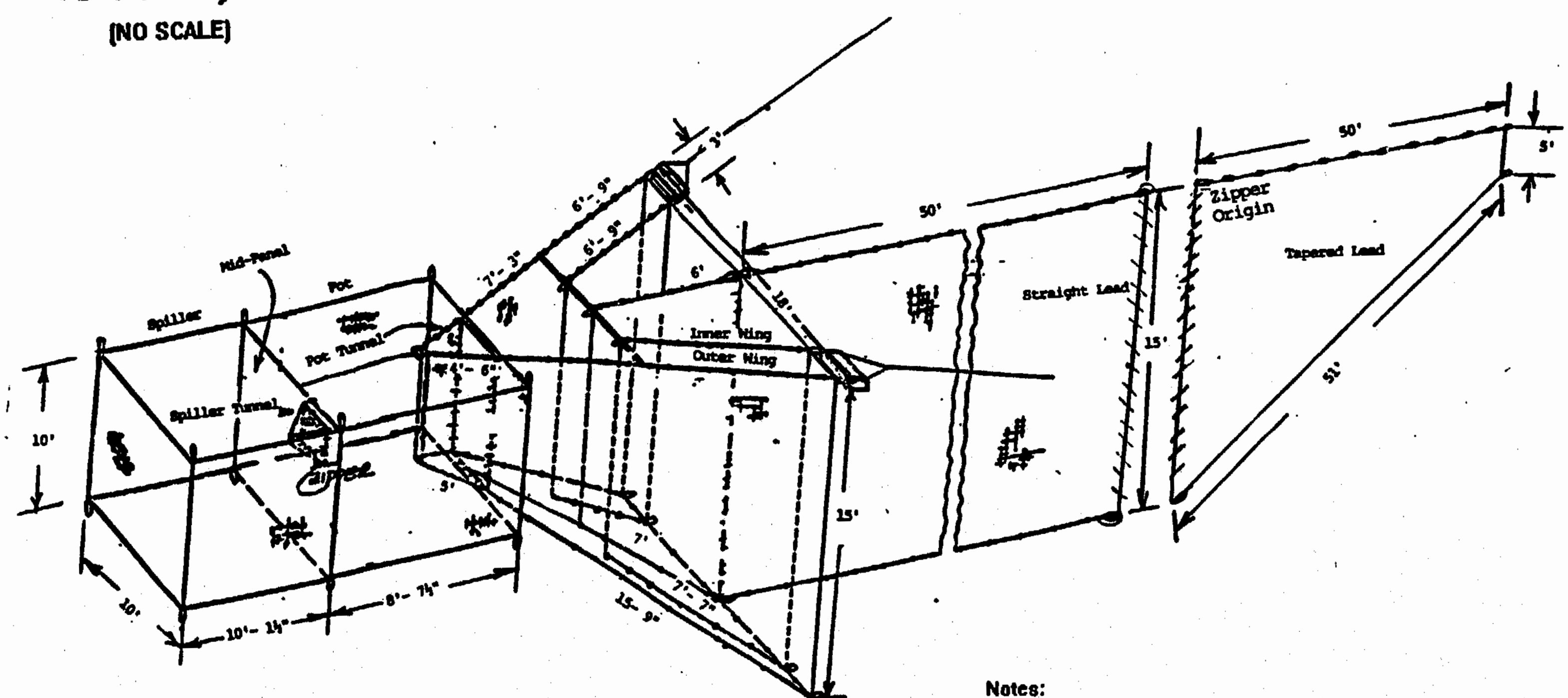
The trap-net trailer is designed to carry two complete floating trap-net frames, two trap nets, and the necessary ancillary gear such as anchors, lines, etc. Design is such that a crew of three persons can load the frames and gear. The trailer is approximately 26 feet long and 7 feet wide. Construction is of 2x2-inch and 2x4-inch tandem axle design, with “walking axle” configuration. The coupler is fitted near the front of the trailer. Tail lights, break lights, and turn indicator are provided and wired to an industry standard seven-prong coupler. Two amber and one red reflector are placed on each side. A license plate bracket is placed at the rear of the trailer. The center of the trailer is a net and gear storage galley. The side boards and deck of the galley are one-inch plyboard. A removable plyboard tailgate is at the rear of the net galley. Tie-down rings are welded to the trailer as per prints. Areas where the pontoons bear on the trailer frame is to be completely sandblasted prior to painting. Finish is to consist of a two-part epoxy primer and gloss top coat.

Appendix Figure A-2.1. Floating trap net.

University of Washington Mobile Squawfish Trap

15' Net Layout

(NO SCALE)



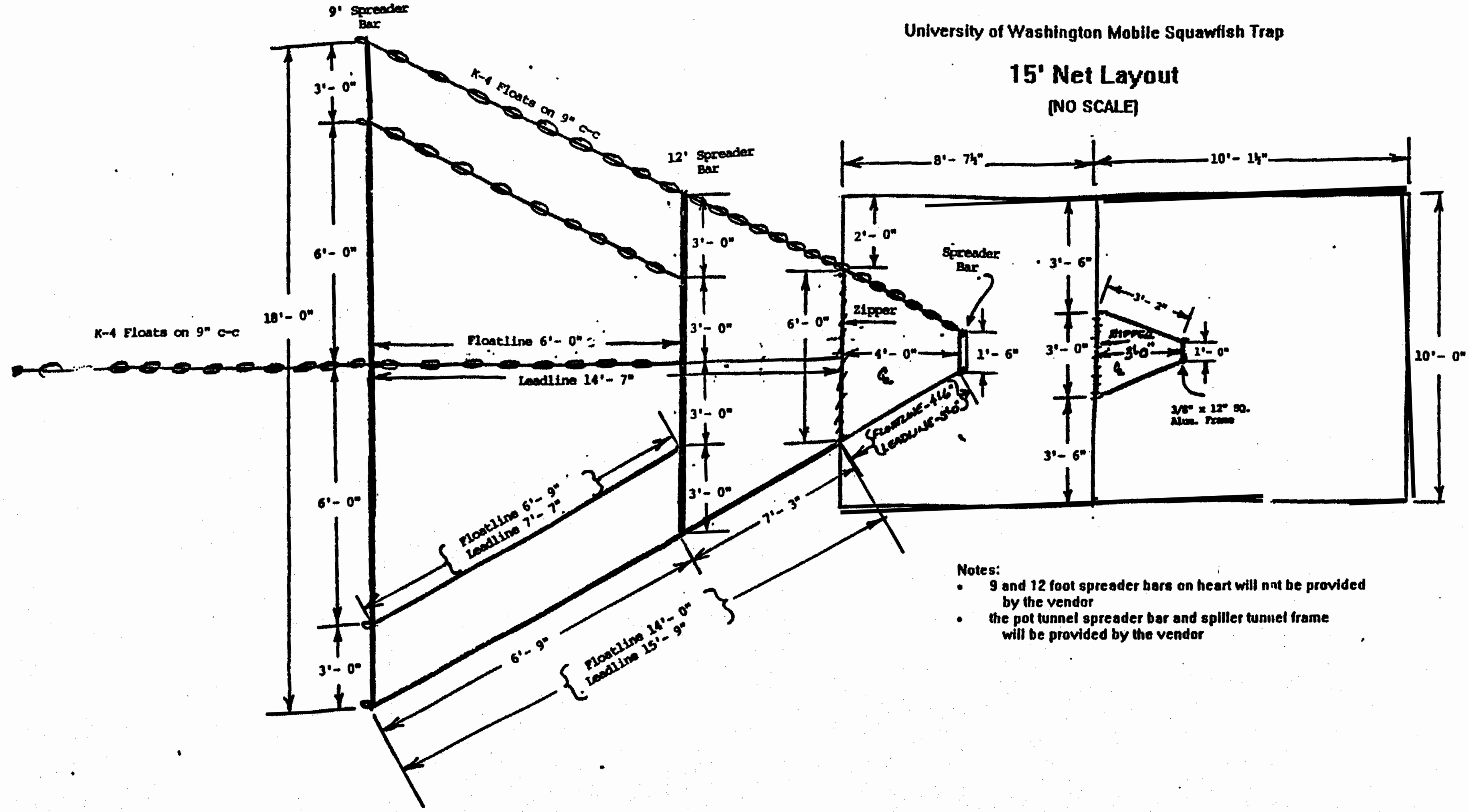
Notes:

- 1½ 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

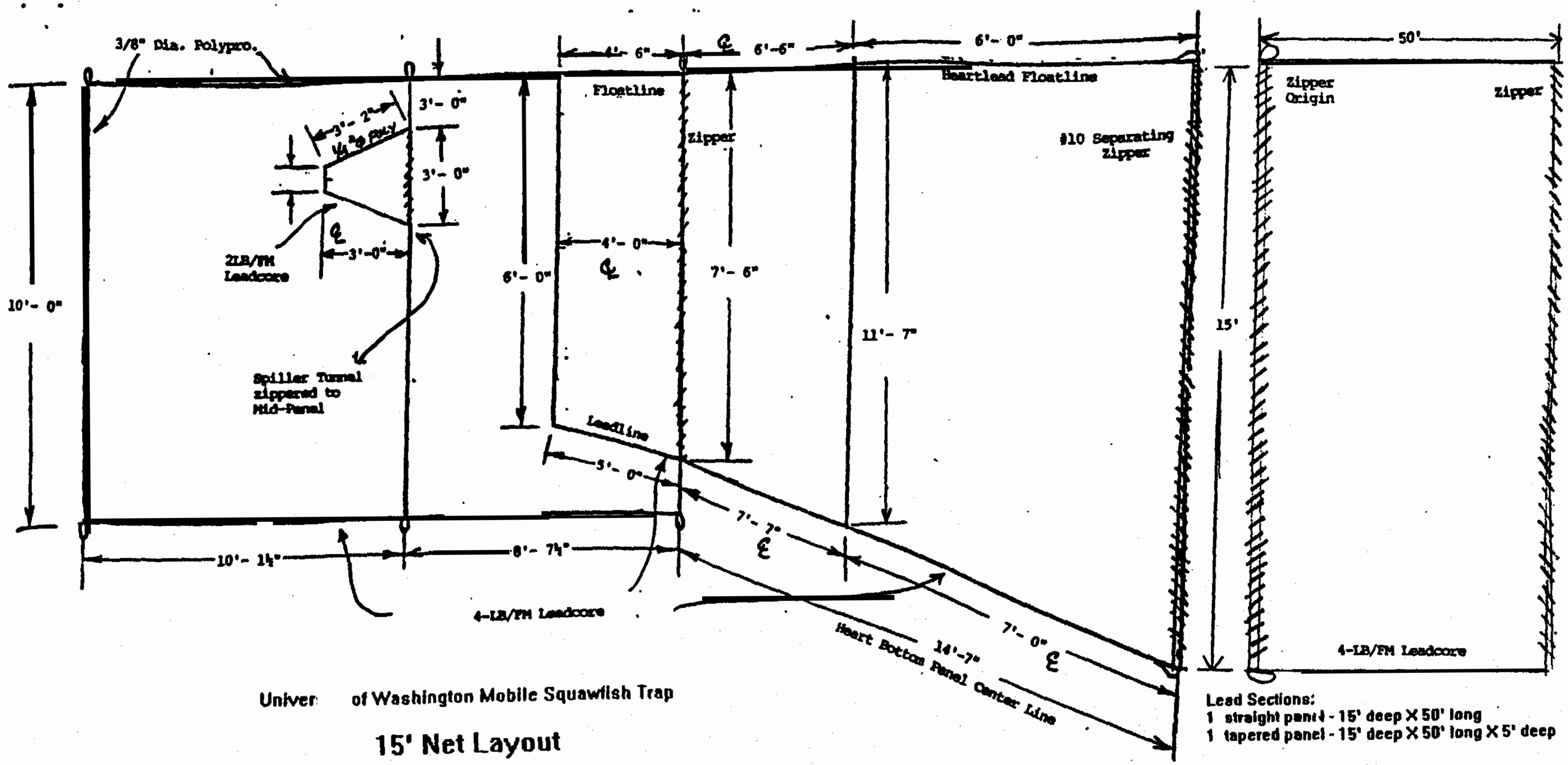
15' Net Layout

(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



Lead Sections:
1 straight panel - 15' deep X 50' long
1 tapered panel - 15' deep X 50' long X 5' deep

Univer of Washington Mobile Squawfish Trap

15' Net Layout

(NO SCALE)

APPENDXX A-3

Data Forms

Appendix Figure A-3.1.
ODFW floating trap-net catch and effort form.

1993 ODFW FLOATING TRAP NET FISHERY

№ 005001

PAGE ____ OF ____

PERSONNEL ____________

TRAP NUMBER ____________

SITE DESC. ____________

AREA	LOCATION MILE	¼	START MO	START DAY	START TIME	STOP MO	STOP DAY	STOP TIME	DEPTH (ft)	LEAD LENGTH (ft)	TEMP °F	SECC (m)

LINE NUMBER	SPECIES	L STAGE	TALLY	COUNT	FORK LENGTH (mm)	DISP	MARK	TAG	COLOR	TAG NUMBER	COMMENTS
1	SQF	S									
2	SQF	L									
3	CRA	0									
4	PM	0									
5	CLM	0									
6	SU	O									
7											
8											
9											
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
0											

AREA
1=CLATS.
2=PRTLND
3=BONNVL
4=DALLES
5=LWR JD
6=UPR JD

LOCATION
1=OR shore
2=OR side of island
3=WA side of island
4=WA shore

L(IFE) STAGE
for salmonids:
A=ADULT
J=JACK
U=JUVENILE
for squawfish:
S=SMALL (under 11in.)
L=LARGE (at or over 11 in.)

DISPOSITION
1 =GOOD
2=FAIR
3=POOR
4=DEAD

COLOR
O-NO INFO W=WHITE
E=ORANGE A=GRAY
Y=YELLOW N=BROWN
R=RED L=LILAC
B=BLUE C=CLEAR
P=PINK G=GREEN

SPECIES
SQF=squawfish
CRA=crappie
PM =peamouth chub
CLM=chiselmouth
SU =sucker
SUN=sunfish
BSU=bridgelip sucker
PK =pumpkinseed sunfish
LAM=lamprey
YP =yellow perch
SH =shad
RB =rainbow trout
CC =channel catfish
B =bullhead
SCU=sculpin
F =flounder
LB =largemouth bass
SB =smallmouth bass
CRP=carp
WF =whitefish
WSG=wht sturgeon
CH =chinook salmon
CO =coho salmon
SS =sockeye salmon
ST =steelhead
SLD=salmonid

Appendix Figure A-3.2.
Columbia River treaty tribes catch and effort form.

OREGON DEPARTMENT OF FISH AND WILDLIFE and COLUMBIA RIVER TREATY TRIBES
1993 Floating Trap Net Fishery

NO, 001002

PAGE ___ OF ___

AREA	LOCATION MILE	¼	START MO	START DAY	START TIME	STOP MO	STOP DAY	STOP TIME	LEAD LNGTH (ft)

PERSONNEL ______________ TRAP # ______

SITE DESCRIPTION ______________

LINE NUMBER	I	L 8	TALLY	COUNT	DISP	MARK	TAG	COLOR	TAG NUMBER	COMMENTS
1	SQF	S								
2	SQF	L								
3	CRA	0								
4	PM	0								
5	CLM	0								
6	SU	0								
7										
8										
9										
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
0										

AREA
1=CLATS.
2=PRTLND
3=BONNVL
4=DALLES
5=LWR JD
6=UPR JD

LOCATION
1=OR shore
2=OR side of island
3=WA side of island
4=WA shore

L(IFE) STAGE
for salmonids:
A=ADULT
J=JACK
U=JUVENILE
for squawfish:
S=SMALL (under 11in.)
L=LARGE (at or over 11 in.)

DISPOSITION
1 =GOOD
2=FAIR
3=POOR
4=DEAD

COLOR
O=NO INFO W=WHITE
E=ORANGE A-GRAY
Y=YELLOW N=BROWN
R=RED L=LI LAC
B=BLUE C=CLEAR
P=PINK G=GREEN

SPECIES

SQF=squawfish
CRA=crappie
PM =peamouth chub
CLM=chiselmouth
SU =sucker
SUN=sunfish

BSU=bridgelip sucker
PK =pumpkinseed sunfish
LAM=lamprey
YP =yellow perch
SH =shad

RB =rainbow trout
CC =channel catfish
B =bullhead
SCU=sculpin
F =flounder

LB =largemouth bass
SB =smallmouth bass
CRP=carp
WF =whitefish
WSG=wht sturgeon

CH =chinook salmon
CO =coho salmon
SS =sockeye salmon
ST =steelhead
SLD=salmonid

Appendix Figure A-3.3. Floating trap-net relocation form.

TRAP NET RELOCATION RECORD

PERSONNEL: ____________

TRAP #	START							STOP						
	AREA	SITE #	LOCATION MILE	¼	MO	DAY	TIME	AREA	SITE #	LOCATION MILE	¼	MO	DAY	TIME
			.							.				

SITE DESC. START ____________

SITE DESC. STOP ____________

COMMENTS: ____________

TRAP #	START							STOP						
	AREA	SITE #	LOCATION MILE	¼	MO	DAY	TIME	AREA	SITE #	LOCATION MILE	¼	MO	DAY	TIME
			.							.				

SITE DESC. START ____________

SITE DESC. STOP ____________

COMMENTS: ____________

TRAP #	START							STOP						
	AREA	SITE #	LOCATION MILE	¼	MO	DAY	TIME	AREA	SITE #	LOCATION MILE	¼	MO	DAY	TIME
			.							.				

SITE DESC. START ____________

SITE DESC. STOP ____________

COMMENTS ____________

TRAP #	START							STOP						
	AREA	SITE #	LOCATION MILE	¼	MO	DAY	TIME	AREA	SITE #	LOCATION MILE	¼	MO	DAY	TIME
			.							.				

SITE DESC. START ____________

SITE DESC. STOP ____________

COMMENTS: ____________

APPENDIX A-4

Result Tables

Appendix Table A-4.1. **Effort in Number of Sets (N) and Soak Time (Hours), Mean Soak Time per Set (Mean), and Standard Deviation (STD) by Area and Week**

	AREA 1				AREA 2				AREA 3				AREA 4			
WEEK	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD
1	8	84.33	10.54	10.02	20	53.45	2.67	0.33					6	21 03	3 51	0 99
2	33	37.27	1.13	5.86	42	114.62	2.73	0.34	3	9.02	3.01	0.01	.		.	.
3	40	108.32	2.71	1.04	43	91.05	2.12	3.67	16	46.73	2.92	0.18	.		.	.
4	39	113.67	2.91	0.89	47	131.83	2.80	0.65	16	23.37	1.46	5.99	.		.	.
5	36	123.32	3.43	1.36	58	160.95	2.78	0.88	9	28.50	3.17	0.33	.		.	.
6	38	141.42	3.72	2.03	64	126.43	1.98	4.24	9	26.35	2.93	0.13	.		.	.
7	56	183.92	3.28	1.02	58	152.42	2.63	0.60	21	58.27	2.77	0.33	14	42.28	3.02	0.75
8	63	245.53	3.90	4.21	60	163.33	2.72	0.52	24	71.45	2.98	0.41	24	73.18	3.05	0.32
9	59	200.48	3.40	0.98	58	158.10	2.73	0.55	82	254.42	3.10	0.45	22	74.18	3.37	0.39
10	7	19.58	2.80	0.42	24	64.53	2.69	0.56	40	123.57	3.09	0.40	17	74.43	4.38	5.70
ALL	379	1257.83	3.32	3.23	474	1216.72	2.57	1.99	220	641.67	2.92	1.67	83	285.12	3.44	2.61

Table A-2. Continued

	AREA 5				AREA 6				AREA 7				ALL			
WEEK	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD	N	HOURS	MEAN	STD
1													34	158.82	4.67	5.70
2	13	36.12	2.78	0.50									91	197.02	2.17	3.59
3	8	17.37	2.17	0.77	7	18.03	2.58	0.36	3	3.62	1.21	1.56	117	285.12	2.44	2.34
4	2	5.07	2.53	0.45	11	29.50	2.68	0.54					115	303.43	2.64	2.33
5	12	33.57	2.80	0.25	17	43.02	2.53	0.43					132	389.35	2.95	0.98
6	16	45.18	2.82	0.30	20	53.78	2.69	0.45					147	393.17	2.67	3.06
7	2	5.70	2.85	0.00	33	100.65	3.05	0.77					184	543.23	2.95	0.81
8	.	.	.		34	93.97	2.76	0.49					205	647.47	3.16	2.41
9	.	.	.		37	105.87	2.86	0.43					258	793.05	3.07	0.67
10	.	.	.		21	58.15	2.77	0.50					109	340.27	3.12	2.31
ALL	53	143.00	2.70	0.48	180	502.97	2.79	0.55	3	3.63	1.21	1.56	1392	4050.92	2.91	2.27

Appendix Table A-4.2. Catch per unit of effort (CPUE) for northern squawfish and salmonids by crew, area, and **week.**

			Effort		CPUE											
					Northern Squawfish						Salmonids					
					¢11"			All			Adults&Jacks			All		
Crew	Area	Week	Sets (S)	Hours (H)	#	/S	/H	#	/S	/H	#	/S	/H	#	/S	/H
CTUIR	6	5	17	43.02	9	0.5	0.21	62	3.6	1.44	70	4.1	1.63	75	4.4	1.74
		6	20	53.78	23	1.2	0.43	109	5.5	2.03	15	0.8	0.28	16	0.8	0.30
		7	33	100.65	76	2.3	0.76	177	5.4	1.76	12	0.4	0.12	29	0.9	0.29
		8	34	93.97	2	0.1	0.02	61	1.8	0.65	10	0.3	0.11	15	0.4	0.16
		9	37	105.87	38	1.0	0.36	186	5.0	1.76	8	0.2	0.08	22	0.6	0.21
		10	21	58.15	28	1.3	0.48	218	10.4	3.75	1	0.0	0.02	9	0.4	0.15
	All		162	455.44	176	1.0	0.38	813	5.3	1.90	116	1.0	0.37	166	1.3	0.48
		2	3	9.02	1	0.3	0.11	32	10.7	3.55	3	1.0	0.33	7	2.3	0.78
CTWSRO	3	3	16	46.73	5	0.3	0.11	160	10.0	3.42	4	0.3	0.09	10	0.6	0.21
		4	16	23.37	8	0.5	0.34	96	6.0	4.11	2	0.1	0.09	23	1.4	0.98
		5	9	28.50	5	0.6	0.18	190	21.1	6.67	1	0.1	0.04	1	0.1	0.04
		All	44	107.62	19	0.4	0.18	478	11.9	4.44	10	0.4	0.13	41	1.1	0.50
	4	1	6	21.03	1	0.2	0.01	18	3.0	0.86	0	0.0	0.00	2	0.3	0.10
	All		50	128.65	20	0.2	0.10	496	7.5	2.65	10	0.2	0.07	43	0.7	0.30
		7	14	42.28												
NPITI	4	8	24	73.18	25	1.8	0.04	58	4.1	1.37	3 0	0.2 0.0	0.07 0.00	15 3	1.1 0.1	0.35 0.04
		9	22	74.18	45	2.0	0.03	89	4.0	1.20		0.0	0.00		0.0	0.00
		10	17	74.43	3	0.2	0.00	52	3.1	0.70		0.0	0.00		0.0	0.00
		All	77	264.07	104	1.3	0.02	255	3.4	1.01	3	0.1	0.02	18	0.3	0.10
		2	13	36.12		0.0	0.00	4	0.3	0.11	2	0.2	0.06	48	3.7	1.33
	5	3	8	17.37	2	0.3	0.01	3	0.4	0.17	1	0.1	0.06	10	1.3	0.58
		4	2	5.07	1	0.5	0.10	3	1.5	0.59	0	0.0	0.00	4	2.0	0.79
		5	12	33.57	1	0.1	0.00	2	0.2	0.06	2	0.2	0.06	5	0.4	0.15
		6	16	45.18	8	0.5	0.01	17	1.1	0.38	1	0.1	0.02	31	1.9	0.69
		7	2	5.70	1	0.5	0.09	1	0.5	0.18	1	0.5	0.18	5	2.5	0.88
		All	53	143.01	13	0.3	0.04	30	0.7	0.25	7	0.2	0.06	103	2.0	0.73
		3	7	18.03		0.0	0.00	13	1.9	0.72	1	0.1	0.06	9	1.3	0.50
	6	4	11	29.50	1	0.1	0.00	27	2.5	0.92	7	0.6	0.24	16	1.5	0.54
		All	18	47.53	1	0.0	0.00	40	2.2	0.82	8	0.4	0.15	25	1.4	0.52

Appendix Table A-4.2. Continued.

			Effort		CPUE											
					Northern Squawfish						Salmonids					
					¢11"			All			Adults&Jacks			All		
Crew	Area	Week	Sets (S)	Hours (H)	#	/S	/H	#	/S	/H	#	/S	/H	#	/S	/H
NPITI	7	3	3	3.62		0.0	0.00	1	0.3	0.28		0.0	0.00		0.0	0.00
	All		151	458.23	118	0.4	0.01	326	1.6	0.59	18	0.2	0.06	146	0.9	0.34
ODFW-A	1	1	8	84.33	2	0.3	0.00	12	1.5	0.14	2	0.3	0.02	21	2.6	0.25
		2	33	37.27	9	0.3	0.01	72	2.2	1.93	19	0.6	0.51	60	1.8	1.61
		3	40	108.32	48	1.0	0.01	414	10.6	3.64	86	2.2	0.76	101	2.0	0.73
			39	113.67	41	1.2	0.01	294	7.4	2.71	32	0.8	0.30	79	2.6	0.89
		5	36	141.42	99	2.5	0.02	405	10.7	3.13	114	3.2	0.92	126	3.5	0.47
		6	38	123.32	96	2.8	0.02	386	10.7	2.86	52	1.4	0.37	67	1.8	1.02
		7	56	245.53	135	2.4	0.01	726	13.0	3.95	55	0.9	0.34	124	2.2	0.67
		8	63	183.92	80	1.3	0.01	509	8.1	2.07	62	1.1	0.22	133	2.1	0.54
		9	59	200.48	108	1.3	0.01	685	11.6	3.42	29	0.4	0.15	77	0.9	0.38
		10	7	19.58	9	1.8	0.07	44	6.3	2.25	3	0.5	0.14	6	1.3	0.31
	All		379	1257.84	627	1.4	0.02	3547	8.2	2.61	454	1.1	0.37	794	2.1	0.69
ODFW-B	2	1	20	53.45	7	0.4	0.01	24	1.2	0.45	3	0.2	0.06	114	5.7	2.13
		2	42	114.62	6	0.1	0.00	61	1.5	0.53	15	0.4	0.13	119	2.8	1.04
		3	43	91.05	14	0.3	0.00	77	1.8	0.85	43	1.0	0.47	69	1.6	0.76
		4	47	131.83	53	1.1	0.01	155	3.3	1.18	57	1.2	0.43	103	2.2	0.78
		5	58	160.95	124	2.1	0.01	546	9.4	3.39	95	1.6	0.59	145	2.5	0.90
		6	64	126.43	94	1.5	0.01	395	6.2	3.12	22	0.3	0.17	59	0.9	0.47
		7	58	152.42	105	1.8	0.01	534	9.2	3.50	106	1.8	0.70	134	2.3	0.88
		8	60	163.33	59	1.0	0.01	409	6.8	2.50	19	0.3	0.12	260	4.3	1.59
		9	58	158.10	87	1.5	0.01	425	7.3	2.69	18	0.3	0.11	140	2.4	0.89
		10	24	64.53	28	1.2	0.02	104	4.3	1.61	3	0.1	0.05	54	2.3	0.84
	All		474	1216.71	577	1.1	0.01	2730	5.1	1.98	381	0.7	0.28	1197	2.7	1.03
ODFW-C	3	6	9	26.35	5	0.6	0.02	160	17.8	6.07	21	2.3	0.80	53	5.9	2.01
		7	21	58.27	18	0.9	0.01	241	11.5	4.14	18	0.9	0.31	33	1.6	0.57
		8	24	254.42	31	1.3	0.02	1244	15.8	5.29	7	0.3	0.10	39	1.2	0.41
		9	82	71.45	75	0.9	0.00	378	15.2	4.89	6	0.1	0.02	29	0.5	0.15
		10	40	123.57	41	1.0	0.01	505	12.6	4.09	5	0.1	0.04	16	0.4	0.13
	All		176	534.06	170	0.9	0.01	2528	14.6	4.89	57	0.7	0.25	170	1.9	0.65
ALL		ALL	1392	4050.93	1688	0.8	0.09	10440	7.0	2.44	1036	0.6	0.23	2516	1.6	0.58

Appendix Table A-4.3. Total catch by family and species.

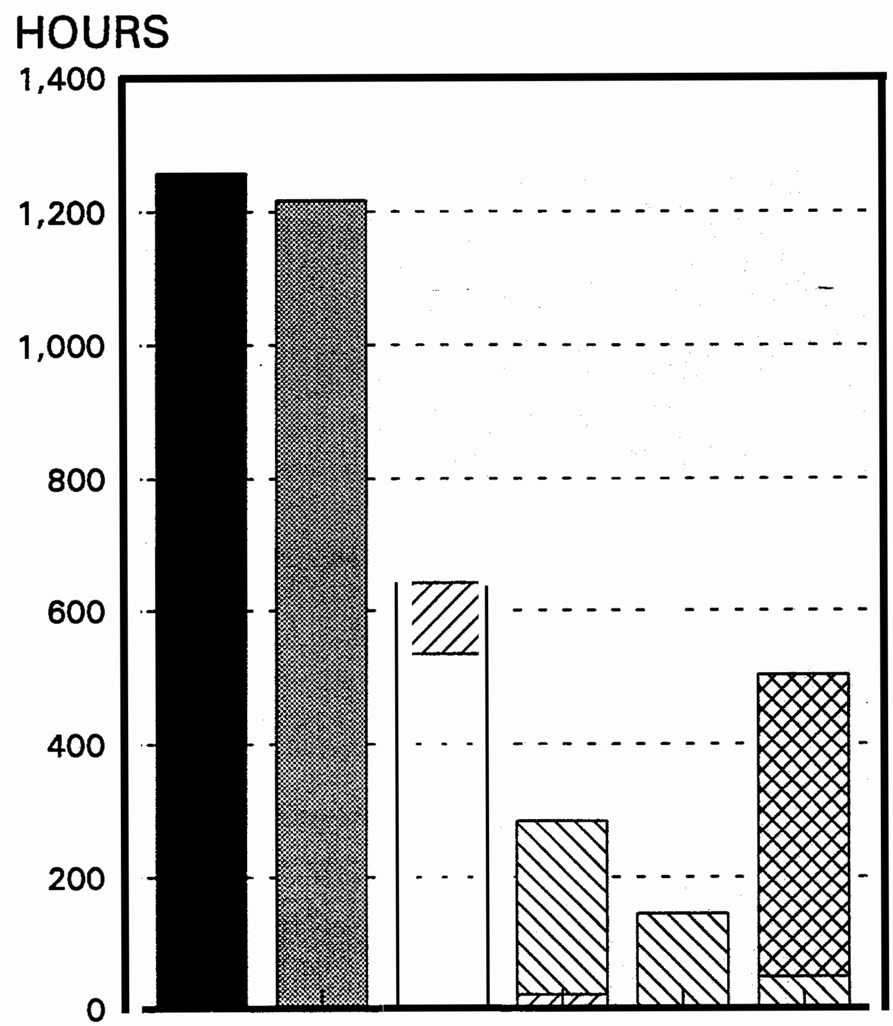
Family	Common Name	Scientific Name	Count	Subtotal	% Tot.Catch
Petromyzontidae (Lampreys)					
	Lamprey spp.		41		
				41	0.09
Acipenseridae (Sturgeons)					
	White Sturgeon	Acipenser transmontanus	8		
				8	0.02
Clupeidae (Herrings)					
	American Shad	Alosa sapidissima	1,500		
				1,500	3.27
Salmonidae (Salmons, Trouts, etc.)					
	Salmonid spp.		1,426		
	Chinook Salmon	Oncorhynchus tshawytscha	41		
	Sockeye Salmon	Oncorhynchus nerka	319		
	Steelhead	Oncorhynchus mykiss	730		
				2,516	5.49
Cyprinidae (Minnows)					
	Carp	Cyprinus carpio	147		
	Goldfish	Carassius auratus	6		
	Chiselmouth	Acrocheilus alutaceus	2,766		
	Redside Shiner	Richardsonius balteatus	3,234		
	N. Squawfish	Ptychocheilus oregonensis	10,440		
	Peamouth	Mylocheilus caurinus	17,571		
				34,164	74.59
Catostomidea (Suckers)					
	Sucker spp.		2,593		
	Largescale S.	Catostomus macrocheilus	5		
	Bridgeliop S.	Catostomus columbianus	52		
				2,650	5.72
Ictaluridae (Catfishes)					
	Channel Catfish	Ictalurus punctatus	74		
	Bullhead spp.		438		
	Yellow Bullhead	Ictalurus matalis	6		
	Brown Bullhead	Ictalurus nebulosus	15		
				533	1.16
Gasterosteidea (Sticklebacks)					
	Three-Spine Stickleback	Gasterosteus aculeatus	32		
				32	0.07
Percopsidea (Troutperches)					
	Sandroller	Percopsis transmontana	210		
				210	0.46

Appendix Table A-4.3. Continued.

Family	Common Name	Scientific Name	Count	Subtotal	% Tot.Catch
Centrarchidea (Sunfishes)					
	Sunfish spp.		416		
	Largemouth Bass	Micropterus salmoides	19		
	Smallmouth Bass	Micropterus dolomieui	45		
	Crappie spp.		1,508		
	Black Crappie	Pomoxis nigromaculatus	5		
	White Crappie	Pomoxis annularis	2		
	Warmouth Bass	Lepomis gulosis	1		
	Green Sunfish	Lepomis cyanellus	1		
	Bluegill	Lepomis macrochirus	182		
	Pumkinseed	Lepomis gibbosus	234		
				2,413	5.27
Percidae (Perches)					
	Walleye	Stizostedion vitreum vitreum	13		
	Yellow Perch	Perca flavescens	46		
				59	0.13
Cottidae (Sculpins)					
	Sculpin spp.		1,127		
				1,127	2.46
Pleuronectidea (Flounders)					
	Starry Flounder	Platichthys stellatus	29		
				29	0.06
Other					
	Unidentified Fish		1		
	Crayfish		520		
				521	1.14
			TOTAL	45,803	100.00

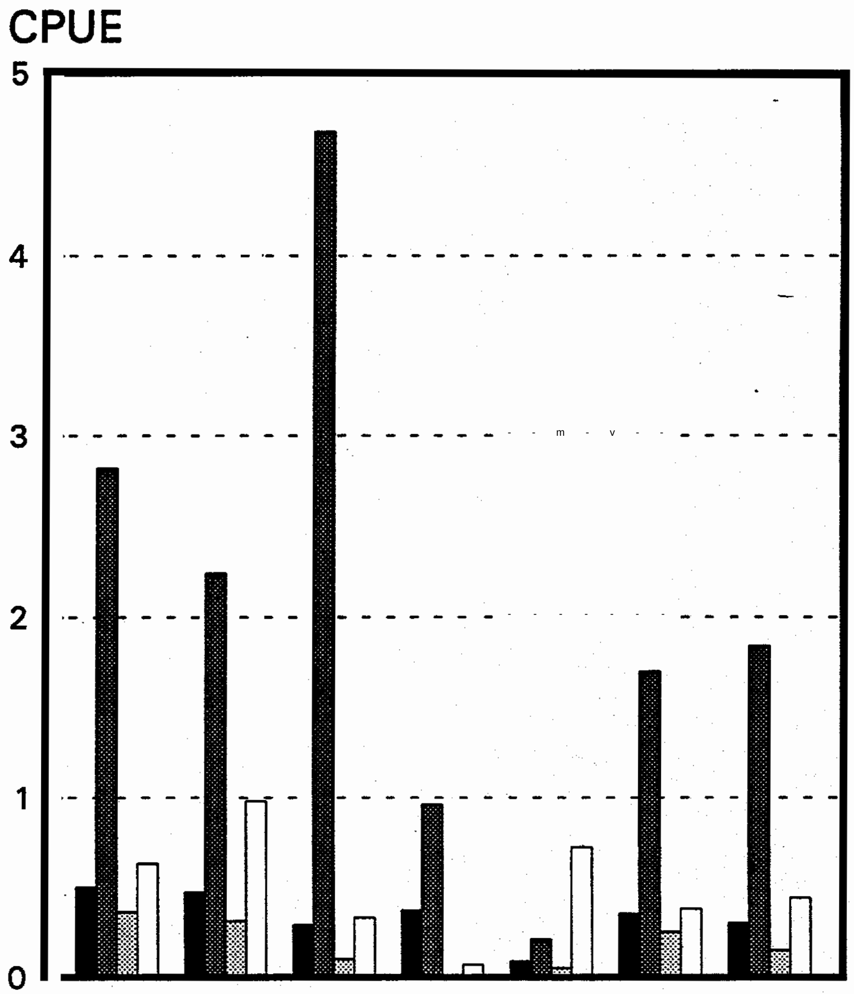
APPENDIX A-5

Result Figures



AREA	1	2	3	4	5	6
ODFW-A	1,257.83					
ODFW-B		1,216.72				
ODFW-C			534.05			
CTWSRO			107.62	21.03		
NPITI				264.08	143.00	47.53
CTUIR						455.43

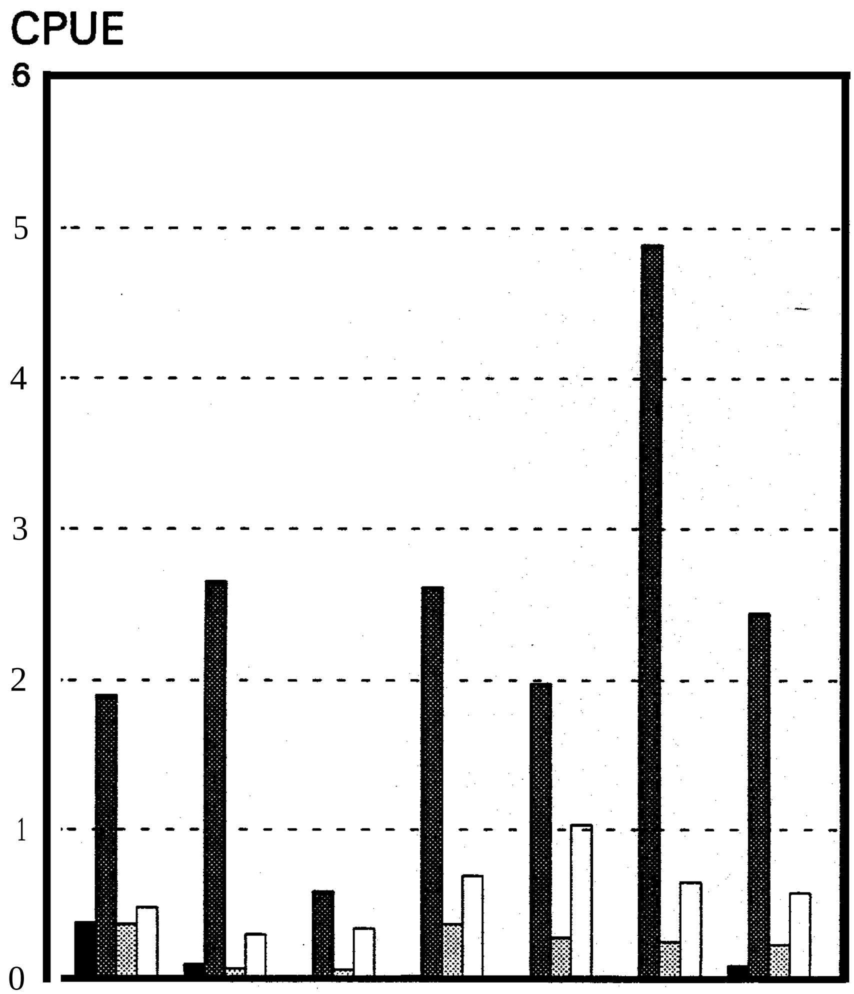
Appendix Figure A-5.1. Effort in hours by area and fishing crew.



AREA	1	2	3	4	5	6	ALL
NSQF(> 11")	0.50	0.47	0.29	0.37	0.09	0.35	0.30
NSQF(All)	2.82	2.24	4.68	0.96	0.21	1.70	1.84
SALM(Adult*)	0.36	0.31	0.10	0.01	0.05	0.25	0.15
SALM(All)	0.63	0.98	0.33	0.07	0.72	0.38	0.44

* Jacks included

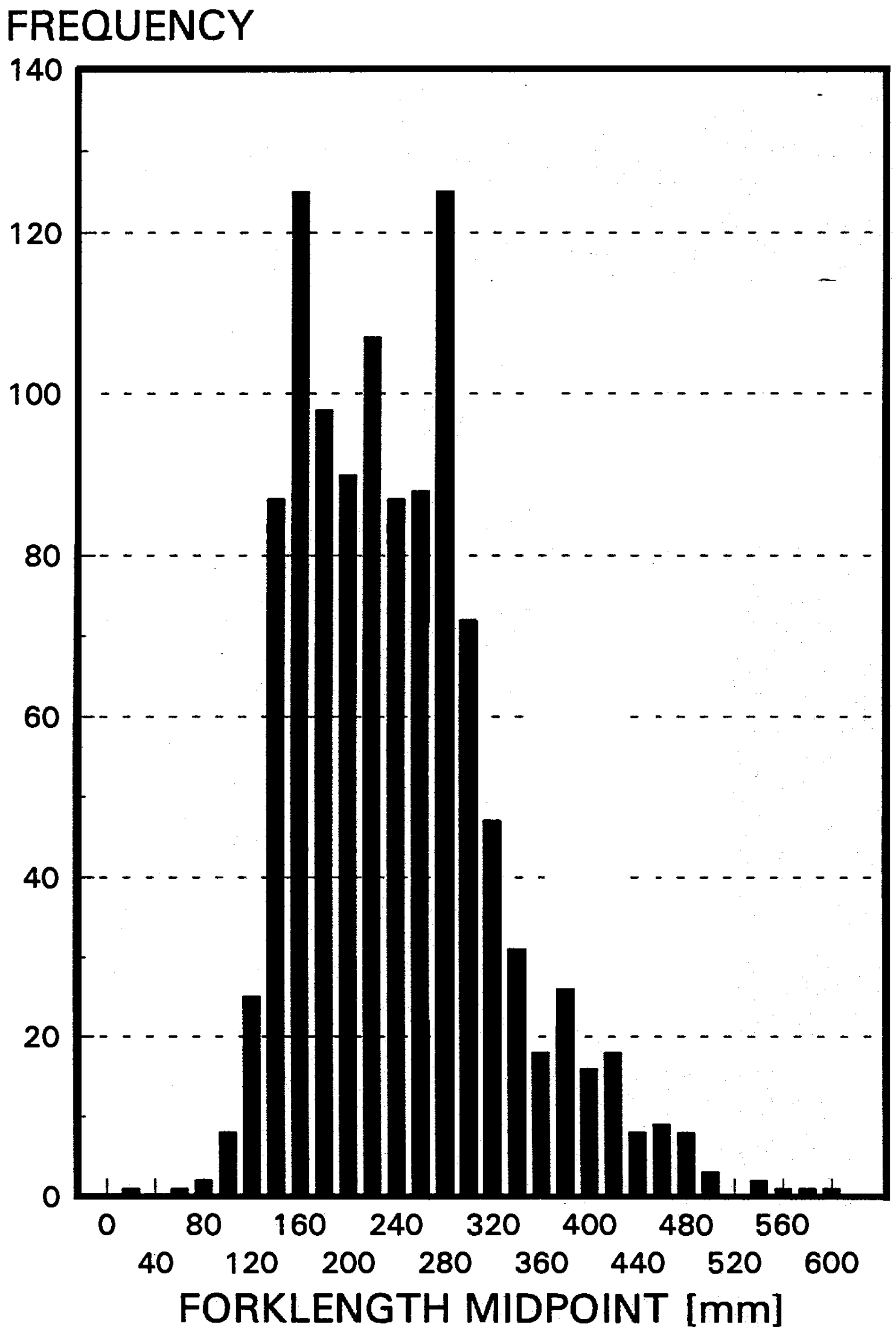
Appendix Figure A-5.2. Catch per unit of effort (CPUE) for northern squawfish and salmonids by area.



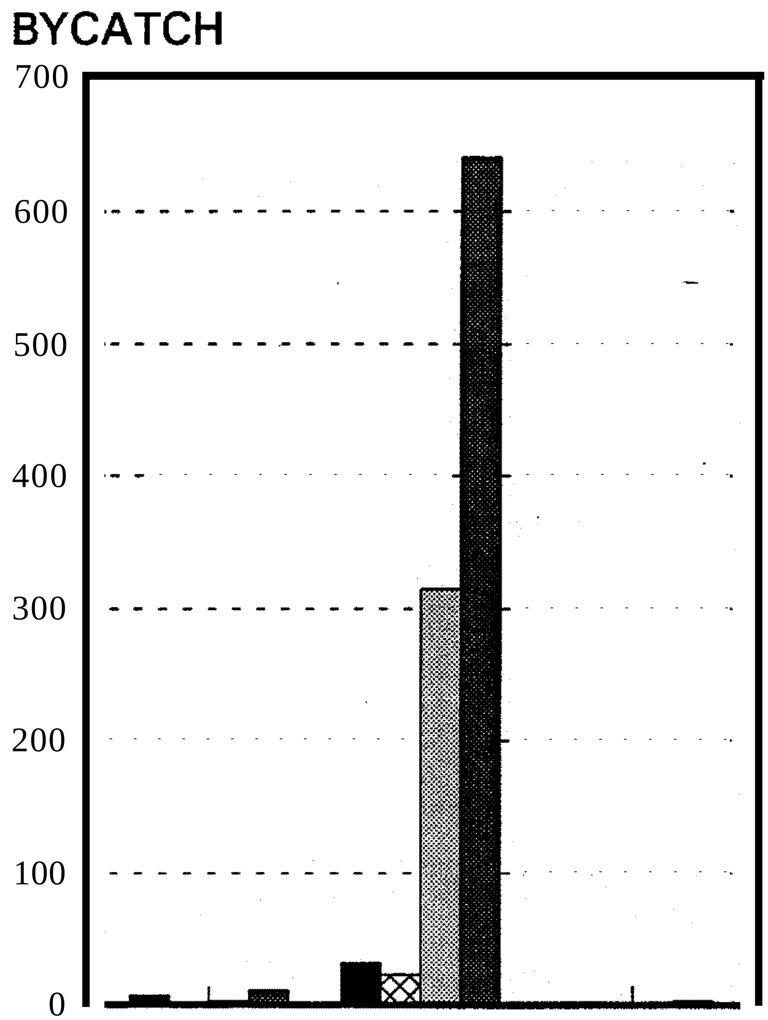
CREW	CTUIR	CTWSRO	NPITI	ODFW-A	ODFW-B	ODFW-C	ALL
NSQF(>11")	0.38	0.10	0.01	0.02	0.01	0.01	0.08
NSQF(All)	1.90	2.66	0.59	2.61	1.98	4.09	2.44
SALM(Adult*)	0.37	0.07	0.06	0.37	0.28	0.26	0.23
SALM(All)	0.48	0.30	0.34	0.09	1.03	0.66	0.58

* Jacks included

Appendix Figure A-5.3. Catch per unit of effort (CPUE) for northern squawfish and salmonids by fishing crew.

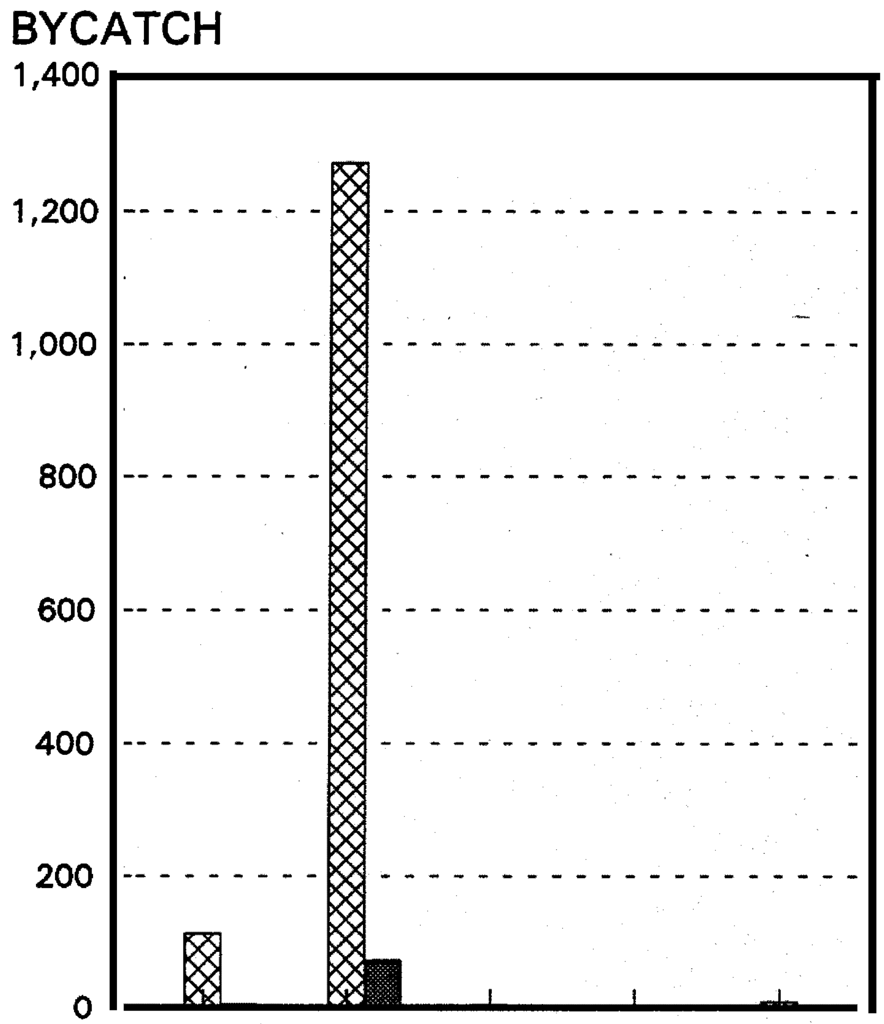


Appendix Figure A-5.4. Northern squawfish fork length frequency.



CONDITION		Not Recorded	Good	Fair
Chinook	■	7	32	
Unidentified	⊠	2	23	
Sockeye	c l	3	315	1
Steelhead	■	11	639	3

Appendix Figure A-5.5. Release condition of adult and jack salmonid bycatch.



CONDITION	Not Recorded	Good	Fair	Poor	Dead
Chinook		2			
Unidentified	113	1,271	4	3	9
Steelhead	5	72			

Appendix Figure A-5.6. Release condition of juvenile salmonid bycatch.

REPORT B

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

Prepared by

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1993 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 Fort Rains outlook, LePage Park, Hood Park, and the Greenbelt Boat Ramp. We thank the Washington Department of Transportation for the use of its facilities at the Vemita Rest Area. We thank the City of Rainier for the use of the Rainier Boat Ramp, the City of Richland for the use of Columbia Point Park, the Port of the Dalles for the use of the Dalles Boat Basin, the Port of Klickitat for the use of Bingen Marina, the Port of Cathlamet for the use of Cathlamet Marina, 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 Umatilla for the use of Umatilla Boat Ramp, the Port of Whitman County for the use of Boyer Park, the Port of Columbia County for the use of Lyons Ferry Marina, the Port of Camas/Washougal for the use of the Camas/Washougal Boat Ramp, and Multnomah County Parks Department for the use of its facilities at M.J. Gleason Park. We thank Sheila Cannon for the use of The Fishery at Covert's Landing.

We thank Jeff Adams, John Aleckson, Jack Anderson, Liane Anderson, Shawn Anderson, Peter Bergman, Lars Bergstrom, Tony Blaine, Jason Bradley, John Brady, Kathleen Byrd, John P. Brown, Scott Clark, Kathy Clawson, Mike Dawkins, Tom Dobbs, Angela Duling, Scott Fielding, Beverly Frantum, Kristi Gadwa, Bryce Glaser, Barbara Griggs, Evelyn Haase, Carrie Holmes, Maria Holmes, John Hone, Kevin Hooker, Kurt Hubbard, Lyle Jansma, Tyson Jerald, Mark Kramer, Shawna Lomen, John Maher, Matthew Marshall, Steve Martin, Merl May, Derrick Meaghers, Eric Meyer, Linda Moore, Robert Morgan, Kathleen Moyer, Bryan Murphie, Travis Nelson, Brian Pederson, Bob Phelps, Bill Rogers, Jeanne Pogue, Dean Selby, Steve Skorheim, Eric Schneider, Eric Soder, John Songster, Joe F. Steele, Shannon Stein, Howard Takata, Mark Thompson, Vicky Troastle, David Van Schoiack, Mark Wachtal, Russ Waitt, Rick Watson, Merrilynn Weeks, and Melvin Whittle for their work operating the sport-reward fishery registration stations.

We thank Carolyn Crandall, Conrad Dickson, Randy Drew, John Randall, Cynthia Rief, and Nickie Royse for computer data entry and verification of volumes of documents. We thank Dr. John Tarnai from Washington State University and Dr. Dale Everson from the University of Idaho for their input to the phone survey analysis. We thank Daylene Cahill, and Diane DuCommun for their numerous phone survey interviews and data entry. We give special thanks to Dennis Gilliland for overseeing data entry integrity and quality control along with computer programming and data base queries for analyses. We give special thanks to Stacie Kelsey for her organization and verification of weekly field data summaries along with scale and tag collection information. We give thanks to Janice Orr for her contributions in completing the annual report.

ABSTRACT

We report progress of the Northern Squawfish (*Ptychocheilus oregonensis*) Sport-Reward Fishery in the Columbia and Snake River basins for the period of May 3-September 12, 1993. Program parameters involved (1) registering anglers to participate; (2) issuing pay voucher/questionnaires to successful anglers; (3) collecting biological data on northern squawfish and other fish species turned in at the registration stations; (4) conducting a phone survey to assess non-returning anglers for trip specific information; (5) conducting a comparison study utilizing a computerized data collection unit verses manual data collecting; and (6) reporting the overall dynamics of the fishery.

A total of 104,536 northern squawfish were harvested and turned in to registration stations for reward payment ($3 per northern squawfish 11 inches or greater). A total of 34,879 registered angler days were spent fishing for northern squawfish. Of the total registered anglers, 43 % (15,106) returned to the registration stations for processing. An additional 7,786 northern squawfish under 11 inches were turned in (no payment was issued for northern squawfish less than 11 inches).

The 1993 season harvest of northern squawfish eligible for payment was 44% lower than in 1992 and 34 % lower than in 1991. Participation (effort) was 60% lower than in 1992 and 48% lower than in 1991. The catch per unit effort (CPUE, fish/angler day) in 1993 (2.46) was not significantly different ($P < 0{,}0905$) than the 1991 CPUE (2.37), but the CPUE for 1992 (2.74) was significantly different ($P < 0.0001$) from 1991 and 1993.

Fork lengths were measured from 75,219 northern squawfish of which 68,797 had a fork length measurement greater or equal to 250 mm (approximately 11 inches total length). The overall mean fork length of northern squawfish greater or equal to 250 mm was 334.7 mm (S.D. 61.6). We observed a statistically significant decrease in mean fork length from 1991 to 1993 for all reservoirs combined.

A total of 2,100 fish other than northern squawfish were brought to the registration stations from registered anglers for data collection (2.0% of all fish species returned). Peamouth chub (*Mylocheilus caurinus*) accounted for the highest reported harvest (702) of the game fish species. A total of 493 smallmouth bass (*Micropterus dolomieui*), 202 channel catfish (*Ictalurus punctatus*), and 12 1 walleye (*Stizostedion vitreum*) were observed at the registration stations.

The comparison study to assess the use of a computerized data collection unit verses manual data collection concluded that the computerized data entry system was significantly faster than manual data processing for the exit interview and biological data collection process, but computerized data entry was not significantly faster than manual'data processing for the registration process. Biological data collection could be entered approximately twice as fast using the computerized system.

A phone survey was used to address fishing trip information for non-returning anglers. Contacts were made to 1,744 (8.8%) of the 19,758 non-returning registered anglers. A recall bias study was conducted for returning anglers to estimate the accuracy of anglers' responses to phone survey questions. The recall bias study found anglers' average responses to questions concerning past fishing trips to be accurate. Marked differences were observed in the proportions of other fish species caught between the phone survey data and actual returning angler data.

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 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 on the harvest of 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 fork length). 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 for each northern squawfish 11 inches or longer (Burley et al. 1992). The sport-reward test fishery started 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 general objective of this project was to implement the sport-reward fishery for northern squawfish at 18 registration stations on the Washington and Oregon shores in the lower Columbia and Snake rivers from May 3-September 12, 1993. Specific objectives were to register participating anglers in the fishery, issue vouchers for payment to successful anglers, collect biological data on northern squawfish and other fish species caught and turned into the registration stations, and to report on the inseason dynamics of the fishery. Changes in mean fork length of northern squawfish caught in 1991, 1992 and 1993 were compared to determine if the average size of northern squawfish caught was decreasing. The feasibility of using a phone survey to collect information from non-returning registered anglers, and a comparison study between computerized data collection and manual data collection were also tested.

METHODS

Study Area

The sport-reward fishery for northern squawfish was conducted on the Columbia River from the mouth to the boat-restricted zone of Priest Rapids Dam, and on the Snake River from the mouth to the boat-restricted zone of Hells Canyon Dam. 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. Eighteen registration stations were located on the lower Columbia and Snake rivers (Figure 1).

A "tailrace" was defined as the section of river immediately below a dam. A "forebay" was defined as the section of river immediately above a dam. A "reservoir" was defined as the section of river from the tailrace of an upstream dam to the forebay of the next dam downstream, except for the section of river below Bonneville Dam, which ranged from the tailrace of Bonneville Dam to the mouth of the Columbia River.

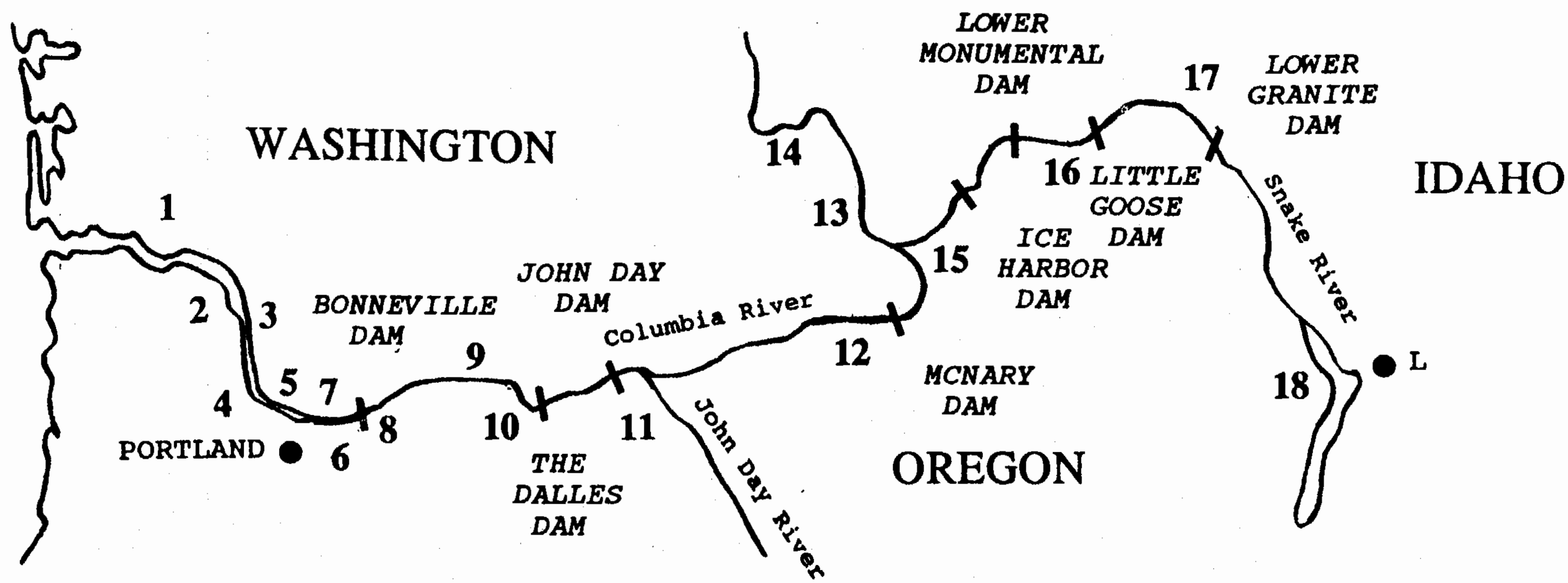
Field Procedures

New state regulations were implemented in 1993 to improve the processing of angler information and to reduce opportunities for fraud. Angler compliance rules were adopted as follows:

A. Each angler must register in person, prior to fishing, at one of the registration stations each fishing day. A fishing day is a 24-hour period from 9:01 p.m. through 9 p.m. of the following day.

B. Each angler, in person, must exchange their eligible northern squawfish for a voucher between the hours 9 a.m. and 9 p.m. at the same registration station where the angler is registered during the same fishing day.

C. To be eligible for a voucher, each northern squawfish must be 11 inches or longer in total length and presented in fresh condition or alive.



1.	Cathlamet (WA)	7.	Hamilton Island (WA)	13.	Columbia Point (WA)
2.	Rainier (OR)	8.	Cascade Locks (OR)	14.	Vernita (WA)
3.	Kalama (WA)	9.	Bingen (WA)	15.	Hood Park (WA)
4.	Gleason (OR)	10.	The Dalles (OR)	16.	Lyons Ferry (WA)
5.	Camas (WA)	11.	LePage (OR)	17.	Boyer Park (WA)
6.	The Fishery (OR)	12.	Umatilla (OR)	18.	Greenbelt (WA)

Figure 1. Location of the Northern Squawfish Sport-Reward Fishery registration stations on the Columbia and Snake rivers during the 1993 field season.

D. Anglers shall provide information regarding their catch as requested by department personnel at the registration site and mail-in survey forms.

E. Anglers shall obtain a Washington, Oregon, or Idaho state fishing license to fish for northern squawfish and must use a single rod, reel and line with up to three hooks with no more than three points.

Several fish species in Washington were classified as game fish in 1993. These included northern squawfish (*Ptychocheilus oregonensis*); peamouth chub (*Mylocheilus caurinus*); bridgelip sucker (*Catostomus columbianus*); largescale sucker (*Catostomus microps*); and longnose sucker (*Catostomus catostomus*).

Registration Interview

Washington Department of Fish and Wildlife (WDFW) technicians were present to register anglers from 9 a.m. to 9 p.m. seven days per week. Anglers could self-register at a registration box near the site between 9:01 p.m. and 8:59 a.m. A short registration form was completed to record information pertinent to the anglers fishing day.

Exit Interview

Upon completion of fishing, anglers were requested to return to the same station where they registered. A WDFW technician retrieved the angler's 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), 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 verified and 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 and mail it to the Pacific States Marine Fisheries Commission (PSMFC) in Portland. Sport-reward payment was funded by the Bonneville Power Administration (BPA).

Biological Data Collection

Fish brought to the registration station by registered anglers were sampled for biological data when time permitted. 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.

Biological data collected for northern squawfish catches numbering 30 or fewer consisted of a fork length, weight and scale sample. Complete biological data were then taken on every fifth northern squawfish (fork length, weight, scale sample, and sex determined by opening up the fish). Catches greater than 30 northern squawfish were subsampled for fish species and fork length. Every fifth fish was sampled for species, length, weight, and scales. By dissecting the northern squawfish for sex determination, the fish became a "poor" quality grade due to the body fluids and internal organ exposure. In an effort to increase "food grade" northern squawfish, every 10th fish had species, length, weight, scale, and sex data collected in a 30 plus fish scenario. Other fish species brought to the site were processed for biological data then returned to the angler. Technicians would record biological data on all tagged fish. Complete biological information on all tagged fish was provided to the Oregon Department of Fish and Wildlife (ODFW) on a weekly basis.

Mean fork lengths were compared for statistically significant differences among reservoirs using a general linear model for analysis of variance.

Northern Squawfish Processing

All reward-size northern squawfish were tail clipped to indicate processing by a WDFW technician. Each northern squawfish was graded according to guidelines provided by Oregon State University (OSU) to determine whether a fish would be processed as "food-grade" or "fertilizer-grade" fish. Food-grade fish were placed on ice in insulated coolers marked "good" and fertilizer-grade fish were placed in insulated coolers marked "poor." At the end of each shift, technicians delivered the fish to a designated facility for processing or storage by facility personnel. Empty coolers and ice were picked up by technicians for the next day.

RESULTS

Northern Squawfish Harvest Data

The 1993 overall harvest of northern squawfish eligible for payment (11 inches or longer) was 104,536 fish. Participation (effort) associated with this harvest amounted to 34,879 angler days yielding a systemwide catch per unit effort (CPUE) of 2.46 (fish/angler day). In addition, 7,786 northern squawfish less than 11 inches were returned (no payment was issued for northern squawfish less than 11 inches).

The systemwide mean weekly harvest was 5,506 northern squawfish with a range of 2,566 to 10,381 fish (Figure 2). The mean angler effort by week was 1,836 angler days and ranged from 885 to 2,792 angler day (Figure 2). The mean CPUE was 2.46 fish/angler day with a range of 1.11 to 3.44 fish/angler day by week (Figure 2).

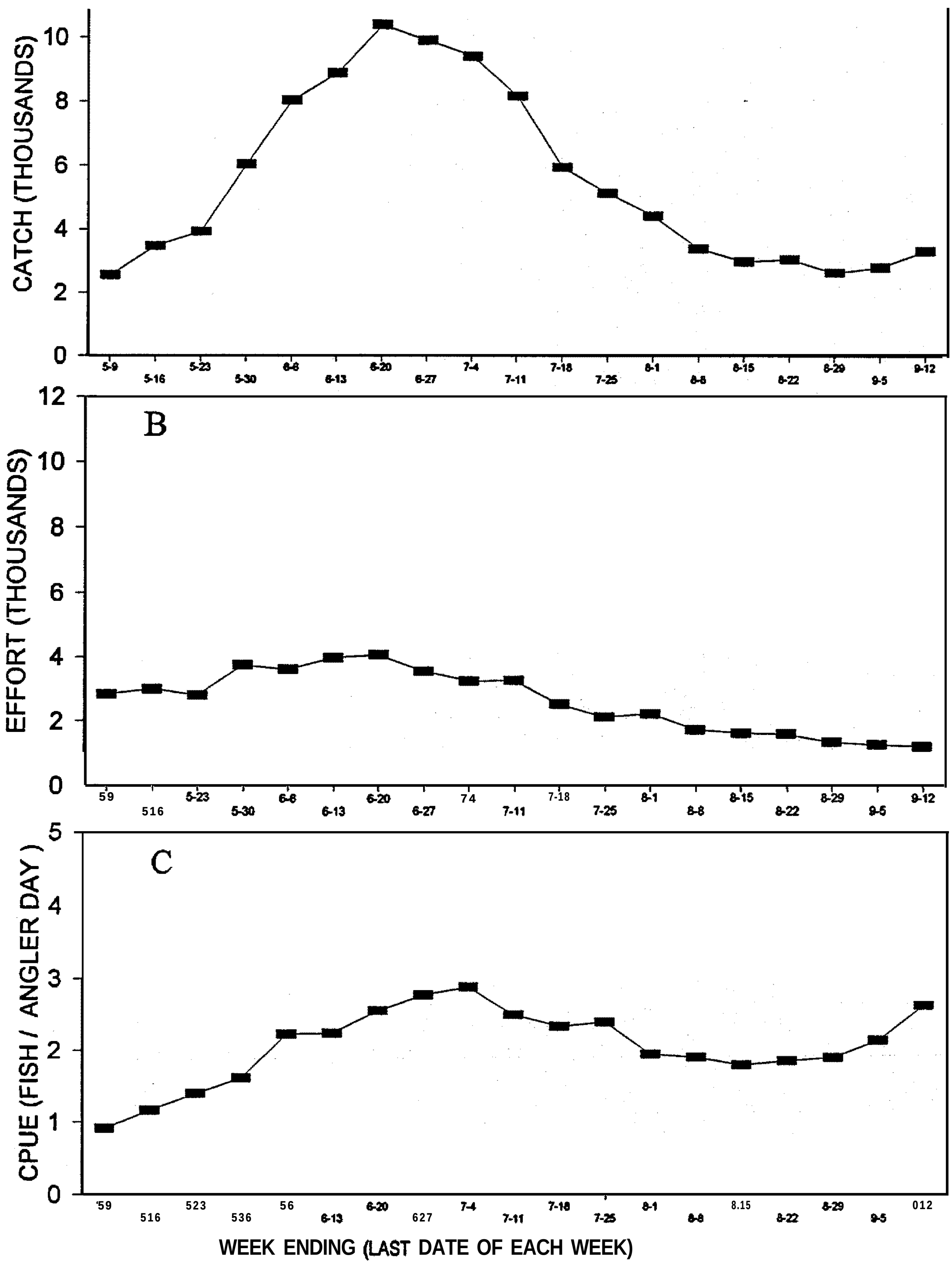


Figure 2. Sport-reward fishery data by week for 1993. A - Northern squawfish catch by week for 1993. B - Effort (angler days) by week for 1993. C - CPUE (fish / angler day) by week for 1993.

Harvest ranged from 1,076 northern squawfish in John Day Reservoir to 48,707 in the Bonneville tailrace (Figure 3). There was no registration station in Ice Harbor Reservoir in 1993, however, the reservoir was open to participation and a harvest of 45 northern squawfish was recorded. Effort in registered returning angler days (fishing location could only be recorded for anglers returning to the stations) ranged from 24 in Ice Harbor Reservoir to 10,838 in Bonneville Tailrace. The average CPUE by reservoir was 5.02 fish/returning angler day. The CPUE ranged from 1.95 fish/returning angler day in John Day Reservoir to 9.04 fish/returning angler day in McNary Reservoir (Figure 3).

All nine reservoirs in 1993 showed a decrease in harvest when compared with 1992 reservoir data. The largest decrease in harvest from 1993 to 1992 was in the Bonneville tailrace (30,689 northern squawfish). Eight of the nine reservoirs showed reduced harvest when compared to the 1991 reservoir data. The largest decrease in harvest from 1993 to 1991 was in The Dalles Reservoir (24,814 northern squawfish). McNary Reservoir was the only reservoir to show an increase in harvest (11,786 northern squawfish) in 1993 compared to 1991.

The mean catch of northern squawfish per registration station was 5,807 fish and ranged from 1,000 fish at Umatilla Boat Ramp to 16,308 fish at The Fishery (Figure 4). The mean effort (angler days) by registration station was 2,779 and ranged from 1,315 angler days at Boyer Park to 4,720 at Greenbelt Boat Ramp (Figure 4). The mean CPUE by registration station was 2.46 fish/angler day and ranged from 0.67 fish/angler day at Umatilla Boat Ramp to 5.39 fish/angler day at The Fishery (Figure 4).

Ten of the 18 registration stations in 1993 were operated in 1991 and 1992. All 10 stations showed decreases in harvest of northern squawfish. The lo-station comparison to 1992 harvest showed LePage Park to have the largest decrease in harvest of 21,498 northern squawfish. The Fishery (Covert's Landing) had the largest decrease in 1993 in comparison to 1991 of 24,366 fish (Table 1).

Northern squawfish catch was highest (27,180 fish) in Fishing Location 10 (Appendix Table B-l), which extends from the tailrace of Bonneville Dam downstream to Reed Island. The catch from Fishing Locations 10 (27,180), 9 (12,604), and 16 (10,334) accounted for approximately 48% of the total catch of northern squawfish eligible for payment (Appendix Tables B l-3). The top one-third, which represented 17 fishing locations, that produced the highest catch ranged from 27.180 to 1,423 northern squawfish and accounted for approximately 88% of the total catch of northern squawfish eligible for payment. Effort was also highest in Fishing Locations 10 (4,547), 9 (3,502), and 16 (1,477; Appendix Tables B 4-6), but CPUE was highest in Fishing Locations 31 (23.4), 30 (14.79) and 32 (11.03; Appendix Tables B 7-9).

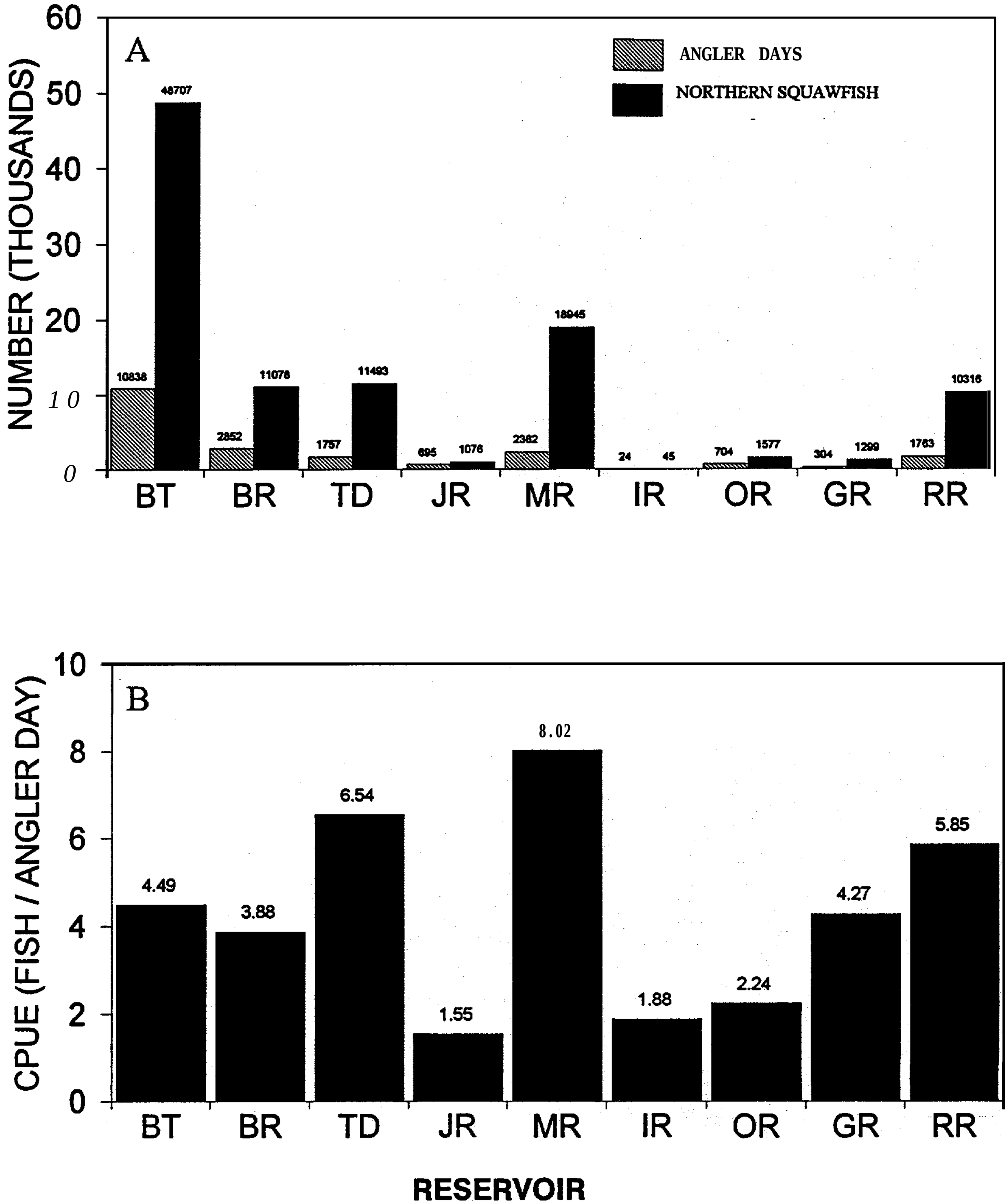


Figure 3. Sport-reward fishery data by reservoir for 1993. A - Effort (angler days) and northern squawfish catch by reservoir for 1993. B - CPUE (fish / angler day) by reservoir for 1993. BT - Bonneville Tailrace, BR - Bonneville Res., DR - The Dalles Res., JR - John Day Res., MR - McNary Res., IR - Ice Harbor Res., OR - Lower Monumental Res., GR - Little Goose Res., RR - Lower Granite Res.

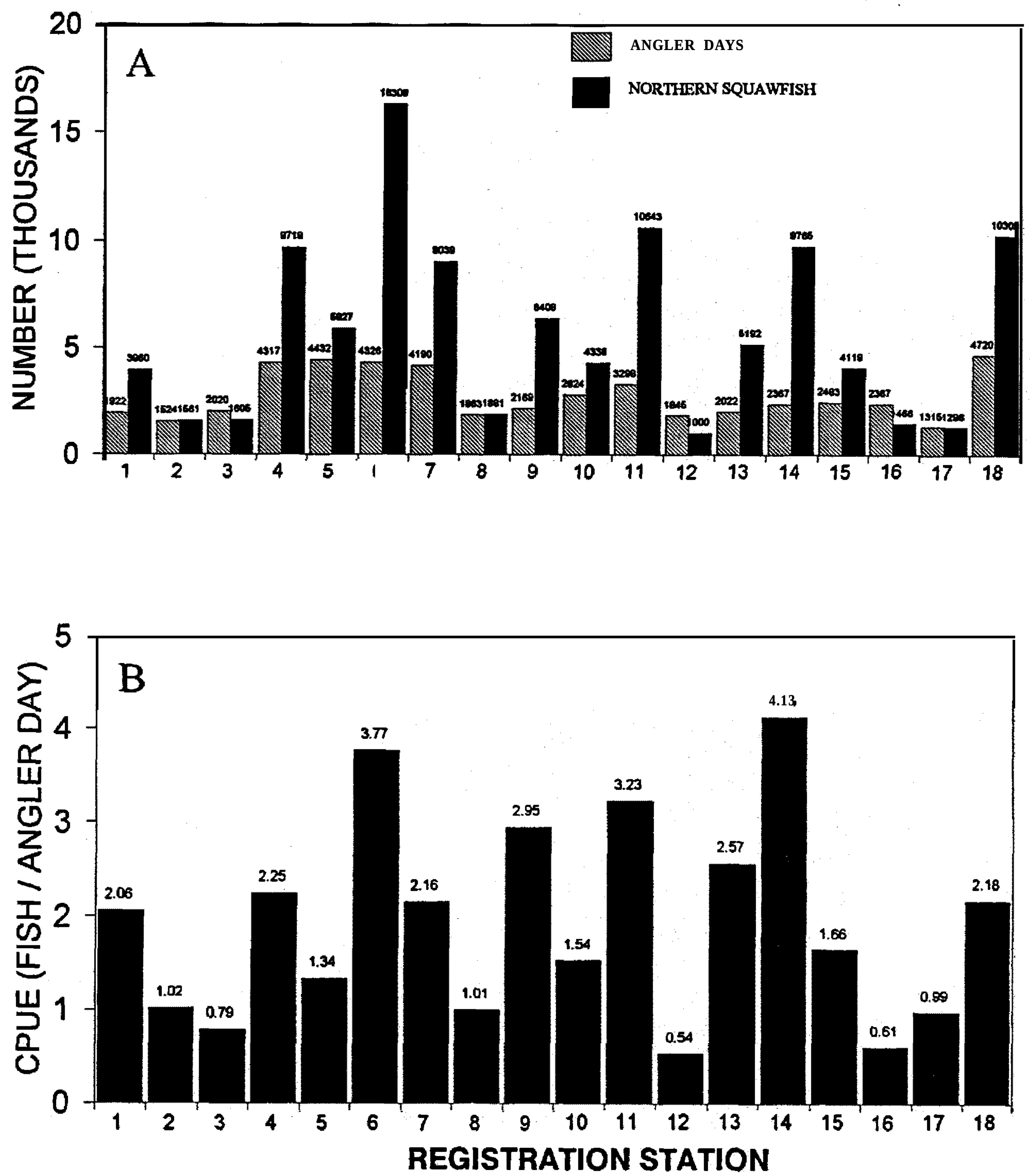


Figure 4. Sport-reward fishery data by registration station for 1993. A - Effort (angler days) and northern squawfish catch by registration station for 1993. B - CPUE (fish / angler day) by registration station for 1993. 1 - Cathlamet, 2 - Rainier, 3 - Kalama, 4 - Gleason, 5 - Camas, 6 - The Fishery, 7 - Hamilton, 8 - Cascade Locks, 9 - Bingen, 10 - The Dalles, 11 - LePage, 12 - Umatilla, 13 - Columbia Park, 14 - Vernita, 15 - Hood Park, 16 - Lyons Ferry, 17 - Boyer Park, 18 - Greenbelt.

Table 1. Comparison of registration stations during the 1991 (May 27-September 30), 1992 (May 18-September 30), and 1993 (May 3-September 12) seasons for northern squawfish harvest greater than 11 inches.

Station	1991	1992	1993
Hamilton Island	18219	17048	9126
The Fishery	40674	23851	16308
Cascade Locks	9143	6779	1881
Bingen Marina	12711	12513	6408
Dalles Boat Basin	3828[1]	6806	4338
LePage Park	32141	16926	10643
Columbia Point Park	1104[1]	11148	5192
Hood Park	3676[1]	9199	4119
Lyons Ferry	4211’	3131	1466
Greenbelt Boat Ramp	17466	21333	10309
Kalama Marina	--	6799	1605
Gleason Boat Ramp	--	15494	9719
Boyer Park	--	5875	1296
Cathlamet Marina	--	--	3960
Rainier Boat Ramp	--	--	1561
Camas/Washougal Boat Ramp	--		5920
Umatilla Boat Ramp	--	--	1000
Vemita Rest Area	--	--	9765
Maryhill State Park	1001[1]	5074	
Plymouth Boat Ramp	5556	2414	--
Windust Park	919[1]	--	--
Central Ferry State Park	7845	--	--
Chief Timothy State Park	1048	--	--
Willow Grove Park	--	5676	--
Marine Park (Portco)	--	8637	--
Ringold	--	5139	--
Bayport Marina	--	1606	--

[1] Stations did not open until July 15, 1991.
-- Not in operation.

A total of 75,219 northern squawfish were sampled for fork length in 1993. The mean length for all reservoirs combined was 326.6 mm (Figure 5). Mean lengths ranged from 309 mm in Bonneville Reservoir to 362.1 mm in The Dalles Reservoir (Figures 6-8). The range of fork lengths with the highest frequency that contained approximately 50% of the northern squawfish catch was 250-325 mm (53% of catch) for the Bonneville tailrace, 250-300 mm (63% of catch) for Bonneville Reservoir, 326425 mm (49% of catch) for The Dalles Reservoir, 326425 mm (39% of catch) for John Day Reservoir, 276-375 mm (46% of catch) for McNary Reservoir, 276-350 mm (54% of catch) for Ice Harbor Reservoir, 276-325 mm (66% of catch) for Lower Monumental Reservoir, 300-350 mm (69% of catch) for Little Goose Reservoir, and 300-400 mm (44% of catch) for Lower Granite Reservoir (Figures 6-8).

The northern squawfish catch for 1991, 1992 and 1993 peaked prior to July 15 in all years (Figure 9). The 1992 catch (186,904) was 79% greater than the 1993 catch (104,616) and 17% greater than the 1991 catch (159,162). The catch from each of the first -five weeks in 1992 was approximately 20,000 northern squawfish, which represented the major difference between the 1991-1992 catch and the 1993-1992 catch (Figure 9).

Effort (88,495 angler days) in 1992 was 154% greater than the 1993 effort (34,879 angler days) and 31% greater than the 1991 effort (67,384 angler days). Effort in 1992 was approximately three times greater than either 1991 or 1993 in the first five weeks of the fishery, which represented the major difference between the 1991-1992 effort and the 1993-1992 effort (Figure 9).

The mean CPUE for 1991 (2.37) was found to be significantly lower ($P<0.0001$) than the mean CPUE in 1992 (2.74) and the mean CPUE for 1993 (2.46) was found to be significantly lower ($P<0.0001$) than the mean CPUE for 1992 (2.74). The mean CPUE for 1991 (2.37) was not found to be significantly different ($P<0.0905$) than 1993 (2.46). CPUE peaked prior to July 15 in all three years (Figure 9).

A total of 68,797 fork lengths of northern squawfish greater than or equal to 250 mm were taken during the 1993 season, 119,437 during the 1992 season, and 59,650 during the 1991 season. The mean fork length for all reservoirs combined was 327 mm in 1993, 344 mm in 1992, and 349 mm in 1991. A statistically significant decrease in mean fork length was found between 1991-1992 ($P<0.0001$), 1992-1993 ($P<0.0001$) and 1991-1993 ($P<0.0001$).

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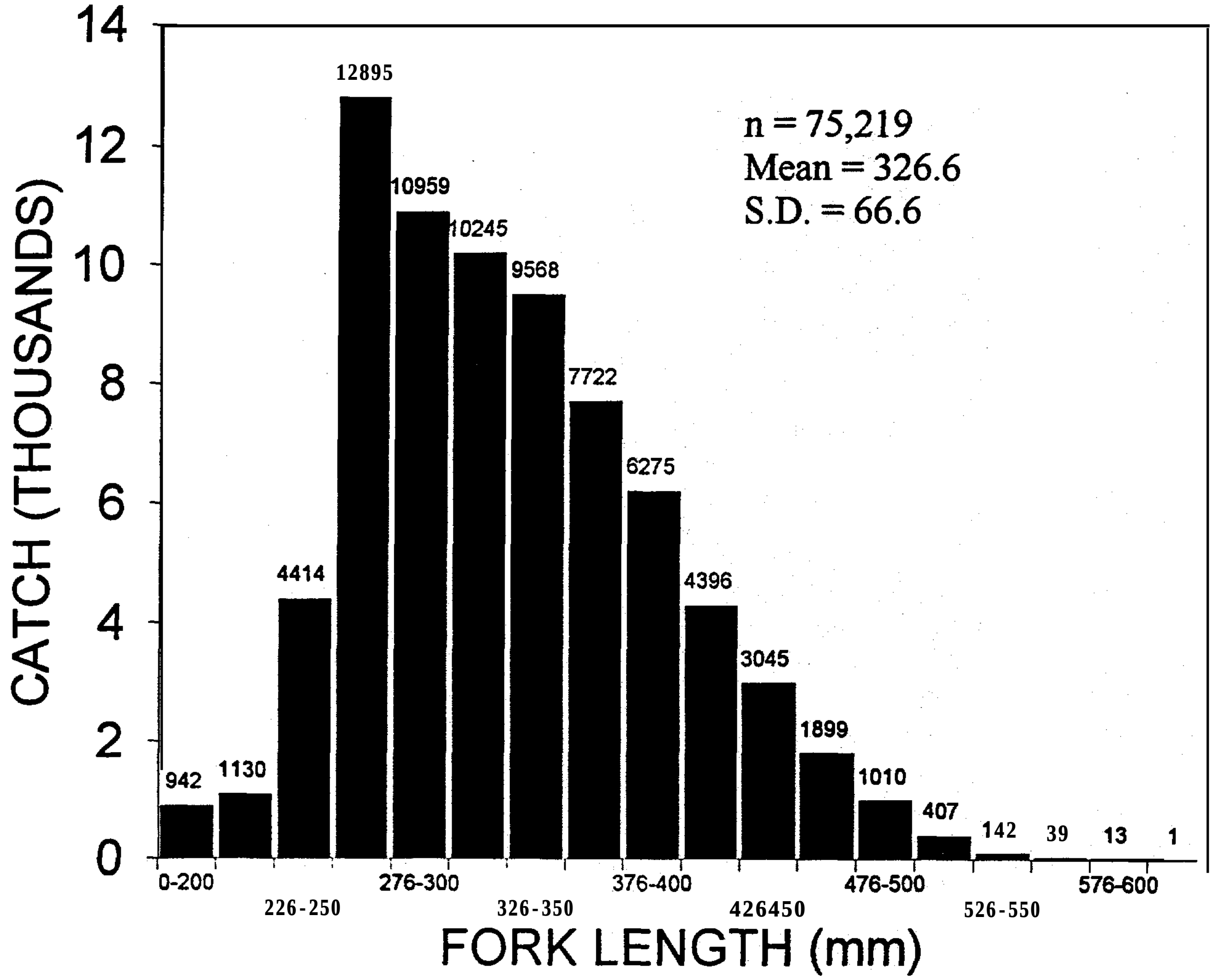

Figure 5. Overall length frequency distribution of northern squawfish sampled for fork length in the sport-reward fishery for 1993.

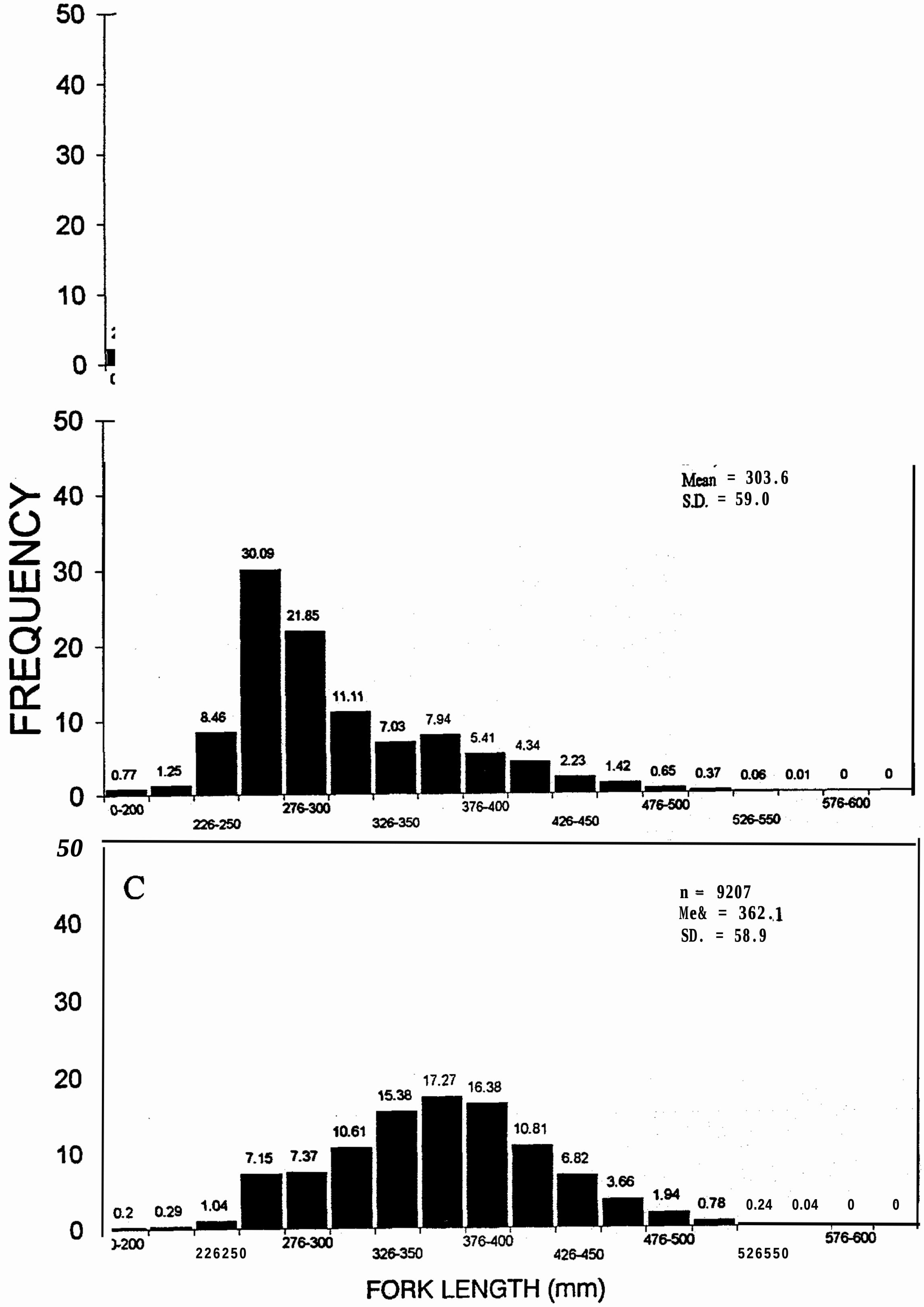

Figure 6. The percent of northern squawfish sampled in 25 mm length intervals by reservoir for 1993. A - Bonneville Tailrace. B - Bonneville Reservoir. C - The Dalles Reservoir.

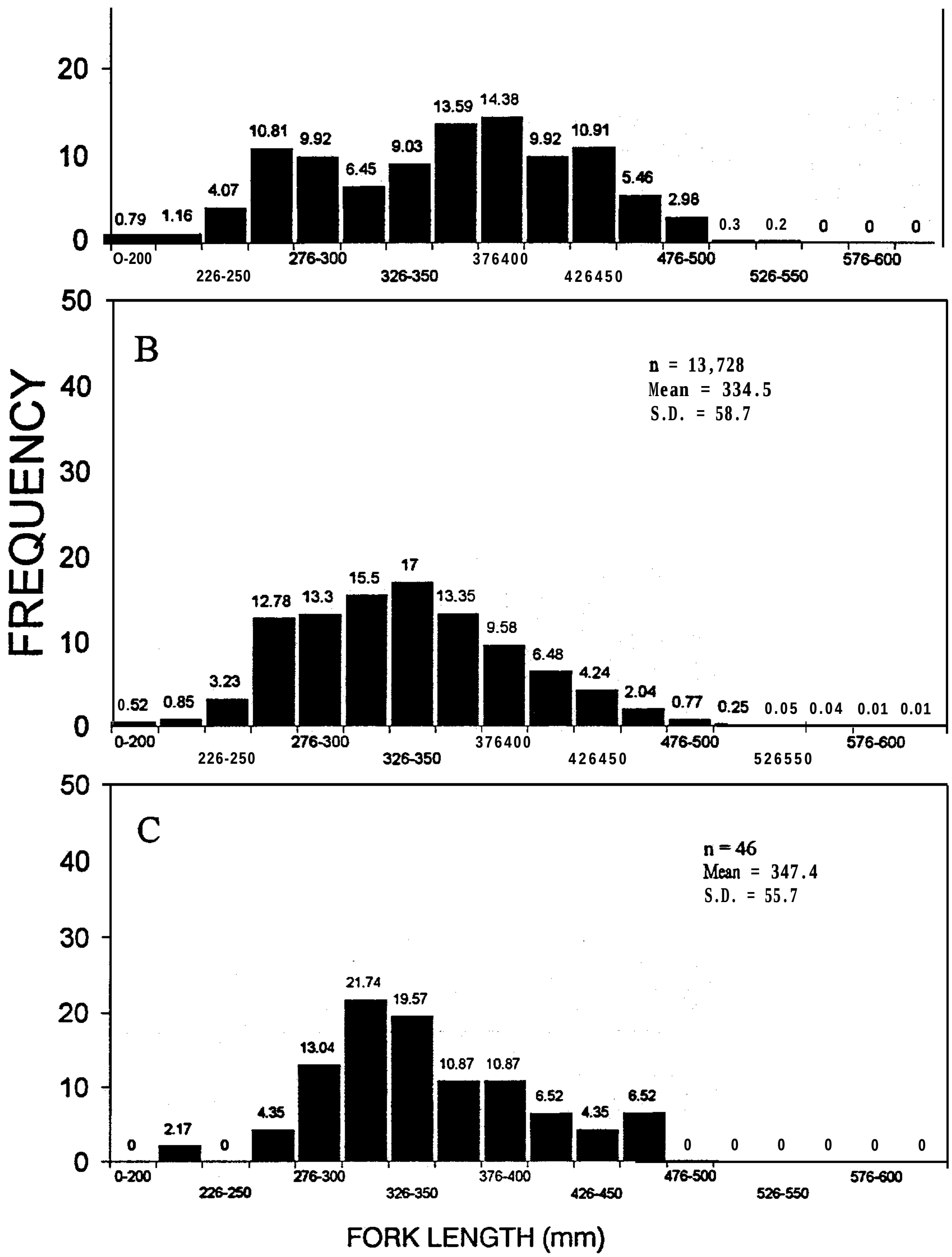

Figure 7. The percent of northern squawfish sampled in 25 mm length intervals by reservoir for 1993. A - John Day Reservoir. B - McNary Reservoir. C - Ice Harbor Reservoir.

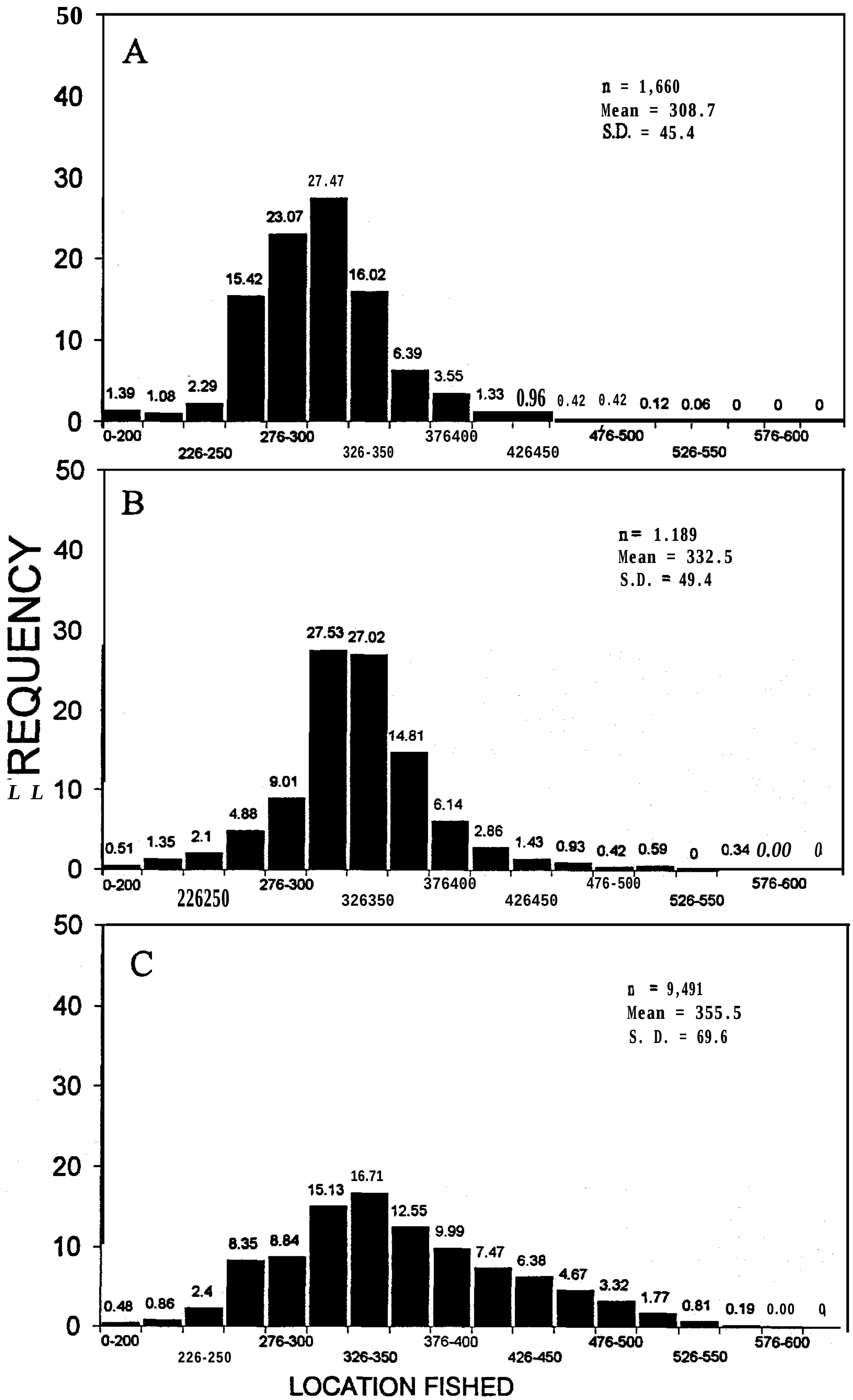

Figure 8. The percent of northern squawfish sampled in 25 mm length intervals by reservoir for 1993. A - Lower Mounumental Reservoir. B - Little Goose Reservoir. C - Lower Granite Reservoir.

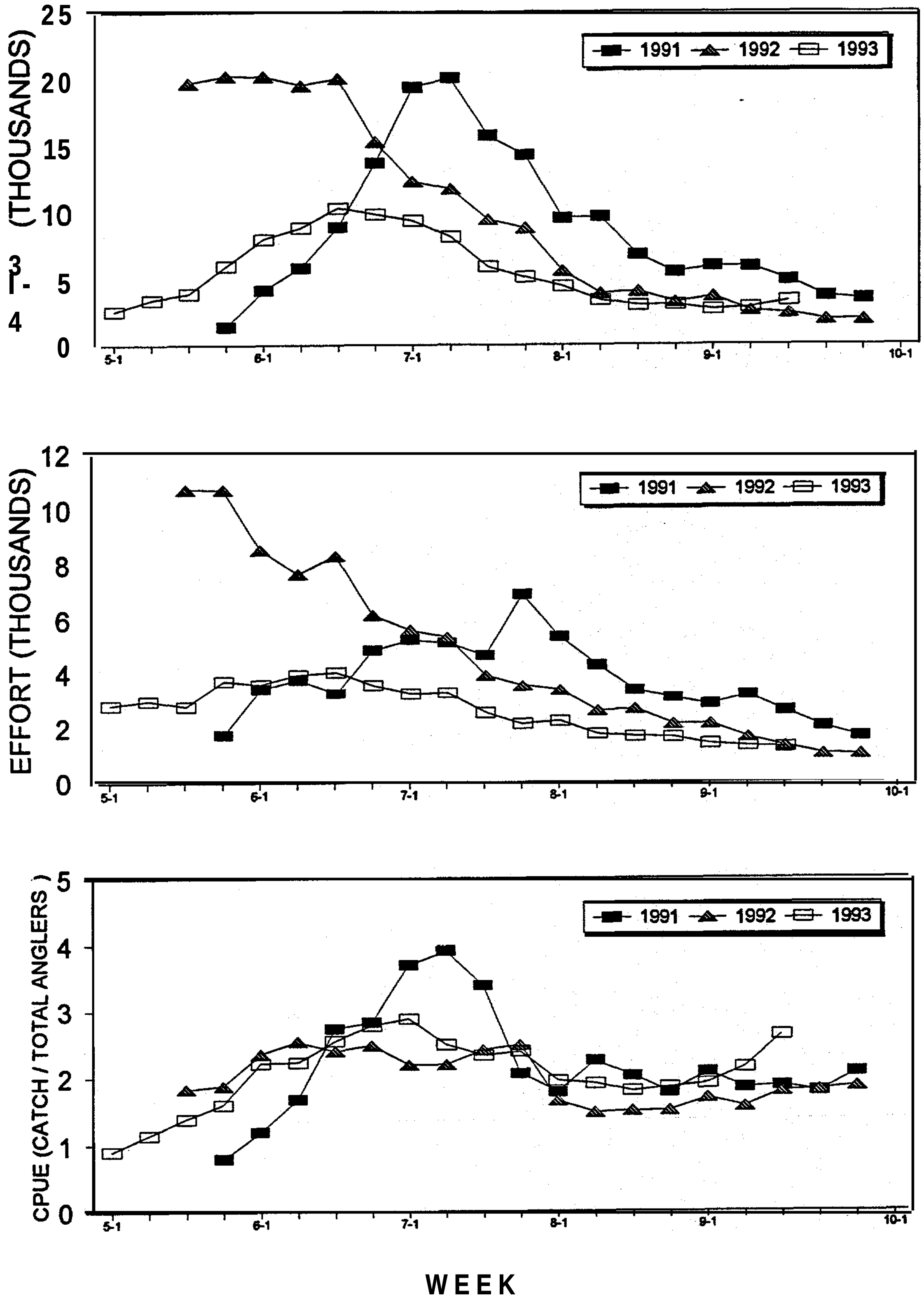

Figure 9. Comparison of the sport-reward fishery catch data by week for 1991, 1992, and 1993. A - Catch by week. B - Effort (angler days) by week. C - CPUE (fish / angler day) by week.

We observed that five out of nine reservoirs showed a statistically significant decrease in mean fork length from 1991 to 1993 (Table ***2).*** Little Goose Reservoir, John Day Reservoir and Ice Harbor Reservoir showed no significant change in mean fork lengths from 1991 to 1993. The model was not significant $(P<0.7)$ for the mean fork length comparison in John Day Reservoir even though the lsmeans test $(P<0.0275)$ did show a significance decrease in mean fork length between 1991 and 1993. The mean fork length in Ice Harbor Reservoir did decrease from 361 mm to 350 mm, but the 1993 sample size of 45 fish was too small to give an accurate estimate. No registration station operated in Ice Harbor Reservoir for the 1993 season. Lower Granite Reservoir showed a statistically significant increase in mean fork length from 1991 to 1993.

Game, Food, and Unclassified Fish Species Catch Data

A total of 2,100 fish other than northern squawfish were turned into the registration stations by returning anglers (Table 3). We observed a harvest of 702 peamouth chub (*Mylocheilus caurinus*) which was the most observed of the game fish species. There were 493 smallmouth bass (*Micropterus dolomieui*) harvested, followed by 202 channel catfish ***(Ictalurus punctatus,)*** and 121 walleye ***(Stizostedion vitreum).*** We also observed harvest of a suspected hybrid between the northern squawfish and chislemouth chub ***(316*** fish). These fish were termed "Columbia River chub" for reporting purposes.

Harvest of fish species other than northern squawfish were examined in regards to an angler's target species. Peamouth chub were returned to the check stations more frequently than any other fish species, other than northern squawfish. All peamouth chub were caught incidental to the program. Smallmouth bass, channel catfish and walleye are popular game fish. Seventy-one percent of the 493 smallmouth bass harvested were taken by anglers targeting smallmouth bass. Of the 202 channel catfish harvested, 66% were targeted; 76% of the 121 walleye harvested were targeted.

The 2,100 fish, other than northern squawfish, harvested by registered anglers in 1993 was 249 fish less than the 1992 season (2,349) and 258 less than the 1991 season (2,358; Table 4). Warmwater species accounted for the majority of the harvest.

Table 2. Mean fork length comparison of 1991, 1992, and 1993 (Pr > [t] estimates the probability of the mean fork length being significantly different from 1991 to 1993).

Reservoir	Year	n	mean	Pr > [t]
Bonneville Tailrace	1991	9698	341	
	1992	41842	334	0.0001
	1993	28047	321	
Bonneville	1991	7550	349	
	1992	8457	353	0.0001
	1993	6481	310	
The Dalles	1991	8563	371	
	1992	17043	364	0.0001
	1993	9101	364	
John Day	1991	2821	371	
	1992	2508	370	0.0275
	1993	956	365	
McNary	1991	4701	356	
	1992	17024	350	0.0001
	1993	13197	339	
Ice Harbor	1991	890	360	
	1992	4565	362	0.2419
	1993	45	350	
Lower Monumental	1991	3642	319	
	1992	2897	309	0.0001
	1993	1586	313	
Little Goose	1991	1902	337	
	1992	4748	330	0.8650
	1993	1147	337	
Lower Granite	1991	19122	348	
	1992	19464	350	0.0001
	1993	9150	360	
Combined Totals	1991	59650	350	
	1992	119437	346	0.0001
	1993	68797	335	

Table 3. Total of all species of fish excluding northern squawfish turned in to the registration stations during 1993.

Common Name	Scientific Name	Code	Total
American shad	*Alosa sapidissima*	AMS	28
Bridgelip sucker	*Catostomus columbianus*	BRS	20
Brown bullhead	*Ictalurus nebulosus*	BBH	7
Bullhead (general)	*Ameiurus spp.*	BH	10
Carp	*Cyprinus carpio*	CP	7
Channel catfish	*Ictalurus punctatus*	CC	202
Chinook Salmon	*Oncorhynchus tshawytscha*	CK	5
Chiselmouth	*Acrocheilus alutaceus*	CMO	87
Coho Salmon	*Oncorhynchus kisutch*	CO	1
Columbia River chub[1]		CRC	316
Crappie (general)	*Pomoxis spp.*	C	4
Largemouth bass	*Micropterus salmoides*	LMB	2
Largescale sucker	*Catostomus microps*	LRS	7
Peamouth	*Mylocheilus caurinus*	PMO	702
Pumpkinseed	*Lepomis gibbosus*	PS	1
Rainbow trout(res.)	*Oncorhynchus mykiss*	RB	7
Rainbow trout(unk.)	*Oncorhynchus mykiss*	RU	2
Sandroller	*Percopsis transmontana*	SAN	1
Sculpin (general)	*Cottus spp.*	COT	1
Sculpin, Torrent	*Cottus rhotheus*	TRS	1
Searun cutthroat	*Oncorhynchus clarki*	SCT	2
Smallmouth bass	*Micropterus dolomieui*	SMB	493
Starry flounder	*Platichthys stellatus*	SF	2
Steelhead (summer)	*Oncorhynchus mykiss*	SS	20
Steelhead (unknown)	*Oncorhynchus mykiss*	SH	3
Sucker (general)	*Catostomus spp.*	SK	3
Trout (unknown)	*Oncorhynchus spp.*	TR	5
Walleye	*Stizostedion vitreum*	WAL	121
White crappie	*Pomoxsis annularis*	WC	1
Whitefish, mtn.	*Prosopium williamsoni*	WF	3
White sturgeon	*Acipenser transmontanus*	WS	11
Yellow bullhead	*Ictalurus natalis*	YBH	9
Yellow perch	*Perca flavescens*	YP	16
Total			2100

[1] Probable northern squawfish/chiselmouth hybrid; named "Columbia River chub" for reporting purposes.

Table 4. Yearly totals of all species of fish excluding northern squawfish turned in to the registration stations.

Common Name	Code	1991	1992	1993
American shad	AMS	6	54	28
Black crappie	BC	44	3	0
Bluegill	BG	3	3	0
Bridgelip sucker	BRS	9	8	20
Brown bullhead	BBH	8	18	7
Bullhead (general)	BH	4	4	10
Bull trout	BLC	‘1	0	0
Carp	CP	6	19	7
Channel catfish	c c	453	141	202
Chinook Salmon	CK	0	7	5
Chiselmouth	CMO	106	139	87
Chum salmon	CH	0	1	0
Coho Salmon	c o	0	0	1
Columbia River chub’	CRC	192	125	316
Crappie (general)	C	23	3	4
Cutthroat trout	CT	5	0	0
Largemouth bass	LMB	3	9	2
Longnose sucker	LNS	0	1	0
Large-scale sucker	LRS	4	11	7
Peamouth	PMO	368	588	702
Pumpkinseed	PS	1	2	1
Rainbow trout (res.)	RB	25	9	7
Rainbow trout (unk.)	RB	20	113	2
Redside shiner	RS	1	2	0
Sandroller	SAN	0	0	1
Sculpin (general)	COT	2	10	1
Sculpin, Prickly	PRS	0	1	0
Sculpin, Torrent	TRS	0	0	1
Searun cutthroat	SCT	0	1	2
Smallmouth bass	SMB	770	693	493
Sockeye salmon	s o	0	2	0
Starry flounder	SF	2	9	2
Steelhead (summer)	s s	10	40	20
Steelhead (unknown)	SH	18	9	3
Steelhead (winter)	SW	1	13	0

Table 4. Continued.

Common Name	Code	1991	1992	1993
Sucker (general)	SK	11	21	3
Tench	TNC	1	0	0
Trout (unknown)	TR	0	0	5
Walleye	WAL	184	231	121
Warmouth	WM	2	0	0
White crappie	WC	20	0	1
Whitefish, mountain	WF	3	5	3
White sturgeon	w s	9	17	11
Yellow bullhead	YBH	0	0	9
Yellow perch	YP	43	36	16
Totals		2358	2349	2100

[1] Probable NSF/CMO hybrid; named "Columbia River chub" for this report.

DISCUSSION

Northern Squawfish Harvest Data

Harvest varied by week in 1991, 1992 and 1993, but the peak harvest occurred prior to July 15 in all years. Northern squawfish aggregate in spawning areas prior to spawning (Patten and Rodman 1969). Anglers have informally reported to technicians that northern squawfish feed more aggressively prior to spawning in the Columbia and Snake rivers from mid-May until mid-July, which would make them more vulnerable to catch and explain why the harvest peaks prior to July 15. Water conditions such as temperature can also affect the spawning time of northern squawfish (Patten and Rodman 1969). Variation in spawning time among years could partially explain the variation in the timing of peak catch among years (Figure 9). Anglers participating in the 1993 program often complained to technicians that the high and turbid water conditions, along with the frequent rain, were decreasing their participation in the program. Angler effort in 1993 was lower than effort in 1991 and 1992, which was the major factor contributing to the low catch in 1993. The catch and catch-per-unit-effort were higher in 1992 than 1991 or 1993 (Figure 9) because 1992 was the only year that effort was high in the beginning of the field season prior to spawning. High angler effort prior to July 15 will be necessary to produce high catches in future sport-reward program field seasons.

The decrease in the 1993 effort was not due to reservoir specific factors since effort (returning angler days) by reservoir in 1993 decreased in all nine reservoirs when compared to 1992 data. When the 1993 data was compared to 1991, McNary Reservoir showed the only increase in effort (613 returning angler days) while the other eight reservoirs showed reduced effort.

In evaluating the number of registration stations and their placement for the 1994 sport-reward fishery, we used three variables: (1) overall harvest of northern squawfish by registration station, (2) the reservoir specific predation index values, and (3) the current annual exploitation of northern squawfish in that reservoir. Boyer Park, in Little Goose Reservoir, Lyons Ferry Marina in Lower Monumental Reservoir, Cascade Locks in Bonneville Reservoir, and Rainier Boat Ramp in Bonneville Tailrace were excluded from the 1994 fishery since the closure of these stations would have the least impact on the overall goal to achieve a 10-20% exploitation rate systemwide and still allow for the required budget reductions. By request from the Corps of Engineers, Lepage Park (John Day Reservoir) will be relocated to Giles French Boat Ramp (The Dalles Reservoir). We do have some concerns that closing stations will eliminate or greatly reduce harvest in Lower Monumental and Little Goose reservoirs, as was the case in Ice Harbor Reservoir during the 1993 fishery (Windust Park was eliminated).

Registration station operations should be reduced to one shift a day from 1 p.m. to 9 p.m. seven days per week to maximize participation while reducing overall costs of the program. Data from past years indicated that 70% of the anglers participating in the program would not have to change the normal time they turn in fish under the proposed change in hours of operation. Self registration will be available during unstaffed hours and the 30% of anglers that will have to adjust their schedules will hopefully continue participation in the program.

It is unclear if the reduction in mean fork length found in northern squawfish returned to the sport-reward fishery represents a change in the mean fork length of the respective populations of northern squawfish or if those changes could be attributed to increased exploitation. Other factors such as changes in northern squawfish year-class strength, sport-reward fishery sample not being representative of the true northern squawfish population, mixing of northern squawfish between reservoirs, or illegally caught northern squawfish could cause changes in mean fork length. A significant decrease in mean fork length in five out of nine reservoirs and a significant decrease in overall mean fork length may indicate that exploitation lowered the average size of northern squawfish and thereby reduced predation on juvenile salmonids (Table 2). Continued monitoring of the sport-reward fisheries mean fork length along with ODFW's analysis of year-class strength estimates should confirm if the observed fork length decreases were representative of the population.

The overall exploitation rate systemwide for the three harvest techniques (sport-reward, dam-angling, and trap net) was 8.54% (Zimmerman et al., unpublished data). The sport-reward fishery was shown to be the most successful northern squawfish harvest technique since the program was responsible for 79% of total, systemwide exploitation. The program goal of 10-20% exploitation was not reached, but the current level of participation in the sport-reward program was achieved with no organized promotion. An organized promotional campaign, implemented at the beginning of the field season, could help to achieve the exploitation goals. Additional incentives to increase participation should be addressed in 1994 by incorporating an aggressive media campaign (on and off season), organized derbies, tournaments, and lottery type events.

The Washington Department of Fish and Wildlife in coordination with the Oregon Department of Fish and Wildlife have taken steps to codify rules and regulations for the sport-reward fishery. We will be reviewing the regulations to evaluate the effectiveness of current guidelines and apply adjustments to the 1994 sport-reward fishery where necessary.

Changing the time for the field season by itself does not sufficiently increase catch since the 1993 sport-reward fishery began and ended two weeks earlier (May 3-September 12) than the 1992 season (May 18-September 30) and the 1993 fishery began three weeks earlier and ended two weeks earlier than the 1991 season (May 27-September 30). The adjustment in field season timing will only be effective if increased angler participation can also be achieved, especially during the time prior to northern squawfish spawning.

Game, Food, and Unclassified Fish Species Catch Data

The 1993 phone survey estimates of the non-returning anglers' catch was higher for every species than the proportional estimate obtained from the number of fish observed at the registration stations. Technicians are required to observe the fish caught by returning anglers before recording them in the catch data. Anglers are in a hurry when they return to the registration stations and often do not wish to take the time to show all of their catch. The anglers' potential unwillingness to show their entire catch could account for the discrepancy between the telephone survey catch estimates and the registration station catch data. We feel the phone survey reflects a more accurate account of other fish species harvested. The harvest on other fish species is currently at low levels, but we need continued monitoring of this trend through angler exit interviews and the phone survey to aid in obtaining information on harvest of ESA listed species as well as non-listed species.

Recommendations For 1994 Sport-Reward Fishery Season

1. The timing of the fishery should be similar to last year's early May through mid-September schedule.

2. Field operations should be limited to one shift per day (e.g., 1 p.m. - 9 p.m.) seven days per week. Self registration should continue to be available during unstaffed hours.

3. Location and number of registration stations should be placed systemwide in areas that will contribute and maintain targeted systemwide exploitation rates to reduce salmonid losses due to predation while reducing the budget. Specifically, eliminate Boyer Park, Lyons Ferry Marina, Cascade Locks Marina, and Rainier Boat Ramp.

4. Relocate LePage Park registration station to Giles French Boat ramp.

5. Discontinue the use of the computerized data collection unit due to limited success and efforts to reduce budget.

6. Continue a streamlined phone survey to address the non-returning angler in relation to other fish species harvest and registration station personnel interactions.

7. Implement an aggressive public relations effort to increase awareness of the program and increase participation.

8. Coordinate with outside groups to conduct supplemental incentive programs to increase participation in the fishery.

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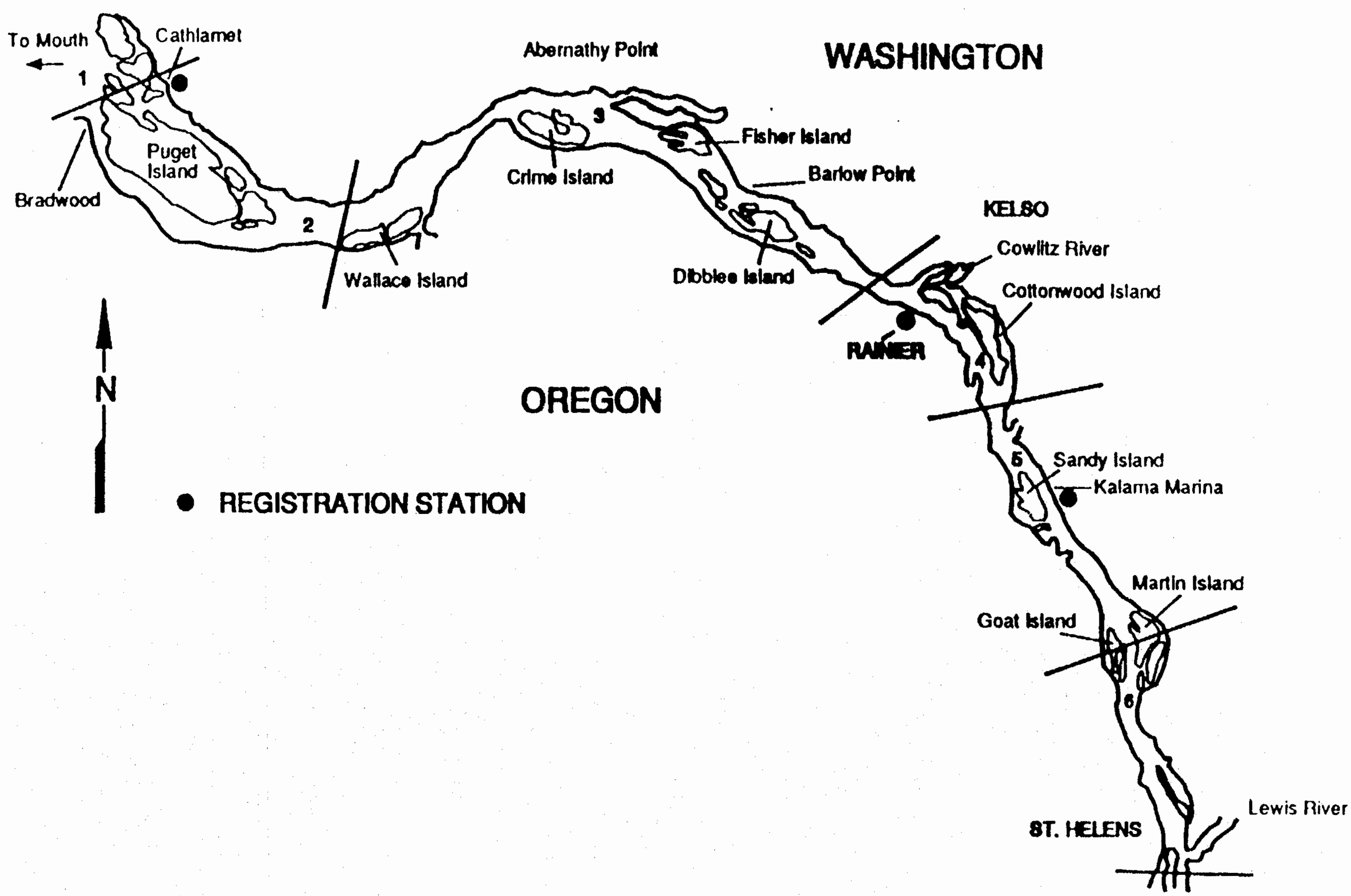
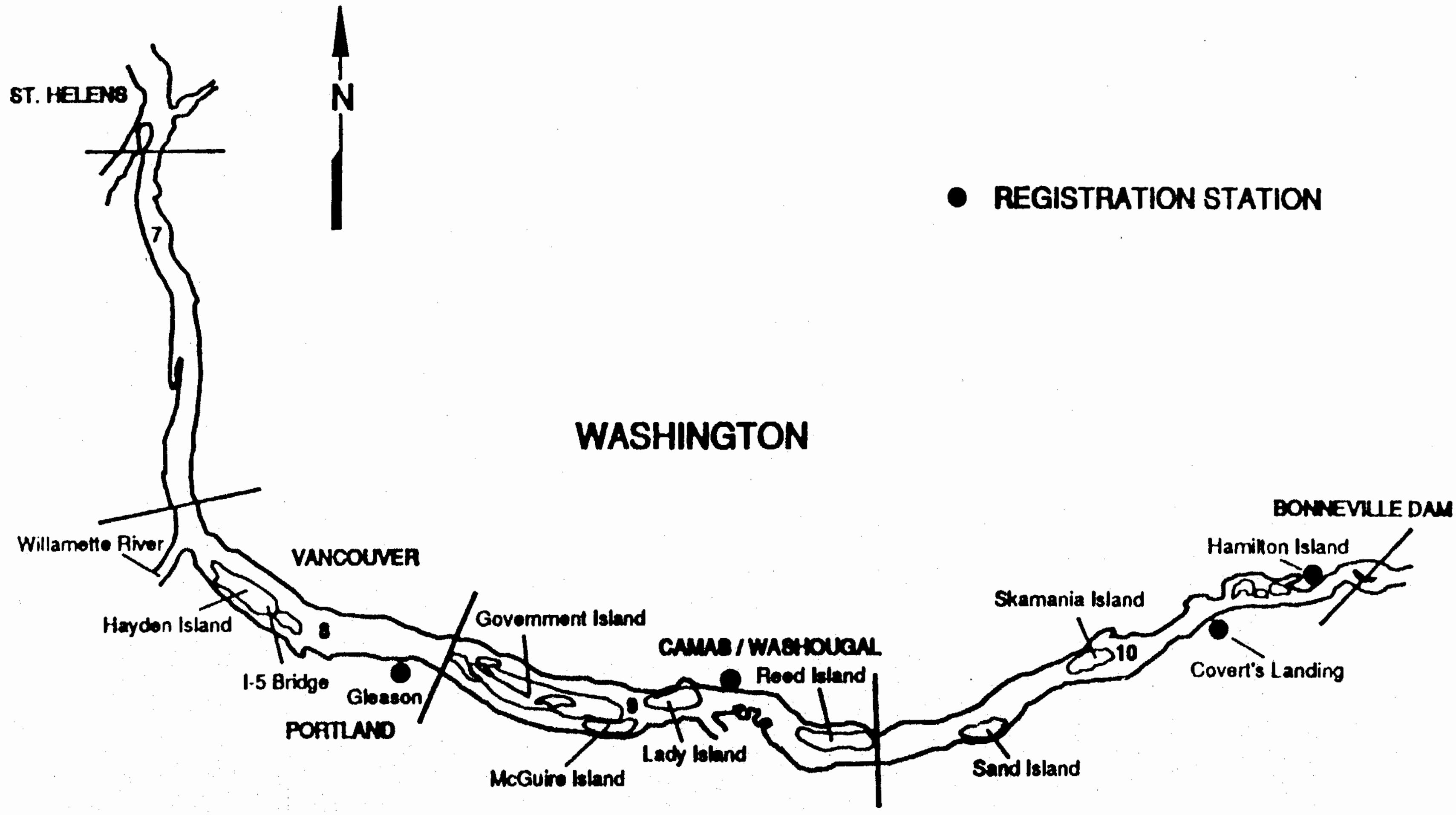
APPENDIX A

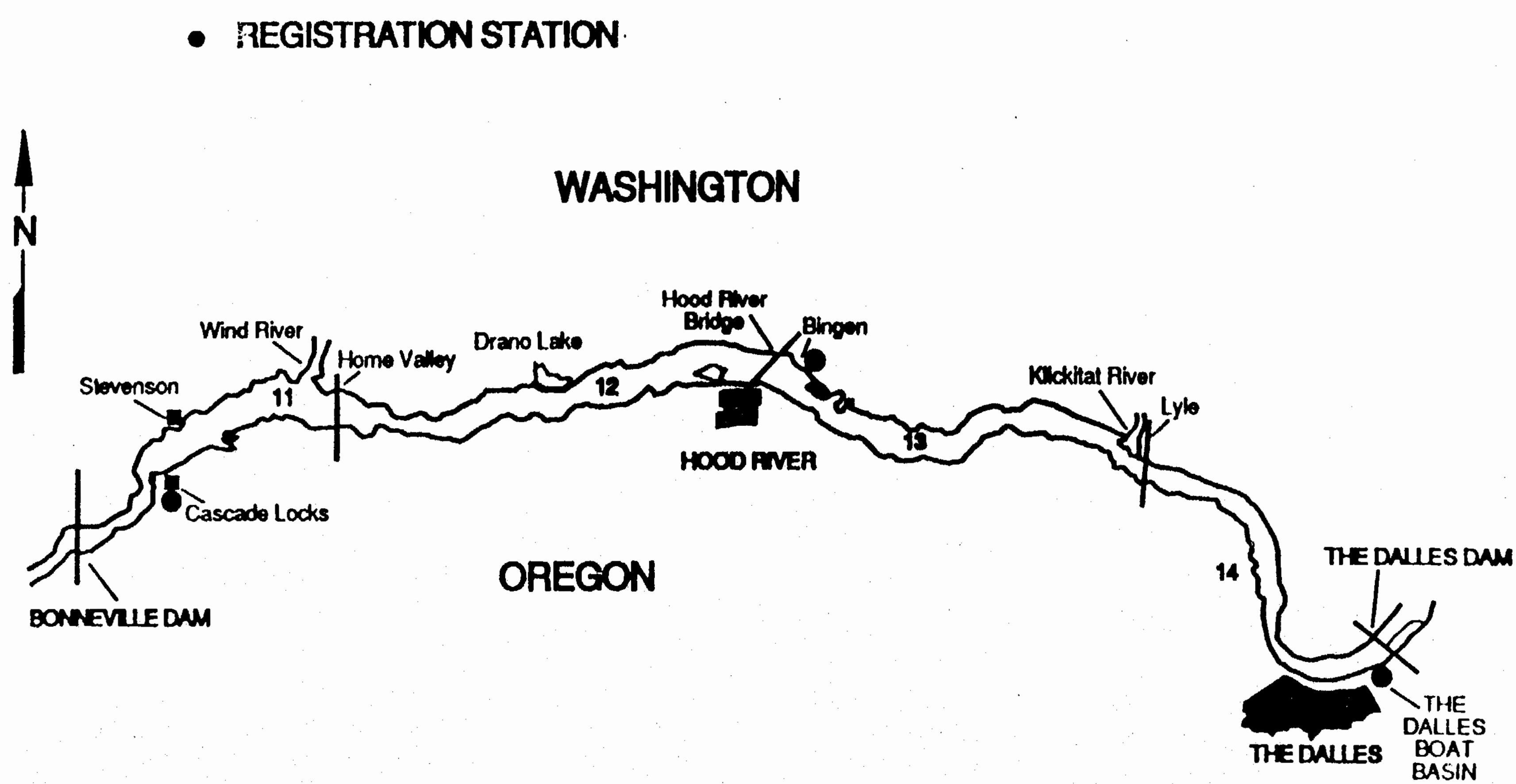
Maps Showing Fishing Locations and Codes



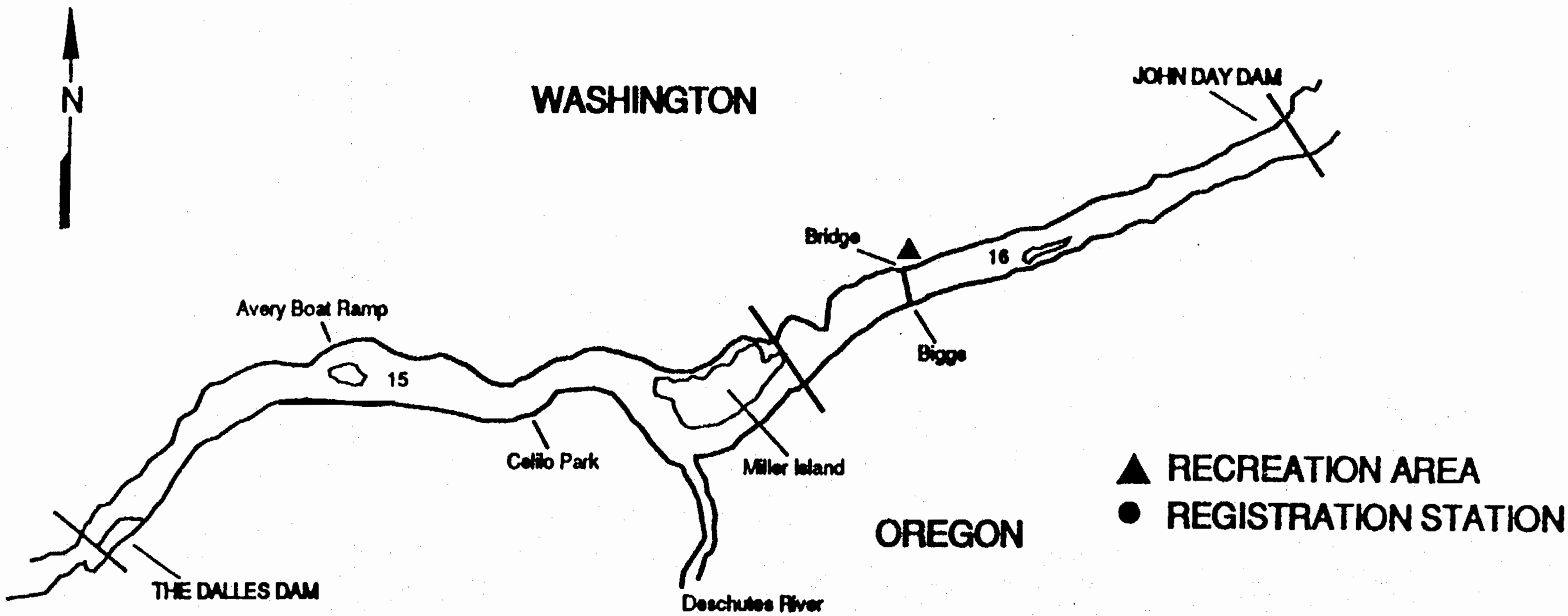
Appendix Figure A-1. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, mouth of Columbia River to Lewis River.



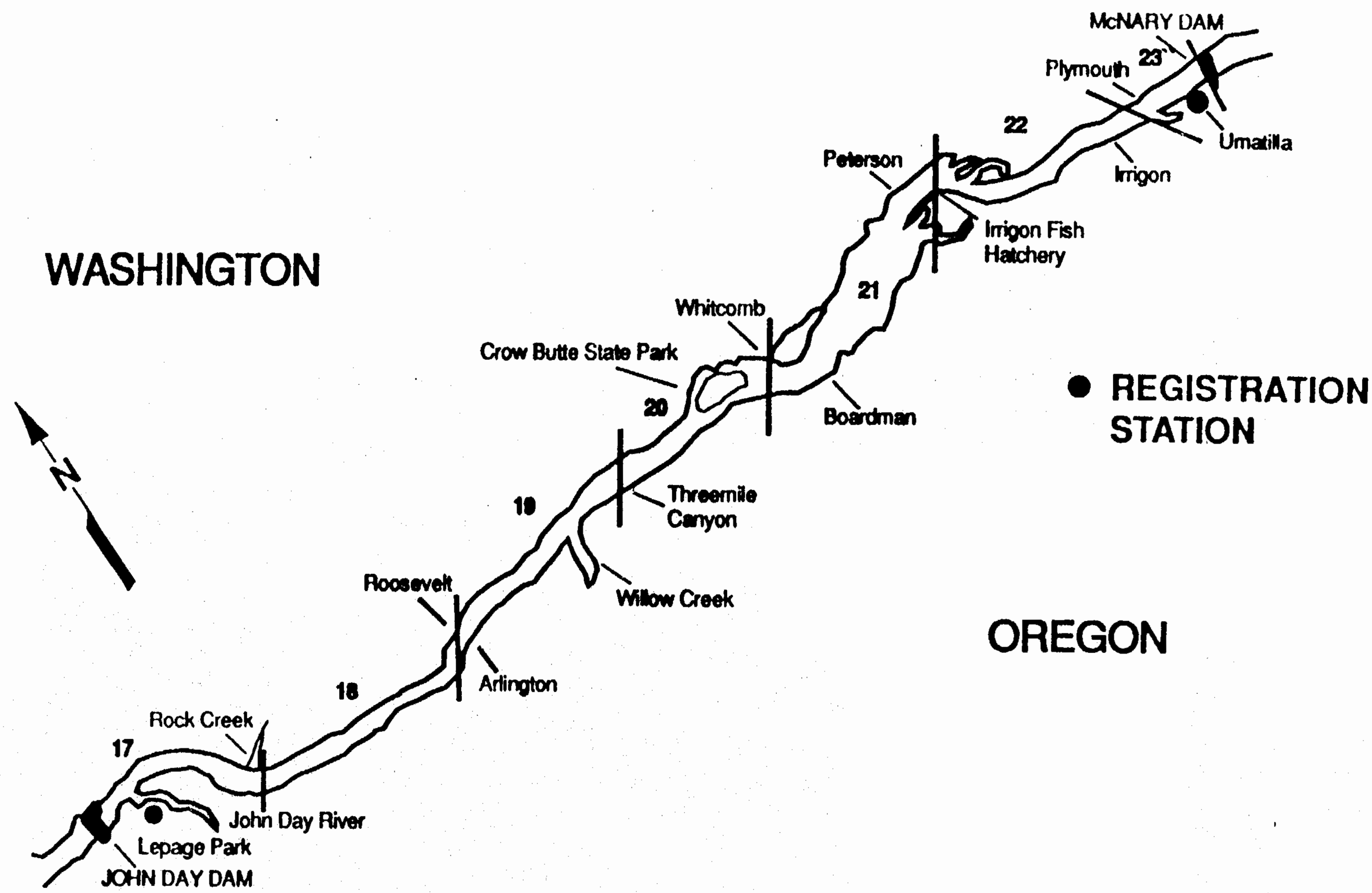
Appendix Figure A-2. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, Lewis River to Bonneville Dam.



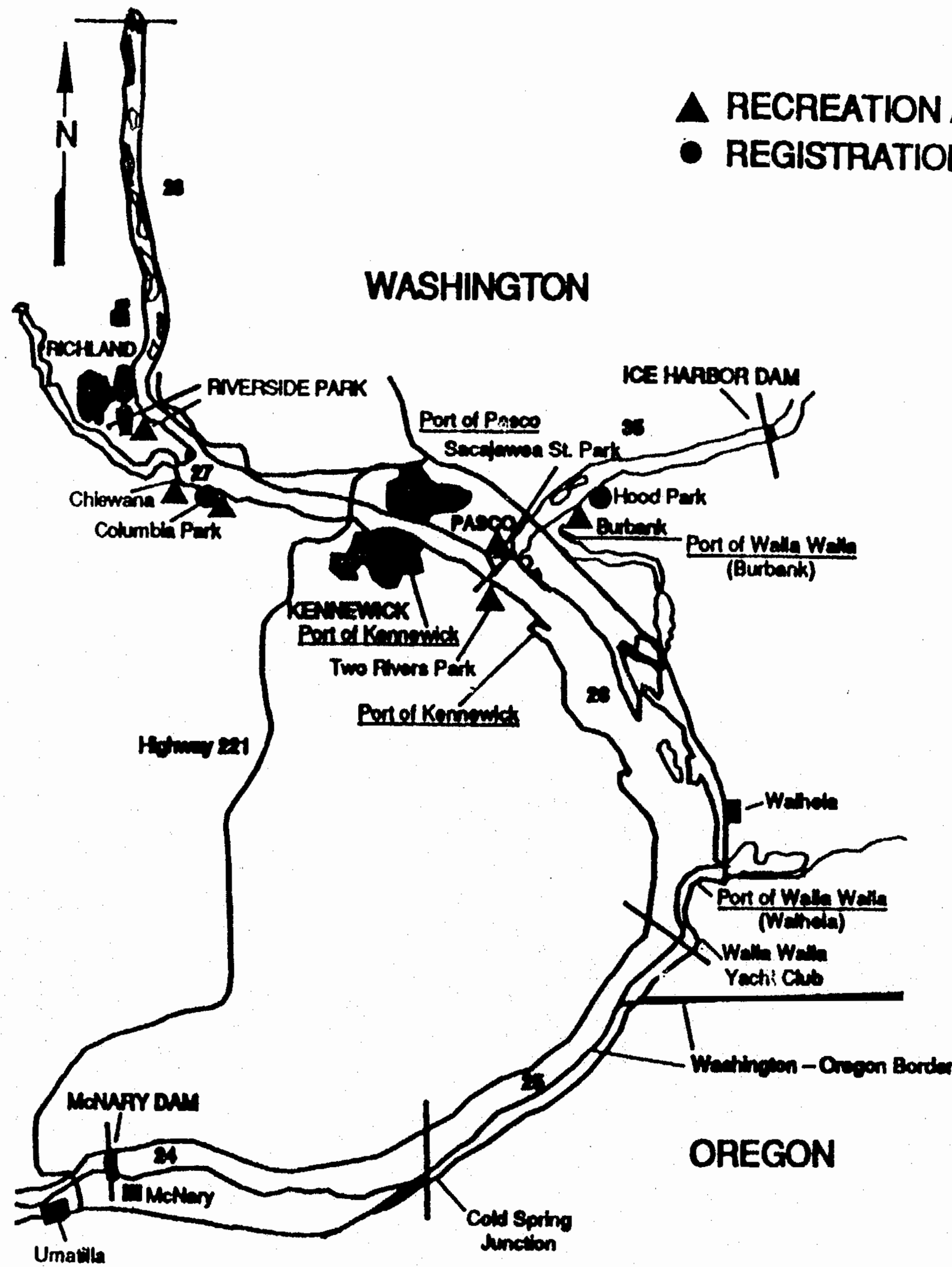
Appendix Figure A-3. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, Bonneville Dam to The Dalles Dam.



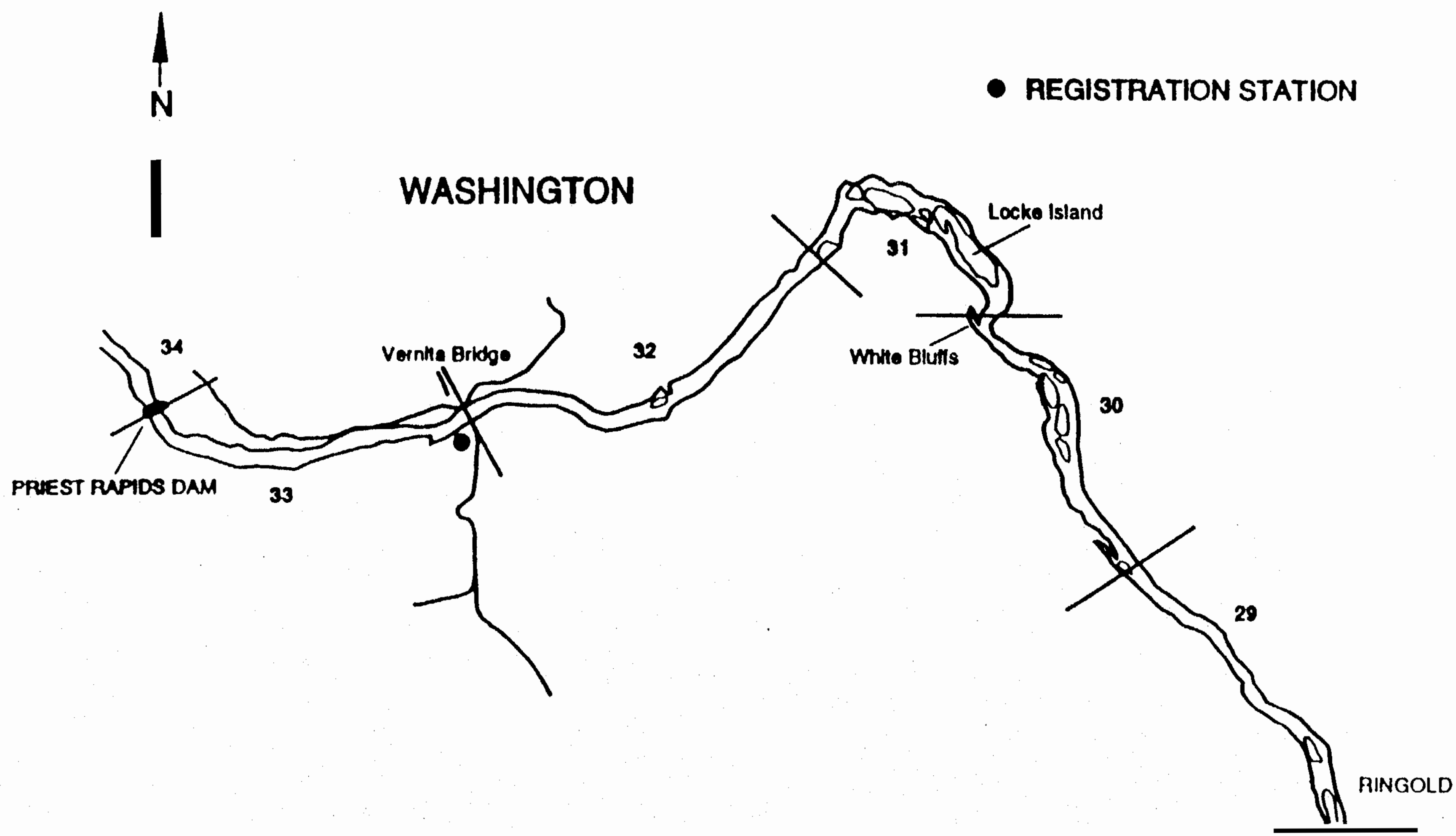
Appendix Figure A-4. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, The Dalles Dam to John Day Dam.



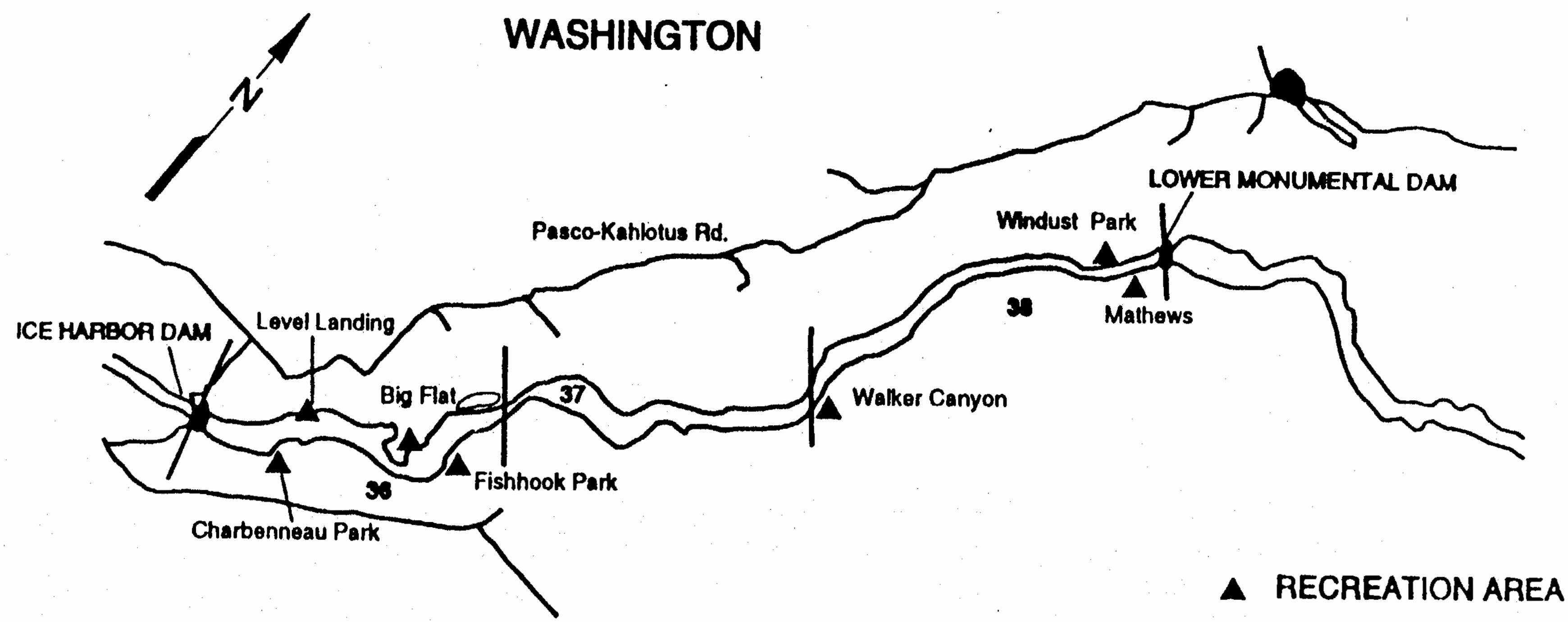
Appendix Figure A-5. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, John Day Dam to McNary Dam.



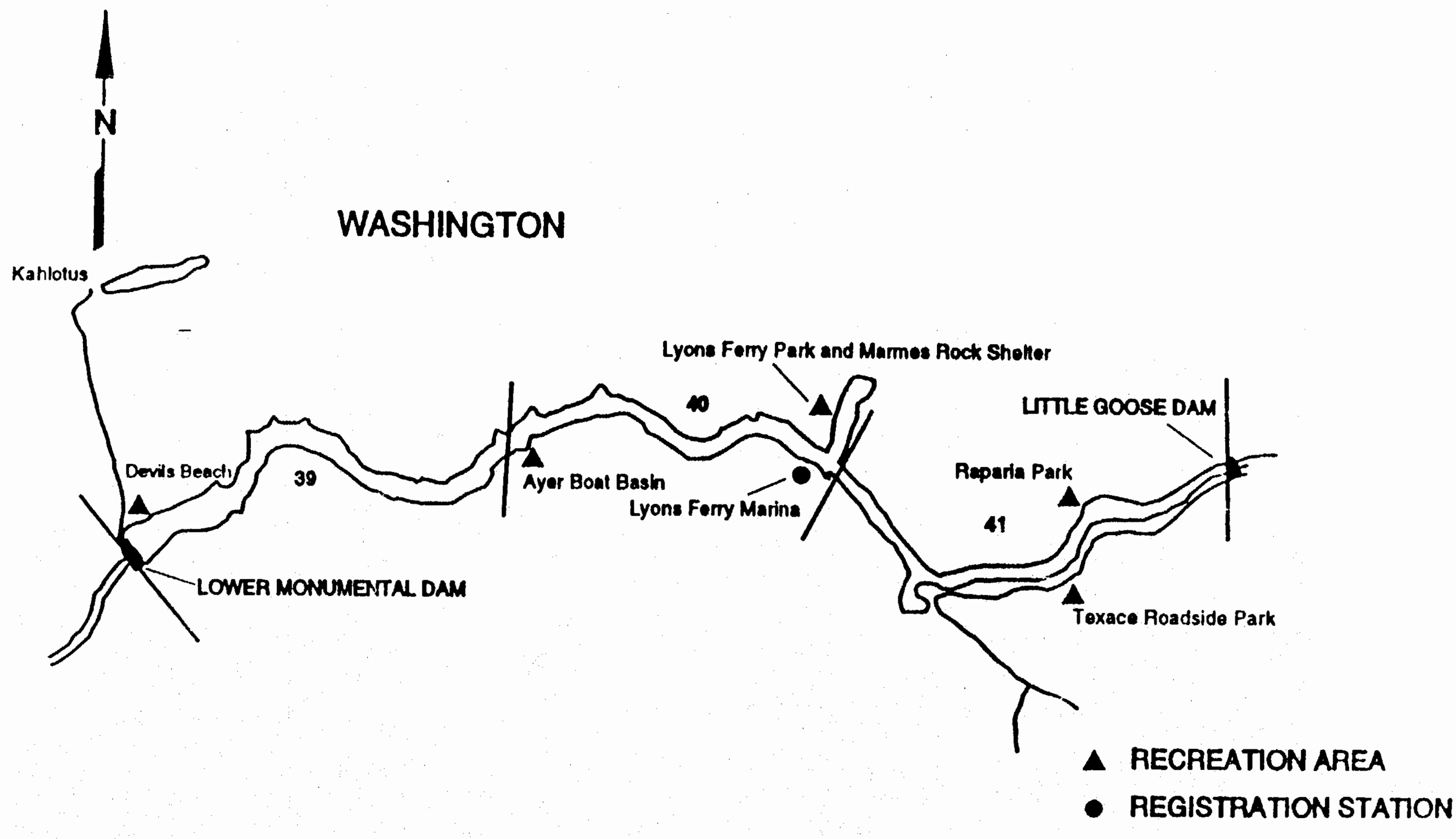
Appendix Figure A-6. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, McNary Dam to Ringold Boat Ramp and mouth of Snake River to Ice Harbor Dam.



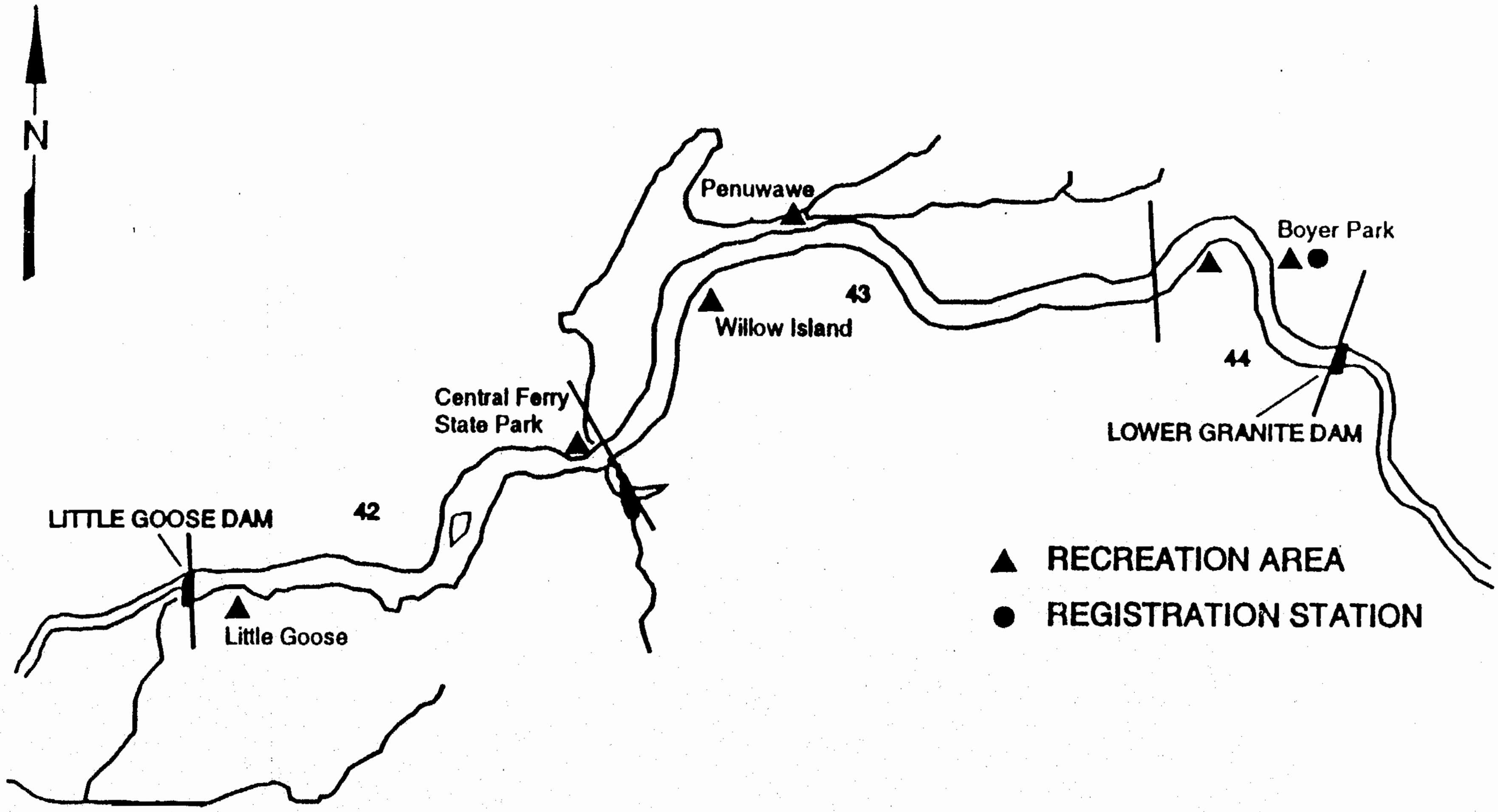
Appendix Figure A-7. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, Ringold Boat Ramp to Priest Rapids Dam.



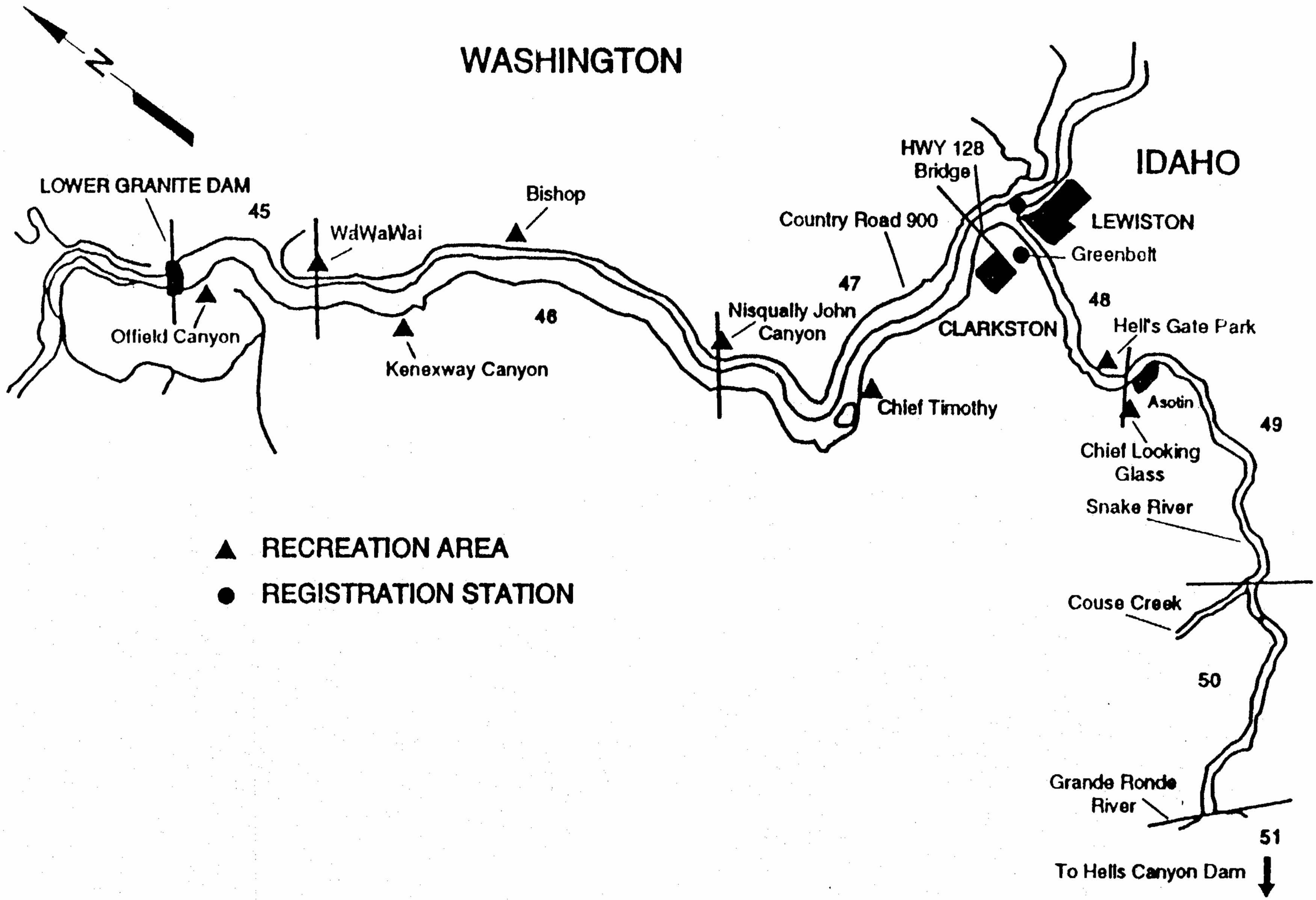
Appendix Figure A-8. 1993 Northern Squawfish Sport-Reward Fshery fishing location codes, Ice Harbor Dam to Lower Monumental Dam.



Appendix Figure A-9 993 Northern Squawfish Sport-Reward Fishery fishing location codes, Lower Monumental Dam to Little Goose Dam.



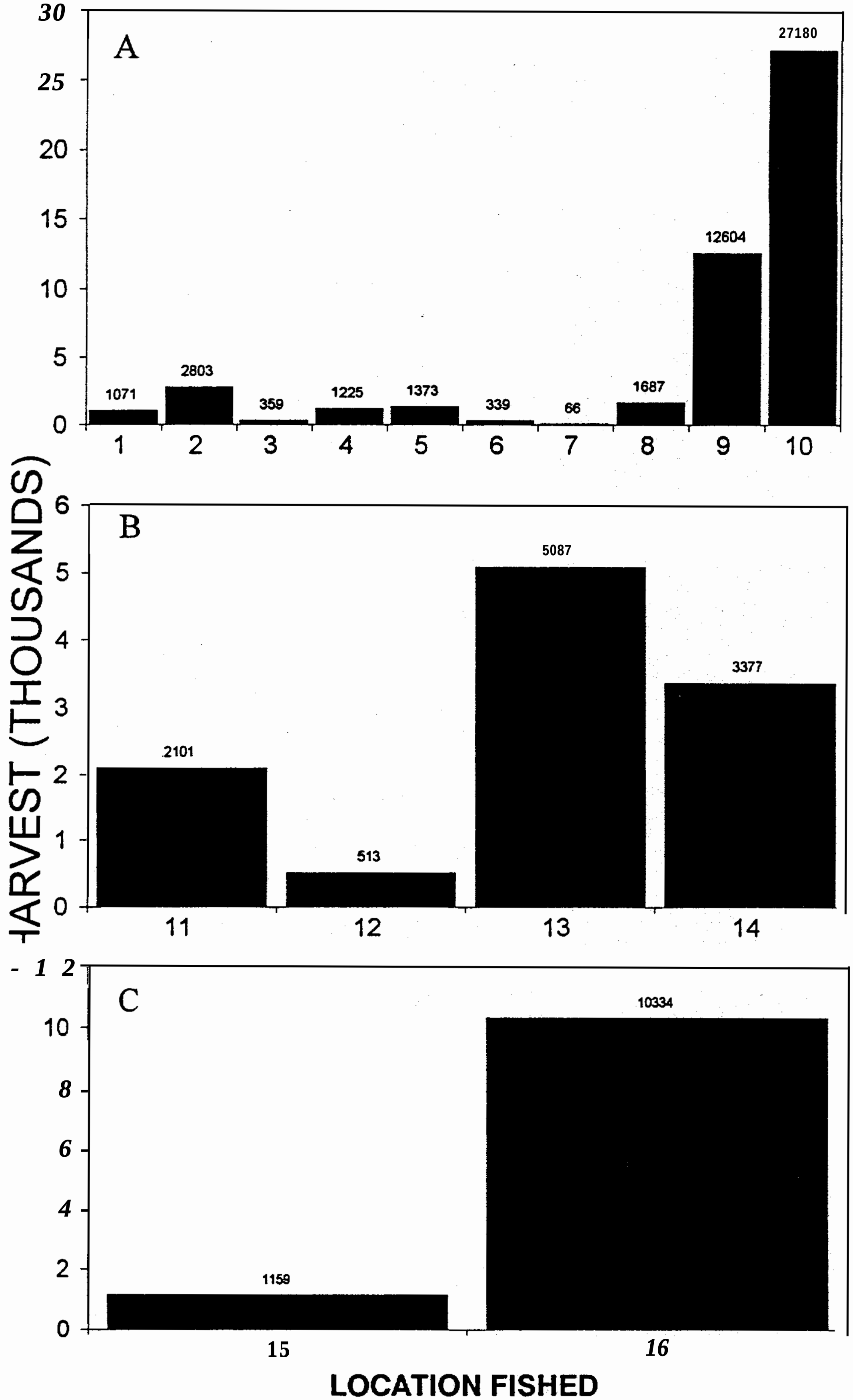
Appendix Figure A-10. 1993 Northern Squawfish Sport-Reward Fishery fishing locat codes, Little Goose Dam to Lower Granite Dam.



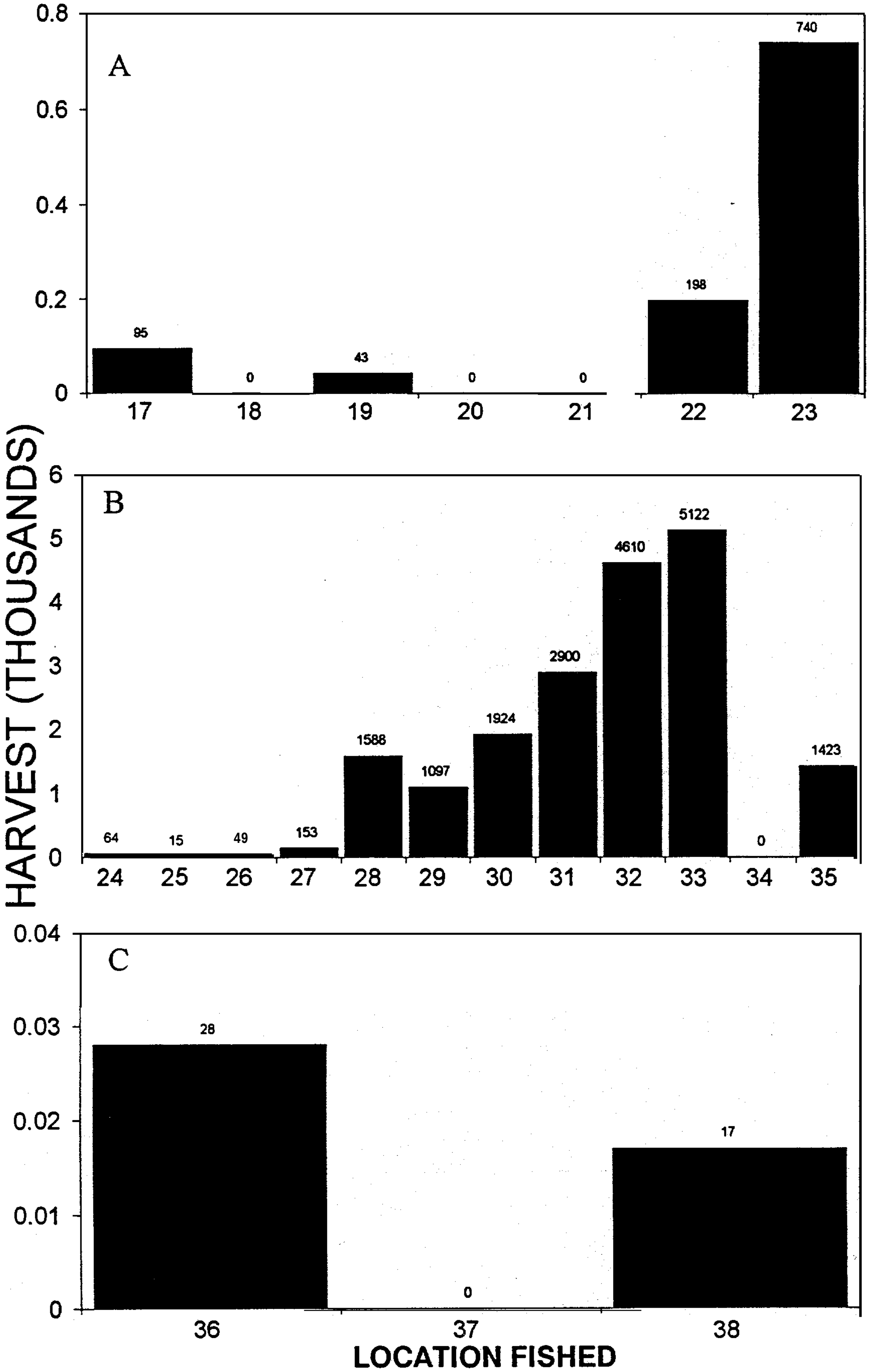
Appendix Figure A-11. 1993 Northern Squawfish Sport-Reward Fishery fishing location codes, Lower Granite Dam to Hells Canyon Dam.

APPENDIX B

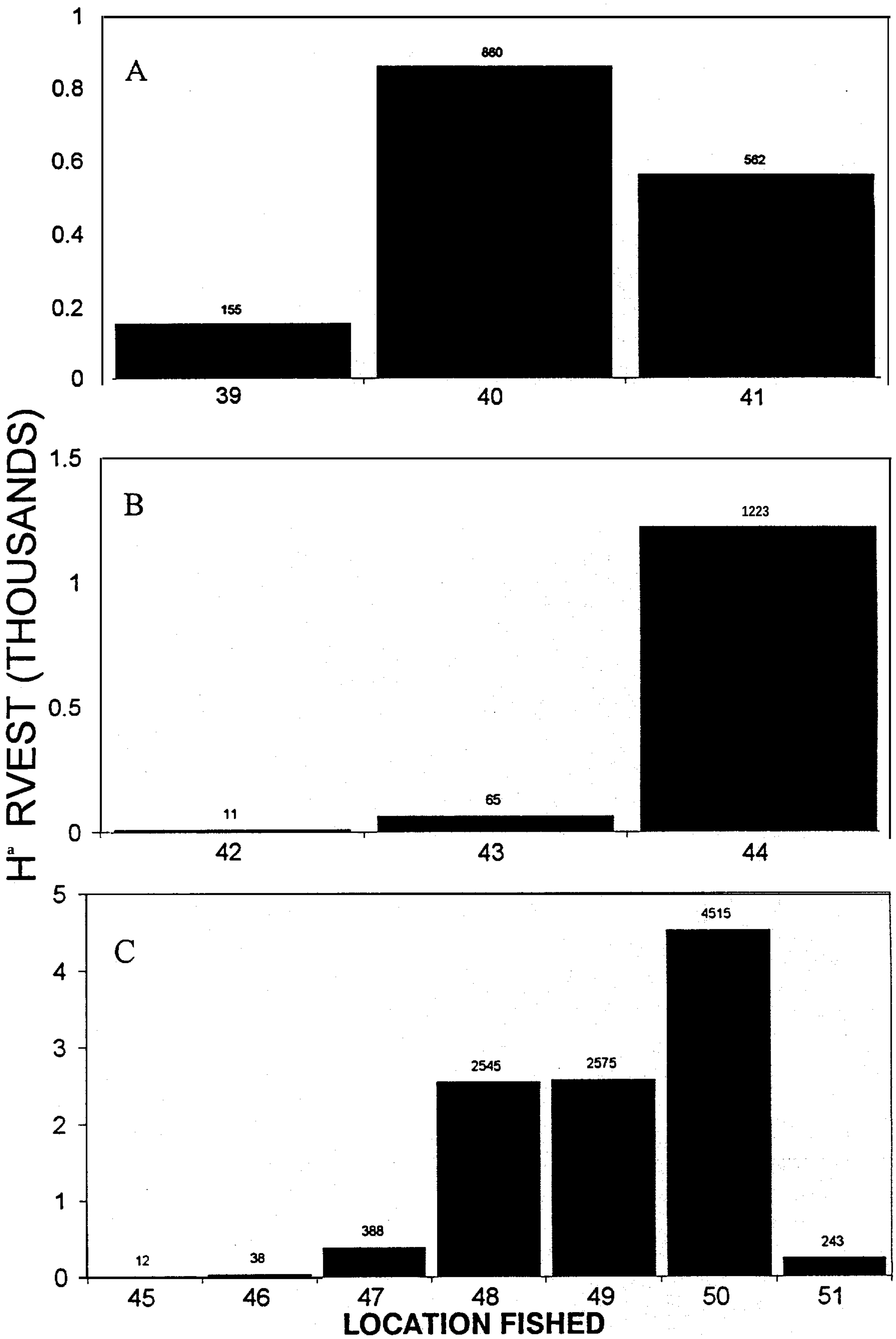
Bar Charts of Fishing Location Data by Reservoir



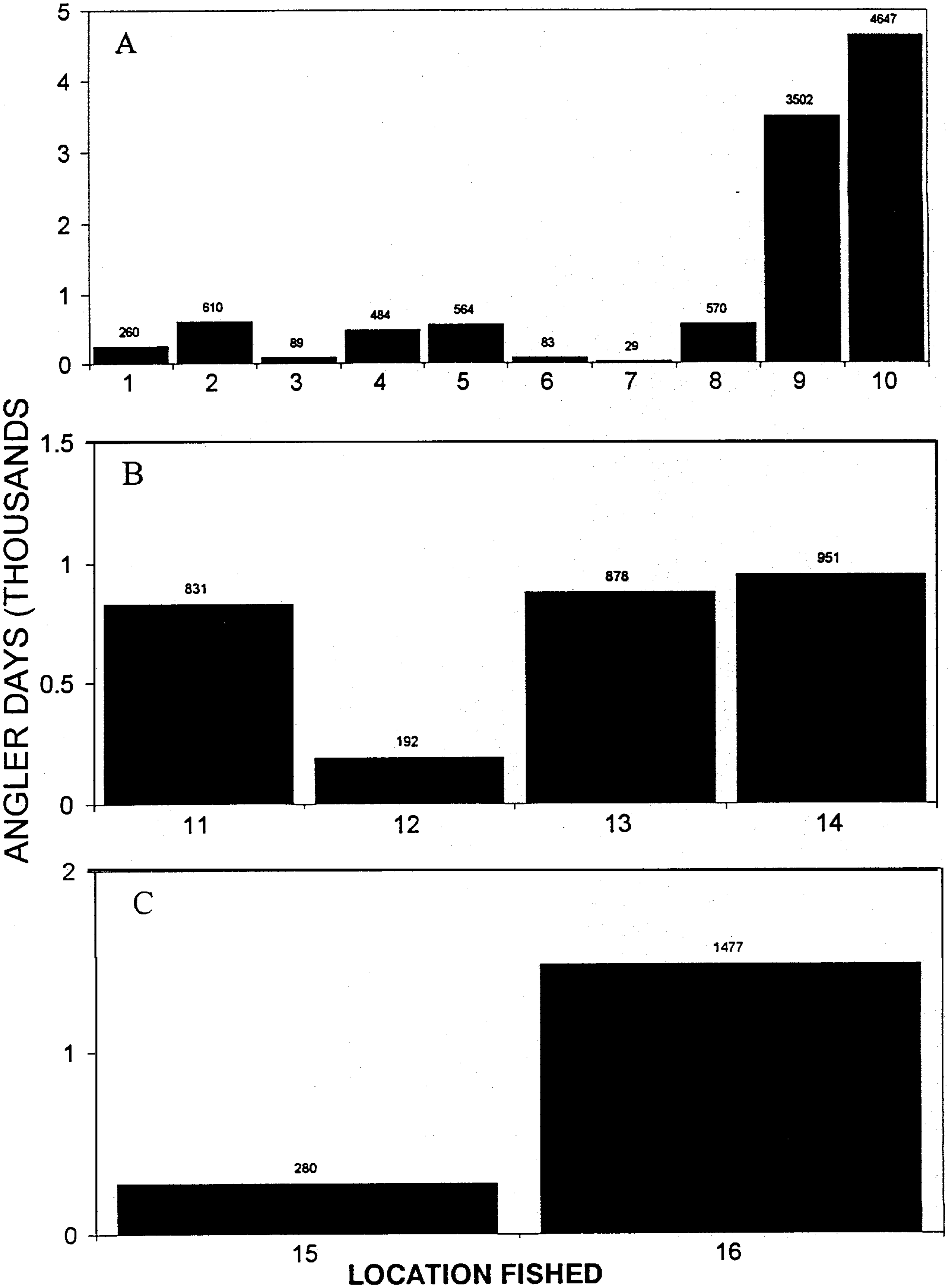
Appendix Figure B-1. Northern squawfish harvest by reservoir and location fished; A - Bonneville Tailrace, B - Bonneville Reservoir, C - The Dalles Reservoir. (Numbers above the bar represent the number of northern squawfish harvested). Please note the difference in scales.



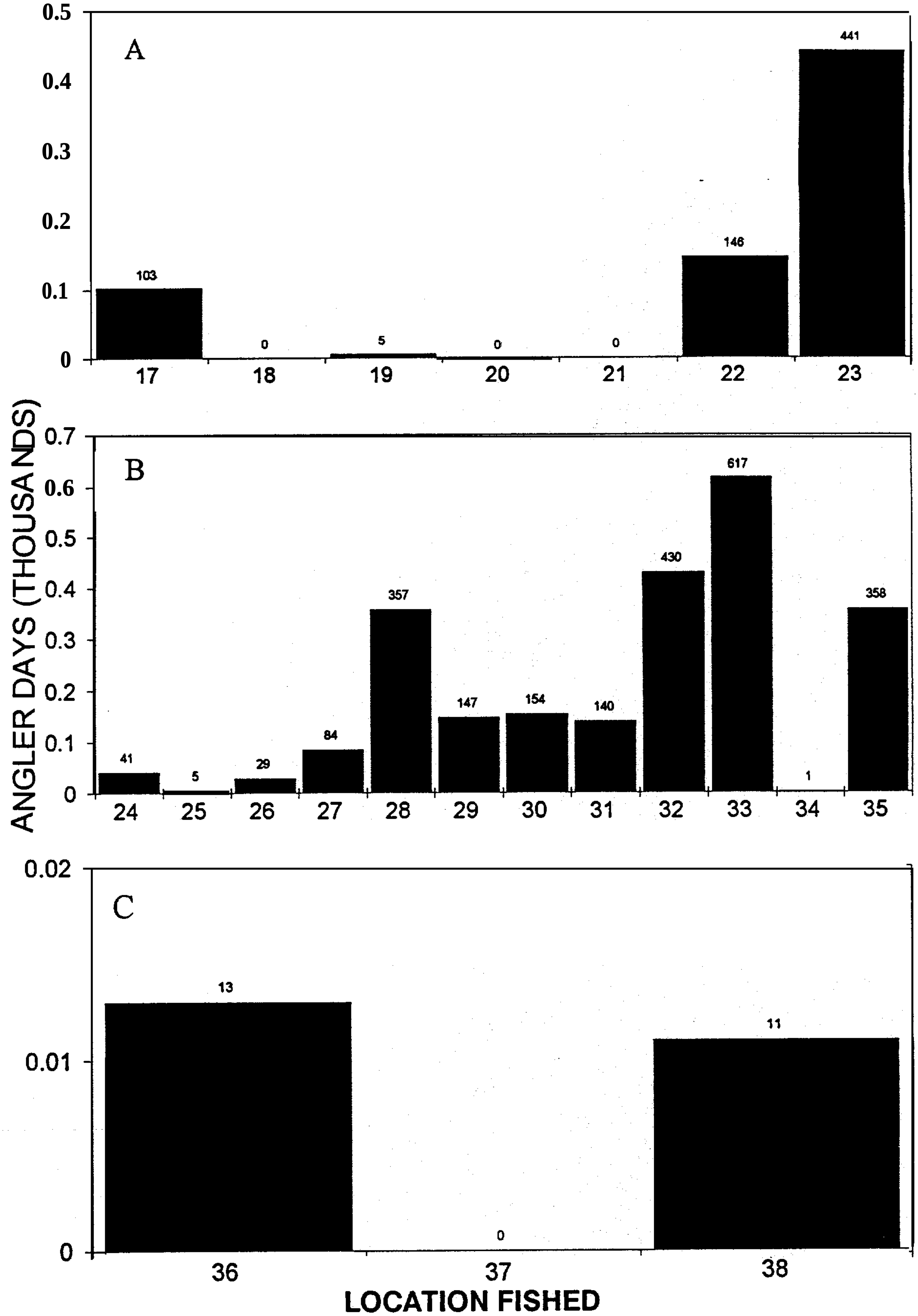
Appendix Figure B-2. Northern squawfish harvest by reservoir and location fished; A - John Day Reservoir, B - McNary Reservoir, C - Ice Harbor Reservoir. (Numbers above the bar represent the number of northern squawfish harvested). Please note the difference in scales.



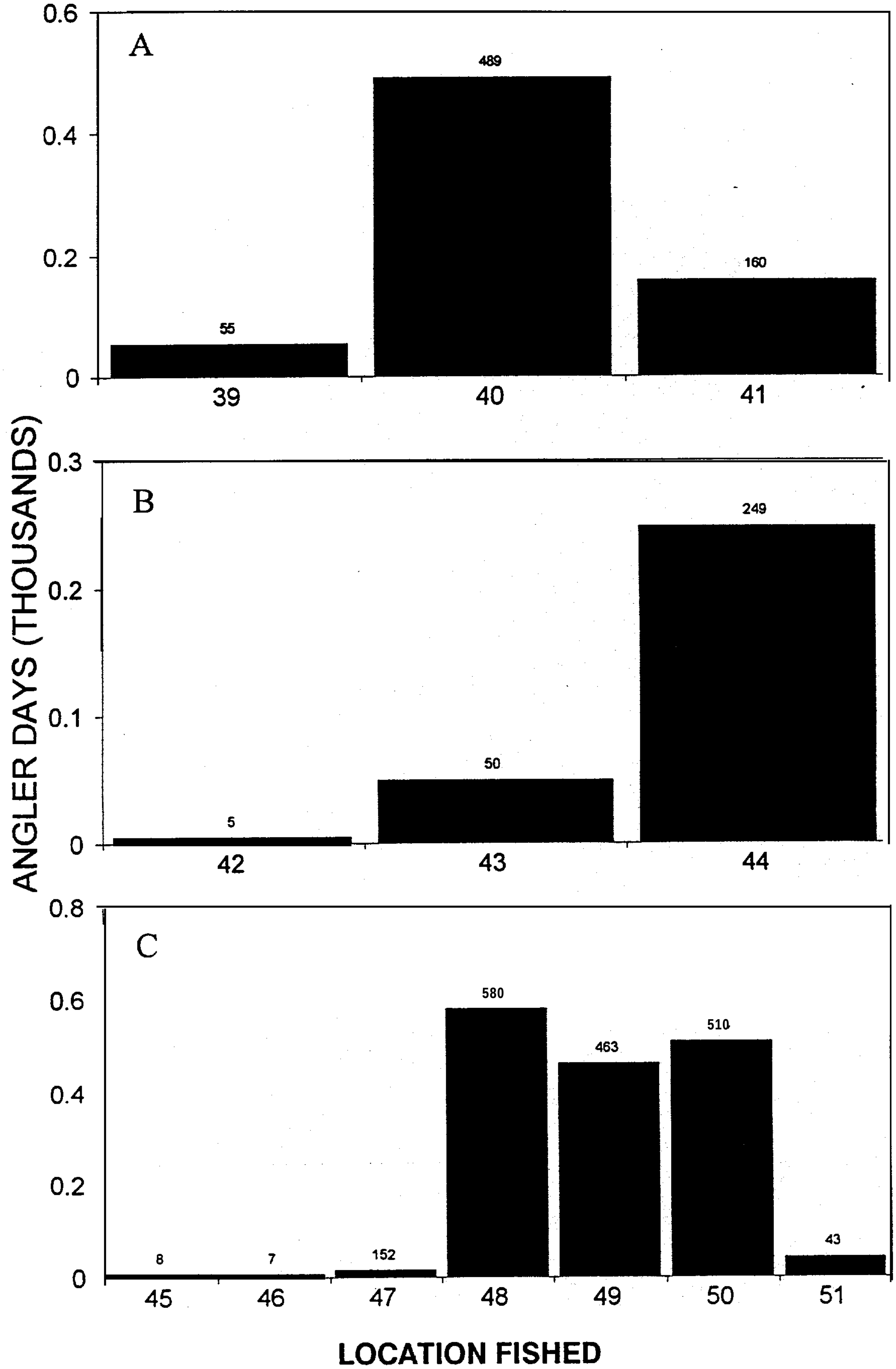
Appendix Figure B-3. Northern squawfish harvest by reservoir and location fished; A - Lower Monumental Reservoir, B - Little Goose Reservoir, C - Lower Granite Reservoir. (Numbers above the bar represent the number of northern squawfish harvested). Please note the difference in scales.



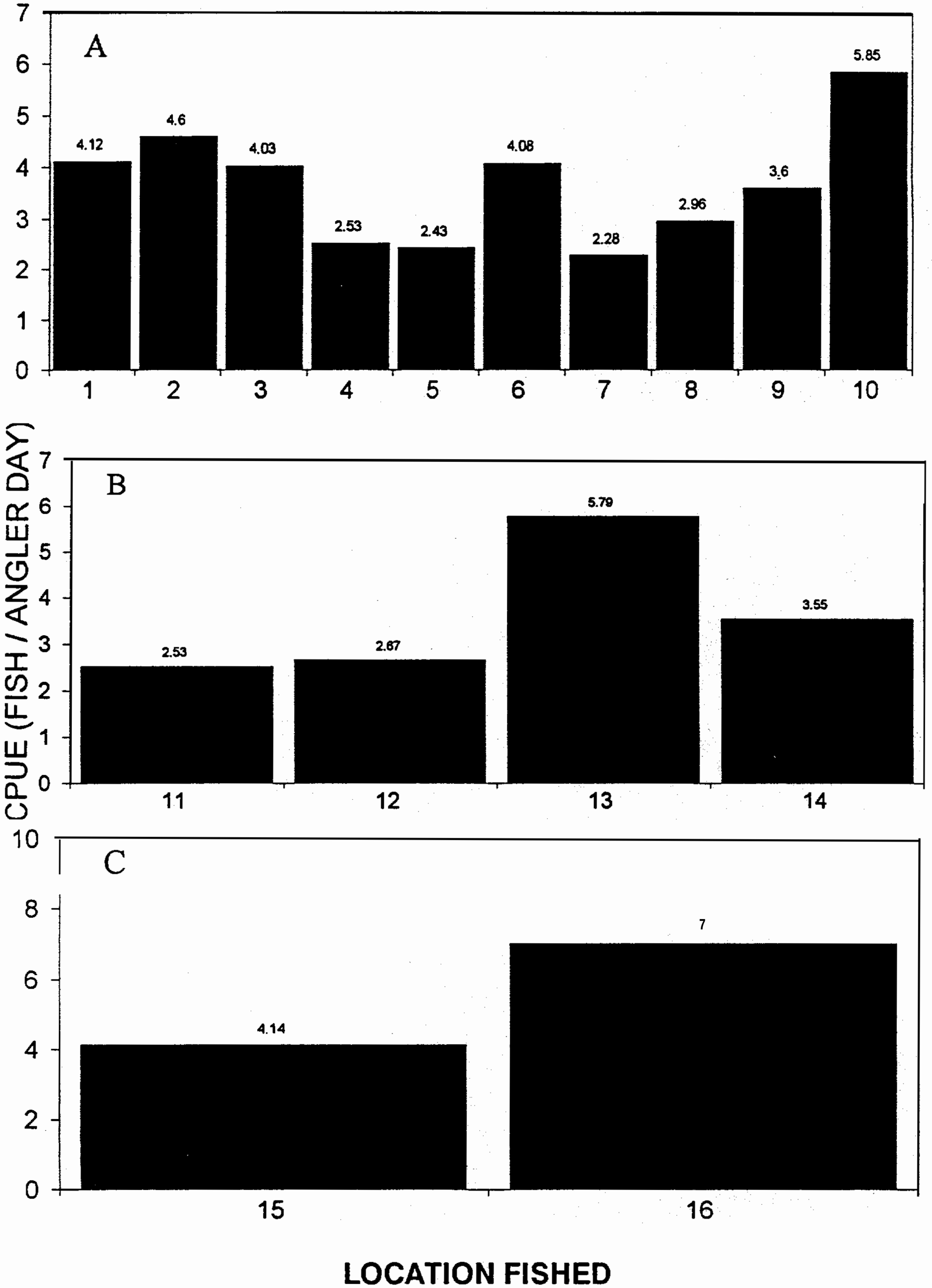
Appendix Figure B-4. Effort (angler days) by reservoir and location fished; A - Bonneville Tailrace, B - Bonneville Reservoir, C - The Dalles Reservoir. (Numbers above the bar represent the number of angler days). Please note the difference in scales.



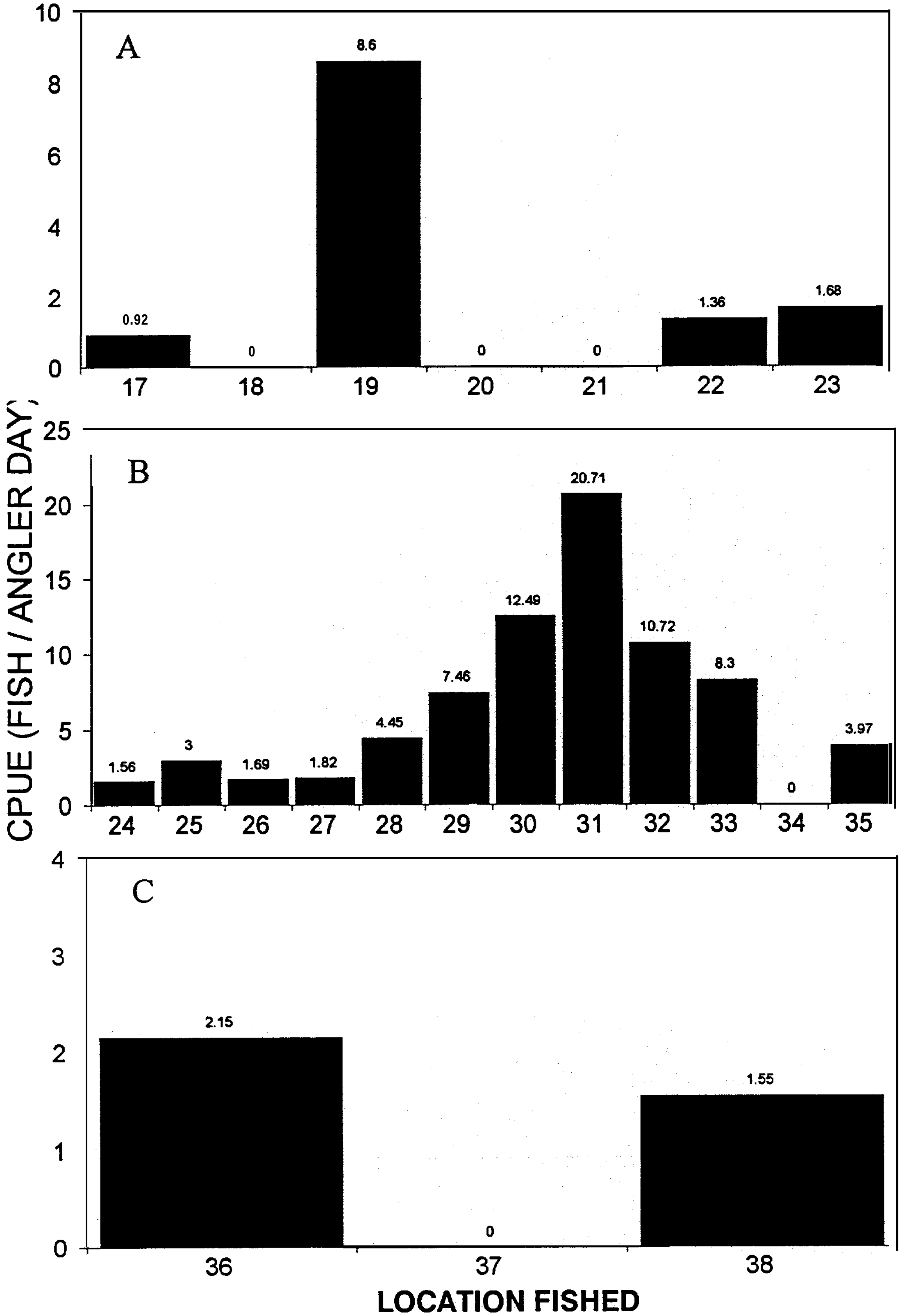
Appendix Figure B-5. Effort (angler days) by reservoir and location fished; A - John Day Reservoir, B - McNary Reservoir, C - Ice Harbor Reservoir. (Numbers above the bar represent the number of angler days). Please note the difference in scales.



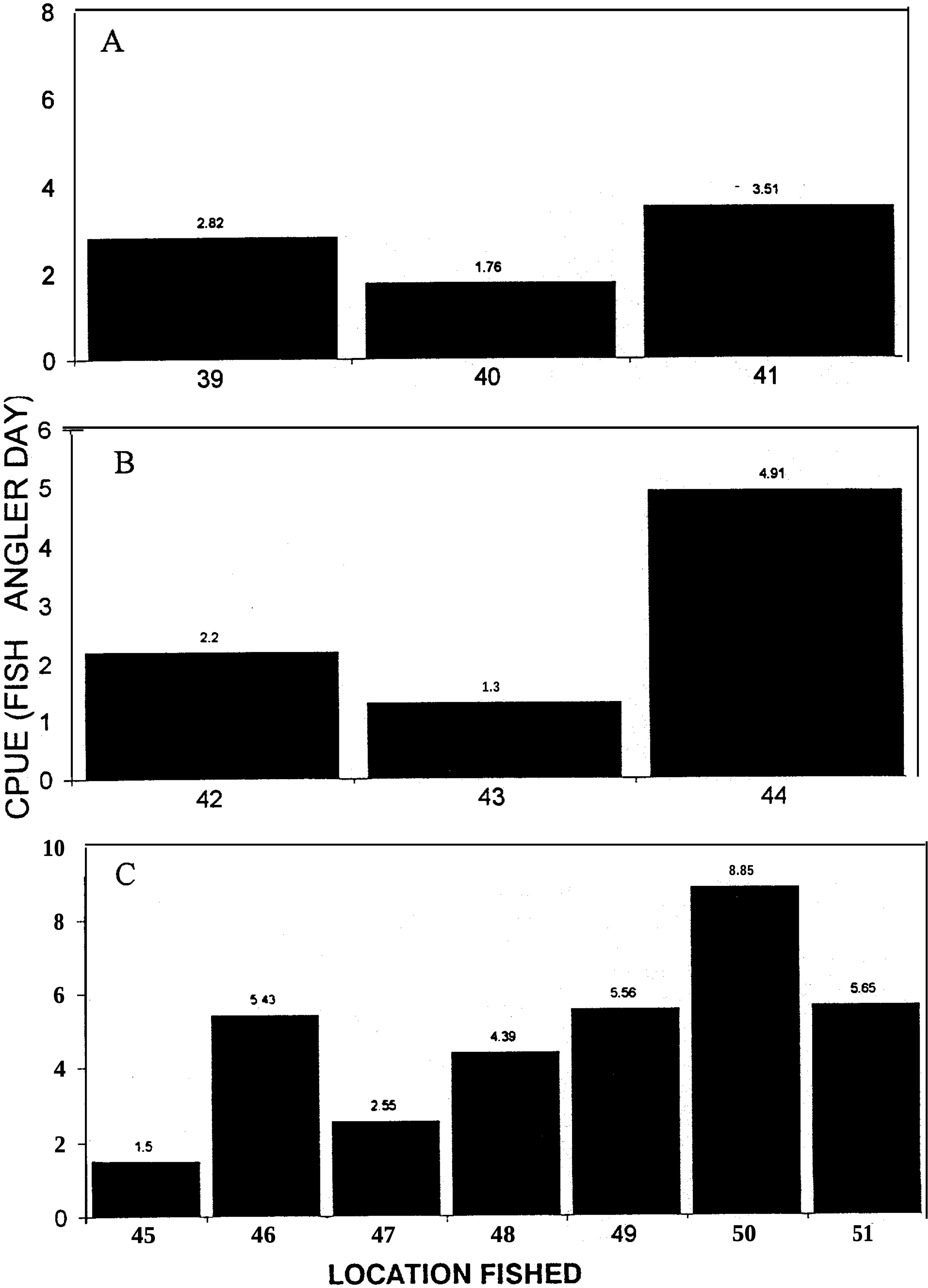
Appendix Figure B-6. Effort (angler days) by reservoir and location fished; A - Lower Monumental Reservoir, B - Little Goose Reservoir, C - Lower Granite Reservoir. (Numbers above the bar represent the number of angler days). Please note the difference in scales.



Appendix Figure B-7. CPUE (fish / angler day) by reservoir and location fished; A - Bonneville Tailrace, B - Bonneville Reservoir, C - The Dalles Reservoir. (Numbers above the bar represent the catch per unit effort). Please note the difference in scales.



Appendix Figure B-8. CPUE (fish / angler day) by reservoir and location fished; A - John Day Reservoir, B - McNary Reservoir, C - Ice Harbor Reservoir. (Numbers above the bar represent the catch per unit effort (fish / angler day)). Please note the difference in scales.



Appendix Figure B-9. CPUE (fish / angler day) by reservoir and location fished; A - Lower Monumental Reservoir, B - Little Goose Reservoir, C - Lower Granite Reservoir. (Numbers above the bar represent the catch per unit effort (fish / angler day)). Please note the difference in scales.

APPENDIX C

Telephone Survey: Estimated Catch and General Fishing Information Gathered From Northern Squawfiih Sport-Reward Fishery Anglers Who did not Report the Results of a Fishing Trip

Abstract

A random sample of anglers that registered with the 1993 northern squawfish sport-reward fishery and did not return to report the days catch were surveyed by telephone. Surveyed anglers cited poor success in catching northern squawfish large enough to be eligible for a $3 reward payment for not returning to the registration station to report the days catch. The survey estimated 24,731 northern squawfish, too small to qualify for the $3 reward, were caught by non-returning anglers. Approximately 48% of the 24,731 northern squawfish were returned to the water unharmed. The survey estimated that 2,968 northern squawfish, eligible for a $3 reward, were caught by non-returning anglers while only 19% were returned to the water unharmed. An estimated 4,146 smallmouth bass, 136 white sturgeon, 91 summer steelhead, 397 walleye and 11 chinook salmon were removed from the Columbia and Snake rivers by non-returning anglers. Catch estimates of fishes caught by non-returning anglers were not sufficiently high to indicate the sport-reward fishery was overexploiting any species. Approximately 95% of anglers surveyed cited helping to protect salmon as an important factor in motivating participation within the sport-reward fishery. The majority of anglers surveyed (77%) would have taken the fishing trip even if the sport-reward fishery did not exist, indicating that a majority of the fishing effort expended by non-returning anglers would have occurred without the sport-reward fishery.

A recall bias study was also conducted to determine if the anglers surveyed were accurately recalling the number of fish caught on a particular day. The estimated catch results were not shown to be significantly affected by the anglers ability to accurately recall the number of fish caught on a particular fishing trip.

Introduction

Northern squawfish are the dominant predator of juvenile salmonids in the lower Columbia and Snake River systems (Beamesderfer and Rieman 1991). Rieman and Beamesderfer (1990) used simulation modeling to demonstrate that predation on juvenile salmonids could be reduced to 50% with limited (10%-20%), but sustained exploitation of northern squawfish greater than 275 mm fork length. The Columbia River Northern Squawfish Management Program was created in 1990 to achieve the 10-20% exploitation of northern squawfish recommended by Rieman and Beamesderfer (1990). The northern squawfish sport-reward fishery was implemented within the lower Columbia and Snake River systems in 1991 as part of the Columbia River Northern Squawfish Management Program's effort to increase exploitation of northern squawfish greater than 275 mm total length. The sport-reward fishery offered a reward payment of $3 per northern squawfish greater than 275 mm total length. Anglers participating in the sport-reward fishery were required to register daily, prior to going fishing. A total of 18 sport-reward fishery registration Stations (Appendix Table C-l) were located on the Columbia and Snake rivers in 1993. Registered anglers were encouraged to return to the registration stations after fishing to complete an exit interview. The exit interview allowed sport-reward fishery technicians to collect data on the anglers catch. Anglers were issued a voucher in the exit interview, which enabled the angler to receive a $3 reward for each eligible northern squawfish. Anglers who registered with the program and did not return to complete an exit interview were referred to as "non-returning anglers. " Data from previous years showed that approximately 60% (20,000) of the registered sport-reward fishery anglers were non-returning anglers. A similar telephone survey of non-returning sport-reward fishery anglers was conducted in 1992 by Dr. Susan Hanna at Oregon State University (Hanna et al. 1992). Some of the questions in this survey were taken from Hanna et al. (1992), but Dr. Hanna's study did not estimate the catch of non-returning anglers. The primary purpose of this study was to estimate non-returning angler's catch and ensure the sport-reward fishery was not causing overexploitation of any species of fish within the Columbia and Snake river systems. Other objectives of this study were to estimate why anglers participate in the sport-reward fishery, why anglers did not return to complete an exit interview, and the types of fishing gear used by anglers. Catch estimates from returning-angler data were also compared to catch estimates from the telephone survey data for the purpose of determining if the two methods produced similar estimates.

A recall bias study was also conducted for the purpose of determining if the answers given to telephone survey questions were accurate.

Telephone Survey Methods

Non-returning anglers surveyed in this report were contacted by telephone and asked to complete a questionnaire (Appendix Table C-2). A sample of non-returning anglers was generated weekly by random selection using a data base program. A stratified random sample was selected from the 18 registration stations and the total number of non-returning anglers to be sampled from each registration station was determined by the percentage of non-returning anglers registering at each registration station (Appendix Table C-l).

A maximum of five attempts were made to reach an angler by phone. If the initial attempt resulted in no answer, the angler was scheduled for a call on the next evening of interviews. The second attempt was scheduled for an evening call on the weekend. If after three attempts, no one had been reached, a morning attempt was scheduled. A fifth and final attempt was made in the afternoon before recording the angler as unreachable. The telephone calling schedule was adopted from the Social and Science Research Center at Washington State University (Dillman 1978).

Appendix Table C-l. Sample size and error bound by registration station for the number of anglers sampled in the telephone survey of non-returning anglers.

Registration Stations	Total Non-Returning Anglers	%Total[1]	Non-Returning Anglers Sampled	Error Bound[2]
1. CATHLAMET	862	4.36	76	0.110
2. RAINIER	678	3.43	60	0.124
3. KALAMA	1299	6.57	117	0.088
4. GLEASON	1354	6.85	121	0.087
5. CAMAS	1524	7.71	138	0.081
6. THE FISHERY	1116	5.60	101	0.095
7. HAMILTON I.	1216	6.15	99	0.096
8. CASCADE L.	693	3.51	61	0.123
9. BINGEN	779	3.94	69	0.116
10. THE DALLES	881	4.46	76	0.110
11. LEPAGE	923	4.67	73	0.112
12. UMATILLA	789	3.99	72	0.116
13. COLUMBIA PT.	942	4.77	85	0.104
14. VERNITA	1127	5.70	100	0.096
15. HOOD PARR	1488	7.53	133	0.083
16. LYONS FERRY	775	3.92	65	0.119
17. BOYER PARR	716	3.62	65	0.120
18. GREENBELT	2596	1.31	233	0.063
TOTALS	19,758	100	1744	0.023

1 The percentage of non-returning anglers registering at each registration station.
2 Error bound was estimated weekly to assist in determining the adequacy of the sample size using $p=.5$ and $q=.5$.

Appendix Table C-2, Telephone questionnaire for non-returning anglers for the northern **squawfish** sport-reward fishery 1993.

Q1. How well do you remember the events of your fishing trip on (date)?

1. Very well
2. Moderately well
3. Not well (I only have a few questions and perhaps they will refresh your memory.)

We have created maps that divide the Columbia and Snake rivers into large sections. These maps will help us to determine the effect our program is having on the fish populations in those areas. We are not trying to locate your favorite fishing hole. I just need to know approximately where you were fishing that day.

Q2. Reservoir Code _______

Q2A. Location Code _______

Q3. What were the top three species that you were fishing for that day?

A. ____ **B.** ____ **C.** ____

Q4. What is your best estimate of the number of hours that you fished for northern squawfish that day? (If 0 go to Q7)

___ **HRS.**

Were you targeting northern **squawfish** the entire time?

Q5. Did you catch any fish while you were fishing for northern squawfish?

0. DID NOT REMEMBER 9. DID NOT FISH
1. YES ___ **2. NO** ___ (If no go to **Q7)**

If yes: Please estimate what species you caught and how many of each?
Please tell me one species at a time so that I can record them.

Q6A. Were the northern **squawfish** over or under 11 inches?
(> = 11 inches NSF-G) (*c* 11 inches NSF-L)

Appendix Table C-2. Continued.

Q6. **SPECIES** **Q6B.** **QUANTITY**

____	____
____	____
____	____

Q6C. What did you do with the fish? Did you:

1. Return them to the water unharmed.
2. Kill them and return them to the water.
3. Keep them to eat.
4. Keep them for other uses.
5. Return them to the registration site.
6. Other **Q6D.** Memo

Q7. Please estimate how many hours you fished for species other than northern squawfish? **(If 0 go to Q9)**

___ **HRS.**

Were you targeting other species the entire time?

QS. Did you catch any fish while you were fishing for other species?

0. **DID NOT REMEMBER** **9. DID NOT FISH**
1. YES ___ **2. NO** ___ (If no go to **Q10)**

If yes: Please estimate what species you caught and how many of each?
Please tell me one species at a time so that I can record them.

Q9A. Were the northern squawfish over or under 11 inches?
(> = 11 inches NSF-G) **(<** 11 inches NSF-L)

Q9. **SPECIES** **Q9B.** **QUANTITY**

____	____
____	____
____	____

Appendix Table C-2. Continued.

Q9C. What did you do with the fish? Did you:

1. Return them to the water unharmed.
2. Kill them and return them to the water.
3. Keep them to eat.
4. Keep them for other uses.
5. Return them to the registration site.
6. Other **Q9D.** Memo

Q10. Did you fish from:

1. Boat
2. Shore
3. **Both**

What type of fishing gear did you use?

	YES	NO
Q11A. Trolling lures	1	2
Q11B. Casting bait	1	2
Q11C. Casting lures	1	2

Q11D. Other (If no on llA,B and C)

412. What was the main reason that you did not return to the registration site?

1. You had no fish to turn in.
2. There were not enough fish to make returning worthwhile.
3. All northern squawfish caught were under 11".
4. Other reasons: **Q12A.** Please explain: ________

I am going to read a list of reasons that people participate in the northern squawfish program, As I read each one, please tell me how important it is to you.

	VERY	**SOMEWHAT**	**NOT**
Q13A Payment for northern squawfish	1	2	3
Q13B Recreational opportunity	1	2	3
Q13C Opportunity to cover expenses while targeting game species	1	2	3
Q13D Helping to protect salmon	1	2	3

Appendix Table C-2. Continued.

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414. Are the check stations conveniently located for you?

1 YES **2 N 0**

Q14A If no: What new locations would you suggest?

Q15. Do you plan to register again with the program?

1 YES **2 N 0**

Q15A If no: What is the main reason you do not plan to register with the program? (Wait for a response and then categorize)

1. Poor success catching northern squawfish.
2. Registration is too much trouble.
3. Too far to registration site.
4. Other reasons: **Q15B** Please explain: ________

Q16 Would you have taken this fishing trip if the sport reward program did not exist?

1 YES **2 N 0**

Q17 How would you rate your interaction with the technicians at the check station?

1. Very good
2. Good
3. Poor (Record comments on all number 3 responses)

Q17A Comments

A data base program was created that contained fields to record answers from each phone survey question (Appendix Table C-2). The data was checked for errors using a program designed to detect non-relevant responses in each field.

Northern squawfish, smallmouth bass, white sturgeon, summer steelhead, walleye, and chinook salmon were used to compare phone survey proportional estimates (the number of fish removed by phone survey anglers/the number of phone survey anglers x the total number of non-returning anglers) and returning anglers proportional estimates (the number of fish removed by returning anglers/the number of returning anglers x the total number of non-returning anglers) of the number of fish caught by non-returning anglers. The statistically significant difference between phone survey estimates and returning angler estimates was not calculated.

The returning anglers sampled in the recall bias study were randomly selected from the sport-reward fishery data base. The selected anglers were contacted by telephone and asked a series of questions (Appendix Table C-3) that required the recollection of questions previously answered by returning anglers during the exit interview. The recall bias survey responses were compared to the exit interview responses at 2-, 4-, 6-, 8-, 10- and 12-week intervals from the time of registration until the day the angler was surveyed. The number of northern squawfish over and under 11 inches total length were used in our data analysis. The answer given by an angler during the exit interview was subtracted from the answer given in the recall bias study. A value of zero would indicate the angler recalled exactly the number of fish recorded on the anglers exit interview. A positive value meant the angler remembered catching more fish than were recorded on the exit interview and a negative value meant the angler remembered catching less fish. For example, if an angler recorded a catch of five northern squawfish in the exit interview and three northern squawfish in the recall bias survey, then the angler's recall bias score would be -2 fish.

Anglers were also asked how well they remembered the events of a fishing trip and allowed to respond either "very well," "moderately well" or "not well" (Appendix Table C-3). A general linear model was used to test for significant differences in the accuracy of angler responses among the various week intervals (using recall bias scores) and among the three possible responses for how well anglers remembered the fishing trip (Appendix Table C-3). The general linear model test was considered significant at $p < .05$.

Appendix Table C-3, Northern squawfish sport-reward program recall bias study questions,

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Q1. How well do you remember the events of your fishing trip on (Day and Date)?

1. **Very** well
2. Moderately well
3. Not well (I only have a few questions and perhaps they will refresh your memory).
4. Unable to recall the fishing trip **and** cannot complete the questionnaire (Only use when angler cannot respond to the questions).

Q2. What were the top three species that you fished for that day?

A. ____ **B.** ____ C.____

Q3. Give me your best estimate of how many hours you fished that day? Please estimate to the nearest quarter hour.

____ Hours

Q4. I have a map of the Columbia and Snake Rivers. Could you tell me approximately where you were fishing that day?

____ Location code

Give me your best estimate of how many northern squawfish you returned to the check station?

Q5. ___ **# Over 11 inches** **Q6.** __ **# Under 11 inches**

Q7. Did you fish from:

1. Boat 2. Shore 3. Both

Results

Phone Survey Results

The majority (58%) of anglers surveyed fished from shore. Fresh bait was more commonly used by anglers (82%) than either trolling (13 %) or casting lures (47 %).

Approximately 96% of the non-returning anglers surveyed did not return to the check stations because they had no fish eligible for the reward (Appendix Table C-4). The remaining 4% (78 non-returning anglers) either gave their northern squawfish catch to other anglers to return to the check station or did return the catch to the registration station, but did not complete an exit interview.

Questions Q13A, B, C and D (Appendix Table C-2) address why people participate in the sport-reward fishery. Payment for northern squawfish was at least somewhat important to 77% of the non-returning anglers surveyed. The recreational opportunity offered by the sport-reward fishery was attractive to 89% of the surveyed anglers, but 95 % of the non-returning anglers sampled wanted to protect the salmon (Appendix Table C-4).

Angler satisfaction with the administration of the sport-reward program was high. The registration stations were conveniently located for 84% of all anglers surveyed. The majority (94%) of non-returning anglers sampled plan to register with the program again while the remaining would not continue in the fishery and cited poor catch and not enough time as major reasons for discontinuing participation in the program. Non-returning anglers rated interaction with the check station technicians to be “very good” or “good” in 99% of the surveys.

Anglers targeting northern squawfish had smaller catches of other species of fish, since northern squawfish composed 34% of the total catch for non-returning anglers who targeted northern squawfish (Appendix Table C-5), but composed only 13% of the total catch of non-returning anglers who did not target them (Appendix Table C-6). Anglers who targeted northern squawfish caught smallmouth bass (17%) and peamouth (11.5 %) more frequently than other species of fish, except for northern squawfish.

Appendix Table C-4. Frequency of angler responses to categorized questions asked in the 1993 telephone survey.

Q#[1]	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q1				
1	713	40.9	713	40.9
2	588	33.7	1301	74.6
3	443	25.4	1744	100.0
Q2				
1	711	40.8	711	40.8
2	185	10.6	896	51.4
3	61	3.5	957	54.9
4	101	5.8	1058	60.7
5	316	18.1	1374	78.8
6	9	0.5	1383	79.3
7	63	3.6	1446	82.9
8	66	3.8	1512	86.7
9	232	13.3	1744	100.0
Q2A				
1[2]	7	0.4	7	0.4
2	119	6.8	126	7.2
3	8	0.5	134	7.7
4	6	0.3	140	8.0
5	114	6.5	254	14.6
6	2	0.1	256	14.7
7	3	0.2	259	14.9
8	78	4.5	337	19.3
9	147	8.4	484	27.8
10	232	13.3	716	41.1
11	48	2.8	764	43.9
12	22	1.3	786	45.1
13	49	2.8	835	47.9
14	62	3.6	897	51.5
15	11	0.6	908	52.1
16	52	3.0	960	55.1
17	30	1.7	990	56.8
22	3	0.2	993	57.0
23	64	3.7	1057	60.7
24	4	0.2	1061	60.9
25	3	0.2	1064	61.1
26	1	0.1	1065	61.1
27	43	2.5	1108	63.6

[1] Refer to Appendix Table D-l for the questions represented by each code as well as the meaning of each response.
[2] Appendix Tables A-l through A-11 show the area of the Columbia or Snake rivers represented by each number.

Appendix Table C-4. Continued.

Q#	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q2A (Continued)				
28	24	1.4	1132	65.0
29	25	1.4	1157	66.4
30	8	0.5	1165	66.9
31	2	0.1	1167	67.0
32	2	0.1	1169	67.1
33	87	5.0	1256	72.1
34	1	0.1	1257	72.2
35	113	6.5	1370	78.6
36	8	0.5	1378	79.1
38	2	0.1	1380	79.2
40	51	2.9	1431	82.1
41	12	0.7	1443	82.8
42	2	0.1	1445	83.0
44	64	3.7	1509	86.6
45	3	0.2	1512	86.8
46	4	0.2	1516	87.0
47	18	1.0	1534	88.1
48	101	5.8	1635	93.9
49	89	5.1	1724	99.0
50	18	1.0	1742	100.0
Q3A				
AMS[3]	31	1.8	31	1.8
C	9	0.5	40	2.3
CC	93	5.3	133	7.6
CK	2	0.1	135	7.7
CP	1	0.1	136	7.8
LCH	1	0.1	137	7.9
LMB	9	0.5	146	8.4
NSF[4]	1054	60.4	1200	68.8
RU	19	1.1	1219	69.9
SA	15	0.9	1234	70.8
SK	2	0.1	1236	70.9
SMB	278	15.9	1514	86.8
SS	46	2.6	1560	89.4
TR	3	0.2	1563	89.6
WAL	47	2.6	1611	92.3
WS	129	7.4	1739	99.7
YP	5	0.3	1744	100.0

[3] Refer to Appendix Table D-l for a list of fish species represented by each code.
[4] Northern squawfish.

Appendix Table C-4. Continued.

Q#	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q3B				
RU	1	0.1	1	0.1
AMS	14	1.6	16	1.8
BG	3	0.3	19	2.2
BH	1	0.1	20	2.3
C	15	1.7	35	4.0
CC	92	10.6	127	14.6
CK	2	0.2	129	14.8
CMO	1	0.1	130	14.9
CP	2	0.2	132	15.2
LMB	12	1.4	144	16.5
NSF	275	31.6	419	48.1
PMO	3	0.3	422	48.5
RU	26	3.0	448	51.4
SA	12	1.4	460	52.8
SK	2	0.2	462	53.0
SMB	237	27.2	699	80.3
SNB	1	0.1	700	80.4
SP	1	0.1	701	80.5
SS	36	4.0	736	84.5
TR	1	0.1	737	84.6
WAL	57	6.5	794	91.2
WS	59	6.8	853	97.9
YBH	1	0.1	854	98.0
YP	17	2.0	871	100.0
Q3C				
C	1	0.2	1	0.2
SM	1	0.2	2	0.5
AMS	8	1.8	10	2.3
BG	3	0.7	13	2.9
C	17	3.9	30	6.8
CC	49	11.1	79	17.9
CK	5	1.1	84	19.0
CP	2	0.5	86	19.5
LMB	9	2.0	95	21.5
NSF	173	39.2	268	60.8
PMO	1	0.2	269	61.0
RU	17	3.9	286	64.9
SA	5	1.1	291	66.0
SK	2	0.5	293	66.4
SMB	67	15.2	360	81.6
SS	15	3.4	375	85.0
TR	1	0.2	376	85.3
WAL	27	6.1	403	91.4
WS	23	5.2	426	96.6
YP	15	3.4	441	100.0

Appendix Table C-4. Continued.

Q#	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q5				
0	34	2.0	34	2.0
1	757	43.5	791	45.4
2	478	27.5	1269	72.9
9	472	27.1	1741	100.0
Q6C AND Q9C				
1	1287	65.0	1287	65.1
2	206	10.4	1494	75.5
3	297	15.0	1791	90.5
4	109	5.5	1900	96.0
5	64	3.2	1964	99.2
6	16	0.8	1980	100.0
Q8				
0	36	2.1	36	2.1
1	429	24.6	465	26.7
2	254	14.6	719	41.3
9	1022	58.7	1741	100.0
Q10				
1	673	38.6	673	38.6
2	1015	58.3	1688	96.9
3	54	3.1	1742	100.0
Q11A				
1	219	12.6	219	12.6
2	1525	87.4	1744	100.0
Q11B				
1	1435	82.3	1435	82.3
2	309	17.7	1744	100.0
Q11C				
1	814	46.7	814	46.7
2	930	53.3	1744	100.0
Q12				
1	935	53.7	935	53.7
2	360	20.7	1295	74.3
3	369	-21.2	1664	95.5
4	78	4.5	1742	100.0
Q13A				
1	693	39.7	693	39.7
2	651	37.3	1344	77.1
3	400	22.9	1744	100.0

Appendix Table C-4. Continued.

Q#	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Q13B				
1	1190	68.2	1190	68.2
2	364	20.9	1554	89.1
3	190	10.9	1744	100.0
Q13C				
1	567	32.5	567	32.5
2	435	24.9	1002	57.5
3	742	42.5	1744	100.0
Q13D				
1	1460	83.7	1460	83.7
2	201	11.5	1661	95.2
3	83	4.8	1744	100.0
Q14				
1	1469	84.2	1469	84.2
2	275	15.8	1744	100.0
Q15				
1	1637	93.9	1637	93.9
2	107	6.1	1744	100.0
Q15A				
1	23	23.2	23	23.2
2	8	8.1	31	31.3
3	9	9.1	40	40.4
4	59	59.6	99	100.0
Q16				
1	1332	76.5	1332	76.5
2	410	23.5	1742	100.0
Q17				
1	1410	80.9	1410	80.9
2	317	18.2	1727	99.1
3	15	0.9	1742	100.0

The sport-reward fishery non-returning anglers were shown to have increased angler effort in the Columbia and Snake rivers only by a small amount, since the majority of the anglers surveyed (77%) would have taken the fishing trip even if the sport-reward fishery did not exist (Appendix Table C-4). Fish caught most frequently by anglers who would have taken the fishing trip even if the sport-reward fishery did not exist were smallmouth bass (25.7%), northern squawfish (24%), peamouth (8.9%) and white sturgeon (8.7%; Appendix Table C-7). The fish caught most frequently by anglers who would not have taken the fishing trip if the sport-reward fishery did not exist were northern squawfish (38.5%), smallmouth bass (14.7%), peamouth (10.7%) and white sturgeon (5.7%; Appendix Table C-8). Anglers, who would have been fishing regardless of the sport-reward fishery's existence, caught 82% of all fish caught by non-returning anglers.

The phone survey catch estimate for northern squawfish under 11 inches (12,825) and the returning angler catch estimates (10,171) were more similar than estimates of other fishes (Appendix Table C-9). Phone survey catch estimates for smailmouth bass (4,146) were approximately six times larger than returning angler estimates (644). Since returning angler catch estimates were lower than phone survey catch estimates for all species of fish tested (Appendix Table C-9), no further test of statistical significance was required to make the management decision to continue using the phone survey for estimating the catch of non-returning anglers.

Non-returning anglers total catch of northern squawfish under 11 inches was estimated to be 24,731 fish (+/- 4,761 fish- 95% confidence intervals). Anglers returned 48% of the 24,73 1 northern squawfish under 11 inches to the water unharmed (Appendix Table C-10). The percentage of northern squawfish under 11 inches returned to the water unharmed ranged from 11% to 89 % among registration stations.

The non-returning anglers estimated catch of northern squawfish over 11 inches was 2,968 (+/- 1,222 fish-95% confidence intervals). Nineteen percent were returned to the water unharmed. The percentage of northern squawfish over 11 inches returned to the water unharmed ranged from 0% to 100% among registration stations (Appendix Table C-11).

Appendix Table C-5. Frequency of fish species caught by anglers while targeting northern squawfish.

Species[1] Codes	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AMS	23	0.4	31	0.5
BG	19	0.3	50	0.9
BH	317	5.5	367	6.4
BLB	1	0.0	368	6.4
BT	2	0.0	370	6.5
C	185	3.2	555	9.7
CC	187	3.3	742	12.9
CCT	10	0.2	752	13.1
CF	1	0.0	753	13.1
CK	1	0.0	754	13.1
CMO	52	0.9	806	14.1
COT	92	1.6	898	15.7
CP	73	1.3	971	16.9
CR	3	0.1	974	17.0
CT	1	0.0	975	17.0
LCH	91	1.6	1066	18.6
LMB	10	0.2	1076	18.8
LW	1	0.0	1077	18.8
NSF	1972	34.4	3049	53.2
PGW	6	0.1	3055	53.3
PMO	660	11.5	3715	64.8
RS	50	0.9	3765	65.6
RU	46	0.8	3811	66.5
S	5	0.1	3816	66.5
SA	15	0.3	3831	66.8
SF	34	0.6	3865	67.4
SH	6	0.1	3871	67.5
SK	434	7.6	4305	75.1
SMB	974	17.0	5279	92.0
SP	7	0.1	5286	92.2
SS	11	0.2	5297	92.4
TR	3	0.1	5300	92.4
WAL	32	0.6	5332	93.0
WF	1	0.0	5333	93.0
WS	310	5.4	5643	98.4
YBH	5	0.1	5648	98.5
YP	87	1.5	5735	100.0

[1] Refer to Appendix Table D-1 for a list of fish species represented by each code.

Appendix Table C-6. Frequency of fish species caught by anglers while targeting species other than northern squawfish.

Species[1] codes	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AMS	250	6.9	250	6.9
BG	8	0.2	258	7.2
BH	6	0.2	264	7.3
C	210	5.8	474	13.2
CC	309	8.6	783	21.7
CK	1	0.0	784	21.8
CMO	1	0.0	785	21.8
COT	20	0.6	805	22.3
CP	23	0.6	828	23.0
CR	1	0.0	829	23.0
LCH	2	0.1	831	23.1
LMB	18	0.5	849	23.6
LW	2	0.1	851	23.6
NSF	473	13.1	1324	36.7
PMO	193	5.4	1517	42.1
RU	19	0.5	1536	42.6
SA	6	0.2	1542	42.8
SF	1	0.0	1543	42.8
SK	113	3.1	1656	46.0
SMB	1268	35.2	2924	81.2
SP	2	0.1	2926	81.2
SS	10	0.3	2936	81.5
WAL	21	0.6	2957	82.1
WS	462	12.8	3419	94.9
YBH	40	1.1	3459	96.0
YP	144	4.0	3603	100.0
CMO	1	100.0	3604	100.0

[1] Refer to Appendix Table D-1 for a list of fish species represented by each code.

Appendix Table C-7. Frequency of fish species caught by anglers who would have taken this fishing trip if the sport-reward program did not exist.

Species[1] codes	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AMS	228	2.9	236	3.0
BG	27	0.3	263	3.3
BH	249	3.1	512	6.5
BLB	1	0.0	513	6.5
BT	2	0.0	515	6.5
C	390	4.9	905	11.4
CC	466	5.9	1371	17.3
CCT	10	0.1	1381	17.4
CF	1	0.0	1382	17.5
CK	2	0.0	1384	17.5
CMO	30	0.4	1414	17.9
COT	74	0.9	1488	18.8
CP	79	1.0	1567	19.8
CR	3	0.0	1570	19.8
CT	1	0.0	1571	19.8
LCH	81	1.0	1652	20.9
LMB	27	0.3	1679	21.2
LW	2	0.0	1681	21.2
NSF	1897	24.0	3578	45.2
PMO	701	8.9	4279	54.1
RS	50	0.6	4329	54.7
RU	57	0.7	4386	55.4
S	5	0.1	4391	55.5
SA	17	0.2	4408	55.7
SF	28	0.4	4436	56.0
SH	6	0.1	4442	56.1
SK	424	5.4	4866	61.5
SMB	2034	25.7	6900	87.2
SP	6	0.1	6906	87.3
SS	15	0.2	6921	87.4
WAL	40	0.5	6961	87.9
WF	1	0.0	6962	88.0
WS	691	8.7	7653	96.7
YBH	44	0.6	7697	97.2
YP	218	2.8	7915	100.0

[1] Refer to Appendix Table D-l for a list of fish species represented by each code.

Appendix Table C-8. Frequency of fish species caught by anglers who would not have taken this fishing trip if the sport reward program did not exist.

Species[1] codes	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AMS	45	3.2	45	3.2
BH	74	5.2	119	8.4
C	5	0.4	124	8.8
CC	30	2.1	154	10.9
CMO	24	1.7	178	12.6
COT	38	2.7	216	15.2
CP	15	1.1	231	16.3
CR	1	0.1	232	16.4
LCH	10	0.7	242	17.1
LMB	1	0.1	243	17.1
LW	1	0.1	244	17.2
NSF	545	38.5	789	55.7
PGW	6	0.4	795	56.1
PMO	152	10.7	947	66.8
RU	8	0.6	955	67.4
SA	4	0.3	959	67.7
SF	7	0.5	966	68.2
SK	123	8.7	1089	76.9
SMB	208	14.7	1297	91.5
SP	3	0.2	1300	91.7
SS	6	0.4	1306	92.2
TR	3	0.2	1309	92.4
WAL	13	0.9	1322	93.3
WS	81	5.7	1403	99.0
YBH	1	0.1	1404	99.1
YP	13	0.9	1417	100.0

[1] Refer to Appendix Table D-1 for a list of fish species represented by each code.

Appendix Table C-9. Comparison of proportional catch estimates obtained from phone survey data and exit interview data for various fish species caught by non-returning sport-reward program anglers.

Registration	Squawfish under 11"[1]		Smallmouth Bass		White Sturgeon		Summer Steelhead		Walleye		Chinook Salmon	
Station	PHN.[2]	RTN.[3]	PHN.	RTN.	PHN.	RTN.	PHN.	RTN.	PHN.	RTN.	PHN.	RTN.
CATHLAMET	817	538	57	0	11	1	11	3	0	0	0	0
RAINIER	1153	716	0	0	0	1	0	3	0	0	0	0
KALAMA	1721	1306	67	0	0	0	22	10	0	0	0	0
GLEASON	1052	1200	302	16	34	1	0	0	22	25	0	0
CAMAS	398	623	210	91	11	0	0	4	66	11	0	3
FISHERY	972	1180	177	5	0	0	33	1	88	10	11	0
HAMILTON	430	409	111	19	0	1	0	0	0	3	0	0
CAS. L.	761	247	182	47	23	6	23	0	0	4	0	0
BINGEN	1298	336	147	8	34	0	0	1	0	0	0	0
DALLES	1136	589	522	26	23	0	0	0	151	5	0	0
LEPAGE	139	121	329	13	0	1	0	0	25	14	0	0
UMATILLA	142	255	44	52	0	0	0	0	11	70	0	0
COL. P.	144	707	155	71	0	0	0	2	0	0	0	2
VERNITA	1296	161	0	5	0	1	0	1	34	9	0	1
HOOD P.	492	346	425	13	0	0	0	0	0	4	0	0
LYONS F.	358	193	143	38	0	0	0	0	0	0	0	0
BOYER P.	66	149	330	25	0	0	0	0	0	0	0	0
GREENBELT	423	615	958	251	0	0	0	3	0	0	0	0
TOTAL	12825	10171	4146	644	136	14	91	26	397	158	11	6

[1] The phone survey estimates of the number of each species removed does not include fish that were returned to the water unharmed.
[2] Phone survey proportional estimates (the number of fish removed by phone survey anglers/the number of phone survey anglers) x the total number of non-returning anglers.
[3] Returning anglers proportional estimates (the number of fish removed by returning anglers/the number of returning anglers) x the total number of non-returning anglers.

Table 10. Total catch estimates of northern squawfish under 11 inches by non-returning anglers, along with confidence intervals and the percent of the catch returned to the water unharmed.

REGISTATION STATIONS	NON RETURN TOTAL	NON RETURN SAMPLE	NUM.NSF CAUGHT UNDER11	EST. NSF CAUGHT UNDER11	UNDER11 VARIANCE	UNDER11 CONFIDENCE INTERVAL	NUM.NSF RETURNE UNDER11	% of NSF RETURNED UNHARMED
CATHLAMET	862	76	117	1327	12.82	676	45	0.38
RANIER	678	60	159	1797	21.64	777	57	0.36
KALAMA	1299	117	271	3009	58.2	1748	116	0.43
GLEASON	1354	121	222	2484	48.21	1631	128	0.58
CAMAS	1524	138	109	1204	4.08	500	73	0.67
FISHERY	1116	101	99	1094	14.52	807	11	0.11
HAMILTON	1216	99	57	700	3.69	450	22	0.39
CASCADE L.	693	61	185	2102	83.24	1546	118	0.64
BINGEN	779	69	158	1784	116.82	1935	43	0.27
DALLES	881	76	122	1414	20.66	878	24	0.20
LEPAGE	923	73	97	1226	69.36	1727	86	0.89
UMATILLA	789	72	44	482	4.41	372	31	0.70
COLUMBIA P.	942	85	19	211	1.56	243	6	0.32
VERNITA	1127	100	172	1938	35.25	1277	57	0.33
HOOD P.	1488	133	77	861	8.76	729	33	0.43
LYONS F.	775	65	110	1312	28.09	975	80	0.73
BOYER P.	716	65	24	264	16.27	683	18	0.75
GREENBELT	2596	233	141	1571	6.31	815	103	0.73
TOTAL	19758	1744	2183	24731	27.77	4761	1051	0.48

Table 11. Total catch estimates of northern squawfish over 11 inches by non-returning anglers, along with confidence intervals and the percent of the catch returned to the water unharmed.

REGISTRATION STATIONS	NON RETURN TOTAL	NON RETURN SAMPLE	NUM.NSF CAUGHT OVER 11"	EST. NSF CAUGHT OVER 11"	OVER 11" VARIANCE	OVER 11" CONFIDENCE INTERVAL	NUM.NSF RETURNE OVER11	% of NSF RETURNED UNHARMED
CATHLAMET	862	76	1	11	0.03	33	1	1.00
RANIER	678	60	16	181	11.81	574	15	0.94
KALAMA	1299	117	6	67	0.48	159	0	0.00
GLEASON	1354	121	13	145	1.02	237	0	0.00
CAMAS	1524	138	27	298	2.21	368	20	0.74
FISHERY	1116	101	20	221	3.31	385	0	0.00
HAMILTON	1216	99	9	111	0.65	189	2	0.22
CASCADE L.	693	61	2	23	0.18	72	0	0.00
BINGEN	779	69	1	11	0.05	40	0	0.00
DALLES	881	76	7	81	0.61	151	2	0.29
LEPAGE	923	73	31	392	8	586	3	0.10
UMATILLA	789	72	8	88	0.94	172	0	0.00
COLUMBIA P.	942	85	25	277	1.55	243	0	0.00
VERNITA	1127	100	31	349	2.4	333	0	0.00
HOOD P.	1488	133	23	257	1.19	269	1	0.04
LYONS F.	775	65	9	107	0.53	134	0	0.00
BOYER P.	716	65	0	0	0	0	0	0.00
GREENBELT	2596	233	33	368	1.06	334	5	0.15
TOTAL	19758	1744	262	2968	1.83	1222	49	0.19

Recall Bias Survey Results

No statistically significant differences ($P > 0.222$) were found in the anglers' ability to recall the catch of northern squawfish over 11 inches among any of the week intervals (Appendix E). Anglers did not recall the number of northern squawfish over 11 inches caught at two weeks from the fishing trip more accurately than anglers surveyed at 12 weeks from the fishing trip. Anglers who classified their memory of a particular fishing trip as "very well" did not remember the catch of northern squawfish over 11 inches more accurately than anglers who classified their memory of a particular fishing trip as "not well" ($P > 0.721$). No statistically significant differences ($P > 0.936$) were found among anglers when comparing weeks and memory levels for northern squawfish over 11 inches.

Anglers who caught northern squawfish under 11 inches showed no statistically significant differences among weeks ($P > 0.823$), memory ($P > 0.287$), or week and memory ($P > 0.253$).

Discussion

Phone Survey Discussion

Future sport-reward fishery promotional efforts should emphasize the value of the program in protecting salmon populations, since 95% of surveyed anglers participated to help salmon (Appendix Table C-4). Oregon Department of Fish and Wildlife estimates regarding the percent reduction in juvenile salmonid losses due to predation should be publicized to anglers. Participation in the sport-reward fishery could increase if anglers were shown how their efforts increased salmon survival. A majority (77%) of non-returning anglers participated in the fishery because of the reward. Promotional programs, such as derbies, reward tags, and drawings could offer additional incentive for anglers to participate in the program.

Angler satisfaction with registration station locations was high (84%), but should be monitored as registration station locations change to ensure that participation in the sport-reward fishery does not drop due to low angler satisfaction with the registration locations. The current procedures for hiring and training technicians met the expectations of the sport-reward fishery anglers, since 99% of surveyed anglers rated interaction with the registration station technicians to be either "very good" or "good."

Anglers can accept occasionally not catching reward-size northern squawfish and still continue participating in the fishery. Non-returning anglers did not catch enough northern squawfish to make it worthwhile returning to the check station for a pay voucher and an exit interview, but 94% of the non-returning anglers were sufficiently satisfied with the fishery to continue future participation.

Anglers who target fishes other than northern squawfish register with the sport-reward fishery to collect the $3 reward on northern squawfish caught incidentally. Other anglers register with the sport-reward fishery specifically to target northern squawfish and to receive the reward. The majority of sport-reward anglers (61%) caught fish while targeting northern squawfish; anglers who target northern squawfish caught approximately 20% more northern squawfish than anglers who targeted other fishes, which shows sport-reward fishery anglers were more likely to exploit northern squawfish than other fishes.

Approximately 77% of anglers surveyed would have taken the fishing trip even if the sport-reward program did not exist and they caught 82% of all fish caught by non-returning anglers, which shows that many of the fish caught by non-returning anglers would have been caught regardless of the sport-reward fishery's existence. The majority of non-returning anglers simply wanted to go fishing and the sport-reward fishery offered the opportunity plus a reward. The sport-reward fishery may have reduced fishing pressure on other game fish species, since anglers would most likely target species other than northern squawfish in the absence of a reward. Appendix Table C-9 also shows the number of popular game and food fish caught incidentally by non-returning anglers was low and had little impact on the population size of any fish species other than northern squawfish. The fact that non-returning anglers returned 65% of all fish caught to the water unharmed also lowered the sport-reward fisheries effect on Columbia and Snake river fishes.

Since phone survey estimates of the number of fish removed by non-returning anglers were higher than returning anglers' estimates for all fishes compared (Appendix Table C-9), no further statistical analysis was necessary to justify the continuation of the phone survey estimates in 1994. The preservation of sensitive populations of fishes requires us to favor liberal catch estimates. Estimates of the number and type of fish caught by non-returning anglers could be made from returning angler data if returning anglers were shown to catch the same number and type of fishes as non-returning anglers and allowed all fish caught to be recorded in the exit interview. Some returning anglers were unwilling to take the time to show their catch to technicians. Under the 1993 rules, a technician could not record an angler's catch if the angler was unwilling to show their catch. Low returning angler estimates for 1993 data were due to incomplete catch data. The 1994 returning angler estimates for game and food fish will be improved by not requiring anglers to show the day's catch to technicians and by the addition of voucher questions that require returning anglers to record catch information. Comparisons will be made of the 1994 phone survey catch estimates, returning angler catch estimates, and voucher catch estimates to verify the findings of the 1993 phone survey. Returning angler estimates of northern squawfish removed under 11 inches were the closest to the phone survey estimates because returning anglers commonly turn in all northern squawfish caught.

The percentage of northern squawfish under 11 inches returned to the water unharmed varied among check stations from 11% to 75% (Appendix Table C-10). Returning fish to the water unharmed reduced our removal estimate of the number of northern squawfish under 11 inches from 24,731 (Appendix Table C-10) to 12,825 (Appendix Table C-9). Non-returning anglers are harvesting insignificant numbers of northern squawfish under 11 inches, which is consistent with the goals of the sport-reward fishery.

The estimated number of northern squawfish over 11 inches caught by non-returning anglers (2,968) was low, since most anglers want to receive the $3 reward. An unexpected finding was that 37% of northern squawfish over 11 inches caught by non-returning anglers were returned to the registration station. The phone survey question addressing how anglers disposed of the fish was not designed to determine why a non-returning angler would profess to be a returning angler. Surveyed anglers may have confused a day when they did not return to the registration station with a day they did return. Some anglers could have considered that giving northern squawfish to another angler to return to the registration station was the same as returning the fish themselves. The 1994 phone survey will be designed to find out exactly what non-returning anglers mean when they profess to have returned the day's catch to the registration station. Less than 1% (0.38 %) of the northern squawfish over 11 inches were kept to eat by anglers, indicating that northern squawfish are not a popular food fish. Anglers who caught only one or two northern squawfish over 11 inches may find it impractical to drive back to the registration station for such a small reward. Rather than waste a fish worth $3, non-returning anglers gave 21% of the catch of northern squawfish over 11 inches to other anglers. Approximately 19% of the northern squawfish over 11 inches caught by non-returning anglers were returned to the water unharmed, perhaps by anglers hoping to catch the fish on a more productive day.

Recall Bias Study Discussion

The recall of non-returning anglers was assumed to be equal to the recall of returning anglers so that inferences could be made about the accuracy of the phone survey data (non-returning anglers) from the results of the recall bias study (returning anglers). No significant difference was found in anglers' recall of the number of northern squawfish caught over 11 inches ($P < .222$) or under 11 inches ($P < .824$) at 2-, 4-, 6-, 8-, 10- or 12-week periods. The recall bias study showed that even though an individual angler's response may be incorrect, when all of the anglers' data were analyzed, catch data from anglers surveyed at two weeks from the fishing tip was not significantly ($P > 0.05$) less accurate than catch data gathered at 12 weeks.

Anglers evaluated memory of a particular fishing day as either "very good," "good" or "not good" (Appendix Table C-3). No significant difference was found among the three levels of memory for northern squawfish over 11 inches ($P < .721$) or under 11 inches ($P < .287$), which shows that an angler's evaluation of the accuracy of their memory was not the same as the true accuracy of the angler's memory.

The overall accuracy of the phone survey results was not found to be significantly changed by anglers' ability to recall the correct number of fish caught on a fishing trip.

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APPENDIX D

Fiih Species Codes

Appendix Table D-l. Sport-reward fishery field species codes.

LMB	Bass, Largemouth
RKB	Bass, Rock
SMB	Bass, Smallmouth
SB	Bass, Striped
BG	Bluegill
BH	Bullhead (General)
YBH	Bullhead, Yellow
BBH	Bullhead, Brown
BLB	Bullhead, Black
CP	Carp
BCF	Catfish, Blue
CC	Catfish, Channel
FCF	Catfish, Flathead
AC	Char, Atlantic
C	Crappie (General)
BC	Crappie, Black
WC	Crappie, White
EUL	Eulachon
SF	Flounder, Starry
AG	Grayling, Arctic
TMK	Musky, Tiger
SP	Perch, Shiner
YP	Perch, Yellow
NP	Pike, Northern
PS	Pumpkinseed
AT	Salmon, Atlantic
CK	Salmon, Chinook
CH	Salmon, Chum
CO	Salmon, Coho
K	Salmon, Kokanee
SA	Salmon, Pacific Unknown
PK	Salmon, Pink
SO	Salmon, Sockeye
AMS	American Shad
LFS	Smelt, Longfin
SS	Steelhead, Summer-Run
SW	Steelhead, Winter-Run
SH	Steelhead, Unknown Race
GRS	Sturgeon, Green
WS	Sturgeon, White
S	Sunfish (General)
GS	Sunfish, Green
BT	Trout, Brown
CT	Trout, Cutthroat General
CCT	Trout, Cutthroat Coastal
SCT	Trout, Cutthroat, Coastal
LCT	Trout, Cutthroat Lahontan
WCT	Trout, Cutthroat West
DB	Trout, Dolly Varden/Bull
BLC	Trout, Bull Trout (Char)
DVC	Trout, Dolly Varden (Char)
EB	Trout, Eastern Brook
GT	Trout, Golden
LT	Trout, Lake
RB	Trout, Rainbow Resident
RU	Trout, Rainbow Unknown
TR	Trout, Unknown
WAL	Walleye
WM	Warmouth
LW	Whitefish, Lake
WF	Whitefish, Mountain
NONGAME FISH SPECIES	
BUR	Burbot
CMO	Chiselmouth
LCH	Chub, Lake
TCH	Chub, Tui
[1]CRC	Columbia River Chub
LED	Dace, Leopard
LND	Dace, Longnose
SD	Dace, Speckled
GF	Goldfish
LM	Lamprey (General)
PL	Lamprey, Pacific
RL	Lamprey, River
WL	Lamprey, Western Brook
MQF	Mosquitofish
OMM	Mudminnow, Olympic
PMO	Peamouth
P	Pickerel, Grass
SAN	Sandroller
COT	Sculpin (General)
CSS	Sculpin, Coastrange
MRS	Sculpin, Margined
MTS	Sculpin, Mottled
PSS	Sculpin, Pacific
PTS	Sculpin, Piute
PRS	Sculpin, Prickly
RTS	Sculpin, Reticulate
RFS	Sculpin, Riffle
SHS	Sculpin, Shorthead
SLS	Sculpin, Slimy
TRS	Sculpin, Torrent
RS	Shiner, Redside
NSF	Squawfish, Northern
TSS	Stickleback,Three-Spine
SK	Sucker (General)
BRS	Sucker, Bridgelip
RS	Sucker, Largescale
LNS	Sucker, Longnose
MNS	Sucker, Mountain
TMT	Tadpole Madtom
TNC	Tench
WAD	White Amur-diploid
WAT	White Amur-triploid
PGW	Whitefish, Pygmy

[1] Conventional naming for NSF sport-reward program.

APPENDIX E

Recall Bias Study ANOVA Results

Appendix Table E-l. General linear model results for the difference between exit interview and recall bias study answers for northern squawfish over 11 inches in total length.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WEEK	6	2 4 6 8 10 12
MEMORY	3	1 2 3

Number of observations in data set = 414

General Linear Models Procedure

Dependent Variable: DIFFl

Source	DF	Sum of Sauares	Mean Sauare	F Value	Pr > F[1]
Model	17	744.726	43.807	0.70	0.8032
Error	396	24775.401	62.564		
Total	413	25520.128			

R-Sauare	C.V.	Root MSE	DIFF1 Mean[2]
0.029182	-4485.803	7.90975	-0.17633

Source	DF	Type I SS	Mean Sauare	F Value	Pr > F
WEEK	5	439.388	87.877	1.40	0.2216
MEMORY	2	40.928	20.464	0.33	0.7212
WEEK*MEMORY	10	264.410	26.441	0.42	0.9356

Source	DF	Type III SS	Mean Sauare	F Value	Pr > F
WEEK	5	504.353	100.870	1.61	0.1557
MEMORY	2	51.539	25.769	0.41	0.6627
WEEK*MEMORY	10	264.410	26.441	0.42	0.9356

[1] Probability of making a type one error.

[2] Average value of the difference between exit interview responses and recall bias study responses to the question: “How many northern squawfish did you catch over 11 inches in total length."

Appendix Table E-2. General linear model results for the difference between exit interview and recall bias study answers for northern squawfish under 11 inches in total length.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
WEEK	6	2 4 6 8 10 12
MEMORY	3	1 2 3

Number of observations in data set = 437

General Linear Models Procedure

Dependent Variable: DIFFl

Source	DF	Sum of Squares	Mean Sauare	F Value	Pr > F[1]
Model	17	112.912	6.641	1.01	0.4408
Error	419	2743.224	6.547		
Total	436	2856.137			

R-Sauare	C.V.	Root MSE	DIFF1 Mean[2]
0.039	-947.595	2.55873	-0.27002

Source	DF	Type I SS	Mean Sauare	F Value	Pr > F
WEEK	5	14.270	2.854	0.44	0.8235
MEMORY	2	16.412	8.206	1.25	0.2866
WEEK*MEMORY	10	82.229	8.222	1.26	0.2534

Source	DF	Type III SS	Mean Suuare	F Value	Pr > F
WEEK	5	17.708	3,541	0.54	0.7452
MEMORY	2	14.257	7.128	1.09	0.3376
WEEK*MEMORY	10	82.229	8.222	1.26	0.2534

[1] Probability of making a type one error.
[2] Average value of the difference between **exit interview** responses and recall bias study responses to the question: "How many northern squawfish did you catch under 11 inches in total length."

APPENDIX F

Computerized Data Collection Analysis

Computerized Data Collection Methods

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-volt DC power source. A customized software package developed by the work station manufacturer, Biomark Inc[1]., enabled Washington Department of Fish and Wildlife (WDFW) technicians to enter registration, exit interview, and biological data directly onto a computer diskette. 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 on hand. At the end of the evening shift, WDFW technicians would remove the labeled computer diskette that included all data from both shifts.

The time required to record data was measured for each of three technicians using the computerized data recording system and the manual data recording system. The study was conducted for two test periods, each consisting of one week of manual data and one week of computer data. The tests were conducted using actual anglers registering and exiting from the northern squawfish sport-reward fishery. Each technician was randomly assigned to either computer method or manual method at the beginning of each two-week test period. Test data from set variables and times were recorded onto weekly data forms and entered into a data base. All three technicians had prior experience recording data manually, but no experience entering data using the computerized method.

Four types of tests were conducted. Each test recorded the amount of time required by a technician to enter a registration form, conduct an exit interview, and to record biological data for 10 northern squawfish and 30 northern squawfish. Biological data consisted of recording the species of fish and measuring the fork length and weight of the fish. Time was measured by a stop watch. Technicians were tested five times per week on the manual and computerized method for comparing registration time. Exit interviews were tested 10 times per week using both manual and computer methods. Biological data recording time was tested five times per week using 10 and 30 northern squawfish for each test.

One person tested all technicians for both test periods. Registration and exit interview data on the manual system was measured by timing from when the pen first marked the form until the pen left the paper on the last data record. Computerized data collection for

[1] Mention of a manufacturer by the Washington Department of Fish and Wildlife does not constitute endorsement.

registration and exit interview data was timed from when the first key was struck to begin data entry until the last key was struck completing data entry. Biological data timing for the manual method began when the first northern squawfish was placed on the measuring board and ended when the last fish was completed. Biological data timing for the computerized method began when the first northern squawfish was placed on the digitizing pad and ended when the last fish was completed.

A paired t-test was used to test for significant differences between treatment groups (alpha=0.05). The sum of the differences between the paired tests was computed. A negative sum indicated the manual system was faster than the computer system and a positive sum indicated the computer system was faster than the manual system.

Computerized Data Collection Station Results

Registration Interview Comparison

The overall results of the six paired registration tests showed no difference between the speed of manual data entry and computer data entry (Appendix Table F-l). However, the general linear model showed the second period to be significantly faster than the first period. No significant difference existed among the three technicians for processing registration information.

Exit Interview Comparison

The overall results of the six paired exit interview tests indicated the computer method was significantly faster than the manual method (Appendix Table F-l). The general linear model showed a significant difference among the technicians. No significant difference was found between periods.

Biological Data Collection Comparison

The overall results of the six paired, 10-fish biological tests indicated the computer method was significantly faster than the manual method (Appendix Table F-l). The general linear model showed a significant difference among the technicians. Significant differences were found between periods. The mean time for a lo-fish biological test on the computer (3.8 minutes) was approximately twice as fast as the manual method mean time (7.27 minutes).

The overall results of the six paired 30-fish biological data tests indicated the computer method was significantly faster than the manual method. The general linear model showed a significant difference among the technicians. Significance was not found between periods. The mean time for a 30-fish biological data test on the computer (10.87 minutes) was approximately twice as fast as the manual method mean time (20.41 minutes). These results matched the results of the lo-fish biological data test.

Appendix Table F-l. Test results of the computerized data collection unit verses manual data collection.

PROC UNIVARIATE RESULTS'	GENERAL LINEAR[2] MODEL RESULTS		
REGISTRATION TEST COMPARISON			
N[3] = 30	DIFF MEAN[4]	-0.20	
SUM[5] = -6.1	MODEL	P<0.008	S[6]
P< 0.0842 NS[7]	TECHNICIAN	P<0.067	NS
	PERIOD	P<0.001	S
EXIT INTERVIER TEST COMPARISON			
N = 60	DIFF MEAN	0.593	
SUM = 35.6	MODEL	P<0.001	S
P<0.0001 S	TECHNICIAN	P<0.001	S
	PERIOD	P<0.817	NS
10 BIOLOGICAL TEST COMPARISON			
N = 30	DIFF MEAN	3.47	
SUM = 104.1	MODEL	P<0.002	S
P<0.0001 S	TECHNICIAN	P<0.013	S
	PERIOD	P<0.002	S
30 BIOLOGICAL TEST COMPARISON			
N = 30	DIFF MEAN	9.54	
SUM = 286.2	MODEL	P<0.001	S
P<0.0001 S	TECHNICIAN	P<0.001	S
	PERIOD	PC0.845	NS

[1] SAS procedure for performing a paired T-Test.
[2] SAS procedure for performing general linear models.
[3] Total number of tests conducted.
[4] Mean value of the difference between each pair of tests (a positive value indicated a faster data entry time for the computer method and a negative value indicates a faster time for the manual method).
[5] Sum of the differences between each pair of tests.
[6] Significant at an alpha level of 0.05.
[7] Not significant at an alpha level of 0.05.

Error Rates

The error rate results (Appendix Table F-2) showed a significant reduction in the number and percent of errors entered by each technician between Period 1 and Period 2 for registration and exit, and biological data entry. The percentage of errors was also higher with technicians that entered data faster as indicated by a higher number of total fields entered.

Computerized Data Collection Station vs Manual Discussion

The general linear model results (Appendix Table F-l) did show the second period was significantly faster than the first period for the registration test comparison, indicating that more experience on the computerized system was necessary for the computerized system to be more efficient than the manual. The registration test was the only test type that did not show a significant difference between the computer and manual systems. More fields are typed into the computer system for a registration test than any of the other test types, perhaps requiring more time for technicians to become proficient. No significant difference existed among the three technicians for a registration test indicating similar levels of efficiency among the technicians.

The general linear model results (Appendix Table F-l) also showed a significant difference among the technicians for the exit interview comparison, indicating that some technicians were faster than others with exit tests. No significance was found between periods, showing no significant improvement with experience in exit interviews. Anglers liked to talk with the technicians after a fishing trip, which sometimes caused delays in the exit interview and added a source of variance. This variance from fishermen conversation could mask any actual gains in speed of the technicians between periods.

The mean time for a 10-fish biological test on the computer (3.8 minutes) was approximately twice as fast as the manual method mean time (7.27 minutes). This indicates that biological data could be entered about twice as fast using the computer method as the manual method. Significance was also found between periods, showing improvement with experience.

The overall results of the six paired, 30-fish biological data tests indicate the computer method is significantly faster than the manual method. The general linear model showed a significant difference among the technicians indicating that some technicians were faster than others. Significance was not found between periods, showing no improvement with experience.

Appendix Table F-2. Technician error rates using the Biomark computerized data collection unit.

REGISTRATION AND EXIT DATA ERROR RATES

	TECHNICIAN		
	A	B	C
PERIOD 1			
TOTAL FIELDS	957	2900	32191
TOTAL ERRORS	71	277	2411
ERROR PERCENT	7.42	9.55	7.49
	A	B	C
PERIOD 2			
TOTAL FIELDS	667	2088	18272
TOTAL ERRORS	11	41	492
ERROR PERCENT	1.65	1.96	2.68

BIOLOGICAL DATA ERROR RATES

	A	B	C
PERIOD 1			
TOTAL FIELDS	810	4014	1539
TOTAL ERRORS	38	236	291
ERROR PERCENT	4.69	5.88	1.88
	A	B	C
PERIOD 2			
TOTAL FIELDS	135	1062	14762
TOTAL ERRORS	0	2	42
ERROR PERCENT	0.00	0.19	0.27

The results of the 10- and 30-fish biological data comparisons indicate that biological data could be entered about twice as fast using the computer method as the manual method.

Appendix Table F-2 illustrates that technicians make a high number of mistakes initially on the computerized system, but adjust quickly to the system and error rates drop with more experience.

The computer method has the advantage of recalling an angler's registration data after an initial entry. An angler who is participating in the program more than once would already have most of the registration data already entered into the computer. In practice, a higher percentage of anglers will have registration data previously entered as the season progresses resulting in the computer system increasing in efficiency. The computerized data unit could be improved by allowing data to be downloaded from the computer using a serial communications program.

The computerized data collection method allows data to be loaded directly into the data base. The manual data method must go one step further requiring additional staff to enter these data. The Hamilton Island registration station had data entry personnel manually enter 2,625 registration documents in 250 hours (technician wage = $9.40/hr.). If the computerized data collection unit was used for the entire season (assuming all computer problems could be solved), a $2,335 savings in data entry costs would have been realized. Cost savings from a computerized data collection unit can only be achieved at registration stations that process large amounts of data. With the collection of biological data not being a contract objective by WDFW, we feel that the computerized data collection unit should not be used for the 1994 sport-reward fishery. We will continue to collect biological data as time allows and provide it to the Oregon Department of Fish and Wildlife.

REPORT C

Northern Squawfish Sport-Reward Payments

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1993 Annual Report

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INTRODUCTION

The Pacific States Marine Fisheries Commission (PSMFC) provided fiscal services for payment of the squawfish sport rewards. Anglers registered and subsequently checked in their catch at the Washington Department of Fish and Wildlife field stations where they received a voucher for all eligible fish checked in. The vouchers were then sent by the angler to the sport-reward post office box in Oregon City. Vouchers were received and paid during the fishery from May through September. A cut-off date of October 15, 1993, was established as the final date vouchers needed to be postmarked to receive payment from PSMFC. These dates were printed in bold on the vouchers. PSMFC allowed one month past the official cut-off date for receipt of the vouchers, then started rejecting late vouchers because of logistics and the need for IRS reporting for the calendar year. The following sections summarize the vouchers paid this year.

VOUCHER PAYMENTS

A total of 12,351 vouchers were received for payment in the 1993 fishing season. They represented 101,697 fish for a total possible reward payment of $305,09 1. Of this total, 141 vouchers for 398 fish ($1,194) remain unpaid. Therefore, the total rewards actually paid were for $303,897, representing 101,299 fish on 12,210 vouchers. Rejected vouchers are addressed in a later section of this report. Table C-l summarizes the vouchers received for payment (including rejects) by month and their potential reward payments.

The voucher files can also be used to readily summarize the date fish were caught by month. This is a more useful statistic for review of the fishery than the payment date of vouchers. Rejected vouchers are included in this summary of month of catch. Some of these rejects had dates associated with them and some did not. Those for which a date is known are included in the appropriate month. Those rejects for which no date is in the system are listed at the bottom of the table. Table C-2 provides information about the month in which fish were caught whether a reward was paid or not.

Voucher processing proceeded smoothly. Depending on volume received, checks were cut and mailed to the angler within l-5 days after receipt of the voucher. Those vouchers that had missing or incomplete information were returned to the angler for completion. A total of 646 vouchers were rejected upon initial receipt for one reason or another. At the end of the season, 141 vouchers remain in the reject file worth $1,194, making the total rewards paid $303,897 for 101,299 fish on 12,210 valid vouchers.

Table C-l. Vouchers received for payment by month and their potential reward payments.

Month received	Vouchers	Number fish	Potential reward payment
May	868	5,705	$ 17,115
Jun	3,612	34,107	$ 102,321
Jul	3,033	29,664	$ 88,992
Aug	2,220	16,401	$ 49,203
Sep	2,081	13,680	$ 41,040
Oct	468	1,946	$ 5,838
Nov	48	145	$ 435
Dec[1]	12	29	$ 87
Jan'	6	10	$ 30
Feb[1]	3	10	$ 30
TOTALS:	12,351	101,697	$305,091

[1] Vouchers paid these months were initially received by the deadline, but subsequently returned to the angler one or more times for missing information.

Table C-2. Month, number of vouchers, and number of fish caught in the 1993 sport-reward fishery.

Month caught	Vouchers	Number fish	Av. fish/ voucher	Potential reward payment
May	2,511	16,429	6.5	$ 49,287
Jun	4,176	39,009	9.3	$117,027
Jul	2,973	27,594	9.3	$ 82,782
Aug	1,940	13,116	6.8	$ 39,348
Sep	637	5,232	8.2	$ 15,696
Rejects: (Date Unavail.)	114	317		$ 951
TOTALS	12,351	101,697		$305,091

REJECTED VOUCHERS/MISCELLANEOUS PAYMENTS

A total of 646 vouchers were rejected for various reasons either upon initial receipt or later when checks were returned by the post office as undeliverable. As the season progressed, 505 of these eventually cleared and were paid. There remain 141 vouchers that cannot be paid for various reasons such as having been sent back to the angler for missing data and not returned to PSMFC, bad addresses, etc. Tables C-3 and C-4 summarize initial reject categories and those 141 vouchers that did not clear.

We received a couple garnishments for anglers from the IRS and the State of Washington Support Enforcement Division. We honored and paid to the two agencies the amount requested from the appropriate angler's reward payments. Legal opinion sought by PSMFC from our state of Oregon assigned assistant attorney general from the Justice Department validated our need to pay the State of Washington Support Enforcement garnishment.

Table C-3. Summary of vouchers initially rejected upon receipt - 646 total.

	Number of vouchers
Returned To WDW for Missing Data:	
Missing # fish Caught	1
Missing Creel Clerk Signature	4
Date Not Filled In	1
No Signatures	1
Missing Signature & Trip Data	1
Missing Site Code	1
Returned to Angler for Missing Data:	
No Angler Signature	5
Missing Social Security #	1
Missing Signature & Social Security #	1
Questionnaire Not Completed	370
Angler Data Missing	170
Questionnaire & Angler Data Missing	10
Bad Address (Check Voided)	27
Past Deadline for Payment	45
TOTAL:	646

Table C-4. Summary of final voucher rejects at end of season - 141 total.

	Number of vouchers
Questionnaire Not Completed[1]	47
Angler Data Missing[1]	19
Questionnaire & Angler Data Missing[1]	3
Bad Address (Check Voided)	27
Past Deadline For Payment	45
TOTAL:	141

[1] Returned to Angler & not returned to PSMFC with missing data completed.

FISCAL STATEMENTS/REPORTS

All IRS Form 1099-Misc. statements were sent to the qualifying anglers for tax purposes the third week in January. Appropriate reports and copies were provided to the IRS by the end of February.

MISCELLANEOUS WORK

In the last quarter of the current contract period, work centered on cleaning up the voucher data entry program and associated accounting cross-checks, reports and voucher tracking and editing routines. The program has become more sophisticated to allow most all options necessary by means of program menus without the need for special programming expense or computer program technician time. We now have the option to look at previous years' data and to carry forward certain files and angler data to shorten data entry time. We have also added the ability to carry forward suspense vouchers and those rejected or on hold, should they clear in the future for payment. Recent additions also allow for the carry forward of IRS or other agency garnishments that extend across two or more fishing periods (years).

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REPORT D

Controlled Angling for Northern Squawfish at Selected Dams on the Columbia and Snake Rivers and Diet Analysis of Incidentally Caught Channel Catfish

Prepared by

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1993 Annual Report

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ACKNOWLEDGEMENTS

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Personnel from the U.S. Army Corps of Engineers were invaluable in their cooperation and coordination: Jim Kuskie and Dennis Schwartz (Bonneville Dam); Jim Williams and Bob Dach (The Dalles and John Day dams); Peter Gibson and Brad Eby (McNary Dam); Bill Spurgeon (Ice Harbor and Lower Monumental dams); Rex Baxter and Rebecca Kalamasz (Little Goose Dam); and Jesse Smiley, Tim Wik, Mike Halter, and Ron Robson (Lower Granite Dam).

We extend a special thanks to the volunteer anglers from the Portland and Tom McCall Chapters of Northwest Steelheaders, The Dalles Rod and Gun Club, Mid Columbia Bass Anglers, and the High Desert Chapter of The Ladies Angle Fishing Society.

For the diet analysis, Tom Poe and Conrad Frost (U.S. Fish and Wildlife Service) provided valuable advice and assistance, and Dave Ward and Chris Knutsen (Oregon Department of Fish and Wildlife) provided laboratory space and other help.

Becky Ashe, Roy E. Beaty, Ken Collis, Kathy McRae and Blaine Parker (alphabetical order) contributed to this report.

ABSTRACT

During our third season, 1993, field crews fished from mid-May through early September at eight lower mainstem dams on the Columbia and Snake rivers and had a confirmed catch of 16,949 northern squawfish (*Ptychocheilus oregonensis*). Total effort and northern squawfish catch were 61% and 58%, respectively, of those in 1992. Overall catch per angler hour (CPAH; 1.7) was essentially unchanged. Effort has been reduced most at Snake River dams (by 79% since 1991) because of continuing low CPAH (0.5 in 1993) relative to Columbia River dams (2.0 in 1993). At Columbia River dams, increased catch rates (relative to 1992) at Bonneville (from 2.7 to 2.9) and John Day dams (from 1.2 to 2.2) were offset by larger decreases at The Dalles (from 3.0 to 1.4) and McNary dams (from 2.9 to 1.9).

We continued to shift effort to the most productive dams and to use volunteer anglers and boat angling to improve efficiency. Volunteer anglers from five sporting groups contributed 266 hours of effort and caught 550 northern squawfish, 3.2% of the season total. Although boat angling in the tailraces was generally more effective than concurrent angling on the dams, we cannot conclude that it is more efficient than dam-based angling.

Incidental species composed a slightly lower percentage of the total catch in 1993 (5.5 %) than in 1992 (5.8%), although the contribution by bass (*Micropterus* spp.) roughly doubled (from 1 .O% to 2.1%) and partially offset a decrease 'in the percentage of catfish (*Ictalurus* spp.; from 3.7% to 2.0%) in our catch. Three juvenile and three adult salmonids (*Oncorhynchus* spp.) were caught, and all except one of the juveniles were released in good condition.

Incidentally caught channel catfish (Z. *punctatus*) sampled at McNary Dam and Snake River dams from June through August contained an average of 0.05 juvenile salmonids (only two, total), one-third of the average (0.16) for northern squawfish sampled from the same dams and months. However, these results have several limitations. A high incidence of fall chinook salmon from Lyons Ferry Hatchery in northern squawfish samples from Lower Monumental Dam suggests a high predation rate on these summer-released fish.

INTRODUCTION

Historically, juvenile salmonids (*Oncorhynchus* spp.) in the Columbia-River and its tributaries encountered few obstacles during their downstream migration to the sea. However, numerous hydroelectric dams have transformed the Columbia and Snake rivers into a series of reservoirs that slow the migration of juvenile salmonids (Raymond 1988). The dams have also created feeding stations for predators, particularly in tailrace areas (Raymond 1988). Northern squawfish (*Ptychocheilus oregonensis*) were identified as the primary predator of juvenile salmonids in the John Day Reservoir during a multi-year study (Poe et al. 1991).

Hook-and-line angling from the dams effectively removes northern squawfish (Vigg et al. 1990; Beaty et al. 1993; Parker et al. 1993) from the areas where predation is most severe (Rieman et al. 1991; Petersen, in review). Through 1992, dam angling removed approximately 78,219 northern squawfish from eight dams on the lower Columbia and Snake rivers (Vigg et al. 1990; Beaty et al. 1993; Parker et al. 1993). In 1993, the Columbia River Inter-Tribal Fish Commission (CRITFC) and its member tribes sought to (1) efficiently remove northern squawfish from areas adjacent to dams; (2) minimize incidental catch of salmonids (*Oncorhynchus* spp.), white sturgeon (*Acipenser transmontanus*), and other species; (3) determine whether incidentally caught channel cattish (*Ictalurus punctatus*) were also preying on juvenile salmonids; and (4) continue developing and implementing more effective and efficient methods (e.g., volunteer and boat angling) for removing northern squawfish near dams.

METHODS

Dam Angling

Angling crews fished at eight U.S. Army Corps of Engineer (Corps) dams on the lower Columbia and Snake rivers in 1993 (Table D-l and Figure D-l). We distributed effort based in part on 1992 results and on inseason CPAH patterns. For example, we delayed starting some crews because of the cool, wet spring. Also, crews sometimes worked split shifts to cover high catch periods at dawn and dusk, and the large crew at McNary Dam divided into two smaller crews during the peak of the season to distribute effort over seven days per week.

The efforts of crews at some dams were augmented by a mobile crew, volunteer anglers, and boat angling (Table D-2). The mobile crew fished the most productive dams on the lower Columbia River and helped supervise volunteer anglers. Members of five sport angling groups volunteered to fish some weekend evenings at Bonneville, The Dalles, and McNary dams during a six-week period in July and August. Boat angling was restricted to the tailrace boat restricted zones (BRZ) during daylight hours. Concurrent angling on the dam, itself, provided the standard for evaluating the effectiveness of boat angling. We did not formally evaluate the performance of the mobile crew and volunteer anglers.

Angling equipment and techniques, including measures to minimize incidental catch, were essentially the same as those used in 1992 (Parker et al. 1993). When dead juvenile salmonids were used for bait, their heads were removed and discarded so that the diagnostic bones (e.g., dentaries and cleithra) would not bias the results of our diet analysis. We continued our "no-touch" policy for all salmonids ≥ 0.50 m (1.5 ft) and sturgeon ≥ 0.75 m (approx. 2.5 ft), which were immediately cut free to avoid unnecessary handling stress and injury. Smaller salmon and sturgeon and other incidental species were reeled in, unhooked, and released. We used debarbed bronzed hooks, which allowed incidental species to be released with less injury and allowed hooks retained by large incidental fish to disintegrate.

Table D-l. Distribution of angling effort at Columbia and Snake River dams in 1993.

Dam (river km)	Season	Supervised by
<u>Columbia River</u>		
Bonneville (233)	May 24-Sept 10	CTWS[a]
The Dalles (310)	May 24-Sept 16	CTWS
John Day (348)	June 7-Sept 16	YIN[b]
McNary (470)	June 2-Sept 2	CTUIR[c]
<u>Snake River</u>		
Ice Harbor (16)	June 21-Aug 31	CTUIR
Lower Monumental (68)	July 12-Aug 30	CTUIR
Little Goose (113)	May 17-Sept 2	NPT[f]
Lower Granite (172)	May 17-Sept 3	NPT

[a] Confederated Tribes of the Warm Springs Reservation of Oregon

[b] Confederated Tribes and Bands of the Yakima Indian Nation

[c] Confederated Tribes of the Umatilla Indian Reservation

[d] Nez Perce Tribe

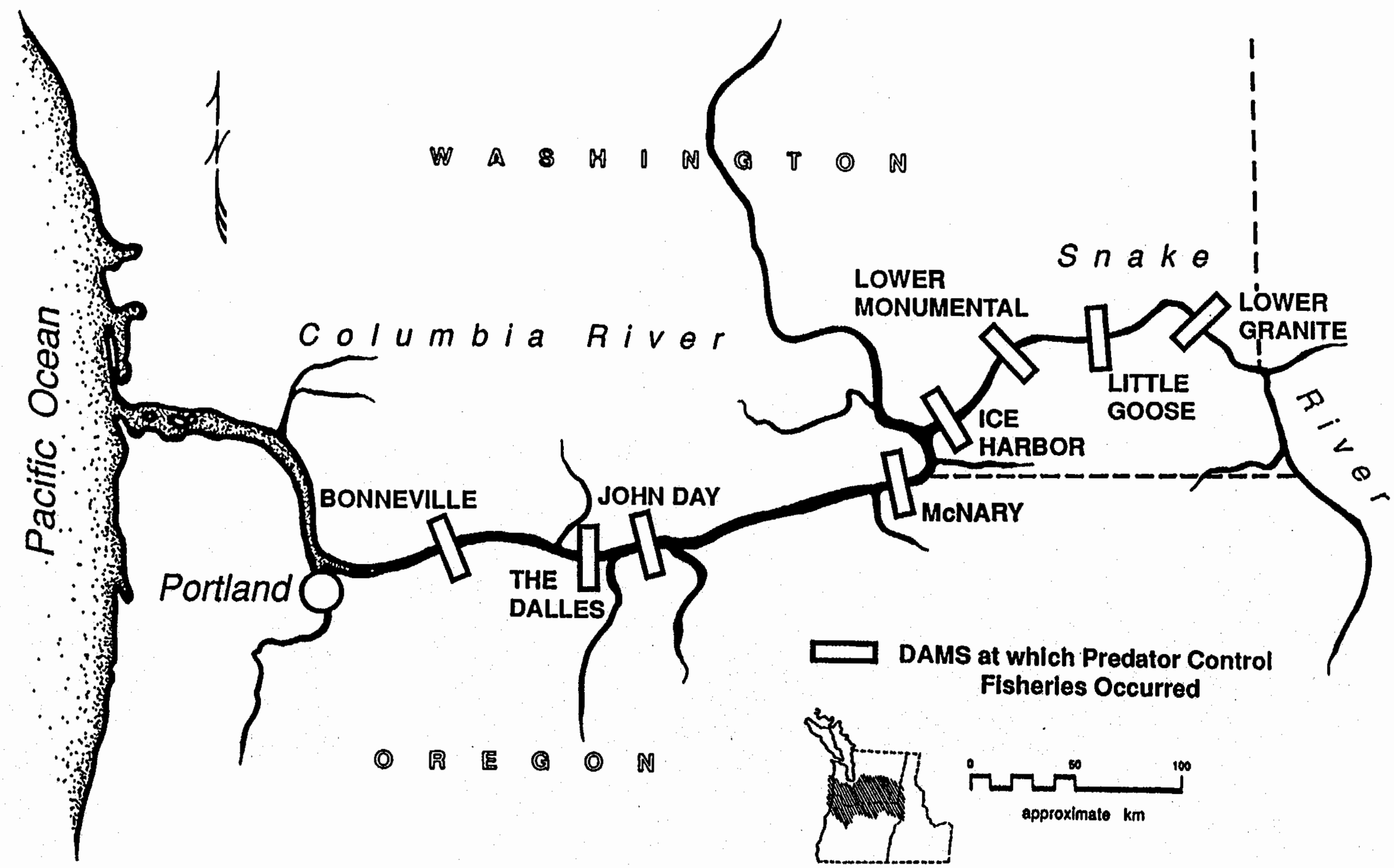

Figure D-1. Dams where controlled angling operations were conducted in 1993.

Table D-2. Supplemental angling activities used in 1993.

Supplemental angling method & personnel source	Dam	Dates
Mobile Crew		
CRITFC	Bonneville, The Dalles, John Day, & McNary	May 25-Sept 16
Volunteer Angling		
NW Steelheaders: Portland Chapter, Tom McCall Chapter	Bonneville	July 10, 17, 24, & Aug 7
The Dalles Rod & Gun Club	The Dalles	June 25, July 16, 23, 30, & Aug 6
The Ladies Angle: High Desert Chapter	McNary	July 10, 24, & Aug 7
Mid Columbia Bass Anglers	McNary	July 17 & Aug 14
Boat Angling		
Warm Springs Tribe	The Dalles	July 21-22, 27-28
	John Day	Aug 11-12
Nez Perce Tribe	Lower Granite	July 21, 26-28, Aug 12, 16-18, 24, & Sept 3
	Little Goose	July 22, Aug 11, 19, 25, & Sept 2
	Lower Monumental	Aug 10
	Ice Harbor	Aug 2
	McNary	Aug 26-27, 31, & Sept 1

We transferred northern squawfish caught to on-site freezers or coolers. Northern squawfish with "spaghetti" tags or radio transmitters were given to the Oregon Department of Fish and Wildlife (ODFW) and U.S. Fish and Wildlife Service (USFWS), respectively. Tagged channel catfish, bass (*Micropterus* spp.), and walleye (*Stizostedion vitreum*) were immediately released after the tag number and capture location were recorded.

We collected and summarized data as in 1992 (Parker et al. 1993). Data were recorded in hand-held computers and transmitted by modem each day to our Portland office. Computer programs filtered incoming data files for anomalous data, which we investigated and corrected, if necessary. Data for all angling types (e.g., dam-based crews, volunteers, boats) were aggregated by dam for weekly reports to ODFW, the contracting agency, and for this report. Channel catfish sacrificed for diet analysis were reported in Release Condition 3 (e.g., dead).

Diet Analysis

We sacrificed approximately 20% of the channel catfish caught incidentally at McNary Dam and Snake River dams (target $N = 5 \cdot dam^{-1} \cdot wk^{-1}$) and removed their digestive tracts for diet analysis. We also sampled the digestive tracts of northern squawfish (target $N = 10 \cdot dam^{-1} \cdot wk^{-1}$ at all eight dams) to provide a relative standard for evaluating the incidence of juvenile salmonids found in channel catfish samples. Sampling rates were not uniform among dams and weeks. The crews, whose schedules (days and hours) varied weekly, generally sampled the first fish caught each week. Sample collection and analysis used the procedures of Collis et al. (1993), except that we injected approximately 50 ml of a saturated sodium bicarbonate solution into each channel catfish sample to neutralize digestive acids that decalcify prey bones. Left pectoral spines were collected (Sneed 1951) from channel catfish for age determination (Marzolf 1955).

RESULTS AND DISCUSSION

Dam Angling

Northern Squawfish Catch

In 1993, anglers fished approximately 9,718[1] h and had a confirmed catch of 16,949[1] northern squawfish, for a seasonal catch per angler hour (CPAH) of 1.7, the same as 1992 (Table D-3). Both total effort and total catch declined approximately 30% from 1992.

We generally succeeded in placing the greatest effort (i.e., angler hours) at dams with the highest catch rates (Figure D-2). Eighty percent of the effort was at Columbia River dams. Unexpected decreases (relative to 1992) in CPAH at The Dalles and McNary dams and the increase at Bonneville Dam (Table D-3) were responsible for some inefficiency. Results of volunteer and boat angling are presented in separate sections below.

Columbia River Dam

In 1993, 7,807 angler hours (18 % decrease from 1992) at Columbia River dams produced 15,944 fish (30% decrease), for a 2.0 seasonal CPAH (17% decrease; Table D-3). Four years of previous removals from consistently productive areas (e.g., the tailraces of The Dalles and McNary dams) probably account for some of the decline in CPAH. The Dalles Dam, which had the highest catch and CPAH of any dam in 1992, had the greatest decline in CPAH (53%, from 3.0 to 1.4) in 1993. Sites near the sluiceway outfall, the most productive in years past, were relatively barren this year. Since 1990, dam anglers have removed 14,850 northern squawfish from the tailrace of The Dalles Dam (Vigg et al. 1990; CRITFC, unpubl. data).

The CPAH at McNary Dam also declined (34%, from 2.9 to 1.9) in 1993, despite splitting the crew and distributing its effort through all days of the week. We hypothesize that CPAH is an inverse function of how intensively effort is focused in space and time (within a limited range of fish abundance and catchability). Therefore, we expect that the McNary Dam CPAH would have been even lower if we had maintained a single large crew on a conventional four-day work week. Dam anglers have removed 24,572 northern squawfish from the tailrace of McNary Dam since 1990 (Vigg et al. 1990; CRITFC, unpubl. data), which may account in part for the decline in CPAH at that dam.

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[1] Data reported by the resident crew at John Day Dam through July 11 have been excluded from these results. The effort (angler hours) reported in those data was overstated to an unknown degree, and we were not able to determine if the corresponding catch data were also inaccurate. Excluded data are provided in footnotes for Table C-3.3 and for Appendix Tables C-3.1.4 and C-3.1.13.

Table D-3. Angling effort and northern squawfish catch by dam for 1991, 1992, and 1993.

Dam	1991			1992			1993		
	Seasonal totals			Seasonal totals			Seasonal Totals		
	Hours fished	Northern squaw-fish	CPAH	Hours fished	Northern squaw-fish	CPAH	Hours fished	Northern squaw-fish	CPAH
Columbia River									
Bonneville	2,621	8,131	3.1	1,781	4,814	2.7	1,991	5,836	2.9
The Dalles	1,333	3,674	2.8	2,496	7,561	3.0	1,992	2,712	1.4
John Day	2,816	5,004	1.8	2,775	3,427	1.2	1,044[a]	2,248[a]	2.2[a]
McNary	3,416	8,348	2.4	2,523	7,297	2.9	2,780	5,148	1.9
Season	**10,187**	**25,157**	**2.5**	**9,575**	**23,099**	**2.4**	**7,807[a]**	**15,944[a]**	**2.0[a]**
Snake River									
Ice Harbor	2,052	1,486	0.7	298	278	0.9	404	122	0.3
Lower Monumental	2,472	3,313	1.3	943	475	0.5	396	105	0.3
Little Goose	2,140	4,915	2.3	3,062	1,664	0.5	378	100	0.3
Lower Granite	2,448	4,480	1.8	2,881	2,352	0.8	734	678	0.9
Season	**9,112**	**14,194**	**1.6**	**7,184**	**4,769**	**0.7**	**1,911**	**1,005**	**0.5**
GRAND TOTALS	**19,298**	**39,351**	**2.0**	**16,759**	**27,868**	**1.7**	**9,718[a]**	**16,949[a]**	**1.7[a]**

[a] Does not include 517 h fished and 261 northern squawfish. See text for rationale.

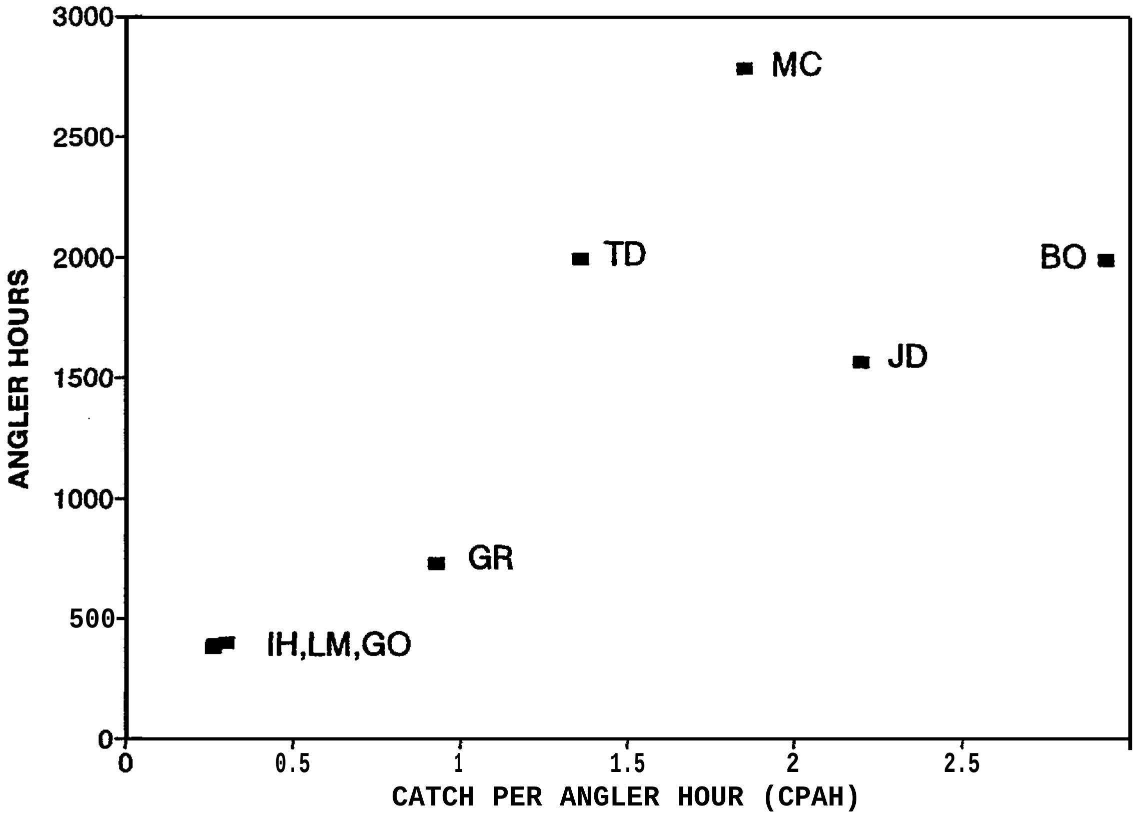

Figure D-2. Plot of seasonal catch per angler hour (CPAH) and total hours fished, by dam for 1993.

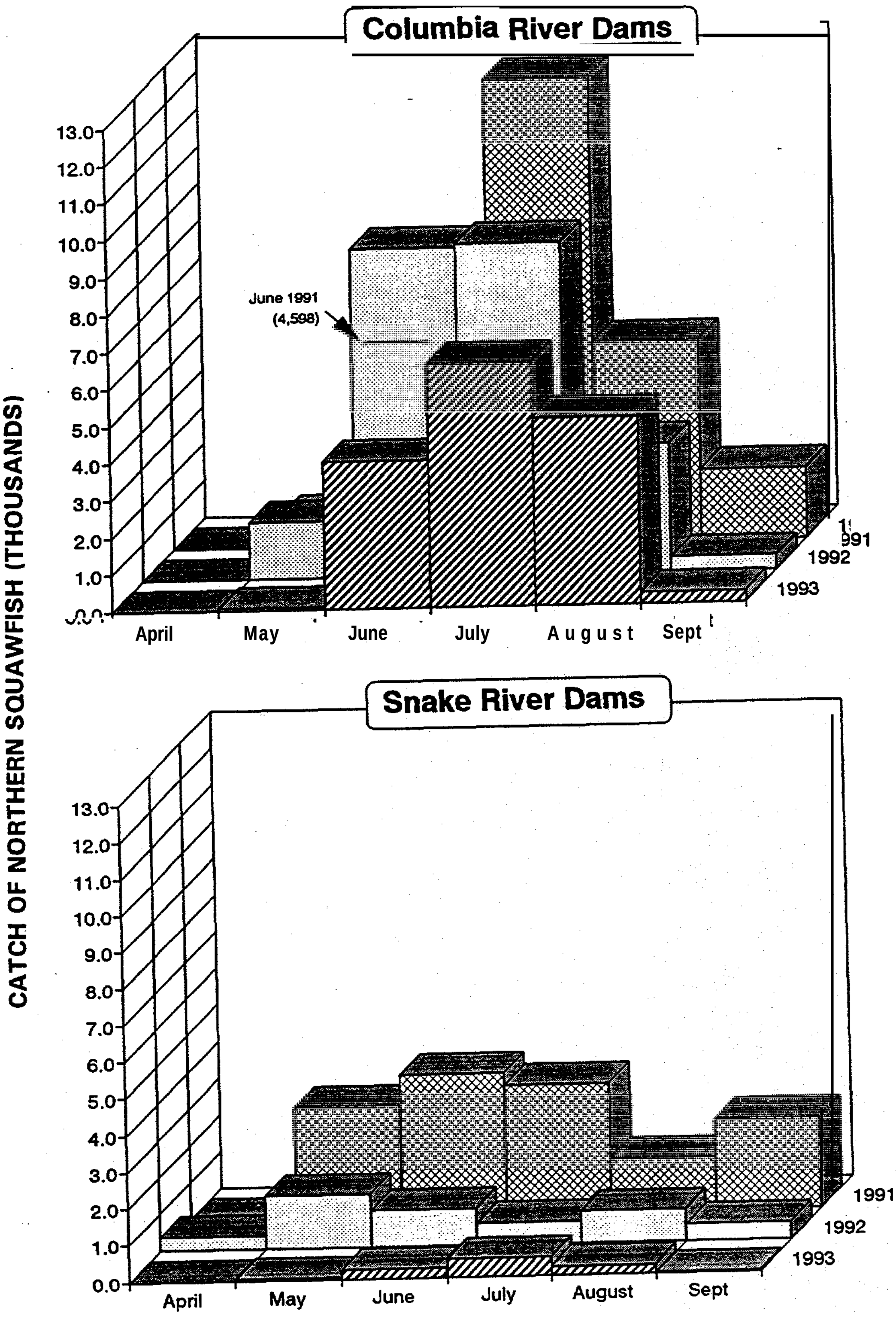

Figure D-3. Monthly catch of northern squawfish at Columbia and Snake River dams for 1991, 1992, and 1993.

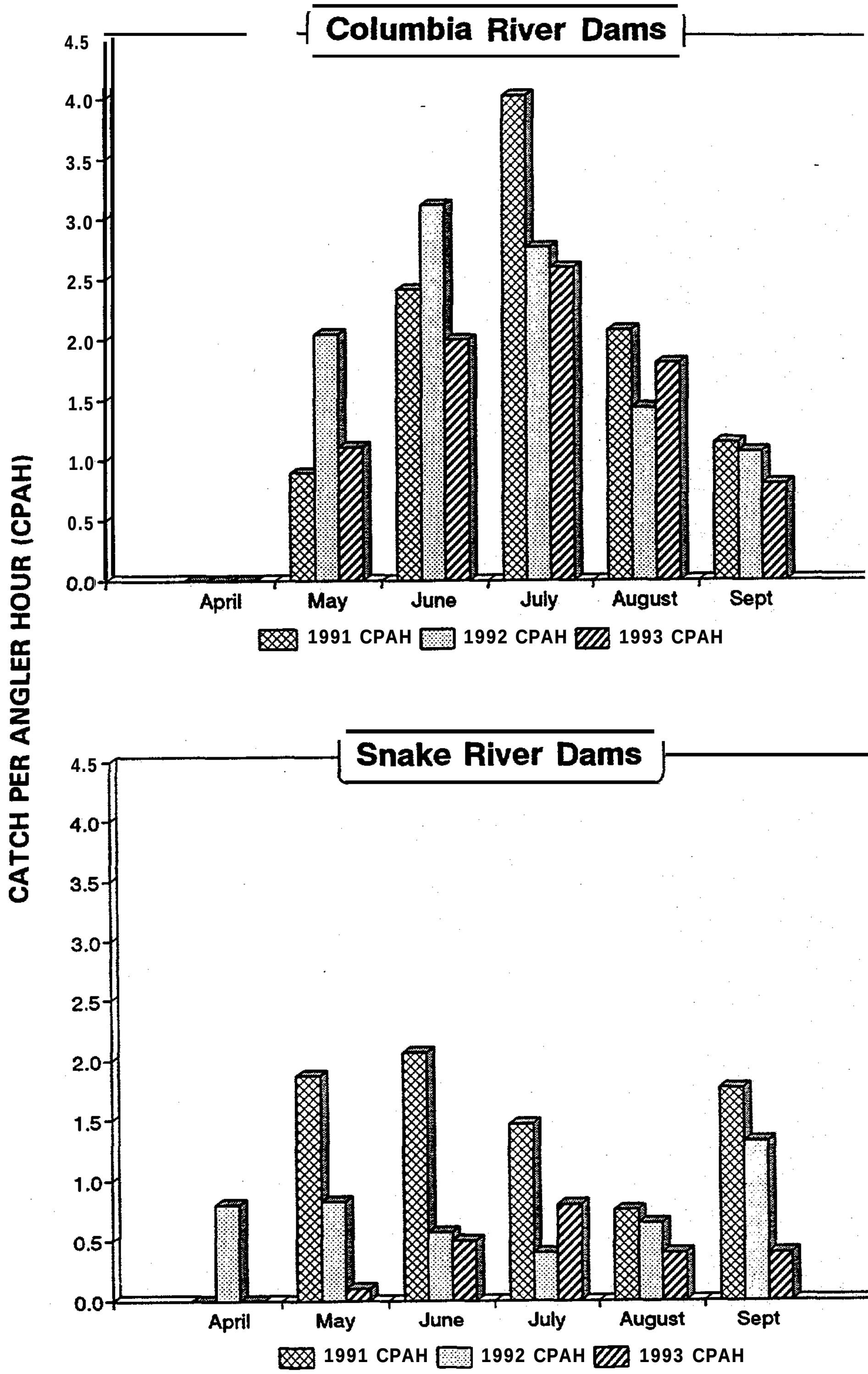

Figure D-4. Monthly average catch per angler hour (CPAH) at Columbia and Snake River dams for 1991, 1992, and 1993.

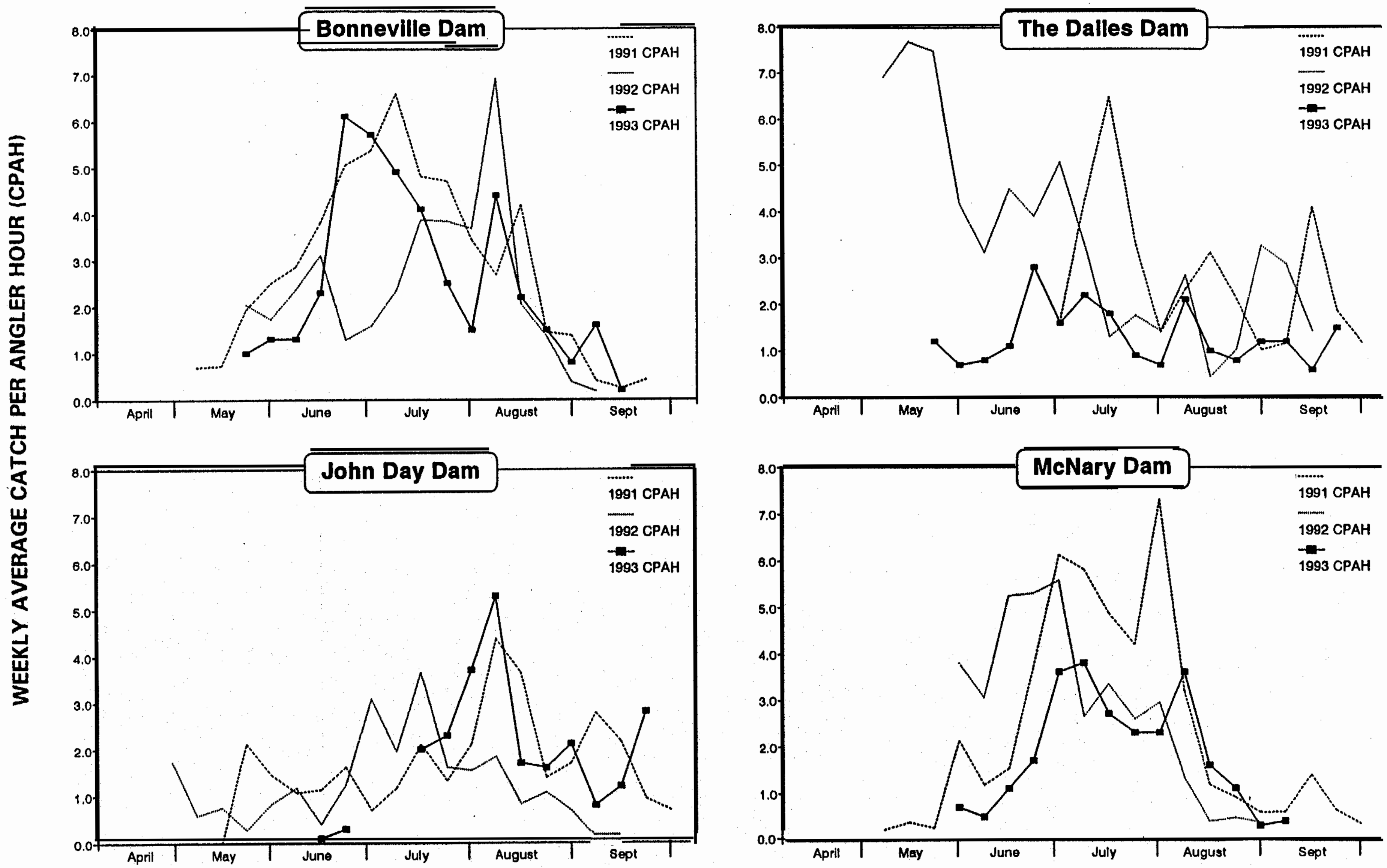

Figure D-5. Weekly average catch per angler hour (CPAH) at Columbia River dams, 1991, 1992, and 1993. Effort varied substantially within and between seasons.

The decline in overall CPAH on the Columbia River was ameliorated in part by a slight increase (7%, from 2.7 to 2.9) at Bonneville Dam and by a substantial increase (83%, from 1.2 fish to 2.2) at John Day Dam. However, the CPAH for John Day Dam would have been lower had part of the data not been excluded.

Environmental conditions, which differed greatly between 1992 and 1993, also may have contributed to the decline in CPAH. Low flows and unseasonably high water temperatures prevailed in the warm, dry spring and summer of 1992. In contrast, 1993 was more like 1991 — cool and wet with higher flow and spill volumes — which may explain the similarities in seasonal trends in catch and CPAH (four dams, combined) between the two years (Figures D-3 and D-4). Likewise, the trend in 1993 weekly average CPAH at individual dams remarkably resembles the trend for 1991, except at The Dalles Dam (Figure D-5). Environmental conditions, such as water temperature and flow, seem to have a strong effect on seasonal trends in CPAH.

The effects of flow were particularly apparent in 1993. Anglers sometimes were frustrated by swift currents and low catches in tailrace sites that had been productive in 1992. Radio-tagged northern squawfish moved away from The Dalles and John Day dams during the period of high flows (R. Shively, USFWS, personal communication), making those fish inaccessible to dam anglers. An earlier study in the tailrace at McNary Dam showed that northern squawfish avoid high velocities (Faler et al. 1988.). Anglers at The Dalles and Bonneville dams observed that during high flows they would catch northern squawfish in small schools or pockets close to tailrace riprap. One such pocket, along the Bradford Island shore of the spill basin at Bonneville Dam, was so specific that an angler fishing in one spot would catch three to five times as many fish as anglers less than 10 m away on either side. Anglers spent much time searching for these small pockets of northern squawfish during high flow periods in 1993.

Very local conditions also affected catches at John Day Dam. Anglers there were generally most successful when spilling began in the evening (G. Lee and S. Parker, YIN, personal communication), catching most of their fish just beyond the edge of the spill turbulence that spread southward across the powerhouse tailrace.

Snake River Dams

The combined catch at Snake River dams (1,005 fish) was 79% lower than in 1992, mostly because of a large (73%) reduction in effort and a moderate (21%) decline in CPAH (to 0.5) in 1993 (Table D-3). We have reduced effort at Snake River dams each year since 1991 as catch rates have continued to decline, and 1993 efforts at the three lower dams (Ice Harbor, Lower Monumental, and Little Goose) were little more than monitoring. Only at Lower Granite Dam did CPAH stay relatively unchanged (0.9 in 1993, 0.8 in 1992) and close to our arbitrary threshold for acceptability (e.g., 1.0). Lower Granite Dam's CPAH probably could not have been sustained without the large reduction (75%) in effort there compared to 1992, assuming that catch rate is inversely related to effort.

We cannot easily account for the continuing decline in CPAH at Snake River dams (Figure D-4; Table D-3). Trends in weekly CPAH for each dam reveal little (Figure D-6), except that Lower Granite Dam had an unusually prominent summer (July)-mode,. which is more characteristic of a Columbia River dam. As in the Columbia, unusually high flows, low water temperatures, and high turbidity persisted through June and probably depressed catch rates during that period, at least at Lower Granite and Little Goose dams (M. Villalobos, NPT, personal communication). University of Idaho researchers informed the angling crew at Lower Granite Dam that many of the radio-tagged northern squawfish released into the tailrace of that dam moved downstream l-3 km and stayed there when flows and turbidity were high (M. Villalobos, NPT, personal communication). Catch rates at Snake River dams in 1991 dropped dramatically during a turbid spate in May of that year (Beaty et al. 1993). Also, removal of northern squawfish over the last three years (approximately 20,000 by dam angling alone) has probably contributed to the large (69%) decline in CPAH at Snake River dams since 1991.

Volunteer Angling

Volunteers fished 266 hours (2.7% of all effort) and caught 550 northern squawfish (3.2% of total catch), for a seasonal CPAH of 2.3. Although we believe that volunteer angling, coordinated and supervised in 1993 by CRITFC employees, was more cost effective than conventional dam angling, we do not yet have data to confirm that belief.

Volunteers were not consistently more or less effective than resident crews at the dams (Table D-4). At Bonneville Dam, Corps of Engineer safety constraints did not allow volunteers to fish in riprap areas, where the resident crew catches were relatively high. At The Dalles Dam, evening hours fished by the volunteers apparently were more productive than the daytime hours, which the resident crew preferred to fish.

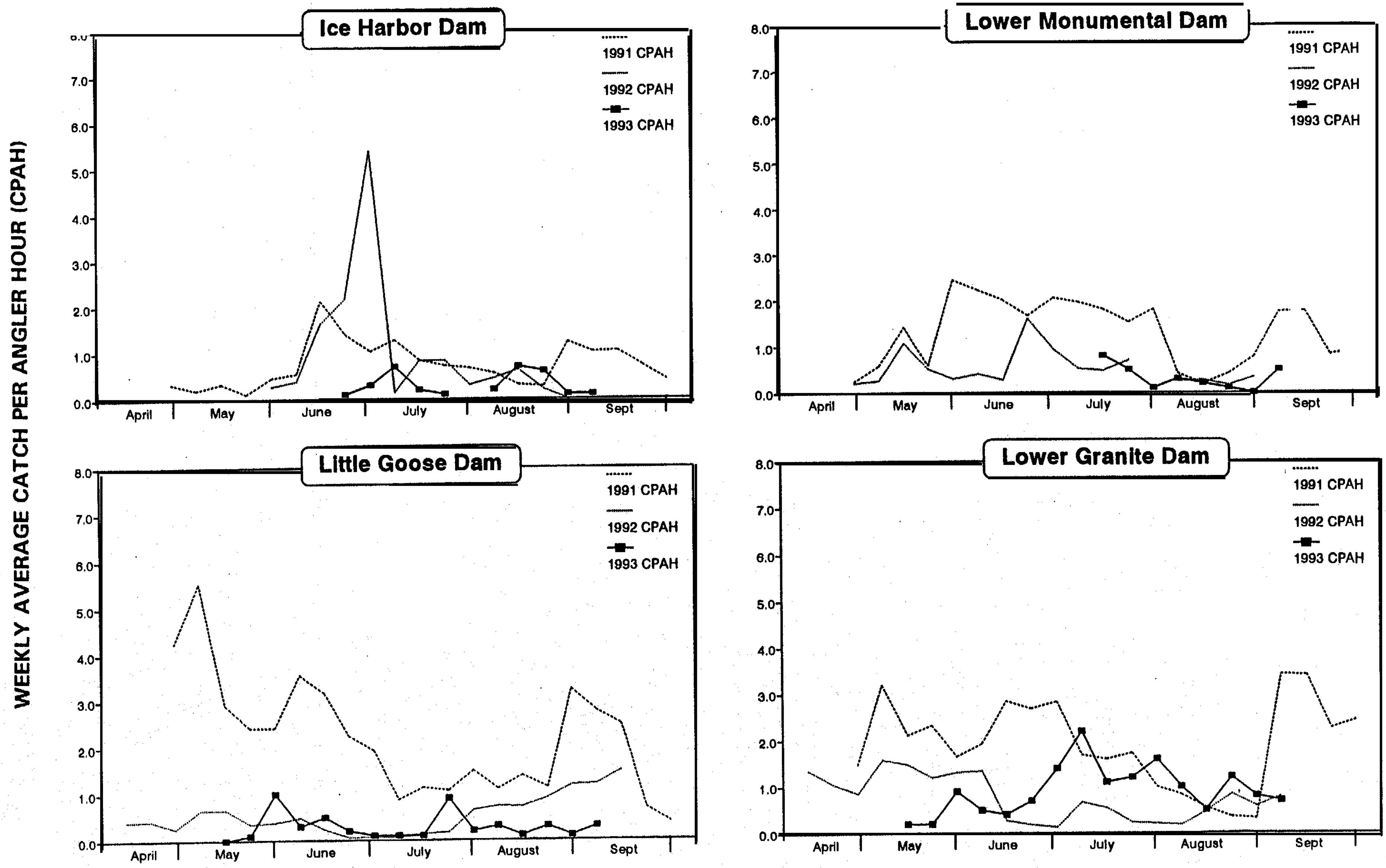

Figure D-6. Weekly average catch per angler hour (CPAH) at Snake River dams, 1991, 1992, and 1993. Effort varied substantially within and between seasons.

Table D-4. Comparison of daily CPAH values for the volunteer anglers with the corresponding weekly CPAH for the resident crew.

	Volunteer anglers			Resident crew	
Dam	Volunteer group	Date	CPAH	Week	CPAH
Bonneville	Portland NW Steelheaders	7/10/93	2.6	28	4.8
	Tom McCall NW Steelheaders	7/17/93	0.5	29	4.9
	Portland NW Steelheaders	7/24/93	2.4	30	2.1
	Tom McCall NW Steelheaders	8/7/93	1.9	32	5.5
	Combined CPAH		**2.0**		**4.3**
The Dalles	The Dalles Rod & Gun Club	6/25/93	2.3	26	2.5
	The Dalles Rod & Gun Club	7/16/93	3.7	29	1.3
	The Dalles Rod & Gun Club	7/23/93	3.1	30	0.7
	The Dalles Rod & Gun Club	7/30/93	1.5	31	0.5
	The Dalles Rod & Gun Club	8/6/93	2.5	32	2.2
	Combined CPAH		**2.6**		**1.5**
McNary	The Ladies Angle	7/10/93	2.2	28	4.0
	Mid-Columbia Bass Anglers	7/17/93	2.6	29	2.7
	The Ladies Angle	7/24/93	2.1	30	2.3
	The Ladies Angle	7/31/93	3.8	31	2.2
	Mid-Columbia Bass Anglers	8/14/93	0.3	33	1.7
	Combined CPAH		**2.2**		**2.5**
Seasonal CPAH			**2.3**		**2.7**

Probably the greatest benefit of the volunteer program has been the productive and amicable cooperation between members of two groups (sport anglers and treaty tribes) whose interests have conflicted at times. Negative stereotypes usually began to dissipate with close personal contact and cooperation on the dams. Volunteers and tribal participants wish to continue this program.

Because of the volunteer angling program, several dozen members of the public, few of whom had participated in the sport-reward fishery, have learned about and become involved in the predator control program and other Columbia River fishery management issues. Pre-season and postseason meetings with the angling groups have provided many opportunities to share information. Also, we often took short breaks during evenings of angling to let the volunteers observe smolt monitoring and other fish-related activities not normally available to the public. Corps personnel at the three dams (Bonneville, The Dalles, and John Day) were very accommodating and generally satisfied with how the volunteer program was conducted. The volunteer program could probably be expanded two or threefold, although doing so would require more project management resources than are available.

Boat Angling

Boat angling was implemented to target northern squawfish that were close to the dams, but inaccessible to dam-based anglers (Parker et al. 1992). We did not begin boat angling in 1993 until midseason, primarily because of unresolved insurance issues and other demands (e.g., from the Merwin trapping fishery) for boats and personnel. At least one day of boat angling was conducted in 1993 at each dam except Bonneville (Table D-5).

Although the average CPAH for boat angling was generally higher (The Dalles Dam excepted) than dam-based anglers on the same days (Table D-S), we cannot conclude that boat angling is more efficient than dam-based angling. The amount and distribution of boat angling effort was not sufficient for a good evaluation at any dam in any month. Also, the data shown in Table D-5 are sometimes based on very low catches, such as for the single days of sampling at Ice Harbor Dam and Lower Monumental Dam, when catches-by all anglers totaled only eight and four fish, respectively. The relatively high costs of boat operations (e.g., fuel and insurance) would also have to be considered in a thorough evaluation. Also, boat operations in the BRZ are restricted to daylight hours, which precludes boat angling during crepuscular and nighttime hours when dam-based angling often is very productive.

Table D-S. CPAH of boat angling and dam angling crews on the same days and dams.

Dam	Date	Boat crew	CPAH Boat	CPAH Dam
The Dalles	21-Jul-93	CTWS	0.2	0.7
	22-Jul-93		0.1	0.6
	28-Jul-93		0.1	1.0
	29-Jul-93		0.0	0.3
	Combined		0.1	0.7
John Day	11-Aug-93	CTWS	2.2	0.4
	12-Aug-93		3.6	0.8
	Combined		3.0	0.6
McNary	26-Aug-93	NPT	0.3	0.4
	27-Aug-93		1.1	0.3
	31-Aug-93		1.8	0.4
	01-Sep-93		1.7	0.2
	Combined		1.2	0.3
Ice Harbor	02-Aug-93	NPT	0.5	0.2
Lower Monumental	10-Aug-93	NPT	0.2	0.1
Little Goose	22-Jul-93	NPT	1.5	0.0
	ll-Aug-93		0.1	0.1
	19-Aug-93		0.3	0.3
	25-Aug-93		0.0	0.1
	02-Sep-93		0.4	0.1
	Combined		0.3	0.1
Lower Granite	21-Jul-93	NPT	3.3	1.2
	26-Jul-93		2.2	1.1
	27-Jul-93		2.4	0.9
	28-Jul-93		1.4	1.3
	12-Aug-93		0.5	0.4
	16-Aug-93		0.3	0.2
	17-Aug-93		1.3	2.1
	18-Aug-93		1.6	1.6
	24-Aug-93		0.8	0.8
	03-Sep-93		0.3	1.2
	Combined		1.4	1.1

Incidental Catch

We caught fewer incidental fish (986; Appendix Table D-l. 11) than in 1992 (1,706; Parker et al. 1993), and they composed a slightly lower percentage of the catch (5.5%; Appendix Table D-l. 10 and Figure D-7) than in 1992 (5.8 % ; Parker et al. 1993). The percentage of bass (*Micropterus* spp.) roughly doubled from 1 .O% in 1992 (Parker et al. 1993) to 2.1% (Appendix Table D-l. 10). Most of the increased bass catch (over 200 more fish) occurred at The Dalles Dam, where anglers abandoned formerly productive sites (e.g., the sluiceway outfall) and prospected for northern squawfish in other areas where bycatch happened to be higher. *The* percentage of catfish (*Ictalurus* spp.) declined from 3.7% in 1992 (Parker et al. 1993) to 2.1% in 1993 (Appendix Table D-l. 10).

We caught three juvenile and three adult salmonids (Appendix Table D-l. 11). All except one juvenile chinook salmon (*Oncorhynchus tshawytscha*; caught August 8, 1993, at McNary Dam) were released in good condition.

Diet Analysis

The digestive tracts of 72 channel catfish caught incidentally at McNary Dam and the four Snake River dams from June through August contained only two juvenile salmonids, for a weighted mean of 0.05 juvenile salmonids per channel catfish (Table D-6). This is approximately one-third of the weighted mean number of juvenile salmonids (0.16) found in northern squawfish at the same dams in the same months (Table D-6). Detailed results of the diet analysis are in Appendix Tables D-l. 16 through D-l .29, which also include data for northern squawfish sampled during other months and at the other three dams.

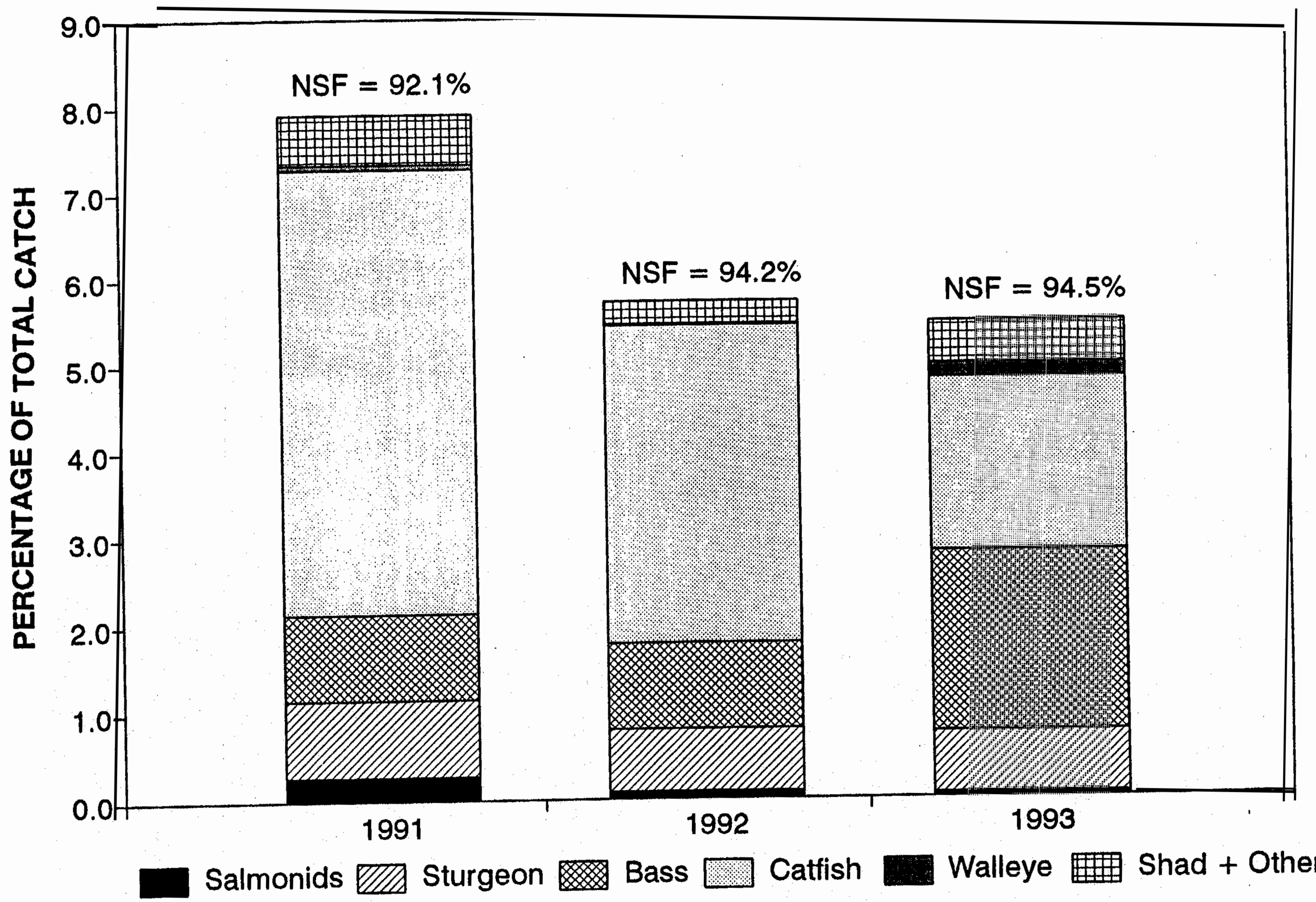

Figure D-7. Percentage of total catch of all incidentally caught fish and northern squawfish (NSF) at Columbia and Snake River dams during 1991, 1992, and 1993.

Table D-6. Incidence of juvenile salmonids (Sal.) in digestive tracts of channel catfish and northern squawfish at McNary Dam and Snake River dams in 1993. Mean number of juvenile salmonids per predator (Mean Sal.) are weighted by catch (Wtd. Mean Sal.).

		Channel Catfish					Northern Squawfish				
Dam	Mo	Catch	*N*	No. Sal.	Mean Sal.	Wtd. Mean Sal.	Catch	*N*	No. Sal.	Mean Sal.	Wtd. Mean Sal.
McNary	Jun	47	11	1	0.09	*0.07*	1273	30	12	0.40	*0.19*
	Aug	13	3	0	0		1459	15	0	0	
Ice Harbor	Jun	15	9	0	0	0.07	10	8	0	0	0
	Jul	89	9	1	0.11		61	12	0	0	
	Aug	33	3	0	0		51	11	0	0	
Lower Monumental	Jul	10	2	0	0	0	60	15	9	0.60	0.36
	Aug	75	23	0	0		45	21	1	0.05	
Little Goose	Jun	4	1	0	0	0	64	16	0	0	0
	Jul	1	1	0	0		13	4	0	0	
	Aug	3	1	0	0		15	5	0	0	
Lower Granite	Jun	21	8	0	0	0	182	24	1	0.04	0.05
	Jul	7	1	0	0		356	19	1	0.05	
Snake River Dams			**58**	**1**	**--**	**0.04**		**135**	**12**	**--**	**0.08**
ALL DAMS			**72**	**2**	**--**	**0.05**		**180**	**24**	**--**	**0.16**

These results must be interpreted carefully. We assumed that regurgitation was negligible, although we could not evaluate that assumption. The two juvenile salmonids found in channel catfish could have been dead or moribund prey that were scavenged. This possiblity is supported by the fishing method being used when the channel catfish were caught. Most channel catfish sampled were caught using smolt bait, which is often fished on or near the river bottom, where northern squawfish are frequently caught. Also, our sampling was probably selective for the smaller, perhaps less predaceous, channel catfish. Many large (> 600 mm) fish broke the line as they were lifted from the water; the mean length of channel catfish sampled was 448 mm. Channel cattish > 400 mm are more piscivorous than smaller fish (Poe et al. 1991). These results may not accurately represent our entire catch because sampling was inconsistent (i.e., we lack samples for some months) and sampling rates varied greatly. Although same-place, same-month samples from northern squawfish may be a relatively meaningful standard, we cannot assume that differences in the contents of their digestive tracts reflect differences in consumption rates. Digestive tract evacuation rates, for example, may differ between the two species.

The incidence of juvenile salmonids in predator digestive tracts is very much a function of prey abundance. For example, the incidence of juvenile salmonids in northern squawfish caught at Lower Monumental Dam (0.36 overall), particularly in July (0.60), was very high relative to other Snake River dams in the same months (Table D-6). Five of the nine juvenile salmonids found in July bore coded-wire tags (Code 63-50-12) identifying them as Snake River fall chinook salmon released at Lyons Ferry Hatchery, 23 km upstream from the dam. The paucity of summer-migrating salmonids in the Snake River probably accounts for their low incidence in samples from other Snake River dams.

Low incidence is not equivalent to low predation rate, however. A species at low abundance, such as wild summer-migrating Snake River fall chinook salmon, could suffer very high rates of predation mortality with very low probability that methods such as ours would detect any of it.

The high incidence of Lyons Ferry fall chinook salmon in samples from Lower Monumental Dam suggests a predation problem on these summer-released fish. Two hundred thousand subyearling fall chinook salmon were released between June 21 and June 25 [Fish Passage Center (FPC) Weekly Report #93-17], 2.5-3 weeks before we began sampling at Lower Monumental Dam. Although the first Lyons Ferry fish passed Lower Monumental Dam a few days after release, many took weeks to move the short distance to the dam (FPC 1993). During those weeks of residence and slow migration, predation rates may have been very high.

RECOMMENDATIONS

1. Continue controlled angling at all eight dams and modify effort to improve efficiency:

Dam	Anglers	Season & effort pattern
Bonneville	5	Late May-June through August
The Dalles	5	Late May-June through August
John Day	4	Mid June through early Sept.
McNary	8	June through August
Ice Harbor/ L. Monumental/ Little Goose/ Lower Granite	4	June through July; all dams staffed by a single crew.

2. Retain the mobile crew to augment resident crew efforts at the most productive Columbia River dams.

3. Continue limited use of boat angling and carefully evaluate its effectiveness when and where used.

4. Continue the volunteer angling at Bonneville, The Dalles, and McNary dams.

5. Continue to develop and refine effective angling strategies, including fishing techniques, lures and bait, and schedules.

6. Coordinate with U.S. Army Corps of Engineer biologists regarding the replacement of existing bird wires and the installation of new wires.

7. Continue analyzing data to better understand the factors affecting catch rates.

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APPENDIX D-l

Tabular Data

Appendix Table D-1.1. Statistical week numbers and corresponding 1993 dates.

Week number	Corresponding dates
21	May 16-May22
22	May 23 - May 29
23	May 30 - June 5
24	June 6 - June 12
25	June 13 - June 19
26	June 20 - June 26
27	June 27 - July 3
28	July 4 - July 10
29	July 11 - July 17
30	July 18 - July 24
31	July 25 - July 31
32	August 1 - August 7
33	August 8 - August 14
34	August 15 - August 21
35	August 22 - August 28
36	August 29 - September 4
37	September 5 - September 11
38	September 12 - September 18

Appendix Table D-1.2. Weekly average CPAH at **Bonneville Dam,** 1993.

Statistical week number[a]	Total hours fished	**Number of northern** squawfish	CPAH
22	24	24	1.0
23	56	71	1.3
24	126	160	1.3
25	99	230	2.3
26	95	577	6.1
27	135	771	5.7
28	202	987	4.9
29	210	863	4.1
30	182	461	2.5
	154	227	
31	162	707	1.5
32			4.4
33	121	261	2.2
34	116		1.5
35	178	172 136	0.8
36	115	185	1.6
37	16	4	0.2
Season	**1991**	5836	2.9

[a] See Appendix Table D-l. 1 for dates associated with statistical weeks.

Appendix Table D-1.3. Weekly average CPAH at The **Dalles Dam,** 1993.

statistical week **number**[a]	Total hours fished	Number of northern squawfish	**CPAH**
22	22	26	1.2
23	89	63	0.7
24	167	126	0.8
25	140	151	1.1
26	181	514	2.8
27	153	246	1.6
28	98	211	2.2
29	140	255	1.8
30	157	148	0.9
31	164	109	0.7
32	154	328	2.1
33	145	148	1.0
34	152	127	0.8
35	111	130	1.2
36	100	116	1.2
37	18	11	0.6
38	2	3	1.5
Season	**1993**	**2712**	**1.4**

[a] See Appendix Table D-l. 1 for dates associated with statistical weeks.

Appendix Table D-1.4. Weekly average CPAH at **John Day Dam,** 1993.

statistical week **number**[a]	Total hours fished	Number of northern squawfish	CPAH
24	--[b]	--[b]	--[b]
25	22[b]	2[b]	0.1[b]
26	20[b]	6[b]	0.3[b]
27	--[b]	--[b]	--[b]
28	--[b]	--[b]	--[b]
29	104	208	2.0
30	101	230	2.3
31	75	278	3.7
32	102	545	5.3
33	144	245	1.7
34	145	234	1.6
35	113	241	2.1
36	150	125	0.8
37	35	43	1.2
38	33	91	2.8
Season	**1044**	2248	**2.2**

[a] See Appendix Table D-1.1 for dates associated with statistical weeks.
[b] Data reported by the resident John Day crew for weeks 24, 25, 26, 27, and 28 are not included, but are listed in the table below.

Statistical week number	Hours fished	Northern squawfish
24	35	8
2.5	116	19
26	119	59
27	146	108
28	101	67

Appendix Table D-1.5. Weekly average CPAH at **McNary Dam,** 1993.

statistical week number[a]	Total hours fished	Number of northern squawfish	CPAH
23	90	64	0.7
24	151	73	0.5
25	213	233	1.1
26	185	306	1.7
27	231	824	3.6
28	178	684	3.8
29	208	555	2.7
30	191	431	2.3
31	212	485	2.3
32	222	791	3.6
33	199	310	1.6
34	200	212	1.1
35	296	100	0.3
36	205	80	0.4
Season	**2781**	**5148**	**1.9**

[a] See Appendix Table D-l. 1 for dates associated with statistical weeks.

Appendix Table D-1.6. Weekly average CPAH at **Ice Harbor Darn,** 1993.

statistical week number[a]	Total hours fished	Number of northern squawfish	CPAH
26	44	3	0.1
27	63	16	0.3
28	63	43	0.7
29	40	7	0.2
30	39	2	0.1
31	0	0	--
32	47	9	0.2
33	34	23	0.7
34	29	16	0.6
35	18	1	0.1
36	26	2	0.1
Season	403	122	0.3

[a] See Appendix Table D-l. 1 for dates associated with statistical weeks.

Appendix Table D-1.7. Weekly average CPAH at **Lower Monumental Dam,** 1993.

statistical week number[a]	Total hours fished	Number of northern squawfish	CPAH
29	25	19	0.8
30	51	27	0.5
31	99	14	0.1
32	49	15	0.3
33	53	11	0.2
34	77	7	0.1
35	17	0	0.0
36	24	12	0.5
Season	**395**	**105**	0.3

[a] See Appendix Table D-l. 1 for dates associated with statistical weeks.

Appendix Table D-1.8. Weekly average CPAH at **Little Goose Darn,** 1993.

statistical week number[a]	Total hours fished	Number of northern squawfish	CPAH
21	34	0	0.0
22	22	3	0.1
23	23	24	1.0
24	40	11	0.3
25	41	19	0.5
26	40	8	0.2
27	35	4	0.1
28	20	2	0.1
29	18	1	0.1
30	7	6	0.9
31	10	2	0.2
32	24	8	0.3
33	20	2	0.1
34	14	4	0.3
35	14	1	0.1
36	18	5	0.3
Season	380	**100**	0.3

[a] See Appendix Table D- 1. 1 for dates associated with statistical weeks.

Appendix Table D-1.9. Weekly average CPAH at **Lower Granite Dam,** 1993.

statistical week **number**[a]	Total hours fished	Number of northern squawfish	CPAH
21	56	11	0.2
22	63	10	0.2
23	52	42	0.8
24	42	19	0.5
25	47	20	0.4
26	50	33	0.7
27	47	68	1.4
28	44	95	2.2
29	73	83	1.1
30	60	72	1.2
31	67	106	1.6
32	25	24	1.0
33	22	10	0.5
34	53	62	1.2
35	19	15	0.8
36	12	8	0.7
Season	732	678	0.9

[a] See Appendix Table D-1. 1 for dates associated with statistical weeks.

Appendix Table D-1.10. Monthly species composition of dam angling catch for **Columbia and Snake** river dams, 1993.

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
COLUMBIA R.									
May	86.21	13.79	1.72	0.00	8.62	0.00	0.00	1.72	1.72
June	94.26	5.74	0.07	0.97	2.42	1.52	0.00	0.28	0.47
July	96.73	3.27	0.01	0.54	2.15	0.24	0.03	0.16	0.13
August	96.52	3.48	0.02	0.67	1.53	0.32	0.44	0.29	0.21
September	90.49	9.51	0.00	0.61	4.29	0.00	1.84	1.53	1.23
Season	**95.88**	**4.12**	**0.04**	**0.69**	**2.09**	**0.58**	**0.19**	**0.26**	**0.27**
SNAKE R.									
May	96.00	4.00	0.00	4.00	0.00	0.00	[illegible]	0.00	0.00
June	82.58	17.42	0.00	1.29	3.23	12.90	[illegible]	0.00	0.00
July	79.93	20.07	0.00	0.98	1.47	17.46	[illegible]	0.00	0.16
August	64.53	35.47	0.00	0.58	1.74	33.14	[illegible]	0.00	0.00
September	92.86	7.14	0.00	0.00	0.00	7.14	[illegible]	0.00	0.00
Season	**76.95**	**23.05**	**0.00**	**1.00**	**1.91**	**20.06**	[illegible]	**0.00**	**0.08**
GRAND TOTAL									
May	89.16	10.84	1.20	1.20	6.02	0.00	0.00	1.20	1.20
June	93.46	6.54	0.07	0.99	2.47	2.30	0.00	0.27	0.44
July	95.34	4.66	0.01	0.58	2.09	1.66	0.03	0.15	0.13
August	94.55	5.45	0.02	0.66	1.54	2.35	0.41	0.27	0.20
September	90.59	9.41	0.00	0.59	4.12	0.29	1.76	1.47	1.18
Season	**94.50**	**5.50**	**0.03**	[illegible]	**2.07**	**2.00**	**0.17**	**0.25**	**0.26**

Appendix Table D-1.11. Monthly catch of incidental species by condition at release for Columbia and Snake river dams, 1993. 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. Catfish sacrificed for diet samples are included as condition 3.

Month	Total catch (all species)	Total incidental catch	Salmonids[a]				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	58	8	0	0	0	1	0	0	0	0	5	0	0	0	0	0	0	0	0	1	1
June[b]	4217	242	1	0	0	2	14	2	0	25	102	0	0	52	0	12	0	0	0	12	20
July[b]	6796	222	1	0	0	0	15	0	0	22	146	0	0	16	0	0	2	0	0	11	9
August	5232	182	0	0	1	0	16	0	0	19	80	0	0	14	0	3	21	2	0	15	11
September	326	31	0	0	0	0	0	0	0	2	14	0	0	0	0	0	6	0	0	5	4
Season[b]	**16629**	**685**	**2**	**0**	**1**	**3**	**45**	**2**	**0**	**68**	**347**	**0**	**0**	**82**	**0**	**15**	**29**	**2**	**0**	**44**	**45**
SNAKE R.																					
May	25	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
June	310	54	0	0	0	0	3	0	0	1	10	0	0	20	0	20	0	0	0	0	0
July	613	123	0	0	0	0	2	0	0	4	9	0	0	93	0	14	0	0	0	0	1
August	344	122	0	0	0	0	1	0	0	1	6	0	0	85	0	29	0	0	0	0	0
September	14	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Season	**1306**	**301**	**0**	**0**	**0**	**0**	**6**	**0**	**0**	**7**	**25**	**0**	**0**	**199**	**0**	**63**	**0**	**0**	**0**	**0**	**1**
GRAND TOTAL																					
May	83	9	0	0	0	1	0	0	0	1	5	0	0	0	0	0	0	0	0	1	1
June[b]	4527	296	1	0	0	2	17	2	0	26	112	0	0	72	0	32	0	0	0	12	20
July[b]	7409	345	1	0	0	0	17	0	0	26	155	0	0	109	0	14	2	0	0	11	10
August	5576	304	0	0	1	0	17	0	0	20	86	0	0	99	0	32	21	2	0	15	11
September	340	32	0	0	0	0	0	0	0	2	14	0	0	1	0	0	6	0	0	5	4
Season[b]	**17935**	**986**	**2**	**0**	**1**	**3**	**51**	**2**	**0**	**75**	**372**	**0**	**0**	**281**	**0**	**78**	**29**	**2**	**0**	**44**	**46**

[a] Note that the 3 salmonids in conditions 1, 2, and 3 were juveniles, and the 3 in "L" (Lost) were adults.
[b] Does not include some data from John Day dam. See text for rationale. Excluded data are footnoted in Appendix Table D-1.13.

Appendix Table D-1.12. Monthly species composition of dam angling catch for **Columbia River** dams, 1993.

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
BONNEVILLE									
May	88.89	11.11	0.00	0.00	7.41	0.00	0.00	3.70	0.00
June	99.21	0.79	0.00	0.43	0.00	0.00	0.00	0.36	0.00
July	99.34	0.66	0.00	0.25	0.04	0.00	0.00	0.37	0.00
August	98.09	1.91	0.00	0.88	0.07	0.00	0.00	0.89	0.07
September	76.32	23.68	0.00	0.00	5.26	0.00	0.00	13.16	5.26
Season	**98.80**	**1.20**	**0.00**	**0.46**	**0.10**	**0.00**	**0.00**	**0.59**	**0.05**
THE DALLES									
May	83.87	16.13	3.23	0.00	9.68	0.00	0.00	0.00	3.22
June	87.55	12.45	0.25	0.91	8.22	1.41	0.00	0.33	1.33
July	82.76	17.24	0.00	1.29	14.66	0.43	0.21	0.00	0.65
August	88.90	11.10	0.00	0.33	7.99	0.44	1.78	0.00	0.56
September	78.48	21.52	0.00	0.00	15.19	0.00	5.06	0.00	1.27
Season	**86.26**	**13.74**	**0.13**	**0.83**	**10.24**	**0.79**	**0.70**	**0.13**	**0.92**
JOHN DAY									
June	66.67	33.33	0.00	0.00	8.33	0.00	0.00	16.67	8.33
July	97.55	2.45	0.00	0.68	1.23	0.54	0.00	0.00	0.00
August	98.98	1.02	0.00	0.07	0.29	0.00	0.44	0.00	0.22
September	97.70	2.30	0.00	1.15	0.00	0.00	1.15	0.00	0.00
Season	**98.25**	**1.75**	**0.00**	**0.35**	**0.61**	**0.18**	**0.35**	**0.09**	**0.17**
McNARY									
June	94.44	5.56	0.00	1.71	0.15	3.48	0.00	0.00	0.22
July	98.92	1.08	0.04	0.54	0.00	0.33	0.00	0.04	0.12
August	97.33	2.67	0.07	1.20	0.20	0.87	0.07	0.13	0.13
September	97.14	2.86	0.00	0.00	0.00	0.00	0.00	0.00	2.86
Season	**97.32**	**2.68**	**0.04**	**1.02**	[illegible]	**1.28**	**0.02**	**0.06**	**0.17**

Appendix Table D-1.13. Monthly catch of incidental species by condition at release for Columbia River dams, 1993. 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. Catfish sacrificed for diet samples are included as condition 3.

Month	Total catch (all species)	Total incidental catch	Salmonids 1	Salmonids 2	Salmonids 3	Salmonids L	Sturgeon 1	Sturgeon 2	Sturgeon 3	Sturgeon L	Bass 1	Bass 2	Bass 3	Catfish 1	Catfish 2	Catfish 3	Walleye 1	Walleye 2	Walleye 3	Shad	Other
BONNEVILLE																					
May	27	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0
June	1652	13	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	6	0
July	2726	18	0	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	10	0
August	1464	28	0	0	0	0	9	0	0	4	1	0	0	0	0	0	0	0	0	13	1
September	38	9	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	5	2
Total	**5907**	**71**	**0**	**0**	**0**	**0**	**9**	**0**	**0**	**18**	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**35**	**3**
THE DALLES																					
May	31	5	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1
June	1205	150	1	0	0	2	2	0	0	9	99	0	0	17	0	0	0	0	0	4	6
July	928	160	0	0	0	0	5	0	0	7	136	0	0	4	0	0	2	0	0	0	6
August	901	100	0	0	0	0	0	0	0	3	72	0	0	4	0	0	16	0	0	0	5
September	79	17	0	0	0	0	0	0	0	0	12	0	0	0	0	0	4	0	0	0	1
Total	**3144**	**432**	**1**	**0**	**0**	**3**	**7**	**0**	**0**	**19**	**322**	**0**	**0**	**25**	**0**	**0**	**22**	**0**	**0**	**4**	**29**
JOHN DAY																					
June[a]	12	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
July[b]	734	18	0	0	0	0	3	0	0	2	9	0	0	4	0	0	0	0	0	0	0
August	1368	14	0	0	0	0	0	0	0	1	4	0	0	0	0	0	4	0	0	0	3
September	174	4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0
Total	**2288**	**40**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**5**	**14**	**0**	**0**	**4**	**0**	**0**	**6**	**0**	**0**	**0**	**4**
McNARY																					
June	1348	75	0	0	0	0	12	2	0	9	2	0	0	35	0	12	0	0	0	0	3
July	2408	26	1	0	0	0	7	0	0	6	0	0	0	8	0	0	0	0	0	1	3
August	1499	40	0	0	1	0	7	0	0	11	3	0	0	10	0	3	1	0	0	2	2
September	35	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total	**5290**	**142**	**1**	**0**	**1**	**0**	**26**	**2**	**0**	**26**	**5**	**0**	**0**	**53**	**0**	**15**	**1**	**0**	**0**	**3**	**9**

[a] Does not include 8 sturgeon (condition 1), 14 bass (condition 1), 10 catfish (condition 1), 11 shad, and 3 other. See text for rationale.

[b] Does not include 2 sturgeon (condition 1), 8 bass (condition 1), 1 walleye (condition 1), and 2 shad. See text for rationale.

Appendix Table D-1.14. Monthly species composition of dam angling catch for **Snake River** dams, 1993.

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
ICE HARBOR									
June	32.26	67.74	0.00	9.68	9.68	48.38	0.00	0.00	0.00
July	39.61	60.39	0.00	1.30	1.30	57.79	0.00	0.00	0.00
August	57.95	42.05	0.00	1.14	3.41	37.50	0.00	0.00	0.00
Season	**44.69**	**5[illegible].31**	0.00	**2.20**	**2.93**	**50.18**	**0.00**	**0.00**	**0.00**
LOWER MONUMENTAL									
July	80.00	20.00	0.00	0.00	5.33	13.33	0.00	0.00	1.33
August	36.59	63.41	0.00	0.81	1.63	60.98	0.00	0.00	0.00
Season	**53.03**	**46.97**	**0.00**	**0.50**	**3.03**	**42.93**	**0.00**	**0.00**	**0.51**
LITTLE GOOSE									
May	75.00	25.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00
June	85.33	14.67	0.00	0.00	9.34	5.33	0.00	0.00	0.00
July	92.86	7.14	0.00	0.00	0.00	7.14	0.00	0.00	0.00
August	78.95	21.05	0.00	0.00	5.26	15.79	0.00	0.00	0.00
September	83.33	16.67	0.00	0.00	0.00	16.67	0.00	0.00	0.00
Season	[illegible]	**15.25**	**0.00**	**0.85**	**6.78**	**7.62**	**0.00**	**0.00**	**0.00**
LOWER GRANITE									
May	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June	89.22	10.78	0.00	0.49	0.00	10.29	0.00	0.00	0.00
July	96.22	3.78	0.00	1.08	0.81	1.89	0.00	0.00	0.00
August	97.37	2.63	0.00	0.00	0.00	2.63	0.00	0.00	0.00
September	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Season	**94.56**	**5.44**	**0.00**	**0.70**	**0.42**	**4.32**	**0.00**	**0.00**	**0.00**

Appendix Table D-1.15. Monthly catch of incidental species by condition at release for Snake River dams, 1993. 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		
ICE HARBOR																					
June	31	21	0	0	0	0	3	0	0	0	3	0	0	6	0	9	0	0	0	0	0
July	154	93	0	0	0	0	2	0	0	0	2	0	0	78	0	11	0	0	0	0	0
August	88	37	0	0	0	0	0	0	0	1	3	0	0	30	0	3	0	0	0	0	0
Total	**273**	**151**	**0**	**0**	**0**	**0**	**5**	**0**	**0**	**1**	**8**	**0**	0	**114**	**0**	**23**	**0**	**0**	0	0	0
LOWER MONUMENTAL																					
July	75	15	0	0	0	0	0	0	0	0	4	0	0	9	0	1	0	0	0	0	1
August	123	78	0	0	0	0	1	0	0	0	2	0	0	50	0	25	0	0	0	0	0
Total	**198**	**93**	**0**	0	**0**	0	**1**	**0**	**0**	**0**	**6**	**0**	**0**	**59**	**0**	**26**	**0**	**0**	**0**	**0**	**1**
LITTLE GOOSE																					
May	4	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
June	75	11	0	0	0	0	0	0	0	0	7	0	0	2	0	2	0	0	0	0	0
July	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
August	19	4	0	0	0	0	0	0	0	0	1	0	0	2	0	1	0	0	0	0	0
September	6	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Total	**118**	**18**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**8**	**0**	**0**	**5**	**0**	**4**	**0**	**0**	**0**	**0**	0
LOWER GRANITE																					
May	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	204	22	0	0	0	0	0	0	0	1	0	0	0	12	0	9	0	0	0	0	0
July	370	14	0	0	0	0	0	0	0	4	3	0	0	6	0	1	0	0	0	0	0
August	114	3	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
September	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**717**	**39**	0	**0**	**0**	**0**	**0**	**0**	0	**5**	**3**	**0**	0	**21**	**0**	**10**	**0**	**0**	**0**	**0**	0

Appendix Table D-1.16. Diet data for channel catfish caught at **McNary Dam.**

	June	July	Aug.
N (containing food)	11(4)	0(0)	3(1)
Predator weight [g]:			
Mean	2501	--	1723
Range	840-5000	--	1300-2100
Predator length [mm FL]:			
Mean	548	--	504
Range	360670		445-545
Mean weight [g] of food	13.1	--	13.7
% weight composition":			
Fish	38.6		42.4
Crustacea	60.2		0
Mollusca	0		0
Insecta	0	--	0
Plants	0	--	1.0
Other	1.2		56.7
Fish [total numbers]:			
Salmonids (CWT)	1(0)	--	0(0)
Mean per catfish	0.09	--	0.00
Sculpin	2	--	0
Stickleback	0	--	0
Shad	0	--	0
Cyprinids	0	--	0
Unidentified	1	--	0

[a] Unidentifiable contents not included.

Appendix Table D-1.17. Diet data for channel catfish caught at **Ice Harbor Dam.**

	June	July	Aug.
N (containing food)	9(5)	9(2)	3(1)
Predator weight [g]:			
Mean	1233	1266	1130
Range	730-2500	700-2360	830-1500
Predator length [mm FL]:			
Mean	444	457	446
Range	390-550	375-550	413-478
Mean weight [g] of food	9.2	9.7	6.0
% weight composition[a]:			
Fish	20.2	41.0	100.0
Crustacea	79.5	59.0	0
Mollusca	0	0	0
Insecta	0	0	0
Plants	0.3	0	0
Other	0	0	0
Fish [total numbers]:			
Salmonids (CWT)	0(0)	1(0)	0(0)
Mean per catfish	0.00	0.11	0.00
Sculpin	0	0	0
Sticlcleback	0	0	0
Shad	0	0	0
C yprinids	0	0	0
Ictalurid (catfish)	0	1	0

[a] Unidentifiable contents not included.

Appendix Table D-1.18. Diet data for channel catfish caught at **Lower Monumental Dam.**

	June	July	Aug.
N (containing food)	0(0)	2(1)	23(5)
Predator weight [g]:		750[a]	
Mean	--		637
Range	--		290-1060
Predator length [mm FL]:		395[a]	
Mean	--		384
Range	--		310-465
Mean weight [g] of food	--	6.1	6.7
% weight composition[b]:			
Fish	--	100.0	0
Crustacea	--	0	26.7
Mollusca	--	0	0
Insecta		0	0
Plants	--	0	32.9
Other	--	0	40.4
Fish [total numbers]:			
Salmonids (CWT)	--	0(0)	0(0)
Mean per catfish	--	0.00	0.00
Sculpin	--	0	0
Stickleback	--	0	0
Shad	--	0	0
Cyprinids	--	0	0
Unidentified	--	0	1

[a] Biological data on one of the two fish caught.

[b] Unidentifiable contents not included.

Appendix Table D-1.19. Diet data for channel catfish caught at **Little Goose Dam.**

	June	July	Aug.
N (containing food)	1(0)	1(0)	1(0)
Predator weight [g]:	3445	1130	1290
Predator length [mm FL]:	608	460	468
Mean weight [g] of food	4.1	3.3	8.2
% weight composition[a]:			
Fish	0	0	0
Crustacea	0	0	0
Mollusca	0	0	0
Insecta	0	0	0
Plants	0	0	0
Other	0	0	0
Fish [total numbers]:			
Salmonids (CWT)	0(0)	0(0)	0(0)
Mean per catfish	0.00	0.00	0.00
Sculpin	0	0	0
Stickleback	0	0	0
Shad	0	0	0
Cyprinids	0	0	0
Unidentified	0	0	0

[a] Unidentifiable contents not included.

Appendix Table D-1.20. Diet data for channel catfish caught at Lower **Granite Dam.**

	June	July	Aug.
N (containing food)	8(7)	1(0)	0(0)
Predator weight [g]:		1960	
Mean	1228		--
Range	630-1590		--
Predator length [mm FL]:		432	
Mean	449		--
Range	395-494		
Mean weight [g] of food	20.6	2.7	--
% weight composition[a]:			
Fish	0	0	--
Crustacea	5.6	0	--
Mollusca	0	0	--
Insecta	0	0	--
Plants	80.8	0	--
Other	13.6	0	--
Fish [total numbers]:			
Salmonids (CWT)	0(0)	0(0)	--
Mean per catfish	0.00	0.00	--
Sculpin	0	0	--
Stickleback	0	0	--
Shad	0	0	--
Cyprinids	0	0	--
Unidentified	0	0	--

[a] Unidentifiable contents not included.

Appendix Table D-1.21. Diet data for northern squawfish (NSF) caught at Bonneville Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	30(13)	38(11)	49(15)	4(2)
Predator weight [g]:					
Mean	--	914	766	700	1049
Range	--	360-1480	380-1520	230-1400	920-1210
Predator length [mm FL]:					
Mean	--	412	398	395	466
Range	--	319-511	318-523	287-490	442-493
Mean weight [g] of food	--	10.6	10.0	8.2	7.8
% weight composition[a]:					
Fish	--	65.7	58.6	93.5	0
Crustacea	--	29.3	0	3.2	96.0
Mollusca	--	0	0	0	0
Insecta	--	0	0	0	0
Plants	--	0.6	0.8	0	4.0
Other	--	4.5	40.6	3.4	0
Fish [total numbers):					
Salmonids (CWT)	--	8(1)	8(0)	8(0)	0(0)
Mean per NSF	--	0.26	0.21	0.16	0.00
Sculpin	--	0	1	0	0
Stickleback	--	1	0	0	0
Shad	--	0	0	0	0
Cyprinids	--	0	0	0	0
Unidentified	--	0	0	1	0
Mean water temperature	--	16.6	19.0	21.0	20.2
Consumption index	--	0.84	0.69	0.89	0.00

[a] Unidentifiable contents not included.

Appendix Table D-1.22. Diet data for northern squawfish (NSF) caught at The Dalles Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	49(6)	40(42)	43(18)	9(3)
Predator weight [g]:					
Mean	--	1142	1047	975	982
Range	--	140-2150	410-2000	380-1310	720-1270
Predator length [mm FL):					
Mean	--	425	437	441	458
Range	--	240-529	324-539	338-487	396-505
Mean weight [g] of food	--	9.4	12.6	12.3	6.5
% weight composition[a]:					
Fish	--	51.7	63.6	89.3	0
Crustacea	--	10.3	9.5	1.5	0
Mollusca	--	0	0	0	0
Insecta	--	0	0	0	15.9
Plants	--	0	16.5	0.8	35.5
Other	--	38.0	10.4	8.5	48.6
Fish [total numbers]:					
Salmonids- (CWT)	--	5(0)	18(1)	6(0)	0(0)
Mean per NSF	--	0.10	0.45	0.14	0.00
Sculpin	--	0	1	0	0
Stickleback	--	0	0	0	0
Shad	--	0	0	9	0
Cyprinids	--	2	0	2	0
Unidentified	--	0	0	0	1
Mean water temperature	--	16.3	19.0	20.6	20.1
Consumption index	--	0.31	1.62	0.37	0.00

[a] Unidentifiable contents not included.

Appendix Table D-1.23. Diet data for northern squawfish (NSF) caught at John Day Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	6(2)	0(0)	50(16)	20(11)
Predator weight [g]:					
Mean	--	1067	--	911	819
Range	--	760-1540	--	560-1630	550-1305
Predator length [mm FL]:					
Mean	--	425	--	434	420
Range	--	351-506	--	359-515	352-492
Mean weight [g] of food	--	10.1	--	11.6	14.8
% weight composition[a]:					
Fish	--	17.3	--	89.3	95.7
Crustacea	--	0	--	0	3.9
Mollusca	--	0	--	0	0
Insecta	--	0	--	0	0
Plants	--	0	--	0.2	0
Other	--	82.7	--	10.5	0.4
Fish [total numbers]:					
Salmonids- (CWT)	--	3(1)	--	7(0)	1(0)
Mean per NSF	--	0.50	--	0.14	0.05
Sculpin	--	0	--	0	0
Stickleback	--	0	--	0	0
Shad	--	0	--	7	10
Cyprinids	--	0	--	0	0
Unidentified	--	0	--	0	0
Mean water temperature	--	16.2	18.6	20.8	19.7
Consumption index	--	1.44	--	0.38	0.29

[a] Unidentifiable contents not included.

Appendix Table D-1.24. Diet data for northern squawfish (NSF) caught at McNary Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	30(15)	20(9)	15(2)	4(2)
Predator weight [g]:					
Mean	--	1126	955	366	835
Range	--	260-1730	600-1260	105-930	620-1400
Predator length [mm FL]:					
Mean	--	433	433	293	415
Range	--	296-507	379-489	205-435	380-485
Mean weight [g] of food	--	11.2	16.7	4.5	11.6
% weight composition[a]:					
Fish	--	74.0	80.8	100.00	100.00
Crustacea	--	24.5	0	0	0
Mollusca	--	0	0	0	0
Insecta	--	1.5	0	0	0
Plants	--	0	0	0	0
Other	--	0	19.2	0	0
Fish [total numbers]:					
Salmonids (CWT)	--	12 (0)	7(1)	0(0)	0(0)
Mean per NSF	--	0.40	0.35	0.00	0.00
Sculpin	--	3	1	1	0
Stickleback	--	0	0	0	0
Shad	--	0	0	1	2
Cyprinids	--	0	0	0	0
Unidentified	--	0	0	0	0
Mean water temperature	--	15.6	18.5	20.7	20.2
Consumption index	--	1.04	1.02	0.00	0.00

[a] Unidentifiable contents not included.

Appendix Table D-1.25. Diet data for northern squawfish (NSF) caught at Ice Harbor Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	8(3)	12(2)	11(4)	0(0)
Predator weight [g]:					
Mean	--	1130	773	829	--
Range	--	550-1450	330-1100	350-1770	--
Predator length [mm FL]:					
Mean	--	451	401	418	--
Range	--	352-505	295-450	338-543	--
Mean weight [g] of food	--	14.0	7.2	12.8	--
% weight composition[a]:					
Fish	--	0	0	97.2	--
Crustacea	--	72.3	5.4	0	--
Mollusca	--	0	0	0	--
Insecta	--	0	0	0	--
Plants	--	27.7	94.6	2.8	--
Other	--	0	0	0	--
Fish [total numbers]:					
Salmonids (CWT)	--	0(0)	0(0)	0(0)	
Mean per NSF	--	0.00	0.00	0.00	--
Sculpin	--	0	0	0	--
Stickleback	--	0	0	0	--
Shad	--	0	0	4	--
Cyprinids	--	0	0	1	--
Unidentified	--	0	0	0	--
Mean water temperature	--	15.0	18.2	19.6	--
Consumption index	--	0.00	0.00	0.00	--

[a] Unidentifiable contents not included.

Appendix Table D-1.26. Diet data for northern squawfish (NSF) caught at **Lower Monumental Dam.**

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	0(0)	15(10)	21(6)	0(0)
Predator weight [g]:					
Mean	--	--	964	643	--
Range	--	--	445-1550	190-2000	--
Predator length [mm FL]:					
Mean	--	--	425	378	--
Range	--	--	347-483	285-540	--
Mean weight [g] of food	--	--	11.6	8.2	--
% weight composition[a]:					
Fish	--	--	87.0	87.9	--
Crustacea	--	--	0	0	--
Mollusca	--	--	0	0	--
Insecta	--	--	0	5.2	--
Plants	--	--	13.0	5.0	--
Other	--	--	0	1.8	--
Fish [total numbers]:					
Salmonids (CWT)	--	--	9(5)	1(0)	--
Mean per NSF	--	--	0.60	0.05	--
Sculpin	--	--	0	0	--
Stickleback	--	--	0	0	--
Shad	--	--	0	2	--
Cyprinids	--	--	0	1	--
Unidentified	--	--	0	0	--
Mean water temperature	--	--	17.4	19.9	--
Consumption index	--	--	1.74	0.20	--

[a] Unidentifiable contents not included.

Appendix Table D-1.27. Diet data for northern squawfish (NSF) caught at Little Goose Dam.

	May	June	July	Aug.	Sept.
N (containing food)	0(0)	16(8)	4(2)	5(4)	0(0)
Predator weight [g]:					
Mean	--	436	491	593	--
Range	--	304-725	300-735	315-1120	--
Predator length [mm FL]:					
Mean	--	337	355	367	--
Range	--	295-410	320-400	311-425	--
Mean weight [g] of food	--	4.4	6.7	6.2	--
% weight composition[a]:					
Fish	--	5.2	0	0	--
Crustacea	--	38.1	0	36.4	--
Mollusca	--	0	0	0	--
Insecta	--	32.1	61.3	0	--
Plants	--	1.5	3.6	63.6	--
Other	--	23.1	35.1	0	--
Fish [total numbers]:					
Salmonids (CWT)	--	0(0)	0(0)	0(0)	--
Mean per NSF	--	0.00	0.00	0.00	--
Sculpin	--	0	0	0	--
Stickleback	--	0	0	0	--
Shad	--	0	0	0	--
Cyprinids	--	1	0	0	--
Unidentified	--	0	0	0	--
Mean water temperature	--	15.5	18.0	20.4	--
Consumption index	--	0.00	0.00	0.00	--

[a] Unidentifiable contents not included.

Appendix Table D-1.28. Diet data for northern squawfish (NSF) caught at Lower Granite Dam.

	May	June	July	Aug.	Sept.
N (containing food)	11(5)	24(6)	19(5)	5(1)	0(0)
Predator weight [g]:					
Mean	506	716	568	513	--
Range	300-1150	300-1710	280-1725	340-725	--
Predator length [mm FL]:					
Mean	349	382	369	357	--
Range	212-418	291-493	283-541	320-393	--
Mean weight [g] of food	6.9	7.9	4.9	3.2	--
% weight composition[a]:					
Fish	73.2	62.1	33.5	72.9	--
Crustacea	0	36.7	60.0	0	--
Mollusca	0	0	0	0	--
Insecta	26.8	0	0	0	--
Plants	0	1.2	0	0	--
Other	0	0	6.5	27.1	--
Fish [total numbers]:					--
Salmonids (CWT)	2(1)	1(0)	1(0)	0(0)	--
Mean per NSF	0.18	0.04	0.05	0.00	--
Sculpin	0	0	0	0	--
Stickleback	0	0	0	0	--
Shad	0	0	0	0	--
Cyprinids	0	0	0	0	--
Unidentified	0	0	2	0	--
Mean water temperature	12.0	14.6	16.6	19.3	--
Consumption index	0.37	0.10	0.39	0.00	--

[a] Unidentifiable contents not included.

Appendix Table D-1.29. Number of catfish in each age group captured from Snake River dams and McNary Dam.

		Age							
Dam	*N*	5+	6+	7-k	8+	9+	10+	11+	12+
McNary	6	1	1	0	1	3	0	0	0
Ice Harbor	22	2	2	8	5	2	0	3	0
Lower Monumental	25	0	3	12	6	2	1	2	1
Little Goose	3	0	0	2	0	1	0	0	0
Lower Granite	10	0	0	2	1	4	1	2	0
Totals		3	6	24	13	12	2	7	1

REPORT E

Removal of Predaceous Northern Squawfish Found near Hatchery Release Sites in Bonneville Pool: An Analysis of Changes in Catch Rates and Diet Associated with the Release of Hatchery-Reared Juvenile Salmonids

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1993 Annual Report

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ABSTRACT

Predator control activities that target areas where northern squawfish (*Ptychocheilus oregonensis*) congregate to feed on juvenile salmonids have the advantage of (1) removing large numbers of mostly predator-sized northern squawfish and (2) focusing management efforts on areas where predation rates are especially high. We investigated the distribution and predation activities of northern squawfish at three locations in Bonneville Pool where hatchery-reared juvenile salmonids were released. Catch rates of northern squawfish increased significantly after hatchery releases at all three locations. In addition, the timing and duration of elevated catch rates in the sampling locations appear to be closely related to the release date and subsequent residence time of the hatchery-released fish in the area. Northern squawfish caught after salmonid releases had a significantly higher frequency of occurrence and mean number of juvenile salmonids in their diet compared to fish caught before releases. Consumption indices, used as a relative measure of consumption rates, were also higher at each location after, as compared to before, release. Our results suggest that northern squawfish respond numerically and functionally to releases of hatchery-reared juvenile salmonids in the spring. Removal efforts that target feeding concentrations of northern squawfish near hatchery release points may be a viable management alternative for reducing juvenile salmonid mortality rates in the Columbia River Basin.

INTRODUCTION

Hydroelectric dams have drastically changed the ecosystems of the mainstem Columbia and Snake rivers by altering natural flow patterns, water temperatures, sediment loads, and overall water quality (see Orth and White 1993). These changes have adversely affected anadromous salmonids (*Oncorhynchus* spp.; Raymond 1968, 1969, 1979, 1988; Trefethen 1972; Ebel 1977; NPPC 1986; Rieman et al. 1991), while benefitting many picivorous fishes that feed on out-migrating juvenile salmonids (NMFS 1991a, 1991b; Poe et al. 1991).

Dams have transformed the once free-flowing lower Columbia and Snake rivers into a series of low-velocity reservoirs. This poses a number of significant problems for juvenile anadromous salmonids (Raymond 1968; Trefethen 1972), among which is the increased risk of predation. Juvenile salmonids, often injured or disoriented after passing a dam, make easy prey (Poe et al. 1991). Impoundments created by the dams increase the travel time of juveniles migrating to the ocean, prolonging their exposure to predators (Raymond 1968, 1969, 1979, 1988; Bentley and Raymond 1976). Mortality estimates of juvenile salmonids passing an individual dam and reservoir range from 15% to 45 % (Sims and Ossiander 1981; Raymond 1979), prompting fisheries managers to investigate the extent to which predation is the cause for these losses.

Predator-prey relations were investigated from 1982-1986 in John Day Reservoir to quantify the effect of predation on annual mortality rates of juvenile salmonids observed in that reservoir. Of the four predators of juvenile salmonids studied — northern squawfish (*Ptychocheilus oregonensis*), walleye (*Stizostedion vitreum*), channel catfish (*Ictalurus punctatus*), and smallmouth bass (*Micropterus dolomieui*) — northern squawfish accounted for 78% of juvenile mortality attributed to predation, estimated to be roughly 2 million fish/year (Reiman et al. 1991). Subsequent indexing efforts below Bonneville Dam and in the other reservoirs on the lower Columbia and Snake rivers suggest that the annual systemwide loss of juvenile salmonids to predation by northern squawfish could be as high as 15-20 million fish (Beamesderfer and Ward 1993). Furthermore, northern squawfish seem particularly well-adapted to the low-velocity microhabitats created by the dams built along the lower Columbia and Snake rivers (Beamesderfer 1983; Faler et al. 1988; Beamesderfer and Rieman 1991), and evidence suggests that their numbers are increasing (Kim et al. 1986; Beamesdefer and Rieman 1991).

In 1991, the Columbia River Northern Squaw&h Management Program (CRNSMP) was implemented to reduce predation by northern squawfish on outmigrating juvenile salmonids in the lower reaches of the Columbia and Snake rivers. The program goal is to sustain a 10-20% annual exploitation rate on predator-sized (≥275 mm total length) northern squawfish, which over several years may result in a 50% reduction in predation on juvenile salmonids (Rieman and Beamesderfer 1990). Removal efforts of the CRNSMP have included (1) a sport-reward program, which pays sport anglers $3 for every predator-sized northern squawfish turned in to check stations; (2) a dam-angling fishery, in which technicians use hook and line to remove northern squawfish from areas near dams where these predators concentrate; and (3) a commercial fishery, which previously used longlines and currently deploys Merwin traps to catch northern squawfish in areas away from dams. In total, these efforts have achieved an exploitation rate that is at the lower end of the targeted goal. Given the rate of decline of many salmonid stocks in the Columbia River Basin and the recent listing of some upriver runs under the Endangered Species Act, the CRNSMP must reach and sustain a greater exploitation rate of northern squawfish to produce the desired benefit (Beamesderfer and Ward 1993). We believe that only through continued development of innovative harvest methods, using the most current information available on northern squawfish behavior and ecology, will the program goal be attained.

Predation by northern squawfish on juvenile salmonids has been shown to be unevenly distributed in space and time (Beamesderfer and Rieman 1991; Poe et al. 1991; Petersen and DeAngelis 1992) and is likely to be directly related to spatial and temporal differences in prey density. During their spring and summer outmigrations, juvenile salmonids are often concentrated unnaturally near mainstem dams and hatchery release points on the lower Columbia and Snake rivers. Northern squawfish, a highly gregarious and opportunistic predator, appear to aggregate in these areas to feed on juvenile salmonids (Brown and Moyle 1981; Beamesderfer and Rieman 1991; Poe et al. 1991). An effective way to catch predator-sized northern squawfish and reduce predation on juvenile salmonids might be to target these areas at times when prey densities are high (i.e., below fish hatcheries following the release of juvenile salmonids).

Here we investigate an alternative harvest method, specifically, the removal of northern squawfish from areas where hatchery-reared juvenile salmonids are released in Bonneville Pool. The objectives of this work were to (1) determine whether northern squawfish concentrate and are vulnerable to capture near hatchery release points and, if so, (2) ascertain the cause(s) for these aggregations (e.g., feeding, spawning, etc.). We will use information gathered here to develop a more comprehensive plan for managing predacious-sized northern squawfish at similar locations on the lower Columbia and Snake rivers.

METHODS

In 1993, we sampled at three locations — Spring Creek, Drano Lake,-and Wind River — in Bonneville Pool (Figure E-l), an impoundment created by Bonneville Dam, the lower-most reservoir on the Columbia River. We fished small-meshed gill nets (8 ft deep x 150 ft long constructed from 25-ft panels with the repeating mesh size sequence: 2 in, 1 3/4 in, and 1 1/4 in bar measures) at sites within upstream and downstream transects at each location (Figure E-2). Sampling took place from late March through late May on dates before and after hatchery releases at Spring Creek National Fish Hatchery (NFH), Little White Salmon NFH, Willard NFH, and Carson NFH (Tables E-l and E-2; **see Sampling Design).**

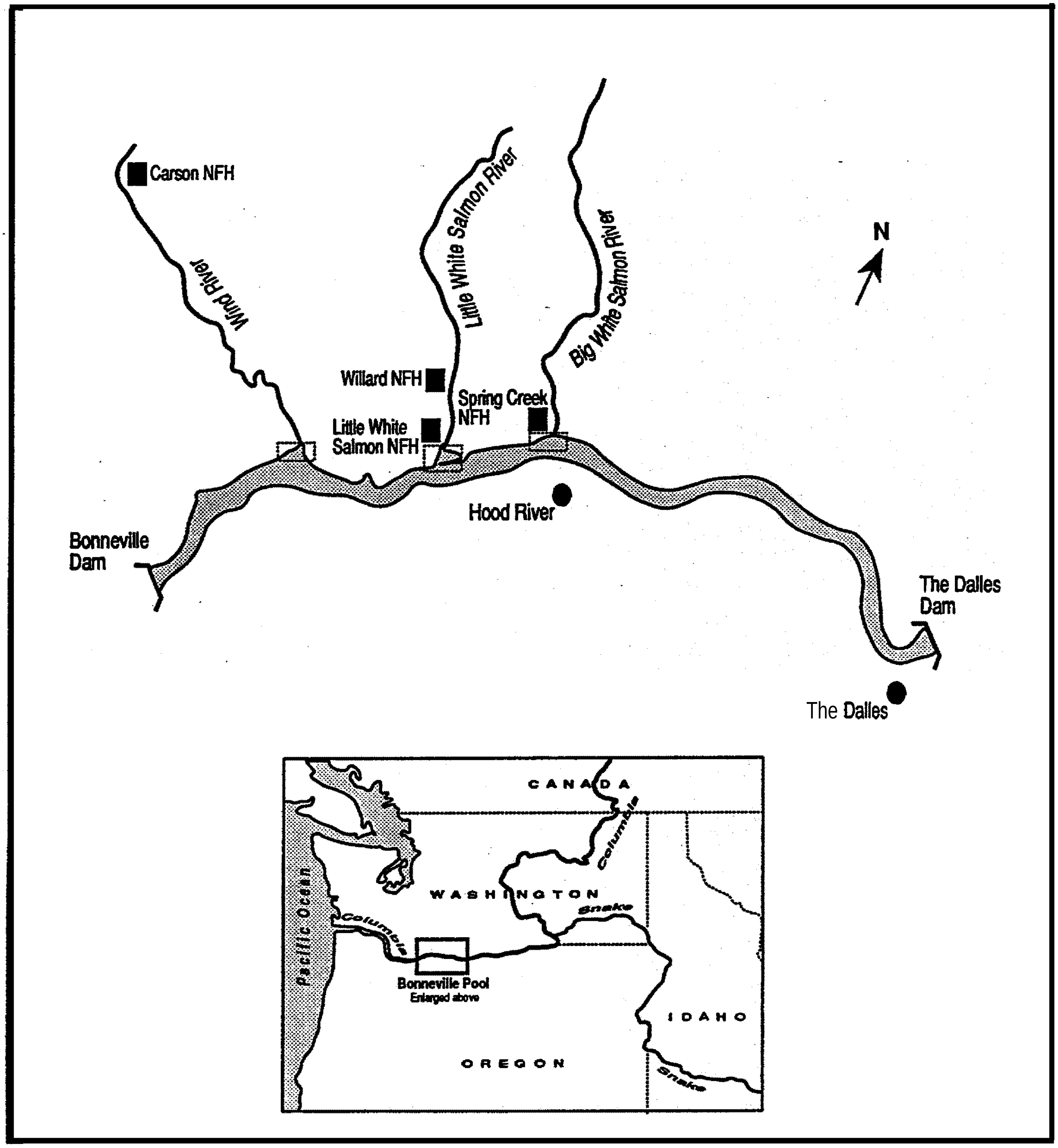

Figure E-l. Sampling locations (shown in dashed boxes) in Bonneville Pool, 1993. Locations (left to right: Wind River, Drano Lake, and Spring Creek) are shown in detail in Figure 2.

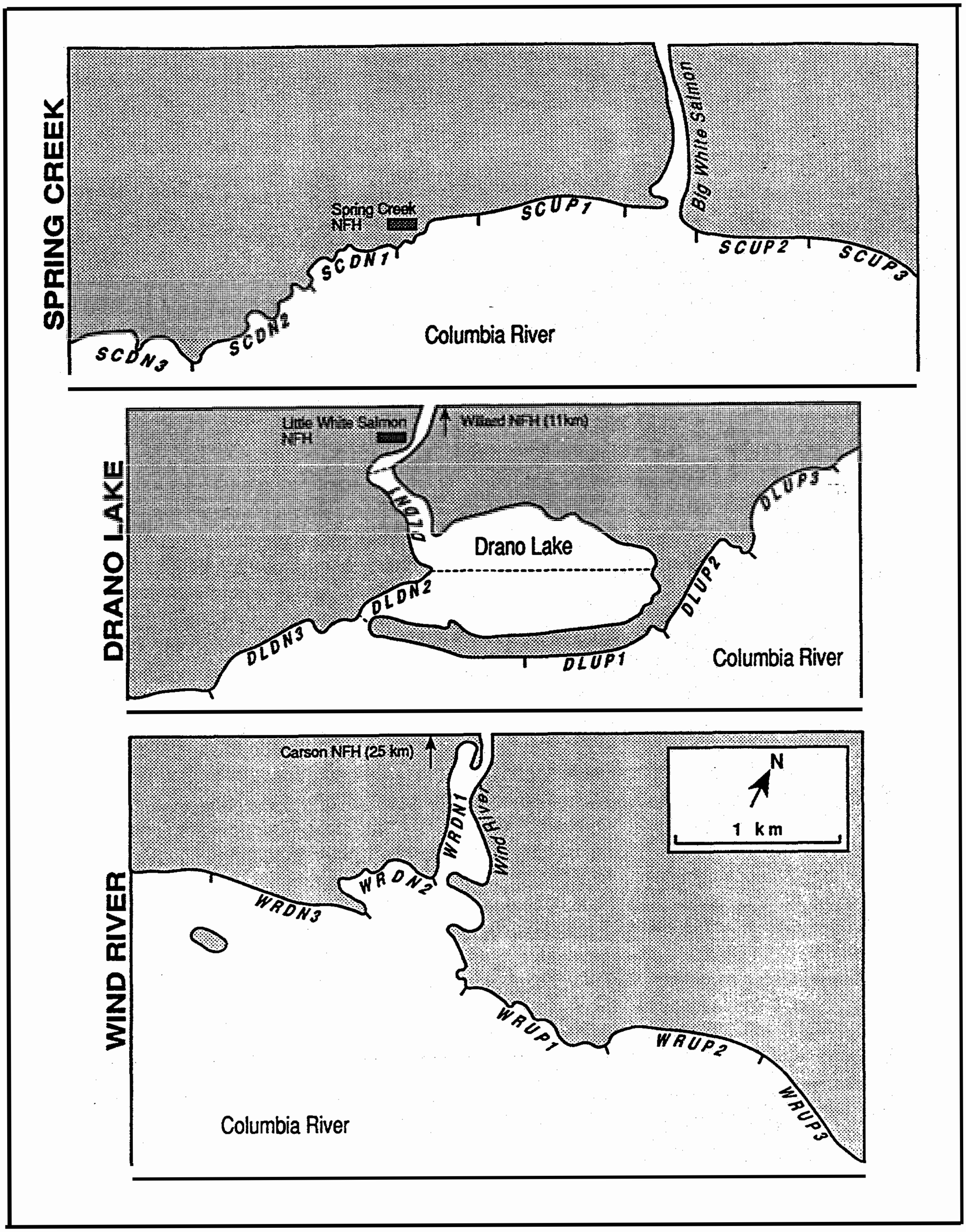

Figure E-2. Downstream (--DN-) and upstream (--UP-) transects at each sampling location in Bonneville Pool, 1993. A *site* is defined in this paper as a place within a transect where a net is fished.

Table E-1. Hatchery and sampling schedules and locations.

Hatchery	Release date	Sampling period (number of nights)		Location	
		Before release	After release	Release	Sampling
Spring Creek NFH	3/18	3/17 (1)	3/18 (1)	Columbia River at hatchery	Columbia River at hatchery
	4/15	4/12[a] (1)	4/15[b] (1)	Columbia River at hatchery	Columbia River at hatchery
	5/20	5/19 (1)	5/20 (1)	Columbia River at hatchery	Columbia River at hatchery
Little White Salmon & Willard NFH	4/15	3/25-4/13 (3)	4/16-5/25 (11)	Little White Salmon River	Drano Lake
Carson NFH	4/14	3/24-4/9 (2)	4/14-5/8 (6)	Wind River (25 km from mouth)	Wind River at mouth

[a] One sampling date (4/7) was removed from the before-release sampling group because juvenile salmonids released upstream were observed in large numbers in the sampling area.

[b] Four sampling dates (4/18, 4/21, 4/27, 5/4) were removed from the after-release sampling group because there was no evidence that hatchery fish released from Spring Creek NFH were still in the sampling area.

Table E2. Summary of spring releases of juvenile salmonids from Carson, Willard, Little White Salmon, and Spring Creek National Fish Hatcheries (NFH), 1993. Preliminary data (CRiS Database) provided by USFWS, Fishery Resources Office, Vancouver-, WA.

Hatchery/ release date	Species	Approx. size #/kg	Number released		
			Untagged	Tagged	TOTAL
Spring Creek NFH					
3/18/93	Chinook	308	6647,708	208,574	6,856,282
4/15/93	Chinook	212	3,143,388	835,476	3,978,864
5/20/93	Chinook	105	3,238,316	236,703	3,475,019
Little White Salmon NFH					
4/15/93	Chinook	40	781,804	27,275	809,079
Willard NFH					
4/15/93	Coho	40	3,013,690	49,925	3,063,615
Carson NFH					
4/14/93	Chinook	45	1,364,823	956,462	2,321,285

We enumerated the catch of each net and collected biological data on all northern squawfish caught, including fork length, weight, sex, and maturity (e.g., undeveloped, developing, ripe, or spawned). Subsequent data summaries and analyses include all northern squawfish caught, including those < 250 mm, fork length **(see Data Analysis). Guts** collected from a randomly selected group of 5-10 northern squawfish$\cdot$gill net^{-1} were frozen for later dietary analysis **(see Laboratory Analysis).** Species other than northern squawfish were identified to genus or species and immediately released back into the river. Incidentally caught game fish were assigned one of three condition codes at the time of release: (1) minimal injury, certain to survive; (2) moderate injury, may or may not survive; or (3) dead, nearly dead, or certain to die. Additionally, all salmonids caught were identified as either a juvenile or an adult and examined for external marks and/or fin clips. We also took detailed notes on the condition of each salmonid at release (i.e., was the fish bleeding, did the fish free itself from the net, how the fish was caught in the net?).

Each night we recorded information on weather and water conditions, including site-specific water temperatures. We also noted whether juvenile salmonids were observed in appreciable numbers (> 100) in the water at each location (e.g., presence or absence). This was important because data not meeting assumptions regarding presence (expected after release) and absence (expected before release) of juvenile salmonids in the sampling area could be removed from statistical comparisons **(see Data Analysis** for further discussion).

Sampling Design

At each location, we fished small-meshed gill nets concurrently at upstream (1 net) and downstream (2 nets) transects before and after release (Table E-l; Figure E-2). The upstream transects were established as a control. We hypothesized that changes in both catch rate and diet of northern squawfish associated with hatchery release would occur only in transects downstream from the release point, since hatchery-released fish were expected to migrate downstream after release.

We sampled at night, placing most gill nets perpendicular to shore on the river bottom for approximately 1 hour. initially, we placed upstream and downstream nets in sites where northern squawfish were likely to concentrate based on the river conditions. Once we sampled a number of different sites, nets were placed in the most productive upstream and downstream sites and moved whenever catch rates fell below l-2 northern squawfish *gill net h^{-1}, or when ≥ 2 adult salmonids$\cdot$gill net-' were caught. Locations were sampled at greater frequency immediately before and after the release dates and less frequently on dates more removed.

Laboratory Procedures

Diet analysis involved three major steps: (1) sorting and weighing gut contents, (2) digesting the soft gut contents, and (3) identifying and enumerating fish diagnostic bones. First, we squeezed the contents from thawed gut samples and sorted the items into seven categories: fish and fish parts, insects, crustaceans, mollusks, plant material, inorganic, and unidentified matter. Items in each category were blotted dry for approximately 60 seconds and then weighed to the nearest 0.1 g. If whole salmonids were present in the gut, they were counted, measured (fork length), and examined for fin clips. Once weighed, the voided gut and its contents were returned to its original sample bag for digestion.

The gut samples were then put through a digestion process according to the methods of Petersen et al. (1990, 1991) so that fish bones could be easily removed and identified. Any coded-wire tags detected in a sample were-removed using a magnetized rod and placed in a vial for later reading.

Finally, diagnostic bones (e.g., cleithra, dentaries, pharyngeal arches, and opercles) were identified and enumerated under a dissecting scope using a key developed by the U.S. Fish and Wildlife Service, Cook, Washington (unpub. data). When the number of prey fish consumed (based on paired diagnostic bones) differed from counts made during earlier sorting, we recorded the greater of the two numbers. Following enumeration, we preserved bones in 95% ethanol.

Data Analysis

We hypothesized that northern squawfish would show both a numerical and functional response to the release of hatchery fish in Bonneville Pool. A prediction of this hypothesis is that significant increases, from before to after release, in both catch rate and number of salmonids in the diet would be observed in downstream transects and not in the upstream transects where, presumably, hatchery-released fish would not be found. When assumptions about the presence or absence of juvenile salmonids in the sampling area were not met, those data were removed from all before-after comparisons and included in a supplemental sampling group. For example, at Spring Creek, where hatchery fish are released directly into the current of the mainstem Columbia River, smolts were observed in the sampling area only during the night following release in mid-April (4/15) and not thereafter. Consequently, nights sampled after 4/15 were excluded from before-after comparisons. Similarly, data from Spring Creek on 4/7 were removed from what would have been the before group because smolts released from an upstream hatchery were observed in large numbers in the sampling area.

Cl&squared and Fisher's exact test for independence were conducted using coded-wire tag recovery data at each location to determine whether the upstream transects served as a good control. We tested this hypothesis by comparing the following proportion, Coded-wire-tag (CWT) Recovery Index, between upstream and downstream transects:

$$\text{CWT Recovery Index} = \frac{\text{NSF w/CWT in gut}}{\text{NSF w/juvenile salmonids in gut}}$$

where: NSF = northern squawfish, and CWT = coded-wire-tagged juvenile salmonids released from the nearby hatchery. If the upstream sites were serving as a good control (i.e., catch rates unaffected by nearby hatchery release), then this proportion should be greater in downstream versus upstream transects.

Catch Data

We compared catch rate (northern squawfish · gill net h^{-1}; CPUE) before and after release at each location (unpaired student t-test); To separate the effects of hatchery release from other time- or site-related factors (e.g., water temperature, flow), we classified the data two ways: by time (before versus after release) and by site (upstream versus downstream from release point). The interaction term (time-by-site) in a two-way analysis of variance (ANOVA; Sokal and Rohlf 1981) was then used to analyze the effects of hatchery release on catch rate separate from other factors. We transformed catch data using $\log_{10}(x+1)$ to meet statistical assumptions (Moyle and Lound 1960; Elliott 1977; Beamesderfer and Rieman 1991). Catch data were also analyzed using likelihood ratio tests, which we present in **APPENDIX El.**

Diet Data

We investigated changes in the diet of northern squawfish associated with hatchery release at each location (functional response). We compared both the frequency of occurrence (chi-squared exact test for independence) and the mean number of salmonids (unpaired student t-test) recovered in the guts of northern squawfish caught before and after release. Counts of juvenile salmonids recovered in guts were transformed $(\sqrt{x+.5})$ to meet statistical assumptions (Sokal and Rohlf 1981). In addition, consumption indices (CI; see Petersen et al. 1990, 1991) were calculated to compare the relative consumption rates of juvenile salmonids by northern squawfish before and after hatchery release:

$$CI = 0.0209 \cdot T^{1.60} \cdot MW^{0.27} \cdot [MT_{sal} \cdot MGW^{-0.61}]$$

where: T = water temperature, MW = mean predator weight (g), MT, = mean number of salmonids/predator, and MGW = mean gut weight /predator (g). CI is not meant to be a rigorous measure of the number of salmonids consumed · $predator^{-1} \cdot day^{-1}$.

At Spring Creek, we also investigated the relationship between the size of the hatchery fish released and the number and biomass of juvenile salmonids consumed by northern squawfish (Spearman rank correlation, Kruskal-Wallis H-test, Mann-Whitney U-test; see Siegel 1988).

RESULTS

From mid-March through mid-May 1993, 1,772 northern squawfish were caught in 394.4 net•h of effort at all locations, for a seasonal catch-per-unit-effort (CPUE) of 4.5. Of the total northern squawfish catch, 98.4% were "predator-size" (i.e., ≥250 mm, determined by the CRNSMP; Figure E-3). However, one of eight northern squawfish less than 250 mm (size range 238 mm - 249 mm) sampled for diet analysis contained juvenile salmonids, suggesting that the CRNSMP "predator-size" range may be conservative (see Thompson 1959; Falter 1969). Most (62.9%) were females, with the remainder classified as either male or immature (actual percentage unknown because some immature fish were misclassified as males). All mature fish were undergoing gonadal development and were not ripe. Seven fish that had been previously tagged ODFW and NMFS were recaptured (Table E-3).

Spring Creek

Catch Rate

The CPUE of northern squawfish was significantly higher (t = 2.56, P = 0.006) after releases of hatchery fish from Spring Creek NFH than before those releases (Table E-4). The distribution of CPUE over time showed peaks in catch rate associated with hatchery releases in April and May at downstream sites, whereas catch rates at upstream sites remained relatively constant (Figure E-4).

The time-by-site interaction in a two-way ANOVA was not significant (Table E-5). One possible explanation for this result is that the upstream sites were not removed far enough from the downstream sites to serve as good controls (see Figure E-2). In downstream and upstream transects, respectively, 6/33 and O/l 1 northern squawfish had CWT fish in their guts, which was not a statistically significant difference (Fisher's exact test, P = 0.16).

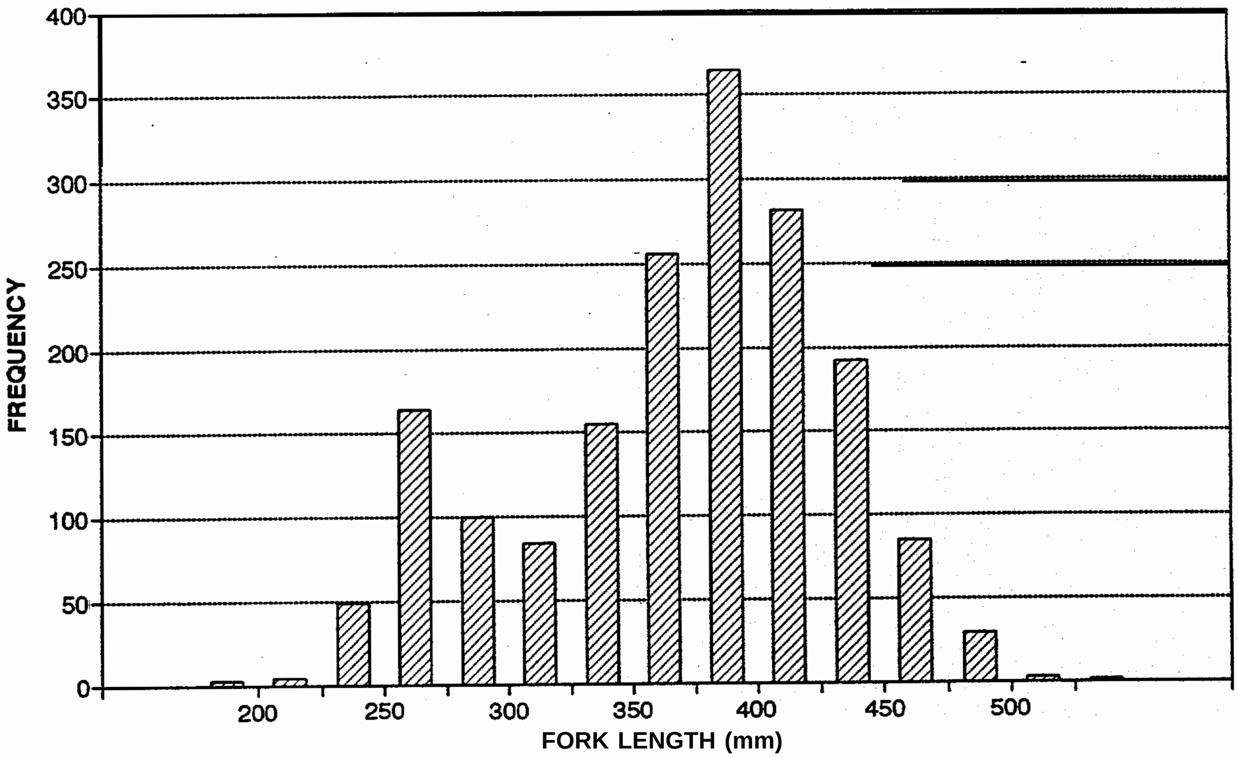

Figure E-3. Size distribution of northern squawfish caught at all sampling locations in 1993.

Table E-3. Northern squawfish recapture data at all locations sampled in 1993. Tagging information was provided by Dave Ward (ODFW, Clackamas, OR) and Bruce Monk (NMFS, Bonneville Field Station, WA).

Tagging information		Recapture information		
Date	Location (river km)	Date	Location (river km)	Distance from tagging location in river km
7/08/89	Bonneville Dam forebay (235)	4/28/93	Drano Lake (261	26
7/08/89	Bonneville Dam forebay (235)	5/07/93	Drano Lake (261)	26
7/25/91	Bonneville Dam forebay (235)	5/13/93	Drano Lake (261)	26
4/06/93	Below Spring Creek NFH (267)	4/15/93	Spring Creek (269)	2
4/06/93	Above Spring Creek NFH (271)	4/18/93	Spring Creek (269)	2
4/08/93	Mouth of Klickitat River (290)	4/22/93	Drano Lake (261)	29
4/29/93	Mouth of Wind River (250)	4/29/93	Wind River (248)	2
				$\bar{X} = 16.1$

Diet Analysis

Fish composed a greater proportion of the diet of northern squawfish caught after release compared to those caught before release (Figure E-5 and Table E-6). -Furthermore, the frequency of occurrence of juvenile salmonids in northern squawfish guts was significantly higher (X^2 = 16.69, $P < 0.0001$) after, as compared to before, release, as was the mean number of salmonids in the diet of all northern squawfish sampled (t = 3.93, $P <$ 0.0001). The consumption index for fish caught after release was higher than before release (Table E-6). The mean number of salmonids in the guts of northern squawfish caught in downstream transects peaked on dates following releases at Spring Creek NFH, whereas the corresponding measure in upstream transects showed no obvious pattern relative to release dates (Figure E-6).

In 1993, Spring Creek NFH had three separate releases, each differing in the average size of the juvenile salmonids released (Table E-2). The size of hatchery fish released (e.g., small, medium, and large based on the average size, see Table E-7) was negatively and significantly correlated (r = -0.23, N = 78, P c 0.0001) with the number of salmonid prey found in the guts of northern squawfish caught on the nights following each release. The biomass of juvenile salmonids *predator-' was also significantly and negatively correlated (r = -0.17, N = 78, P = 0.0002) with the size of the hatchery fish released. (Biomass is estimated as the number of juvenile salmonids in the guts of northern squawfish ÷ the average $\# \cdot kg^{-1}$ of. the hatchery fish released.) Mean comparisons showed significant differences in the biomass of juvenile salmonids consumed by northern squawfish based on average size of hatchery fish released (Table E-7). We assume in these comparisons that differences in the numbers of fish released (see Table E-2) need not be taken into account. These tests include only data from the first night after release (i.e., less than 12 h from the median release and sample times) when prey densities are likely to be sufficiently high that foraging success of northern squawfish probably is not dependent on the total number of fish released.

Table E-4. Northern squawfish gill-net catch and effort (net • h) at sites upstream and downstream from hatchery release points before and after release. The supplemental sampling group is excluded from all before-after comparisons.

		Upstream			Downstream			TOTAL		
Location		NSF[a]	Effort	CPUE	NSF[a]	Effort	CPUE	NSF[a]	Effort	CPUE
Spring Creek	Before:	25	11.0	2.3	46	25.7	1.8	71	36.7	1.9
	After:	32	10.6	3.0	113	29.9	3.8	145	40.5	3.6
	Supplemental:	92	25.3	3.6	91	41.7	2.2	183	67.0	2.7
Drano Lake	Before:	26	10.0	2.6	89	29.5	3.0	115	39.5	2.9
	After:	47	23.4	2.0	722	82.0	8.8	769	105.5	7.3
Wind River	Before:	13	5.6	2.3	67	21.1	3.2	80	26.7	3.0
	After:	136	26.9	5.0	273	51.6	5.3	409	78.5	5.2
TOTAL	Before:	64	26.6	2.4	202	76.3	2.6	266	102.9	2.6
	After:	215	60.9	3.5	1108	163.5	6.0	1323	224.5	5.9
	Supplemental:	92	25.3	3.6	91	41.7	2.2	183	67.0	2.7

[a] Includes northern squawfish (29) that were <250 mm.

Table E-5. Two-way **ANOVA** of northern squawfish CPUE for the three locations sampled in 1993.

Source of variation	df	*F*	*P*
Spring Creek			
Time (before vs. after)	1	4.63	0.03
Site (upstream vs. downstream)	1	0.21	0.22
Time-by-site	1	0.10	0.75
Drano Lake			
Time (before vs. after)	1	3.34	0.07
Site (upstream vs. downstream)	1	7.57	0.007
Time-by-site	1	3.50	0.06
Wind River			
Time (before vs. after)	1	6.11	0.01
Site (upstream vs. downstream)	1	0.00	0.98
Time-by-site	1	0.08	0.77

Table E-6. Comparisons of the diet of northern squawfish caught at each location before and after release.

			% of diet (wet weight)				Salmonids in gut		
		N[a]	Fish	Crayfish	Plants	Other	%[b]	Mean ± SE	CI[c]
Spring Creek	Before:	57	60.1	27.8	1.9	10.2	12.3	0.23 ± 0.10	0.24
	After:	78	93.1	4.7	0.4	1.8	50.0	2.55 ± 0.62	2.29
Drano Lake	Before:	66	35.2	22.9	4.6	37.3	6.1	0.14 ± 0.07	0.08
	After:	193	94.7	3.3	0.1	1.9	33.2	0.74 ± 0.10	0.69
Wind River	Before:	52	17.8	42.5	3.2	36.5	1.9	0.10 ± 0.10	0.05
	After:	117	93.1	6.0	0.1	0.8	30.8	0.55 ± 0.09	0.43
TOTAL	Before:	175	34.5	34.5	3.0	28.0	6.8	0.15 ± 0.05	0.11
	After:	388	94.0	4.3	0.2	1.5	35.8	1.04 ± 0.14	0.92

[a] Includes northern squawfish (9) that were <250 mm.
[b] Percent of northern squawfish with salmonids in gut.
[c] CI = consumption index.

Table E7. Differences (Kruskal-Wallis test, $H = 19.28$, $P < 0.0001$) in the number and biomass of juvenile salmonids consumed by northern squawfish feeding after the releases of small-, medium-, and large-sized juvenile salmonids. Means with different letters are significantly different (Mann-Whitney U-test, $P < 0.0001$).

Release and sampling date	Size of released fish (#/kg)	N	Number of juvenile salmonids consumed	Biomass of juvenile salmonids consumed (g)
			Mean ± SE	Mean ± SE
3/18/93	small (308/kg)	13	11.7 ± 2.5 *a*	37.9 ± 8.0 *a*
4/15/93	medium (212/kg)	46	0.9 ± 0.1 *b*	4.1 ± 0.7 *b*
5/20/93	large (105/kg)	19	0.4 ± 0.2 *b*	3.5 ± 1.7 *b*

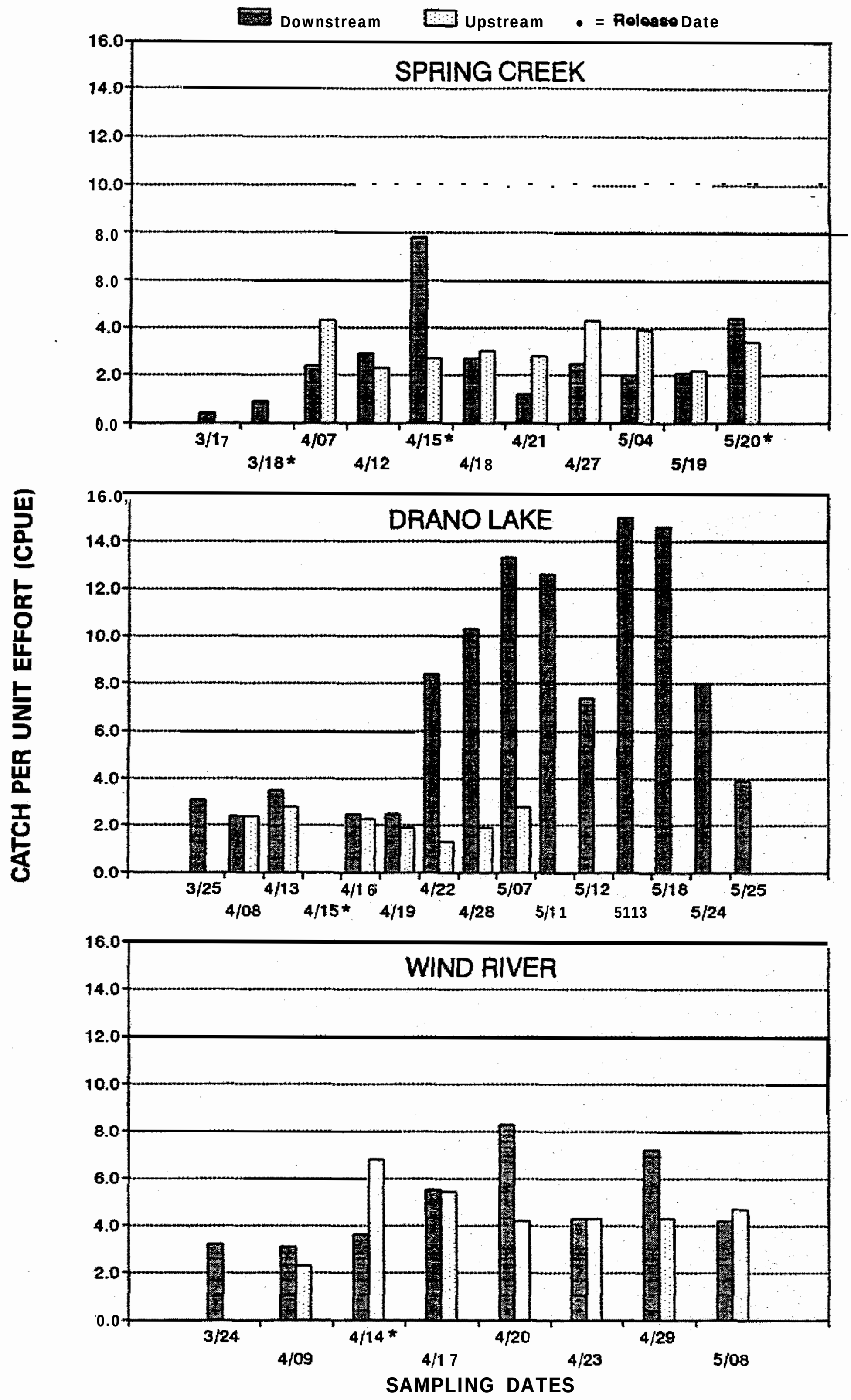

Figure E-4. CPUE of northern squawfish at down&ream and upstream transects on sampling dates before and after hatchery release. Upstream transects were not sampled before 4/7 at any location or after 5/7 at Drano Lake. Drano Lake was not sampled on 4/15.

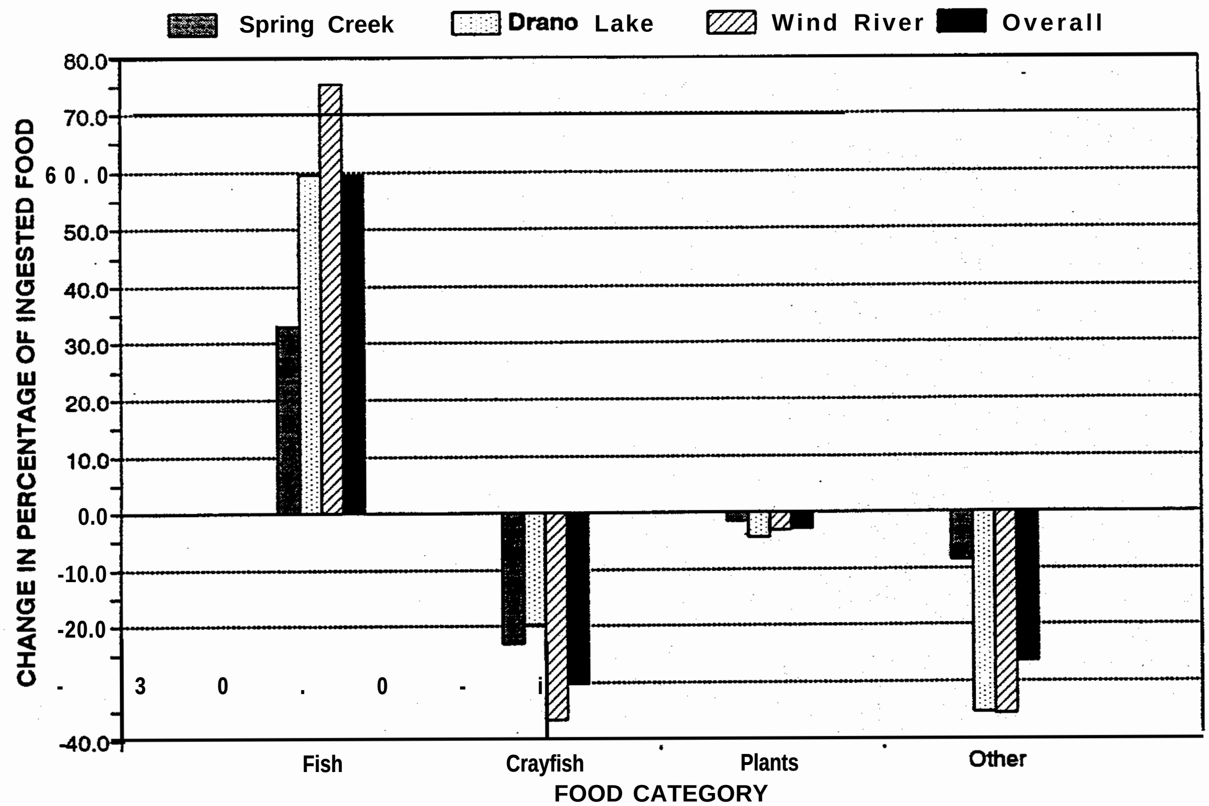

Figure E-5. Change (after release minus before release) of ingested food (% by weight) of northern squawfish caught at hatchery release sites. The "Other" category includes insects, mollusks, inorganic, and unidentified matter.

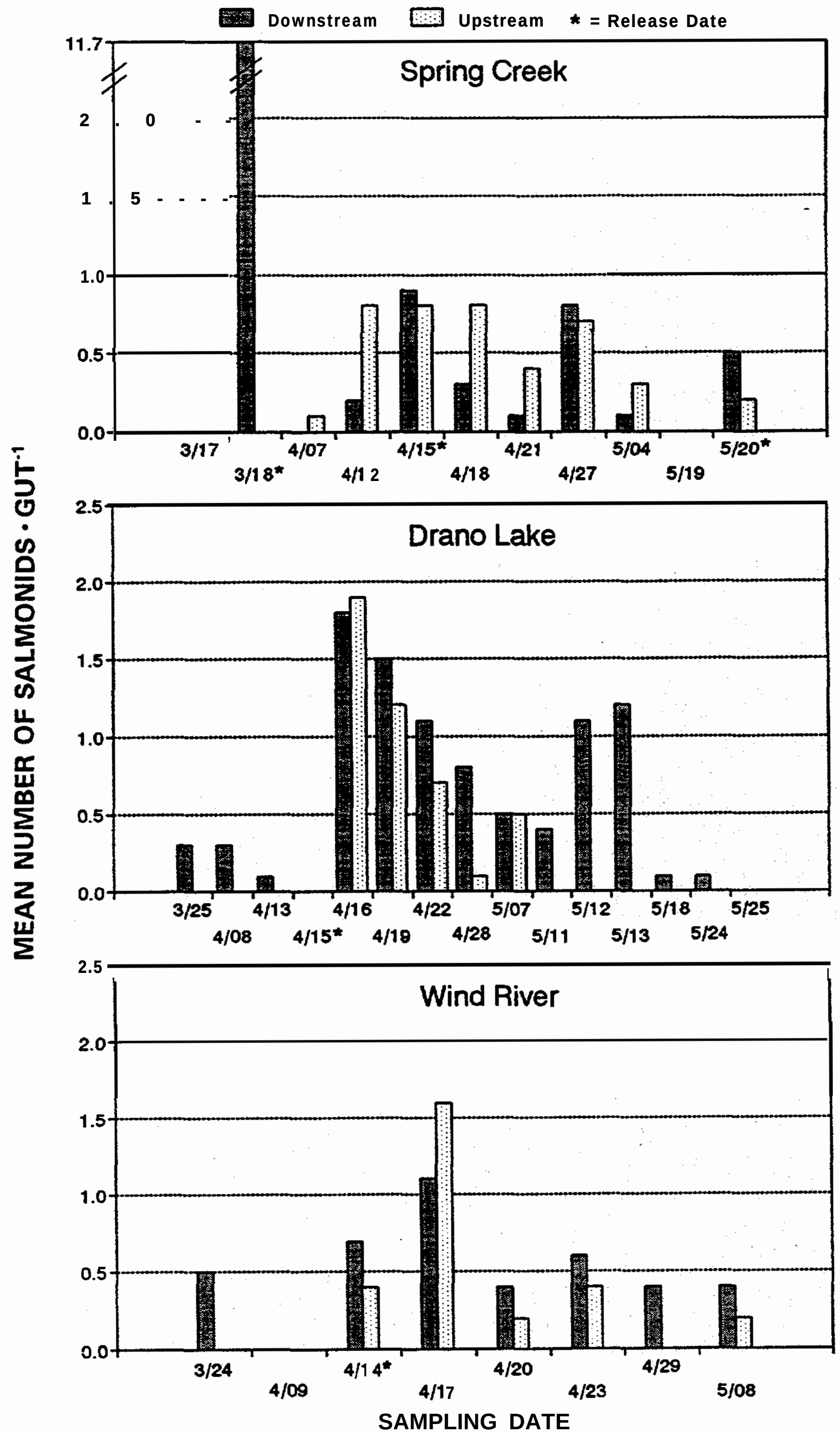

Figure E-6. Mean number of salmonids$\cdot$gut^{-1} of northern squawfish caught at downstream and upstream transects on sampling dates before and after hatchery release. Upstream transects were not sampled before 4/7 at any location or after 5/7 at Drano Lake. Drano Lake was not sampled on 4/15. Please note different scales.

Drano Lake

Catch Rate

Northern squawfish CPUE was significantly higher (*t* = ***3.30, P = 0.0006***) after, as compared to before, the release of hatchery fish into Drano Lake (Table E-4). Plots of CPUE at Drano Lake over time showed a dramatic increase in catch rates in downstream transects after hatchery releases, whereas CPUE in upstream transects was lower and remained relatively constant throughout the sampling period (Figure E-4). Furthermore, elevated catch rates in downstream sites were sustained for more than a month after hatchery release (Figure E-4). The time-by-site interaction was significant (Table E-5). We recovered only one coded-wire-tagged juvenile salmonid released from Little White Salmon and Willard NFHs in the guts of northern squawfish caught at Drano Lake. Consequently, a test to determine whether the upstream transects at Drano Lake served as a good control could not be conducted.

Diet Analysis

Fish and fish parts composed a greater proportion of the diet of northern squawfish after, as compared to before, hatchery releases (Figure E-5 and Table E-6). Also, a higher frequency of occurrence (X^2 = 18.70, $P < 0.0001$), mean number of juvenile salmonids in the diet (t = 3.65, $P < 0.0004$), and consumption index were observed after, as compared to before, release (Table E-6). At Drano Lake, the mean number of juvenile salmonids in the diet of northern squawfish caught in both upstream and downstream transects increased on dates after release and remained above levels observed before release for nearly a month (Figure E-6).

Wind River

Catch Rate

Northern squawfish CPUE was significantly higher (t = 2.49, $P = 0.007$) at the mouth of the Wind River after the release of hatchery fish from Carson NFH as compared to before release (Table E-4). Plots of CPUE over time show increases immediately after release in both downstream and upstream sites (Figure E-4).

The time-by-site interaction in a two-way ANOVA was not significant (Table E-5). Comparisons of the proportions of northern squawfish caught in upstream and downstream transects having CWT fish released from Carson NFH in their guts (see CWT Recovery Index described above) indicate that the upstream sites were not far enough removed to be unaffected by the hatchery release (upstream: 12/21 NSF w/tagged fish in gut; downstream: 12/32 NSF w/tagged fish in gut, X^2 = 1.26, $P = 0.26$).

Diet Analysis

Fish composed a higher percentage of the gut contents of northern squawfish after release (compared to before release) at Wind River (Figure E-5 and Table E-6). Additionally, the frequency of occurrence of juvenile salmonids (X^2 = 16.69, $P < .0001$), mean number of juvenile salmonids (t = 3.93, $P < .0001$), and the consumption index were higher for northern squawfish caught after as compared to before release (Table E-6). The mean number of jwenile salmonids in the guts of northern squawfish caught on dates after release were higher than before release in both upstream and downstream transects (Figure E-6).

Incidental Catch

A total of 2,836 fish were incidentally caught at all locations sampled in 1993 (Table E-8). Salmonids composed 1.4% and 2.3% of the total and incidental catch, respectively, and most were released in good condition (Table E-9).

Table ES. Catches by species and location in 1993.

Species	Spring Creek	Drano Lake	Wind - River	TOTAL
Northern squawfish *Ptychocheilus oregonensis*	399	884	489	1772
Incidental catch				
Peamouth *Mylocheilus caurinus*	327	521	849	1697
Largescale sucker *Catostomus macrocheilus*	302	2 3 6	282	820
White sturgeon *Acipenser transmontanus*	123	47	0	170
Salmonids[a] *Oncorhynchus spp.*	17	33	15	65
Chisehnouth *Acrocheilus alutaceus*	6	2	22	30
Bridgelip sucker *Catostomus coiumbianus*	15	12	1	28
Smalhnouth bass *Micropterus dokmiieui*	1	2	3	6
Brown bullhead *Ictalurus nebulosus*	1	3	1	5
Mountain whitefish *Prosopium williamsoni*	0	I	3	4
Yellow perch *Perca flavescens*	0	2	0	2
Redside shiner *Richardsonius balteatus*	1	1	0	2
Channel catfish *Ictalurus punctatus*	1	0	0	1
Largemouth bass *Micropterus sabnoides*	0	1	0	1
American shad *Alosa sapidissima*	1	0	0	1
Goldfish *Carassius auratus*	1	0	0	1
Sculpin *Cottus spp.*	0	1	0	1
Total incidental catch	796	862	1176	2 8 3 4
TOTAL CATCH	1195	1746	1665	4606

[a] Salmonid catch is described in detail in Table 9.

Table E-9. Salmonid catch by location and condition at release in 1993. Condition codes: 1) minimal injury, certain to survive; 2) moderate injury, may or may not survive; 3) dead, nearly dead, or certain to die.

	Juvenile salmonids"			Adult salmonids		
Location	1	2	3	1	2	3
Spring Creek	6	2	1	6	2	0
Drano Lake	8	0	7	16	1	1
Wiid River	3	0	1	11	0	0
TOTAL	17	2[b]	9[b]	33[c]	3[d]	1[e]

[a] Not identified to species.
[b] Juvenile salmonids caught and released in Conditions 2 and 3 were just-released hatchery smolts that got their teeth tangled in the net.
[c] 18 chinook salmon, 12 steelhead, 2 chinook salmon **(jack),** 1 cutthroat trout.
[d] Steelhead.
[e] Chinook salmon (jack).

DISCUSSION

Catch rates of northern squawfish increased significantly following hatchery release at all three locations sampled, particularly on dates immediately following hatchery release. The duration of increased CPUEs appears to be closely related to the residence time of prey in the sampling area (see Management Implications). Furthermore, northern squawfish caught after release had a significantly higher frequency of occurrence and mean number of juvenile salmonids in their diet when compared to fish caught before release. Consumption indices used as a relative measure of consumption rates were also higher at each location after, as compared to before, release. These data are consistent with the hypothesis that northern squawfish immigrate into areas where hatchery-reared fish are released (numerical response) to feed on juvenile salmonids while they are concentrated (functional response; see Peter-man and Gatto 1978).

Other studies have suggested that northern squawfish are densely concentrated in areas where hatchery fish are released and that they are gathered there to feed. Shively et al. (1991) observed unusually high catch rates (for mid- and upper-reservoir locations) of northern squawfish at sites above Lower Granite Dam, which coincided with nearby hatchery releases. Consumption rates at one site in particular suggested that northern squawfish were there to feed on hatchery-released fish. In 1953, 3,425 northern squawfish were removed from Drano Lake using gill nets before, during, and after hatchery releases at Little White Salmon and Willard National Fish hatcheries (Zimmer 1953; USFWS 1957). Many of the northern squawfish caught were believed to have immigrated from the Columbia River into Drano Lake to feed on the hatchery-released fish. It was concluded, based on intensive sampling in the Columbia River from 1953-1956, that significant predation by northern squawfish occurred only at places where, and times when, hatchery-reared juvenile salmonids were released (USFWS 1957; Thompson 1959).

An alternative, but not mutually exclusive, hypothesis to explain increased catch rates following a hatchery release is that northern squawfish in the area feed more actively following a hatchery release and are therefore more susceptible to capture. A prediction of this hypothesis is that with intensive sampling, as was the case at Drano Lake in particular, one might expect the local population to be depleted over time. This prediction does not seem to be supported by our data. Plots of daily catch rate at Drano Lake remained high and relatively constant for more than a month after release (Figure E-4). Given the relatively small size of this sampling location and distances travelled by northern squawfish (Table E-3; Nigro et al. 1985) it is unlikely that increases in catch rates observed following release were not explained, at least in part, by northern squawfish immigrating into the sampling location from areas outside. In either case, these results support the hypothesis that northern squawfish are more easily caught in these areas after release, when hatchery fish are present in large numbers, than at other times or places that we sampled.

Limitations of Data

There is some evidence to suggest that the upstream transects were not good controls, as indicated by the non-significant time-by-site interactions in the two-way ANOVA's (Table E-5). First, the temporal changes (relative to release dates) in the mean number of salmonids in the guts of northern squawfish caught in downstream and upstream transects were similar at each location (Figure E-6). Furthermore, coded-wire tagged juvenile salmonids were recovered in the guts of northern squawfish caught in both upstream and downstream transects. Based on these data, the upstream transects may not have served as adequate controls (e.g., reference sites); therefore, we cannot rule out the possibility that the observed changes in catch rate and diet were due to other time-related factors such as changes in water temperature or flow.

The results at Drano Lake in particular need to be interpreted with some caution. Two downstream transects were located within the lake and all upstream transects were in the mainstem Columbia River. Therefore, dissimilarities in hydrology and other physical factors may have contributed to the observed differences in catch rate and diet between upstream and downstream transects. This may explain the significant site (upstream versus downstream) main effect in the two-way ANOVA (Table E-5). Also, a "hot spot" (i.e., site within a transect having high catch rates) was found after release that was not sampled before release, which may further influence those data. Nevertheless, we believe that in total our data provide convincing evidence of a functional response of northern squawfish to the release of hatchery fish and are consistent with the aggregation response hypothesis.

Management Implications

Important differences were observed between the three locations we sampled with respect to (1) river velocity, (2) residence time of hatchery-released fish at the sampling location, and (3) the size of the hatchery fish released. These differences and their effect on predation may be important to consider in management decisions aimed at reducing predation on juvenile salmonids, either by predator control or prey protection measures.

River velocities at the three sampling locations were dissimilar and probably influenced the residence times of juvenile salmonids released in these areas. Differences in residence time may explain the different patterns of predation activity observed at these locations. For example, hatchery fish released into Drano Lake, an embayment at the mouth of the Little White Salmon River formed by Bonneville Dam, were observed in abundance there more than a month after release. Conversely, hatchery fish from Spring Creek NFH were released into the main current of the Columbia River and were not observed in the sampling location after the first night following release. Plots of daily catch rates over time at Drano Lake and Spring Creek suggest a direct relationship between the abundance of juvenile salmonids and the abundance or catchability of northern squawfish in these areas (Figure E-4). Similarly, our data suggest that the mean number of juvenile salmonids in the diet of northern squawfish and prey abundance may be positively correlated, assuming prey abundance is greatest immediately following release and declines thereafter (Figure E-6). Based on these results, management activities aimed at reducing predation on juvenile salmonids should consider (1) removing predators from areas where residence times of juvenile salmonids are prolonged and (2) altering hatchery release strategies so that prey do not delay their outmigration and remain concentrated for long periods of time.

Our results suggest that there are significant differences in the predation activities of northern squawfish feeding on juvenile salmonids of different size. Spring Creek NFH had three separate hatchery releases, each differing in the average size of the juvenile salmonids released. We found a significant negative correlation between both the biomass and number of juvenile salmonids consumed by northern squawfish with the size category (e.g., small, medium, and large) of the fish released . Mean comparisons showed that northern squawfish caught after the release of small-sized hatchery fish had significantly greater biomass and numbers of juvenile salmonids in their diet as compared to those northern squawfish feeding on larger fish. There was no difference between the biomass and number of medium- and large-sized juvenile salmonids in the diet of northern squawfish feeding after these releases. These results suggest that, as far as point-source predation by northern squawfish is concerned, there may be an advantage to releasing larger fish. However, large fish (105 fish/kg) may not survive any better than medium-sized fish (212 fish/kg). These data indicate that predation risks faced by hatchery fish of different size should be considered along with other factors in hatchery production plans.

In summary, our data suggest that northern squawfish congregate near hatchery release sites in the spring to feed on juvenile salmonids. Removal efforts that target feeding concentrations of northern squawfish have the advantage of removing large numbers of mostly predator-sized northern squawfish from areas where predation rates are relatively high. Based on these data, predator control efforts targeting these and similar areas may be viable and important management alternatives for reducing juvenile salmonid mortality rates in the Columbia River Basin.

RECOMMENDATIONS

1. Expand the 1993 Bonneville Pool work to include additional sampling locations near hatchery release sites and other areas in the Columbia and Snake rivers where juvenile salmonids might concentrate. Site selection and sampling schedule should be dictated by hatchery release schedules and expected residence times of hatchery-released fish in the sampling location.

2. Use mobile Merwin traps along with small-meshed gill nets to target northern squawfish for removal. Merwin traps should be deployed when and where gill-net catches are high and incidental impacts are likely to be minimal. This integrated use

of sampling gears will result in added flexibility and probably increase efficiency and productivity over previous efforts utilizing these methods.

3. Coordinate with other agencies sampling on the Columbia and Snake rivers within season. Other agencies may identify other "hot spots" that we would not otherwise find. This coordination should also facilitate both project and program biological evaluation (e.g., estimation of exploitation rates, etc.).

4. Eliminate the smallest mesh panels (1 1/4" bar measure) in experimental gill nets. Medium and large-mesh (2" and 1 3/4" bar measure) are more effective in catching predator-sized northern squawfish (K. Collis, CRITFC, personal observation).

5. Continue to collect information on the spatial and temporal distribution, feeding habits, and general life history of northern squawfish. This information will help shape future removal efforts to become more cost-effective, as well as help hatchery managers determine hatchery release schedules and procedures.

6. Minimize potential impacts to salmonids by limiting sampling to late winter and spring months when water temperatures are lower and the abundance of adult salmonids, particularly listed stocks, are relatively low.

7. Continue to develop biologically sound operational criteria that will further minimize impacts to salmonids, particular listed stocks.

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APPENDIX El

Liieliiood Ratio Test: An Alternative Method for Analyzing the Catch Data

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Introduction

This appendix contains an alternative statistical analysis of CPUE data based on the Poisson probability model. We use the abbreviations:

SCDNB = Spring Creek Downstream Before release
SCDNA = Spring Creek Downstream After release
SCUPB = Spring Creek Upstream Before release
SCUPA = Spring Creek Upstream After release

Similar abbreviations are used for Drano Lake data (DLDNB, DLDNA, DLUPB, DLUPA) and Wind River data (WRDNB, WRDNA, WRUPB, WRUPA).

Analysis of the Spring Creek Data

The Spring Creek CPUE data are summarized by the following array:

SCDNB	$n_1=23$	mean, = 1.550
SCDNA	$n_2=29$	$mean_2=3.728$
SCUPB	$n_3=11$	$mean_3=2.316$
SCUPA	$n_4=12$	$mean_4=3.227$

This array gives the individual sample sizes and sample means. The overall sample size and sample mean were $n=75$ and $mean=2.773$. We assume that we have sampled from four different Poisson populations with parameters $\lambda_1,\lambda_2,\lambda_3,\lambda_4$ respectively. Thus we assume that SCDNB data are Poisson(λ_1), SCDNA data are Poisson(&), SCUPB data are Poisson&), and SCUPA data are Poisson(&). This notation allows us to conveniently state various hypotheses of interest in terms of the parameters λ_i.

The first null hvnothesis tested was that ail four Poisson populations are the same, versus the alternative hypothesis that they are not all the same. Symbolically, we test $H_o:\lambda_1=\lambda_2=\lambda_3=\lambda_4$ vs. $H_a:\lambda_i$'s not all equal. The method used was a likelihood ratio test, as described in Mathematical Statistics by Samuel S. Wilks (1962), John Wiley & Sons, New York. Essentially, the likelihood ratio test compares the maximum of the likelihood function of the data under the restriction H_o to the unrestricted maximum of the likelihood function. If we call this ratio A, then $-2\cdot\log(\Lambda)$ will be asymptotically chi-squared (all logarithms here are natural logarithms, or base e). The null hypothesis H_o is rejected when A is small, or equivalently when $-2\cdot\log(\Lambda)$ is large. The degrees of freedom is the loss of dimensionality in the $(\lambda_1,\lambda_2,\lambda_3,\lambda_4)$-space imposed by the restriction H,. In our first test, the loss of dimensionality is 4-l $=3$. The likelihood ratio test statistic (LRTS) turns out to be

$$LRTS = 2\sum_{i=1}^{4} n_i \overline{x}_i \log\left(\overline{x}_i / \overline{x}\right),$$

where $\bar{x}_i$ is an individual sample mean, and $\bar{\bar{x}}$s the overall sample mean.

The results of the test were:

$H_o: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4$ vs. $H_a: \lambda_i$'s not all equal
LRTS = 25.0834
P-value = 0.0000

based on a chi-square distribution with 3 degrees of freedom. Thus H_o is rejected, and conclusion: the four populations are not the same.

The second null hypothesis tested is that there is no difference between Upstream and DowNstream sites. This hypothesis is stated as SCDNB=SCUPB and SCDNA=SCUPA. Equivalently, $H_o: \lambda_1 = \lambda_3$ and $\lambda_2 = \lambda_4$ vs. not H_o. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom. The actual form of the test statistic was:

$$LRTS = 2 \cdot \left\{ \sum_{i=1}^{4} n_i \bar{x}_i \log(\bar{x}_i) - (n_1\bar{x}_1 + n_3\bar{x}_3) \log\left[\frac{n_1\bar{x}_1 + n_3\bar{x}_3}{n_1 + n_3}\right] - (n_2\bar{x}_2 + n_4\bar{x}_4) \log\left[\frac{n_2\bar{x}_2 + n\ \bar{x}_4}{n_2 + n}\right] \right\}$$

The results of the test were:

$H_o: \lambda_1 = \lambda_3$ and $\lambda_2 = \lambda_4$ vs. not H_o
LRTS = 2.93613
P-value = 0.2304

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is not rejected, and conclusion: Upstream is not significantly different than DowNstream.

The third null hypothesis tested is that there is no difference between Before and After data. This hypothesis is stated as SCDNB=SCDNA and SCUPB=SCUPA. Equivalently, $H_o: \lambda_1 = \lambda_2$ and $\lambda_3 = \lambda_4$ vs. not H,. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom.
The actual form of the test statistic was:

$$LRTS = 2 \cdot \left\{ \sum_{i=1}^{4} n_i \bar{x}_i \log(\bar{x}_i) - (n_1\bar{x}_1 + n_2\bar{x}_2) \log\left[\frac{n_1\bar{x}_1 + n_2\bar{x}_2}{n_1 + n_2}\right] - (n_3\bar{x}_3 + n_4\bar{x}_4) \log\left[\frac{n_3\bar{x}_3 + n\ \bar{x}_4}{n_3 + n}\right] \right\}$$

The results of the test were:

$H_o: \lambda_1 = \lambda_2$ and $\lambda_3 = \lambda_4$ vs. not H_o
LRTS = 25.3159
P-value = 0.0000

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is not accepted, and conclusion: Before data and After data are significantly different.

The fourth null hypothesis tested is that the interaction between Before/After and DowNstream/UPstream is zero. This hypothesis is stated as SCDNB-SCDNA=SCUPB-SCUPA, or as SCDNB-SCDNA-SCUPB+SCUPA=O. Equivalently, this is expressed as $H_o:\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H_o. The likelihood ratio test for this hypothesis could not be derived in closed form. A Z-test was substituted instead. The form of the test was:

$$Z\text{-}TEST = \frac{(\bar{x}_1-\bar{x}_2-\bar{x}_3+\bar{x}_4) - (0)}{\sqrt{\sum_{i=1}^{4}\left(\frac{\bar{x}_i}{n_i}\right)}}$$

The results of the test were:

$H_o:\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H_o
Z-TEST = -1.54168
P-value = 0.1232

based on a standard normal (Z) distribution. Thus H_o is not rejected, and conclusion: the DowNstream/UPstream and Before/After interaction is not significant.

Analysis of the Drano Lake Data

The Drano Lake CPUE data is summarized by the following array:

DLDNB	n, =28	mean, =2.973
DLDNA	$n_2=81$	$mean_2=8.830$
DLUPB	$n_3=10$	$mean_3=2.379$
DLUPA	$n_4=21$	$mean_4=2.085$

This array gives the individual sample sizes and sample means. The overall sample size and sample mean were n=140 and mean=6.186. We assume that we have sampled from four different Poisson populations with parameters $\lambda_1,\lambda_2,\lambda_3,\lambda_4$ respectively. Thus we assume that DLDNB data are Poisson(λ_1), DLDNA data are Poisson@,), DLUPB data are Poisson(&), and DLUPA data are Poisson(λ_4). This notation allows us to state various hypotheses of interest in terms of the parameters λ_i.

The first null hypothesis tested was that all four Poisson populations are the same, versus the alternative hypothesis that they are not all the same. Symbolically, we test $H_o:\lambda_1=\lambda_2=\lambda_3=\lambda_4$ vs. $H_a:\lambda_i$'s not all equal. The likelihood ratio test statistic is the same as before.

The results of the test were:

$$H_o:\lambda_1=\lambda_2=\lambda_3=\lambda_4 \text{ vs. } H_a:\lambda_i\text{'s not all equal}$$

LRTS = 246.334

P-value = 0.0000

based on a chi-square distribution with 3 degrees of freedom. Thus H_o is rejected, and conclusion: the four oonulations are not the same.

The second null hvoothesis tested is that there is no difference between Upstream and DowNstream sites. This hypothesis is stated as DLDNB=DLUPB and DLDNA=DLUPA. Equivalently, $H_o:\lambda_1=\lambda_3$ and $\lambda_2=\lambda_4$ vs. not H_o. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom. The actual form of the test statistic is the same as before.

The results of the test were:

$$H_o:\lambda_1=\lambda_3 \text{ and } \lambda_2=\lambda_4 \text{ vs. not } H_o$$

LRTS = 134.304

P-value = 0.0000

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is rejected, and conclusion: there exists a significant difference between Upstream and DowNstream.

The third null hvoothesis tested is that there is no difference between Before and After data. This hypothesis is stated as DLDNB=DLDNA and DLUPB=DLUPA. Equivalently, $H_o:\lambda_1=\lambda_2$ and $\lambda_3=\lambda_4$ vs. not H,. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom.
The actual form of the test statistic is the same as before.

The results of the test were:

$$H_o:\lambda_1=\lambda_2 \text{ and } \lambda_3=\lambda_4 \text{ vs. not } H_o$$

LRTS = 117.339

P-value = 0.0000

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is rejected, and conclusion: Before data and After data are significantly different.

The fourth null hvoothesis tested is that the interaction between Before/After and DowNstream/UPstream is zero. This hypothesis is stated as DLDNB-DLDNA=DLUPB-DLUPA, or as DLDNB-DLDNA-DLUPB+DLUPA=O. Equivalently, this is expressed as $H_o:\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H_o. The form of the test was the same as before.

The results of the test were:

$H_o:\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H_o
Z-TEST = -8.27614
P-value = 0.0000

based on a standard normal (Z) distribution. Thus H_o is rejected, and conclusion: the DowNstream/UPstream and Before/After interaction is significant.

Analysis of the Wiid River Data

The Wind River CPUE data are summarized by the following array:

WRDNB	$n_1=18$	$mean_1=3.181$
WRDNA	$n_2=44$	$mean_2=5.210$
WRUPB	$n_3=5$	$mean_3=2.392$
WRUPA	$n_4=25$	$mean_4=5.085$

This array gives the individual sample sizes and sample means. The overall sample size and sample mean were n =92 and mean =4.626. We assume that we have sampled from four different Poisson populations with parameters $\lambda_1,\lambda_2,\lambda_3,\lambda_4$ respectively. Thus we assume that WRDNB data are Poisson&), WRDNA data are Poisson&), WRUPB data are Poisson@,), and WRUPA data are Poisson(λ_4). This notation allows us to state various hypotheses of interest in terms of the parameters λ_i.

The first null hvnothesis tested was that all four Poisson populations are the same, versus the alternative hvnothesis that thev are not all the same. Symbolically, we test $H_o:\lambda_1=\lambda_2=\lambda_3=\lambda_4$ vs. $H_a:\lambda_i$'s not all equal. The likelihood ratio test statistic is the same as before.

The results of the test were:

$H_o:\lambda_1=\lambda_2=\lambda_3=\lambda_4$ vs. $H_a:\lambda_i$'s not all equal
LRTS = 19.8975
P-value = 0.0002

based on a chi-square distribution with 3 degrees of freedom. Thus H_o is rejected, and conclusion: the four populations are not the same.

The second null hvoothesis tested is that there is no difference between Upstream and DowNstream sites. This hypothesis is stated as WRDNB=WRUPB and WRDNA=WRUPA. Equivalently, $H_o:\lambda_1=\lambda_3$ and $\lambda_2=\lambda_4$ vs. not H_o. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom. The actual form of the test statistic is the same as before.

The results of the test were:

H_o:$\lambda_1=\lambda_3$ and $\lambda_2=\lambda_4$ vs. not H_o
LRTS = 0.902954
P-value = 0.6367

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is not rejected, and conclusion: no significant difference between Upstream and DowNstream.

The third null hypothesis tested is that there is no difference between Before and After data. This hypothesis is stated as **WRDNB=WRDNA** and **WRUPB=WRUPA.** Equivalently, H_o:$\lambda_1=\lambda_2$ and $\lambda_3=\lambda_4$ vs. not H_o. The likelihood ratio test statistic is approximately chi-squared with 4-2=2 degrees of freedom.
The actual form of the test statistic is the same as before.

The results of the test were:

H_o:$\lambda_1=\lambda_2$ and $\lambda_3=\lambda_4$ vs. not H_o
LRTS = 19.9143
P-value = 0.0000

based on a chi-square distribution with 4-2=2 degrees of freedom. Thus H_o is rejected, and conclusion: Before data and After data are significantly different.

The fourth null hypothesis tested is that the interaction between Before/After and DowNstream/UPstream is zero. This hypothesis is stated as **WRDNB-WRDNA=WRUPB-**WRUPA, or as WRDNB-WRDNA-WRUPB+WRUPA=O. Equivalently, this is expressed as H_o:$\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H,. The form of the test was the same as before.

The results of the test were:

H_o:$\lambda_1-\lambda_2-\lambda_3+\lambda_4=0$ vs. not H_o
Z-TEST = 0.671794
P-value = 0.5018

based on a standard normal (Z) distribution. Thus H_o is not rejected, and conclusion: the DowNstream/UPstream and Before/After interaction is not significant.

SPRING CREEK STATISTICAL CPUE DATA SUMMARY

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
SCDNB	23	1.550	1.000	1.353	1.921	0.401
SCDNA	29	3.728	2.410	3.414	4.216	0.783
SCUPB	11	2.316	3.000	2.236	1.912	0.576
SCUPA	12	3.227	2.955	3.175	1.854	0.535
ALL	75	2.773	1.820	2.388	3.117	0.360

	MIN	MAX	Q1	Q3
SCDNB	0.000	7.230	0.000	2.680
SCDNA	0.000	15.930	0.455	5.925
SCUPB	0.000	5.360	0.000	3.660
SCUPA	0.820	6.150	1.388	5.155
ALL	0.000	15.930	0.000	4.000

DRANO LAKE STATISTICAL CPUE DATA SUMMARY

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
DLDNB	28	2.973	2.860	2.823	2.210	0.418
DLDNA	81	8.83	6.25	7.84	9.03	1.00
DLUPB	10	2.379	2.220	2.245	1.866	0.590
DLUPA	21	2.085	2.000	2.094	1.172	0.256
ALL	140	6.186	3.880	5.148	7.621	0.644

	MIN	MAX	Q1	Q3
DLDNB	0.000	9.820	1.385	4.345
DLDNA	0.00	47.86	2.37	12.24
DLUPB	0.000	5.830	0.728	4.000
DLUPA	0.000	4.000	1.275	3.115
ALL	0.000	47.860	1.653	8.000

WIND RIVER STATISTICAL CPUE DATA SUMMARY

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
WRDNB	18	3.181	1.920	2.828	3.470	0.818
WRDNA	44	5.210	4.600	5.050	3.594	0.542
WRUPB	5	2.392	2.110	2.392	1.180	0.528
WRUPA	25	5.085	4.210	4.816	4.053	0.811
ALL	92	4.626	3.905	4.352	3.695	0.385

	MIN	MAX	Q1	Q3
WRDNB	0.000	12.000	0.510	5.705
WRDNA	0.000	14.290	2.130	7.155
WRUPB	0.850	4.000	1.425	3.500
WRUPA	0.000	16.360	1.980	7.095
ALL	0.000	16.360	1.945	6.113

REPORT F

Investigation of Northern Squawfish Concentrations in Tributaries to the Mainstem Columbia, Snake and Clearwater Rivers

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1993 Annual Report

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ABSTRACT

We investigated five tributaries to the mainstem Columbia, Snake and Clearwater rivers for northern squawfish spawning concentrations previously reported by biologists and local anglers. A total of 1,541 northern squawfish were captured from May 11 to July 25 in the upstream migration trap at Threemile Dam on the Umatilla River. The most likely explanation for the large concentration is that these fish are part of a spawning migration, composed either of adfluvial and/or resident fish or part of a random spawning distribution of mainstem fish. Alternative explanations for the large migration include: (1) reascension of

resident fish washed downstream by high spring flows; (2) predatory response to increased prey abundance (smolt outmigration); or *(3)* escape from unsuitable mainstem conditions (i.e., increased saturated gas concentrations).

Sampling efforts in the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek were less successful at locating northern squawfish concentrations. Explanations include: (1) high spring flows may have limited our ability to capture migrating fish, (2) previously reported concentrations may not occur annually, or *(3)* previous removals may have reduced the number of northern squawfish available to migrate into tributaries.

INTRODUCTION

Large concentrations of northern squawfish (*Ptychocheilus oregonensis*) observed by both anglers and biologists at the mouths and in the lower reaches of tributaries to the Columbia, Snake and Clearwater rivers in spring months are probably spawning adults that have migrated upstream from the mainstem river. If fish concentrating in tributaries during certain times of the year can be confirmed as originating from the mainstem, then control efforts targeted on those concentrations may be an effective and efficient way to reduce mainstem predation by northern squawfish.

Life history information available from other water bodies, similar to Snake and Columbia river reservoirs, indicates that northern squawfish commonly migrate from lakes and reservoirs into free-flowing tributaries to spawn. Such migrations have been documented from Sixteenmile Lake, B.C. (Teraguchi 1962), and from Lake Coeur d'Alene, Idaho, (Reid 1971; Beamesderfer 1992; N. Homer, IDFG, pers. comm.). The construction of Post Falls Dam at the outlet of Lake Coeur d'Alene stabilized water levels in the lake and improved habitat for northern squawfish, which migrate up the St. Joe River and St. Maries River in April to spawn in June and July. The concentrations of northern squawfish in these two rivers are massive enough to cause considerable public dissatisfaction; control efforts by IDFG have focused on these spawning concentrations (N. Homer, IDFG, pers. comm.).

Elsewhere, northern squawfish from Cascade Reservoir (Payette River, tributary to Snake River), migrate up the North Fork Payette River and Gold Fork and Lake Fork creeks in May, where control efforts are targeted on these concentrations (Casey 1962; D. Anderson, IDFG, pers. comm.). In the Colorado River, Colorado squawfish (*Ptychocheilus lucius*), a closely related species to northern squawfish, migrate upstream to spawn (Tyus 1986; McAda and Kaeding 1991).

There is a great deal of anecdotal information available regarding concentrations of northern squawfish in tributaries to the Snake and Columbia rivers, although the purpose for these concentrations has never been documented. It is likely that the fish observed in these concentrations are manifesting a general life history pattern of migrating from reservoirs into free-flowing tributaries for spawning. Tributaries in which northern squawfish concentrations have been observed include the Umatilla River (a Columbia River tributary), the Palouse and Tucannon rivers (Snake River tributaries), and Potlatch River and Lapwai Creek (Clearwater River tributaries).

In the Umatilla River, hundreds of squawfish are incidentally captured from late April to mid-July every year in an upstream migration trap operated by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Oregon Department of Fish and Wildlife (ODFW) at Threemile Dam on the Umatilla River (B. Zimmerman, CTUIR, unpublished data).

In the Palouse River, two anglers fishing at the outlet of the pool below Palouse Falls in late May/early June 1988, caught northern squawfish on virtually every cast from a concentration where the fish could be seen rolling and jumping (P. Bentley, NMFS, pers. comm.; J. Dedloff, WDF, pers. comm.). In addition, Merwin traps fished in the Palouse Arm captured a total of 34,607 northern squawfish in four years (Bentley et al. 1976).

In the lower Tucannon River, massive seasonal concentrations of northern squawfish have occurred just below an irrigation diversion dam (known as Fletcher's Dam) approximately two to three miles upstream of Star-buck, Washington (M. Schuck and S. Martin, WDW, pers. comm.; G. Mendel, WDF, pers. comm.). Northern squawfish, probably in the thousands, formed a dense mass across the entire river (60 feet wide) along a 100-foot section during April and May (M. Schuck, WDW, pers. comm.).

In June 1991, two anglers fishing in a short section of the lower mile of Potlatch River caught approximately 200 northern squawfish in a total of about seven hours from a concentration that was estimated to number in the thousands (local resident, pers. comm.).

At the mouth of Lapwai Creek, large northern squawfish can be caught each year as they enter the creek and migrate upstream, particularly in years with good spring flows (local resident, pers. comm.). Northern squawfish in spawning coloration were observed moving up the creek as early as March in 1992, a year with low spring flow (R. Beaty, CRITFC, pers. comm.).

The objectives of this study were to:

1) Investigate and document the presence of northern squawfish concentrations at the mouths, or in the lower reaches, of tributaries to the mainstem Columbia, Snake and Clearwater rivers, specifically the Umatilla, Palouse, Tucannon and Potlatch rivers, and Lapwai Creek.

2) Collect information that might help determine the purpose for northern squawfish concentrations in the tributaries, (e.g., sex, sexual maturity, and diet).

3) Compile anecdotal information about northern squawfish concentrations in other tributaries to the Snake and Columbia rivers.

METHODS AND MATERIALS

Study Areas and Sampling Methods

The Umatilla River (Columbia River tributary), the Palouse and Tucannon rivers (Snake River tributaries), and Potlatch River and Lapwai Creek (Clearwater River tributaries) were sampled for northern squawfish concentrations in 1993.

The Umatilla River empties into the Columbia River at Umatilla, Oregon, approximately 4.5 km downstream from McNary Dam (Figure F-l). The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and Oregon Department of Fish and Wildlife (ODFW) collected northern squawfish from May through July from an upstream migration trap located at Threemile Dam (approximately 4.5 km upstream from the mouth) on the Umatilla River operated to capture adult salmon and steelhead. The trap, a holding tank at the upstream end of the dam's fish ladder, was open 24 hours per day and was emptied each morning by CTUIR and ODFW employees. Incidentally caught northern squawfish were removed, enumerated, examined for tags or marks, and biological data was **collected (see Data Collection and Summary).**

The Palouse, Tucannon, and Potlatch rivers and Lapwai Creek were sampled biweekly. Although sampling was originally scheduled to begin in April, high spring run-off and excessive turbidity in all of the tributaries limited access and delayed sampling until late May. However, water temperature was measured periodically in each of the tributaries during April and May.

The Palouse River enters Lower Monumental Pool from the north at Lyons Ferry, Washington (Figure F-2). We intended to use backpack electrofishers to sample the 1 l-km reach between the mouth of the Palouse River and Palouse Falls, an impassable barrier to upstream-migrating fish. However, extremely high spring flows dictated that we use a boat electrofisher and restricted our sampling to June.

The Tucannon River enters Lower Monumental Pool from the south at Lyons Ferry, Washington (Figure F-2). From late May through July, we sampled from the mouth of the Tucannon River to Fletcher's Dam, an irrigation diversion dam approximately 8 km up the river, which is believed to be a migration barrier to northern squawfish (M. Schuck, WDW, pers. comm.). A backpack electrofisher was primarily used to collect northern squawfish, although hook-and-line was used where shocking was difficult or ineffective. Due to the potential impacts on chinook salmon listed under the Endangered Species Act (ESA) in the Tucannon River, extreme caution was used during sampling so as not to incidentally capture any salmonids. We used inwater observations and strict criteria to determine how to sample a site each sampling day:

1. Adult salmonid(s) present: no sampling.

2. Adult salmonids absent, juvenile salmonid(s) present: sample northern squawfish with hook-and-line.

3. Adult salmonids absent, juvenile salmonids absent: sample northern squawfish with backpack electrofisher and seines, if possible.

Potlatch River, the largest tributary of the lower Clearwater River system, enters the Clearwater River approximately 19 km upstream from its confluence with the Snake River at Lewiston, Idaho (Figure F-3). During field surveys, we determined that there were no migration barriers to northern squawfish in the lower 16 km of Potlatch River, however, due to time constraints and angler reports of northern squawfish concentration locations, we focused all sampling efforts in the lower 1.5 km of the river. Hook-and-line angling was used exclusively for sampling from May through mid-June. From mid-June through July, when flows subsided, backpack electrofishing was used.

Lapwai Creek joins the Clear-water River approximately 16 km upstream from its confluence with the Snake River (Figure F-3). We were unable to rind any obvious migration barriers to northern squawfish in the lower 16 km of Lapwai Creek, and based on angler reports, sampled only the lower 8 km of the creek. Primary method of capture was a backpack electrofisher; hook-and-line was used in areas where electrofishing was difficult or impossible. Sampling was conducted from late May through July.

In addition to the above mentioned sampling locations, other sites were investigated by interviewing biologists and anglers to gather anecdotal information about other major tributaries to the Columbia and Snake rivers in which northern squawfish may concentrate. Tributaries investigated included Hood River, Deschutes River, John Day River, Willow Creek Arm, Klickitat River, Grande Ronde River and Imnaha River. Information provided during the interviews is summarized in this report.

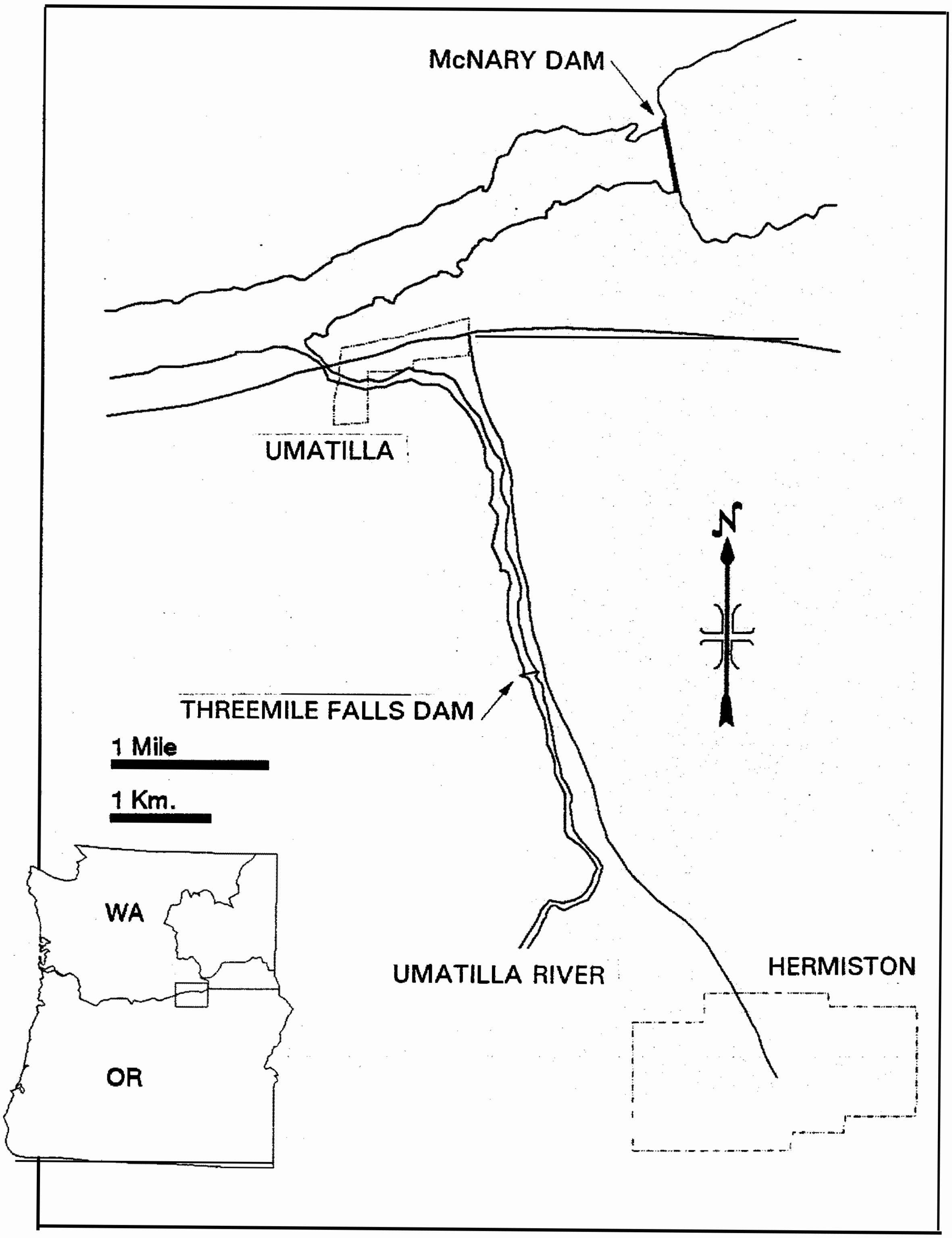

Figure F-l. Sampling area located at Threemile Falls Dam on the Umatilla River.

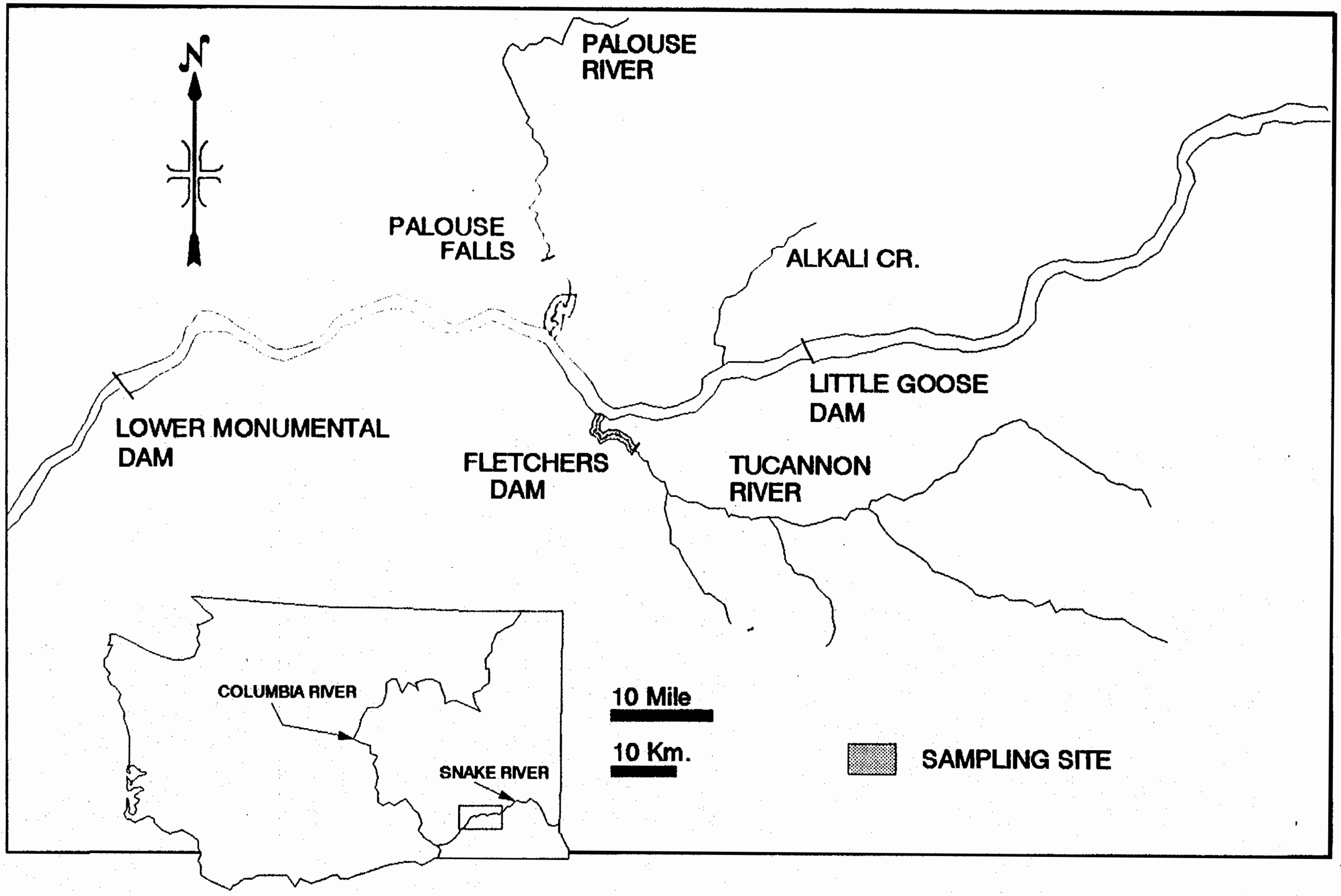

Figure F-2. Sampling locations in the Palouse River and the Tucannon River.

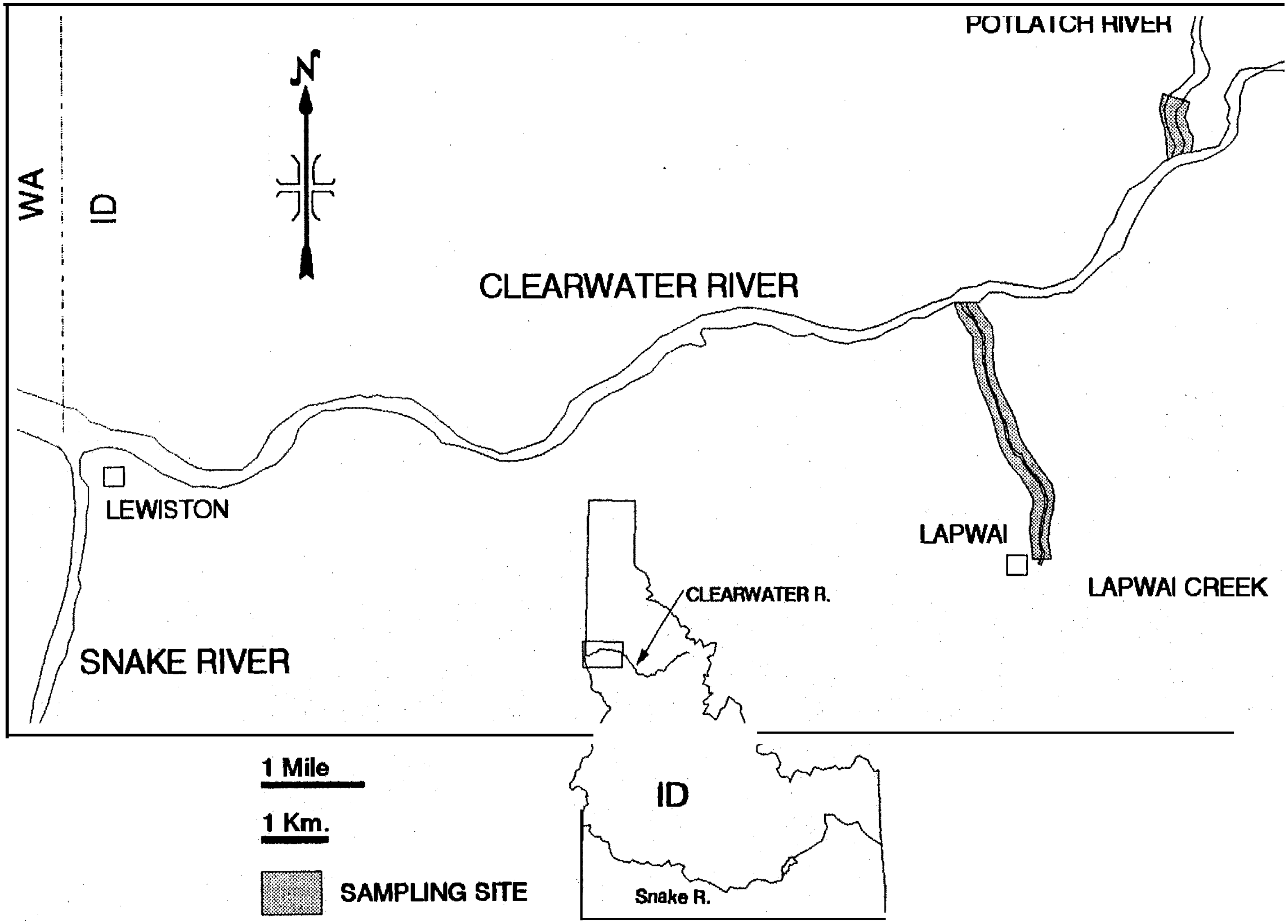

Figure F-3. Sampling locations on the Potlatch River and Lapwai Creek.

Data Collection and Summary

Northern squawfish captured and removed from the Threemile Dam migration trap were enumerated and checked for tags or marks daily by CTUIR and ODFW technicians. In 1993, carcasses were delivered to Washington Department of Wildlife (WDW) personnel at the check station in Umatilla. In previous years, northern squawfish caught in the trap were sacrificed and returned to the river. Arrival of northern squawfish at the Threemile Dam trap was compared to daily water temperature ("Celsius) readings in the Umatilla River at Threemile Dam; Umatilla River discharge (cfs) at Umatilla, Oregon; mainstem (Columbia River) water temperature (°C) at McNary Dam; and dissolved gas concentrations (percent saturation) below McNary Dam (B. Zimmerman, CTUIR, unpublished data; U.S. Army Corps of Engineers, unpublished data).

Northern squawfish captured in the Palouse, Tucannon and Potlatch rivers and Lapwai Creek were enumerated and examined for tags and fin clips. Total numbers of northern squawfish captured were reported (regardless of size), as was the number of predator- sized fish (≥275 mm). Incidentally caught species were also enumerated and then released unharmed. Northern squawfish not sacrificed for biological samples were measured, weighed, and marked with site-specific fin punches (fins were not excised), so that we could later identify recaptured individuals. Total northern squawfish catch reported here does not include recaptured individuals.

Biological information was collected weekly from 20 randomly selected northern squawfish captured in the Umatilla River and from all northern squawfish (up to a maximum of 10 per week) in the other four tributaries (Palouse, Tucannon, Potlatch and Lapwai). We recorded fork length (nearest mm), weight (nearest 10 g), and presence of external spawning characteristics (e.g., dark lateral bands and head tubercles). Gonads were examined to determine sex, and stage of maturity (undeveloped, developed, ripe or spent). Information collected on length, weight, sex and stage of maturity was summarized weekly and monthly for the Umatilla River. Due to small sample sizes, this information was summarized monthly for all other tributaries.

Gut samples were collected following the methods of Petersen et al. (1990), placed in plastic Whirlpak™ bags and preserved by freezing. Methods for analysis of gut contents were slightly modified from Petersen et al. (1990) and are detailed in Report E (Collis et al. 1995). Fish found in northern squawfish gut samples were identified to family. Percent composition (by weight) of prey items found in the gut were summarized by month for each tributary.

RESULTS AND DISCUSSION

A total of 1,686 northern squawfish were captured during our tributary sampling, most (91%) of which were from the Umatilla River (Table F-l). We observed and captured very few fish in the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek.

Umatilla River

A total of 1,541 northern squawfish were captured in the migration trap at Threemile Dam during 63 days of trap operation (Table F-l). Reportedly, none of the fish captured in the trap during this study bore tags or marks. The first northern squawfish arrived at the trap May 11, and the last fish was captured July 25. The majority (58%) were caught during a one-week period, following an increase in the average weekly water temperature from 15°C to 18°C (Figure F-4) and a decrease in the average weekly flow from 1,705 cfs to 419 cfs (Figure F-5). See Appendix Table F-l. 1 for a weekly catch summary.

We collected biological information and samples from 118 (8 % of the total catch) northern squawfish. Our sample was composed of 41% females and 59% males (Table F-2). Of the fish we sampled, 89% were predator size ($\geq$275 mm). See Appendix Table F-l.2 for a weekly summary of biological data.

The sizable migration of northern squawfish up the Umatilla River appears to be the first documented in a tributary to the Columbia River. Although large numbers of northern squawfish have been captured in the Threemile Dam trap for at least the past three years (B. Zimmerman, CTUIR, unpublished data), there is no conclusive evidence as to the cause(s) for these migrations. Determining the origin and cues responsible for the large migrations of northern squawfish in the Umatilla River could play a significant role in describing life history patterns of northern squawfish in the Columbia River system, and therefore be important in developing management activities aimed at reducing predation by northern squawfish on juvenile salmonids.

Table F-1. Sampling effort and catch by tributary.

Location	Gear type	Effort	Northern Squawfish[1]	Salmonids: Adult	Salmonids: Juvenile	Game Fish[2]	Other
Umatilla River	UT	63.0	1541	n/a[3]	n/a[3]	n/a[3]	n/a[3]
Palouse River	HL	0.0	0	0	0	0	0
	EF	4.3	1	0	0	270	260
Tucannon River	HL	2.6	4	0	0	0	64
	EF	1.3	64	0	1	15	466
Potlatch River	HL	15.2	7	0	0	11	2
	EF	0.9	1	0	0	13	50
Lapwai Creek	HL	8.8	1	0	0	2	1
	EF	1.5	67	0	0	12	136
TOTALS		n/a	1686	0	1	323	979
FISH CONDITION							
Good				0	1	323	979
Fair				0	0	0	0
Dead				0	0	0	0

GEAR TYPE - DEFINITION OF EFFORT

UT - Upstream migration trap - Days (trap operated approximately 24 $hr \cdot d^{-1}$)

HL - Hook and line - Angler h

EF - Electrofishing - Shocking time (h)

[1] Numbers reported are not all predator size ($\geq$275 mm) northern squawfish. See detailed size composition data in Appendix Tables F-1.3 through F-1.5.
[2] See Table F-4 for game fish composition by species.
[3] Northern squawfish were captured incidentally in the trap designed to capture adult salmonids, therefore reporting incidental catch of other species is not applicable.

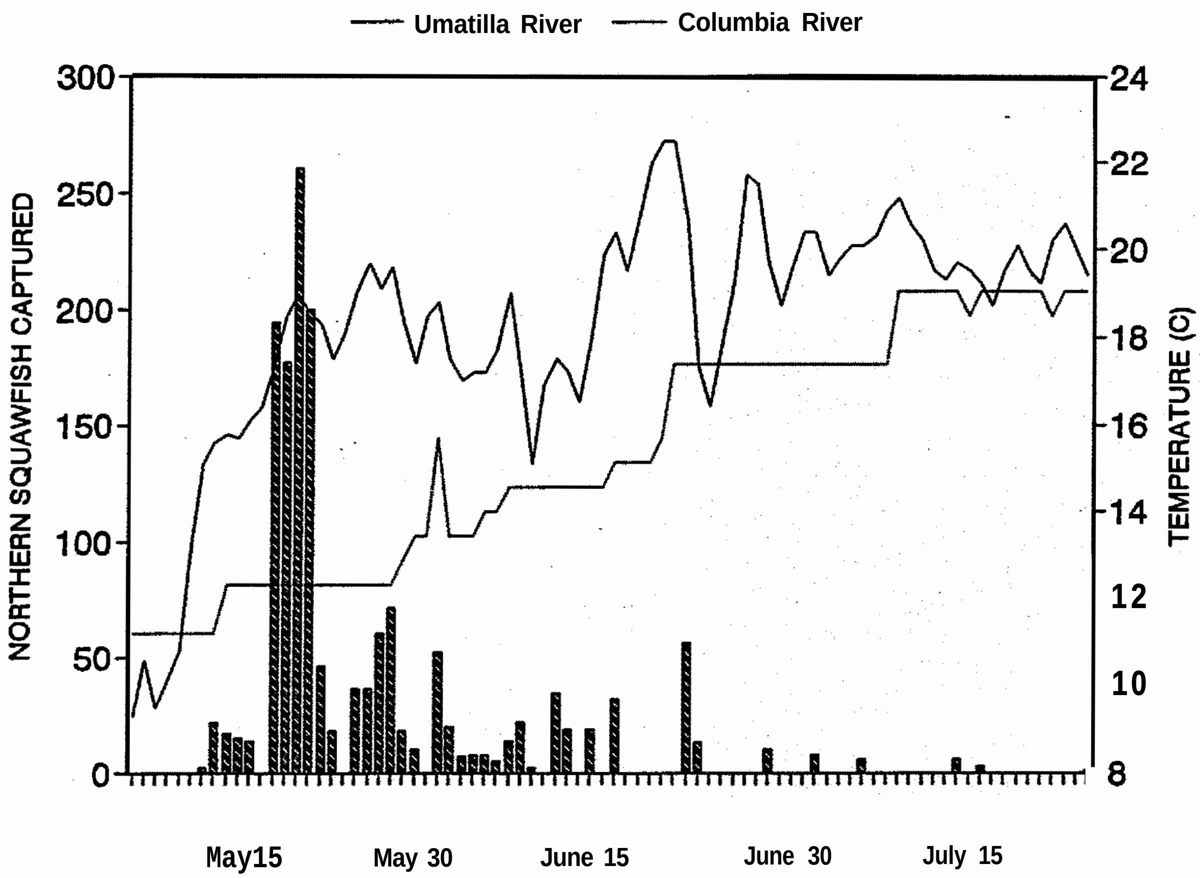

Figure F-4. Daily counts of northern squawfish captured in the Umatilla River and water temperatures (°C) in the Umatilla River at Threemile Dam (B. Zimmerman, CTUIR, unpublished data) and Columbia River below McNary Dam (USACE, unpublished data).

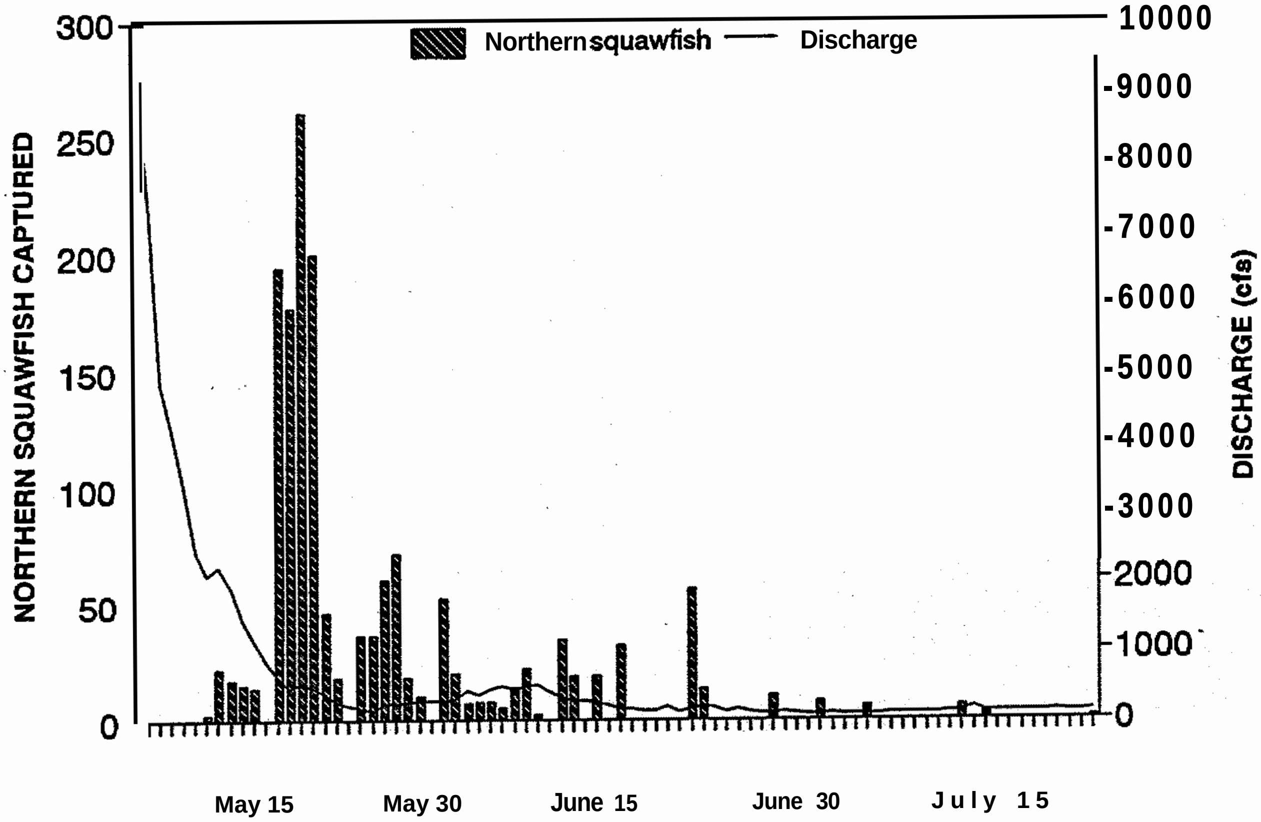

Figure F-5. Daily counts of northern squawfish captured in the Umatilla River and Umatilla River discharge (cfs) at Umatilla, Oregon (B. Zimmerman, CTUIR, unpublished data).

Table F-2. Length, weight and sexual maturity data from northern squawfish captured in the **Umatilla River.**

	May		June	
	Females	Males	Females	Males
Sample size	27	33	21	37
Length: Mean	361	310	330	300
Range	3 14-400	240-394	227-477	238-390
Weight: Mean	553	349	501	354
Range	370-750	190-500	150-760	150-640
Stage of maturity (%)				
Undeveloped			29	14
Developing	100	100	48	57
Ripe			24	24
Spent				5

We believe there are several alternative explanations for the large numbers of northern squawfish in the Umatilla River migration trap: (1) reascension of resident fish washed downstream by high spring flows; (2) predatory response to increased prey abundance (outmigrating smolts); (3) escape from unsuitable mainstem conditions, (i.e., increased saturated gas concentrations); or (4) spawning concentrations, either of resident and/or adfluvial populations, or part of a random spawning distribution of mainstem fish.

Adult northern squawfish may be washed out of the Umatilla River by high spring flows and then attempt to reascend over Threemile Dam as flows decrease. This alternative is supported by the flow-arrival timing relationship (Figure F-5) and the reported absence of tags and marks, which suggests these fish did not spend much time, if any, in the mainstem. We are skeptical, however, that this scenario would provide the magnitude of run witnessed in 1993, and it does not explain the movement of fish witnessed in 1992 during an extremely low flow year.

Although the timing is similar, results of gut content analysis imply that northern squawfish movement into the Umatilla River is not to feed on outmigrating smolts. Smolt migration in the Umatilla River is directly related to flow (G. Rowan, CTUIR, pers. comm.). During high flow years like 1993, salmonid smolts typically outmigrate from late April through early June, with a peak in early May (G. Rowan, CTUIR, pers. comm.) All of the 118 gut samples we collected were empty, with the exception of one that contained diagnostic bones only of one juvenile salmonid (Table F-3).

Another alternative is that northern squawfish captured in the Umatilla River trap may simply be seeking refuge from less favorable environmental conditions in the mainstem. Due to the proximity of McNary Dam, northern squawfish in the mainstem adjacent to the mouth of the Umatilla River are subjected to alterations in the environment caused by dam operation. Appearance of northern squawfish in the Umatilla River appears to be related to dissolved gas concentrations below McNary Dam (Figure F-6). Bentley et al. (1976) and Sims et al. (1976) suggested that large numbers of northern squawfish concentrated in the Palouse Arm (a tributary several miles downstream from Little Goose Dam) to escape the high levels of dissolved gasses in the Snake River. Movement may also be related to selectivity of water temperature. Temperatures in the Umatilla River were warmer earlier than those in the mainstem in 1993 (Figure F-4).

Despite the apparent relationship between northern squawfish movement up the Umatilla River and unfavorable mainstem conditions, this alternative is questionable because we would not expect fish seeking refuge from mainstem conditions to expend the energy to migrate three miles up the Umatilla River. In addition, proving a cause and effect relationship in this situation would be difficult due to the many environmental variables affecting fish behavior and movement.

Table F-3. Gut content analysis of northern squawfish captured in **the Umatilla River.**

	May	June
Sample size	60	58
Guts containing prey items	0[1]	0
Weight composition (%)		
Fish	0	0
Crustacea	0	0
Mollusca	0	0
Insecta	0	0
Plants	0	0
Other	0	0
Salmonids	1[1]	0
Cyprinids	0	0

[1] Diagnostic bones of one juvenile salmonid were found, although no prey had been noted when gut contents were originally examined.

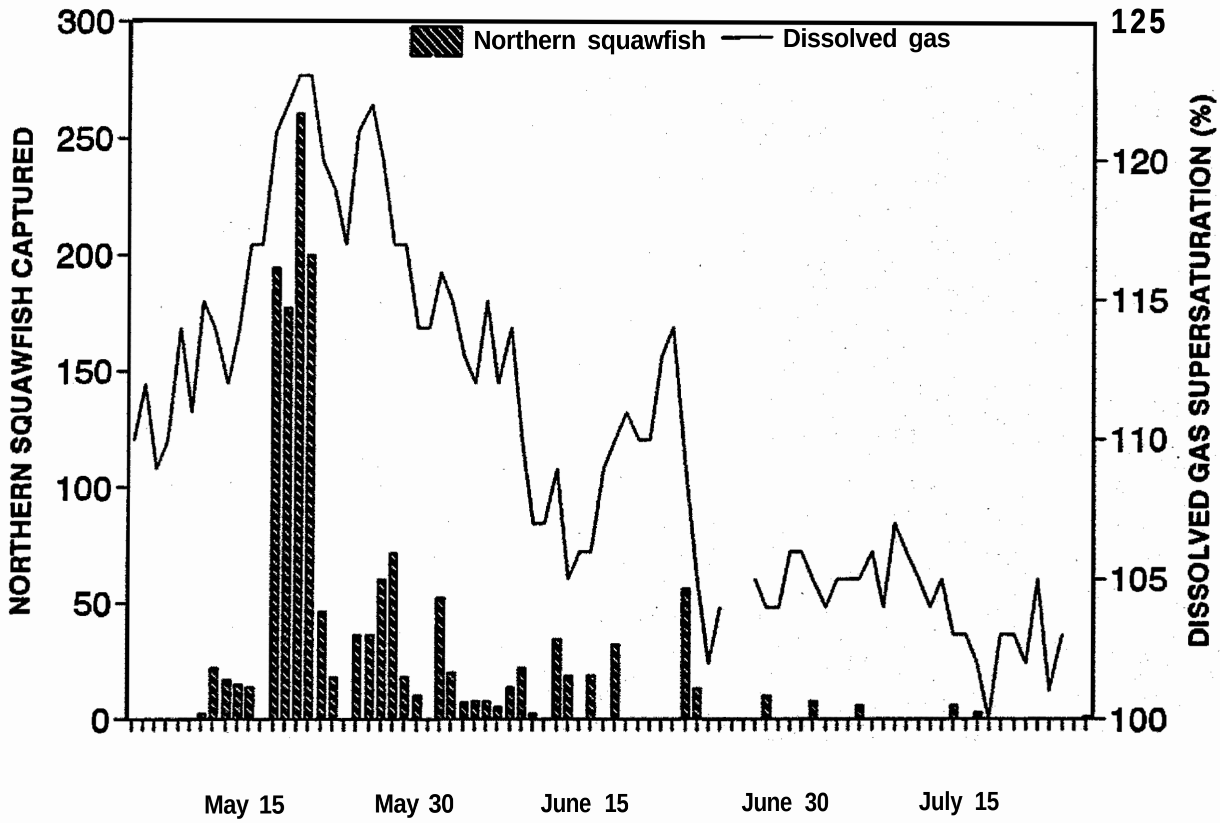

Figure F-6. Daily counts of northern squawfish captured in the Umatilla River and dissolved gas supersaturation (%) recorded below McNary Dam (USACE, unpublished data).

The most likely explanation, based on our data and other evidence,. is that these fish are part of a spawning migration. Arrival of northern squawfish in the Umatilla River trap followed a rapid increase in water temperature (Figure F-4) and decrease in flow (Figure F-5), which have been identified as important factors regulating the seasonal timing of spawning by northern squawfish in other tributaries (Keating 1958, Hill 1962, Reid 1971, Beamesderfer 1992). According to Jeppson and Platts (1959), northern squawfish congregate on the spawning ground when the water temperature nears 60" Fahrenheit (15°C). The first day northern squawfish were captured in the Umatilla River trap followed an increase in water temperature from 13°C on May 10 to 15°C on May 11. Similar activity was noted by trap personnel in 1992, when the first day large numbers were captured followed an increase in water temperature to 59°F (15°C; B. Zimmerman, CTUIR, unpublished data).

To determine if the northern squawfish captured in the Umatilla River were in spawning condition, we examined gonad maturity weekly. None of the fish (either sex) we examined in May were ripe. However, in June 24% of both males and females were ripe and 5 % of the males were already spent (Table F-2). These results are very similar to data collected from northern squawfish captured at McNary Dam in 1991 (a similar water year to 1993), which indicated that spawning occurred in June and July (Ward et al. 1991). The arrival of still-developing fish at the Umatilla River trap in May is similar to behavior displayed by northern squawfish in the St. Joe and St. Maries rivers, Idaho, where concentrations of fish arrive and stage on the spawning grounds several weeks before actual spawning begins (N. Homer, IDFG, pers. comm.).

Despite the strong similarities of northern squawfish migrations in the Umatilla River to movement of known spawning migrations in other river systems, we were unable to prove that the Umatilla River migration was for spawning. Because all northern squawfish were removed from the system at Threemile Dam, we were unable to observe spawning activity in the tributary.

If spawning is the driving force behind the northern squawfish migrations in the Umatilla River, the origin of these fish becomes an important question. There appears to be two major alternatives to their origin, both with significant implications to the effectiveness of the predator control program.

The northern squawfish we captured may be offspring of resident populations upstream of the migration trap. As juveniles, these fish may have been flushed, or migrated of their own volition, to the mainstem Columbia during high spring flows. The major implication of this scenario is that tributary populations of northern squawfish, either resident or adfluvial, may be a major source of mainstem predators. If tributary spawning accounts for a substantial portion of mainstem predators, then removal of adults entering tributaries could be an effective control measure for mainstem predation. In the Umatilla River, however, this alternative is not supported by the continuous high catches of northern squawfish at Threemile Dam. We would expect the magnitude of catches to decline after several years of 100% removal, because the repeat spawners would be eliminated from the population.

The second alternative is that the trapped northern squawfish originated from mainstem populations and that the large movement up the Umatilla River is a result of random spawning distribution. The lack of tagged or marked fish suggests the fish captured in the Umatilla River trap have not spent a great deal of time in the mainstem, however, we are not confident that each fish was examined carefully. Sexual maturity data collected at McNary Dam (Ward et al. 1991) supports this alternative, as it indicates that mainstem northern squawfish are in spawning condition at the same time migrations are occurring up the Umatilla River. Implications of this scenario are: (1) tributaries may be a major source of mainstem predators and therefore removal at the mouth of Umatilla River, and possibly any other tributary, is equivalent to the removal from the mainstem; and (2) northern squawfish populations in the Columbia River system would not be discrete, therefore making extirpation unlikely.

Despite the enormous research efforts being devoted to northern squawfish in the Columbia River Basin, very little is known about spawning habits or the complete life history of mainstem populations. Radio telemetry studies have yet to document "spawning grounds" or localized concentrations of northern squawfish during spawning season (Rip Shively, USFWS, pers. comm.). However, the results of radio telemetry studies to date may be limited by sample size and/or an insufficient number of tagged males. Female northern squawfish are probably chosen for radio tag implantation more frequently than males due to their larger size. Male northern squawfish arrive at the spawning area early and remain for some time, while the ripe females are on the site only when they spawn (Wydoski and Whitney 1979). This coincides with observations by Jeppson and Platts (1959) in Merwin Reservoir and Beamesderfer (1992) in the St. Joe River, where males outnumbered females on the spawning ground by 50-200: 1. Based on this information, radio tracking males may be a more effective method to locate spawning areas.

Conclusions as to origin of northern squawfish trapped in the Umatilla River and purpose for their migration can not be made based on the limited amount of data we collected. We recommend continued monitoring of fish captured in the migration trap at Threemile Dam for the presence of tags or marks, sex and stage of maturity data and that surveys be conducted below Threemile Dam to search for evidence of spawning concentrations. We also recommend collecting information on movement and behavior of fish migrating in the Umatilla River by radio telemetry. Northern squawfish should be captured and tagged at the mouth of the Umatilla River to determine what cues might effect upstream migration. Fish captured in the Threemile Dam trap should also be tagged and released above the dam to determine movement and behavior.

Snake and Clearwater River Tributaries

We captured a total of 145 northern squawfish from the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek combined (Table F-l). Due to high spring runoff and turbidity, sampling in these four tributaries was often difficult, if not impossible. Backpack electrofishing was the most effective method of capture, accounting for 92% of our northern squawfish catch.

We captured one northern squawfish in the Palouse River during 4.3 h of boat electrofishing (Table F-l). Over 500 game and non-game fish were incidentally captured, composed primarily of black crappie, pumpkinseed and suckers (Table F-4).

In the Tucannon River we captured 68 northern squawfish (Table F-l). The majority of these were captured immediately downstream from Fletcher's Dam (Figure F-2). At this same location we also captured large numbers of chiselmouth and suckers (Table F-4) from what appeared to be spawning concentrations.

Sampling in Potlatch River yielded eight northern squawfish, of which seven were captured by hook-and-line at the mouth of the river (Table F-l). We captured 68 northern squawfish in Lapwai Creek (Table F-l), the majority of which found in deep pools within 1.5 km from the mouth of the creek.

We captured one salmonid during our sampling, a juvenile rainbow trout (or steelhead) with an adipose fin in the Tucannon River (Table F-4). It was released in good condition.

Gut content analysis indicated that the fish we sampled were not in the tributaries to feed on juvenile salmonids. Ninety-seven percent of the gut samples from the Tucannon River were empty (Table F-5). Northern squawfish in the Potlatch River were feeding mainly on insects and crayfish (Table F-6) and in Lapwai Creek were feeding almost exclusively on crayfish (Table F-7). Biological information collected on length, weight, and sexual maturity can be found in Appendix Tables F-1.6-8.

There are two hypotheses that may explain our unsuccessful efforts to document northern squawfish concentrations in the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek: (1) concentrations were present in the tributaries, but we were not able to capture them; or (2) concentrations were not present in the tributaries in 1993.

Environmental conditions in the tributaries in 1993 were very different from 1991 and 1992. During spring runoff (late May-early June) it was difficult and sometimes impossible to access the tributaries. In addition, our sampling equipment was seriously limited in its effectiveness during the high flows. The majority (58%) of northern squawfish collected in the Umatilla River were captured in one week, during which time the average flow was 419 cfs. If this scenario was similar in the other four tributaries, concentrations may not have been intercepted due to the biweekly sampling schedule and the ineffectiveness of our sampling gear.

Table F-4. Species composition of game fish and non-game fish incidentally captured during tributary sampling. All fish were released unharmed and in good condition.

	Palouse River	Tucannon River	Potlatch River	Lapwai Creek	Total
Rainbow trout (steelhead) ***Onchorynchus mykiss***	0	1	0	0	1
Smallmouth bass ***Micropterus dolomieui***	49	14	24	14	101
Catfish ***Ictaluris*** spp.	16	1	0	0	17
Black crappie ***Pomoxis nigromaculatus***	154	0	0	0	154
Pumpkinseed ***Lepomis gibbosus***	150	0	0	0	150
Yellow perch ***Perca flavescens***	51	0	0	0	51
Chiselmouth ***Acrocheilus alutaceus***	0	366	23	99	488
Redside shiner ***Richardsonius balteatus***	0	0	10	0	10
Peamouth ***Mylocheilus caurinus***	1	0	0	0	1
Carp ***Cyprinus carpio***	44	0	0	0	44
Suckers ***Catostomus*** spp.	65	164	19	38	286

Table F-5. Gut content analysis of northern squawfish captured in the **Tucannon River.**

	June	July
Sample size	28	3
Guts containing prey items	0	1
Weight composition. (%)		
Fish	0	0
crllstacea	0	0
Mollusca	0	0
Insecta	0	0
Plants	0	100
Other	0	0
Salmonids	0[1]	0
Cyprinids	0	0

[1] Remnants of salmonid scales were found in 3 gut samples--no diagnostic bones were evident.

Table F-6. Gut content analysis of northern squawfish captured in **the Potlatch River.**

	June	July
Sample size	4	4
Guts containing prey items	4	4
Weight composition (%)		
Fish	2.8	0
Crustacea	44.1	0
Mollusca	0	0
Insecta	23.4	100
Plants	29.7	0
Other	0	0
Salmonids	0	0
Cyprinids	1[1]	0

[1] Northern squawfish fry.

Table F-7. Gut content analysis of northern squawfish captured in **Lapwai Creek.**

	June	July
Sample size	10	25
Guts containing prey items	7	13
Weight composition (%)		
Fish	5.9	1.8
Crustacea	94.1	98.2
Mollusca	0	0
Insecta	0	0
Plants	0	0
Other	0	0
Salmonids	0	0
Cyprinids	1[1]	2[1]

[1] Northern squawfish fry.

It is also possible that northern squawfish were not present in the tributaries. Tributary concentrations witnessed by biologists and local residents in the past few years may not occur annually.

Another explanation is that the local concentrations of northern squawfish previously reported in the tributaries sampled have been heavily exploited by local anglers participating in the sport-reward program during the past three years. During our investigation, many of the locals we talked to were very knowledgeable about northern squawfish "hot spots" in the tributaries and which lures or baits were the most effective. Mainstem removals as a result of the sport-reward fishery and the dam-angling fishery may also be responsible for the few numbers of fish we encountered. Approximately 100,000 northern squawfish ($\geq$ 275 mm) reportedly have been removed from the Snake River reservoirs during the past three years, 80,032 by the sport-reward program (D. Klaybor, WDW, pers. comm.) and 19,968 by the dam-angling fishery (B. Parker, CRITIC, pers. comm.).

Although we were unable to document northern squawfish concentrations in the Palouse, Tucannon and Potlatch rivers, and Lapwai Creek this year, we do not believe efforts expended in this direction are futile. Until spawning '*grounds" and behavior are documented in the Columbia and Snake rivers, we believe monitoring mainstem tributaries for northern squawfish concentrations are worthwhile and may provide important information on the life history of northern squawfish allowing for more effective predator control efforts.

Information Survey

Our survey of local anglers and biologists indicated that similar migrations or concentrations may occur in other tributaries to the Columbia and Snake rivers. Large numbers of northern squawfish have been observed at, or near, the mouth of the Klickitat River, the Deschutes River, the John Day River and the Grande Ronde River (Table F-8).

Table F-8. Information survey summary of observations of northern squawfish concentrations in tributaries to the Columbia and Snake rivers. Northern squawfish is abbreviated NSF.

Location	Observation	Reference
	COLUMBIA RIVER	
Klickitat River	• Anglers report catching NSF from mouth up to Fisher Hill Bridge (approximately 3.2 km from mouth). • Tribal fisherman has caught numerous NSF below and in falls at Fisher Hill Bridge. • ODFW evaluation crew experienced an average gillnet catch of 46.5 NSF per net hour at the mouth in 1993.	John Weinhemer, WDW, pers. comm.; Roy Sampson, YIN, pers. comm.; ODFW, unpub. data
Hood River	No NSF concentrations have been documented in lower sections of river or at Powerdale Dam fish trap (approximately 8 km from mouth).	Jim Newton, ODFW, pers. comm.
Deschutes River	In 1992, anglers reported catching 50-60 NSF in a short period of time at the mouth.	Jim Newton, ODFW, pers. comm.
John Day River	• In 1956, the highest catch rate of NSF of 18 Columbia River tributaries sampled was at the confluence. • No recent reports of NSF concentrations, however, few investigations in the lower section of river.	USFWS, 1957; Jim Newton and Jim Phelps, ODFW, pers. comm.
Willow Creek Arm	No available information on non-game species.	John Germand, ODFW, pers. comm
	SNAKE RIVER	
Grande Ronde River	• Large numbers of NSF captured at mouth during electrofishing surveys. • Local anglers have caught NSF at the mouth and as far upstream as Lookingglass Hatchery.	Tom Poe, USFWS, pers. comm.; local resident, pers. comm.
Imnaha River	NSF concentrations observed near mouth during late-spring and early-summer months.	Local resident, pers. comm.

RECOMMENDATIONS

1. Continue monitoring and sampling efforts at the Threemile Dam trap on the Umatilla River.

2. Survey the Umatilla River below the Threemile Dam trap looking for evidence of spawning concentrations.

3. Radio tag northern squawfish captured in Threemile Dam trap and release upstream to determine purpose for migration, and possibly origin.

4. Capture and tag northern squawfish at the mouth of the Umatilla River to evaluate migration up the Umatilla River.

5. Monitor tributaries and holes of known historical northern squawfish concentrations, (e.g. Fletcher's Dam on the Tucannon River) but do not take biological samples.

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APPENDIX F-1

Tabular Data

Appendix Table F-1.1. Weekly summary of number of northern squawfish captured in migration trap at Threemile Dam (Umatilla River), temperature (°C) at Threemile Dam and flow (cfs) at Umatilla (B. Zimmerman, CTUIR, unpublished data).

Dates	Statistical Week	Squawfish captured	Mean temperature	Mean flow
5/3-5/9	19	0	9.9	5027
5/10-5/16	20	70	15.4	1705
5/17-5/23	21	895	18.2	419
5/24-5/30	22	231	18.8	229
5/31-6/6	23	114	17.8	385
6/7-6/13	24	93	16.9	357
6/14-6/20	25	32	21.1	162
6/21-6/27	26	69	19.2	145
6/28-7/4	27	18	19.7	88
7/5-7/11	28	6	20.5	84
7/12-7/18	29	9	19.3	117
7/19-7/25	30	1	19.9	118
Total		**1541**		

Appendix Table F-1.2. Length, weight and sexual maturity data from northern squawfish captured in the Umatilla River.

Statistical week	20	21	22	23	24	25	26
				Females			
Sample size	13	9	-	5	7	3	11
Mean length (mm)	373	351	-	346	340	356	317
Range (mm)	335-400	314-388	-	340-353	227-477	339-380	230-397
Mean weight (g)	560	549	-	544	529	600	457
Range (g)	400-750	370-740	-	490-620	310-750	560-670	150-760
Stage of maturity (%)							
Undeveloped					29	33	27
Developing	100	100		100	71	33	36
Ripe						33	36
Spent							
				Males			
Sample size	7	11	-	15	11	16	9
Mean length (mm)	339	295	-	307	305	298	301
Range (mm)	290-375	266-338	-	240-394	248-334	250-390	238-376
Mean weight (g)	426	296	-	351	385	338	342
Range (g)	300-500	200-500	-	190-440	180-550	210-520	120-640
Stage of maturity (%)							
Undeveloped					9	25	
Developing	100	100		100	36	75	56
Ripe					55		22
Spent							22

Appendix Table F-1.3. Results of sampling efforts in the **Tucannon River**, May-June 1993.

Date (Statistical week)		Effort (hours)		Temperature (°C)	Squawfish		Salmonids	Game fish	Other
		Hook and line	Electro-fishing		<275 mm	≥275 mm			
5/24-5/30	(22)	0	0	-	-	-	-	-	-
5/31-6/6	(23)	0.8	0	13	5	1	0	1	5
6/7-6/13	(24)	0.5	0.3	14	14	18	1[1]	4	235
6/14-6/20	(25)	1.3	0.5	14	6	13	0	5	95
6/21-6/27	(26)	0	0.2	[illegible]	3	7	0	4	154
6/28-7/4	(27)	0	0.	[illegible]	5	0	0	5	36
7/5-7/11	(28)	0	0	-	-	-	-	-	-
7/12-7/18	(29)	0	0.2	20	0	1	0	1	5
Total		2.6	1.3	NA	28	40	1	15[2]	530[2]

[1] 6/10/93; one juvenile salmonid (rainbow trout or steelhead) captured; had adipose fin; swam away immediately upon release.
[2] All game and non-game fish were released in good condition. See **Table F-4** in text for species composition.

Appendix Table F-1.4. Results of sampling efforts in the **Potlatch River**, May-June, 1993.

Date (Statistical week)		Effort (hours)		Temperature (°C)	Squawfish		Salmonids	Game fish	Other
		Hook and line	Electro-fishing		<275 mm	≥275 mm			
5/24-5/30	(22)	1.5	0	18	0	0	0	0	0
5/31-6/6	(23)	2.0	0	16	0	1	0	0	0
6/7-6/13	(24)	0.8	0	16	0	0	0	0	0
6/14-6/20	(25)	1.0	0.8	18	1	0	0	10	48
6/21-6/27	(26)	2.5	0	17	0	1	0	5	0
6/28-7/4	(27)	4.5	0.1	9	0	2	0	9	4
7/5-7/11	(28)	1.4	0	21	0	3	0	0	0
7/12-7/18	(29)	1.5	0	-	-	1	-	-	-
Total		15.2	0.9	NA	1	8	0	24[1]	52[1]

[1] All incidentally captured game and non-game fish were released in good condition. See **Table F-4** in text for species composition.

Appendix Table F-1.5. Results of sampling efforts in **Lapwai Creek**, May-June, 1993.

Date (Statistical week)		Effort (hours)		Temperature (°C)	Squawfish		Salmonids	Game fish	Other
		Hook and line	Electro-fishing		<275 mm	≥275 mm			
5/24-5/30	(22)	0.5	0	16	0	0	0	0	0
5/31-6/6	(23)	3.0	0	17	0	1	0	0	0
6/7-6/13	(24)	1.3	0.4	15	6	10	0	0	0
6/14-6/20	(25)	1.0	0	16	0	0	0	2	1
6/21-6/27	(26)	1.5	0.5	12	11	4	0	6	27
6/28-7/4	(27)	1.5	0.3	18	22	14	0	3	12
7/5-7/11	(28)	0	0	-	-	-	-	-	-
7/12-7/18	(29)	0	0.3	20	0	0	0	3	8
Total		8.8	1.5	NA	39	29	0	14[1]	48[1]

[1] All incidentally captured game and non-game fish were released in good condition. See **Table F-4** in text for species composition.

Appendix Table F-1.6. Length, weight and sexual maturity data of northern squawfish captured in **the Tucannon River.**

	June		July	
	Females	Males	Females	Males
Sample size	16	12	1	2
Mean length (mm)	341	287		269
Range (mm)	292-483	240-318	270	252-285
Mean weight (g)	515	247		178
Range (g)	250-1550	120-400	200	115-240
Stage of maturity **(%)**				
Undeveloped		17		50
Developing	94	66	100	50
Ripe	6	17		
Spent				

Appendix Table F-1.7. Length, weight and sexual maturity data of northern squawfish captured in **Potlatch River.**

	June		July	
	Females	Males	Females	**Males**
Sample size	2	2	4	**0**
Mean length (mm)	381	389	380	
Range (mm)	355-407	358-420	335-425	
Mean weight (g)	640	585	511	
Range (g)	550-730	450-720	440-700	
Stage of maturity **(%)**				
Undeveloped		50		
Developing	100	50	50	
Ripe			50	
Spent				

Appendix Table F-1.8. Length, weight and sexual maturity data of northern squawfish captured in **Lapwai Creek.**

	June		July	
	Females	Males	Females	Males
Sample size	8	13	8	2
Mean length (mm)	330	269	352	268
Range (mm)	271-390	220-325	305-455	266-270
Mean weight (g)	459	269	352	268
Range (g)	255-760	110-400	3 10-980	200-255
Stage of maturity (%)				
Undeveloped		15	50	
Developing	100	85	37	100
Ripe			13	
Spent				

REPORT G

Effectiveness of Predator Removal for Protecting Juvenile Fall Chinook Salmon Released From Bonneville Hatchery, 1993

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1993 Annual Report

CONTENTS

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. In 1987, subyearling chinook salmon (0. *tshawytscha*) released along the shoreline just downstream from Bonneville Dam had poor survival relative to those released in midstream (Ledgerwood et al. 1990). Northern squawfish are known to inhabit protected shoreline areas (Petersen et al. 1990), and the poor survival rates of shoreline-released juvenile salmon was attributed, in part, to higher predation by northern squawfish.

To evaluate the advantage of releasing juvenile salmon in midstream Columbia River, the National Marine Fisheries Service (NMFS), in cooperation with the Oregon Department of Fish and Wildlife (ODFW), conducted salmon survival studies at Bonneville Hatchery from 1989 through 1993 (Ledgerwood et al. 1993, 1994). Each year, subyearling fall chinook salmon (upriver bright stock) were marked, then simultaneously released into Tanner Creek, the normal release site, which enters the Columbia River about 400 m downstream from the hatchery (Figure 2), and into the midstream Columbia River, lateral to the confluence of Tanner Creek. In 1989-1993, differences among seine recoveries of juvenile salmon in the estuary indicated that survival following the 157-km migration was dramatically better (65% better in 1989) for midstream Columbia River-release groups than for Tanner Creek-release groups.

In 1991, 1992, and 1993, with the help of personnel from the U.S. Fish and Wildlife Service (now the National Biological Service), the research was expanded to confirm the effectiveness of removing northern squawfish from the migration route of juvenile salmon from Bonneville Hatchery. Each year, two paired-groups of about 100,000 fish each were released into the midstream Columbia River and into Tanner Creek four days apart. On intervening nights, some 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 coded-wire tags (CWT) from study fish. In 1991 and 1992 it 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 (Ledgerwood et al. 1993, 1994). In addition, recoveries of juvenile salmon in the estuary indicated less benefit for release in midriver over Tanner Creek after northern squawfish removal each year. The decreased benefit was insignificant in 1991 and significant in 1992. These data lend credence to the hypothesis that predation on juvenile salmonids by northern squawfish may be decreased by removal of northern squawfish. The completed set of recovery data from juvenile and adult salmon will be necessary before final conclusions may be drawn.

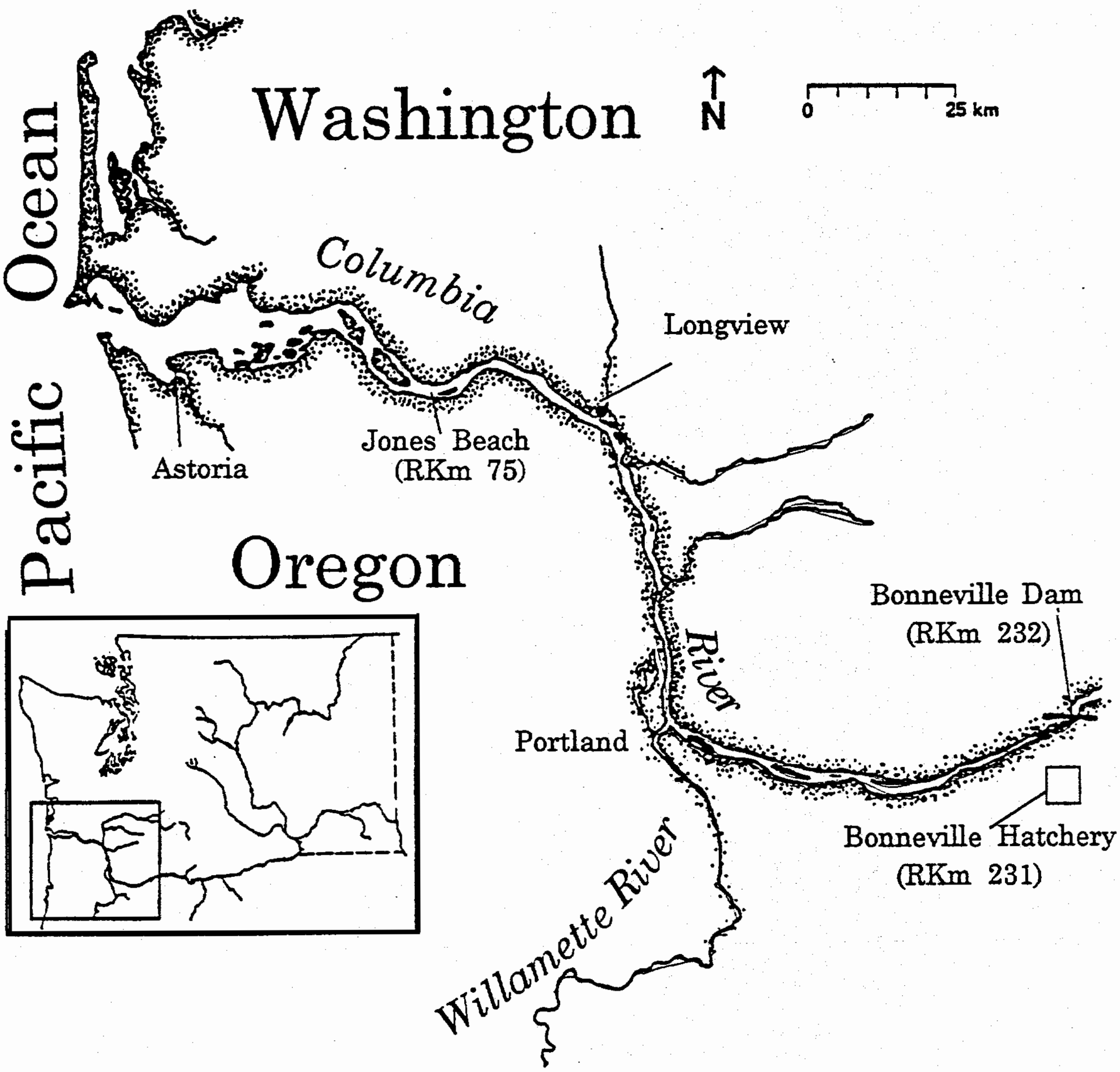

Figure 1. Columbia River Basin showing the study area.

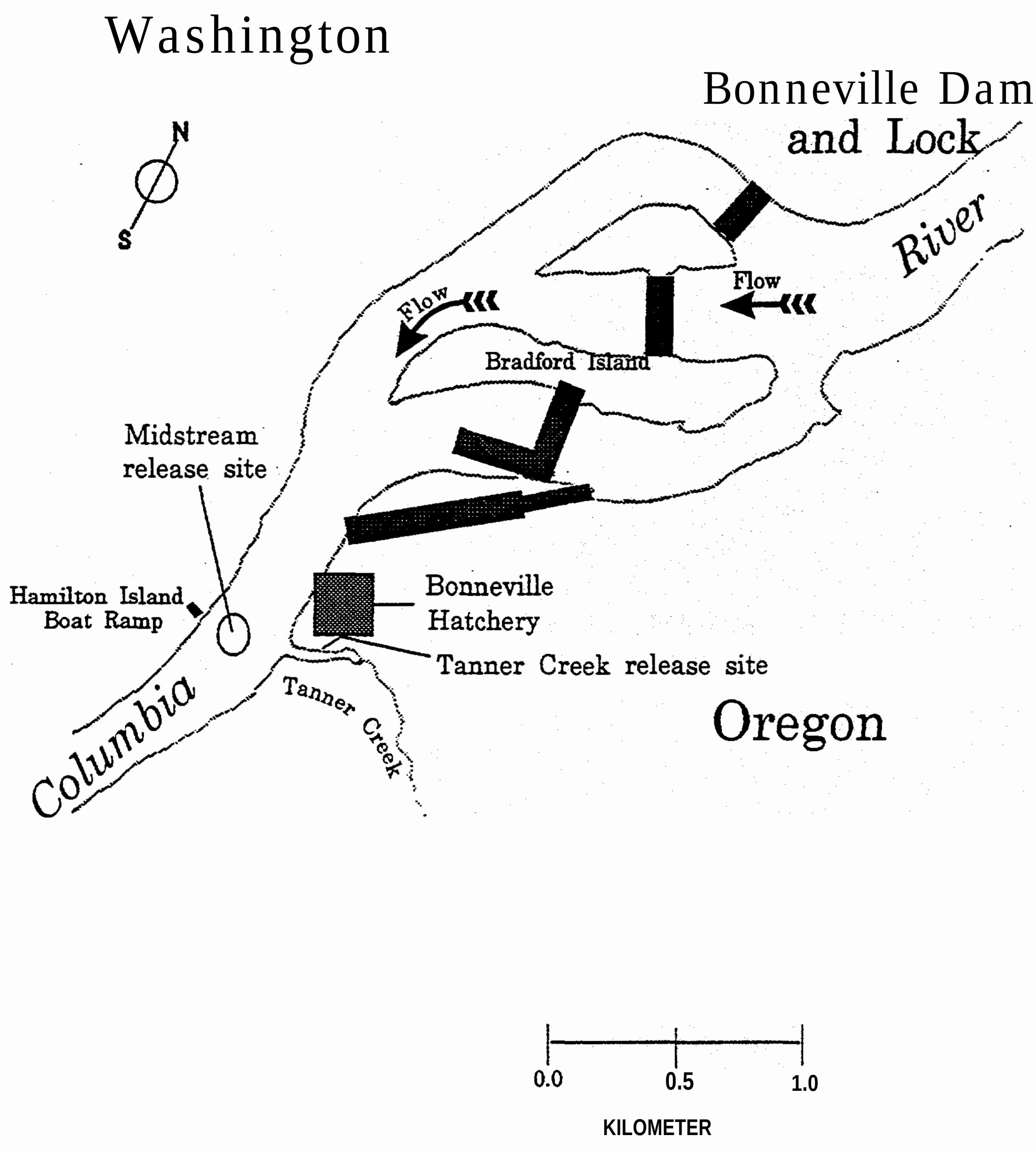

Figure 2. Release locations for subyearling chinook salmon, 1991-1993.

This report summarizes efforts and results of research conducted in 1993. The objectives were similar to those of 1991 and 1992: (1) assess survival differences for juvenile salmon before and after the removal of northern squawfish from Tanner Creek and adjacent shoreline areas of the Columbia River; (2) assess effectiveness of electrofishing to remove northern squawfish from the migration route of juvenile salmon in the vicinity of the hatchery release site; and (3) 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.

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 was conducted 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 population and impact on released salmon. Following the northern squawfish removal, a second pair of uniquely marked 100,000-fish groups was released at the two study sites. The second pair of releases was followed by another two nights of extensive electrofishing for northern squawfish to evaluate population changes in response to the reintroduction of juvenile salmon into the study area.

Purse and beach seining were conducted near the upper boundary of the Columbia River estuary at Jones Beach, River Kilometer (RKm) 75, to recover marked salmon. Recovery percentages of study fish were used to evaluate short-term survival differences between groups released at the two study sites before and after northern squawfish removal. Relative contributions 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 Fiih

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 6.5 g (70.3 fish/lb), similar in size to the fish used in previous years, which ranged in size from 6.0 g to 7.4 g (75.7 to 61.0 fish/lb).

Marking Procedures

Test fish were marked by two 12-person crews on seven days (June 9-11 and June 14-17). About 60,000 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 of fish did not differ in size, condition, rearing history, or mark quality. The four groups were marked simultaneously and differences in mark quality among groups were minimized by rotating 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 quality control in the tagging process, samples of about 100 fish from each marked group were collected and checked for the presence of CWTs. These samples were taken periodically at the outfall pipes from the marking trailer. In addition, samples of about seven fish from each marked group were diverted into a separate holding pond at two-hour intervals throughout the marking day and held for a minimum of 30 days to determine tag loss and brand retention. Samples from each treatment were held in separate net pens. Estimates of tag loss ranged from 2.7% to 7.4% ($\bar{x}$ = 4.6, N = 1,966; Appendix Table G-1.1). Release numbers for each CWT group (treatment) were adjusted for estimated tag loss based on tag loss for the marked fish held a minimum of 30 days.

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 1.5 hours 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 15-cm diameter hose 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 53 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 15-cm diameter hose. Releases occurred between 10 p.m. and 11 p.m. at about RKm 232.

Northern Squawfish Removals

Two electrofishing boats were used to capture and remove 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 that were lowered into the water when fishing. All electrofishing was pulsed direct current using 60 pulses/second, 400-500 volts, and 4-5 amperes.

Electrofishing began at 3 a.m. on June 22, about six hours following the first pair of releases (Appendix Table G-2.1). On subsequent nights through June 25, electrofishing began at 9 p.m. and continued until 9 a.m. the next morning. Electrofishing was delayed the first night to allow test fish to disperse following release. Eight areas located between RKm 232 and RKm 225 were electrofished — one in lower Tanner Creek, and seven others in nearshore areas in the Columbia River (Figure 3)[1]. Each area was electrofished at least twice for about 30 minutes during each electrofishing period. Though transects on both the Oregon and Washington side of the Columbia River were electrofished, efforts were more concentrated in transect areas closest to the release locations.

Northern squawfish, stunned from electrofishing, generally came to the water surface and were collected with a dip net; some stunned fish were lost in the swift currents. Netted fish were placed in a lethal solution of tricaine methanesulfonate (MS-222) and within about 40 minutes of capture were 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 intact diagnostic bones and CWTs from ingested fish (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; the bags were then 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 sample, 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 G-2.2). The solid contents of the bags were then rinsed through a 425-μm 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.

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[1] A ninth transect area (W4) located on the Washington shore was fished in previous years, but was dropped from the sampling scheme in 1993.

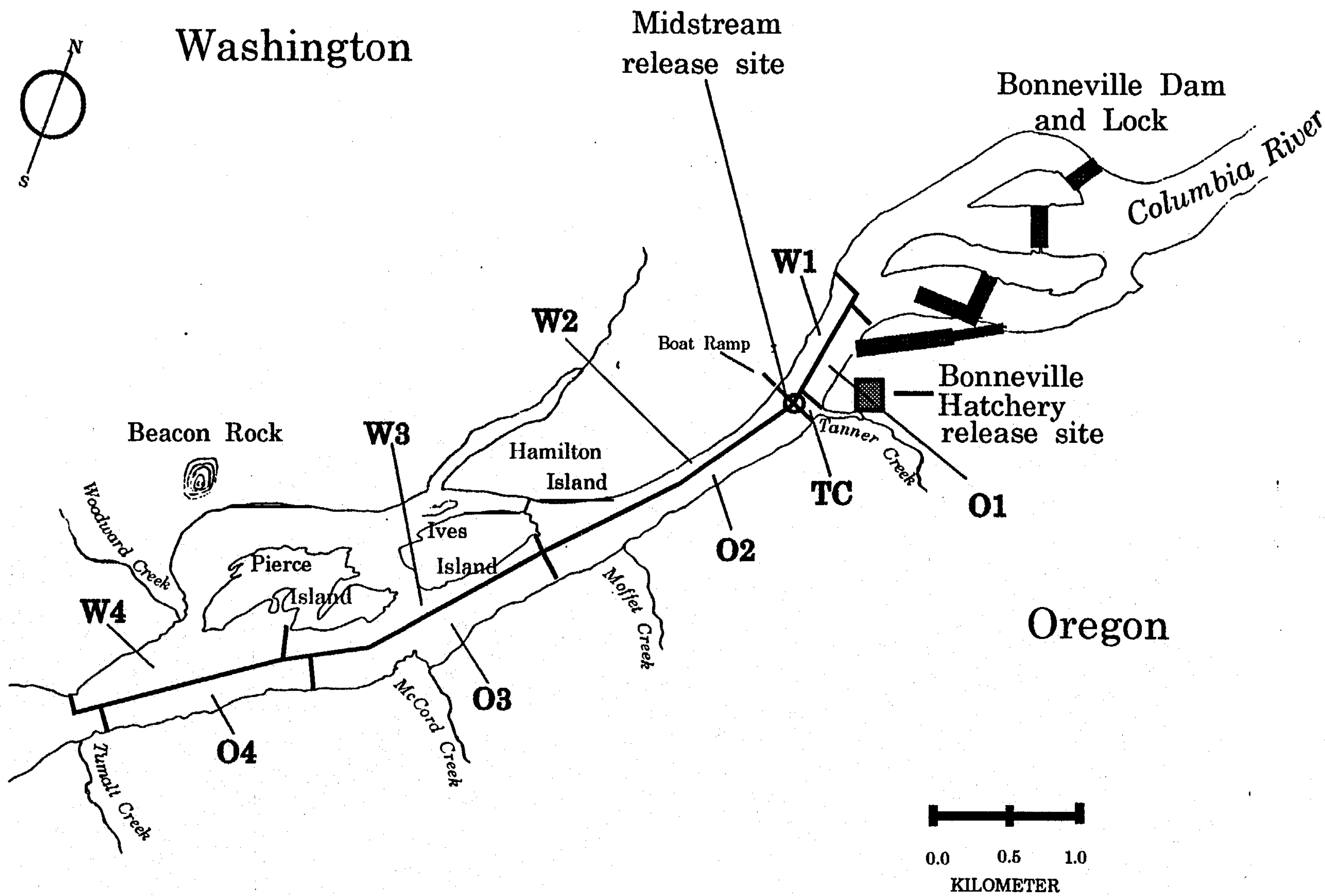

Figure 3. Electrofishing areas in Tanner Creek and adjacent shoreline areas of the Columbia River, 1991-1993.

Sampling Juvenile Salmon at Jones Beach

Short-term relative survival differences among release groups of juvenile salmon were derived from percentage differences of tagged fish recovered near the upper boundary of the Columbia River estuary at Jones Beach (Figure 4). Recovery methods and sampling site were described by Dawley et al. (1985, 1988). In addition to determining recovery differences, captured fish were observed for differences in descaling, injuries, size, and migration behavior.

During the period from June 25 through July 12, sampling was conducted by two crews working seven days per week for eight to 12 hours per day, beginning at sunrise (Appendix Table G-1.2). Both purse seines (midstream) and beach seines (Oregon shore) were used to determine whether study fish were more abundant in midstream or near shore 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 and enumerated by species. Numbers of dead, injured, or descaled salmonids were recorded and subyearling chinook salmon were examined for excised adipose fins and brands. Marked fish were separated for further processing, while unmarked 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.

Freeze brands were used to identify study fish; from these fish, we collected CWTs, obtained biological samples, compared fish size among treatment groups, and adjusted the daily sampling effort to attain the desired minimum sample size of 0.5% of the number of fish released. Brand information and 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.

Branded fish were processed in lots, segregated by recovery day and capture site. An aqueous solution of 40% potassium hydroxide was used to dissolve the heads for ease in extracting CWTs. All CWTs were decoded and later verified; additional details of tag processing followed the methods described by Ledgerwood et al. (1990).

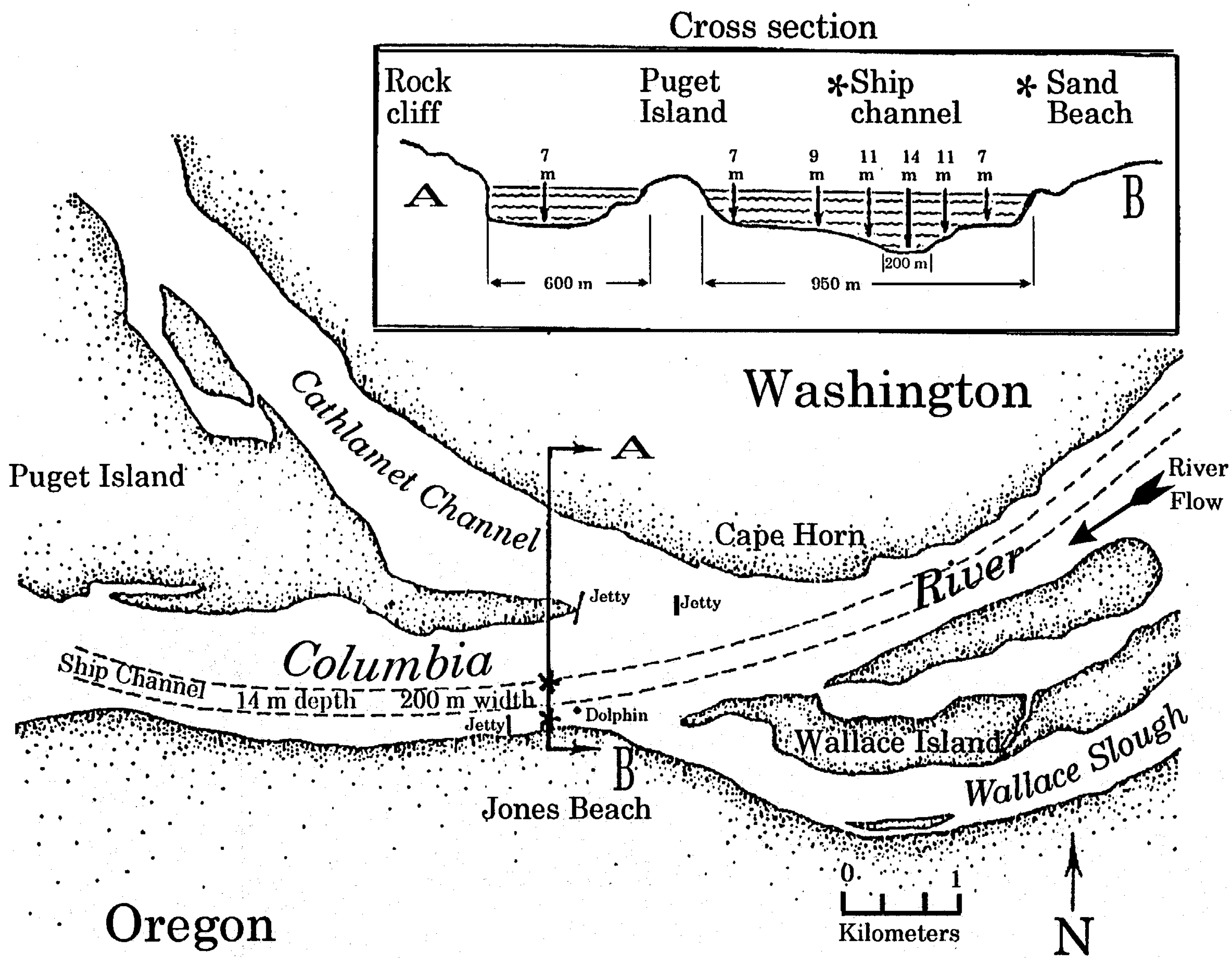

Figure 4. Jones Beach, Columbia River, sampling sites. The beach and purse seining areas are denoted by asterisks.

Purse seine data obtained from June 25 to July 12 were adjusted for effort to obtain a standardized catch per day per group. Beach seine catch data were not similarly adjusted due to low sampling effort. The following formula was used to standardize purse seine data to a 12-set-per-day effort for each marked group:

$$A_i = N_i (S \div P_i)$$

where:

A_i = Standardized purse seine catch on day i;
N_i = Actual purse seine catch on day i;
S = Constant (weighted daily average number of purse seine sets (12) during the sampling period); and
P_i = Actual number of purse seine sets on day i.

Dates of median recovery for each marked fish group were determined using the standardized purse seine. Movement rates for each CWT group were calculated as the distance from the midstream Columbia River release site (RKm 232) to Jones Beach (RKm 75) divided by the travel time (in days) from release date to the date of the median fish recovery.

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

In 1993, a total of 399,040 subyearling chinook salmon were marked with freeze brands, CWTs, and excision of the adipose fin before release (Table G-l). Between the two release dates, 2,291 northern squawfish were captured and removed from the study area (Table G-2). An additional 575 northern squawfish were removed from the study area following the second release. We recovered 1,988 study fish in the estuary (ca. 0.6% of those released); most were midstream migrants captured with purse seines (Appendix Table G-l .3). Handling mortality for all captured juvenile salmon was less than 0.5 % and the descaling rate was less than 2%. Five descaled study fish were captured at Jones Beach, too few for meaningful among-treatment comparison.

Table G-l. Summary of Tanner Creek and midstream Columbia River releases of marked subyearling chinook salmon, 1993.

Marking dates	Release date	Brand[a]	Number released: Total[b]	Untagged[c]	Tagged[d]	wire tag code (AG D1 D2)[e]
Tanner Creek releases						
9-17 June	21 June	RD Z2	99,702	3,689	96,013	23 30 21
9-17 June	25 June	LD Z2	99,272	7,346	91,926	23 30 22
Midstream Columbia River releases						
9-17 June	21 June	RD Z1	99,516	4,578	94,938	23 30 23
9-17 June	25 June	LD Z1	100,550	2,715	97,835	23 30 24
		Total	399,040	18,328	380,712	

[a] Brand codes: first and second characters, RD = right dorsal position; third character is the brand symbol; fourth 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 G-l. 1).

[d] Estimated number of fish released with coded-wire tags.

[e] CWT code key: AG D1 D2 = Agency code, Data 1 code, Data 2 code.

Table G-2. Number of northern squawfish removed by day (all electrofishing sites) and number of coded-wire tags recovered in digestive tracts of northern squawfish, 1993.

Electrofishing date (time)	Northern sauawfish removed: Time shocker on (sec)	Total catch	CPUE[b]	Mean length (mm)	Mean weight (g)	CWTs recovered[a] Release site: Tanner[c] Creek	Mid-[d] stream
Data pertinent to first paired release							
22 June (0300-0900)	10,488	253	87	321	734	114	2
22-23 June (2100-0900)	18,988	872	165	306	412	41	1
23-24 June (2100-0900)	18,738	650	125	293	369	2	--
24-25 June (2100-0900)	18,471	516	101	300	385	--	--
Subtotal	66,685	2,291	119.5	305.0	475.0	157	3
Data pertinent to second paired release							
26-27 June (2100-0900)	18,272	346	68	287	341	--	--
27-28 June (2100-0900)	11,549	229	71	308	410	--	--
Subtotal	29,821	575	69.5	297.5	375.5	--	--
Totals	96,506	2,866	102.8	302.5	441.8	157	3

[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 = 23/30/21, released June 21.
[d] CWT code = 23/30/23, release June 21.

Northern Squawfish Removals

We captured and removed a total of 2,866 northern squawfish from the eight transect areas during about 27 hours (96,506 seconds) of electrofishing (Table G-2). Sixty-one percent (1,759) of those removed were caught in Tanner Creek or adjacent transect areas along the Oregon shore (01, 02, and 03) (Figure 5), similar to catch distributions in 1991 and 1992. During the June 22-25 electrofishing periods (following the June 21 release), catch rates of northern squawfish were higher (mean = 119.5 fish/hour) than during the June 26-28 electrofishing periods (following the June 25 release) (mean = 69.5 fish/hour). There was little indication that northern squawfish recolonized the Tanner Creek or adjacent transect areas immediately after release of juvenile salmon from Bonneville Hatchery (Table 3). The mean fork lengths (302 mm) and weights (442 g) of northern squawfish were fairly consistent throughout the removal periods and considerably less than for northern squawfish captured during 1991 (means 344 mm and 606 g), but similar in size to those captured during 1992 (means 303 mm and 430 g; Figure 6). The number of CWTs recovered in the digestive tracts of northern squawfish (representing ingested juvenile salmon) diminished dramatically following the first electrofishing period. Of the 167 CWTs recovered from the digestive tracts of northern squawfish (Appendix Table G-2.2), 94% were from study fish and all of those except three were from study fish released June 21 into Tanner Creek; the exceptions were study fish released June 21 into the midstream Columbia River. The CPUE for northern squawfish was highest in the Tanner Creek transect area, and 10% of the CWTs from study fish were recovered from those northern squawfish (Table G-3). Although the percentage of CWTs recovered in the Tanner Creek transect area was low, it should be noted that this transect area was considerably smaller than the other transect areas and consequently received correspondingly less electrofishing effort. Also, due to a drop in tailwater elevation at Bonneville Dam on June 26, it was impossible to electrofish within Tanner Creek following the June 25 release of study fish.

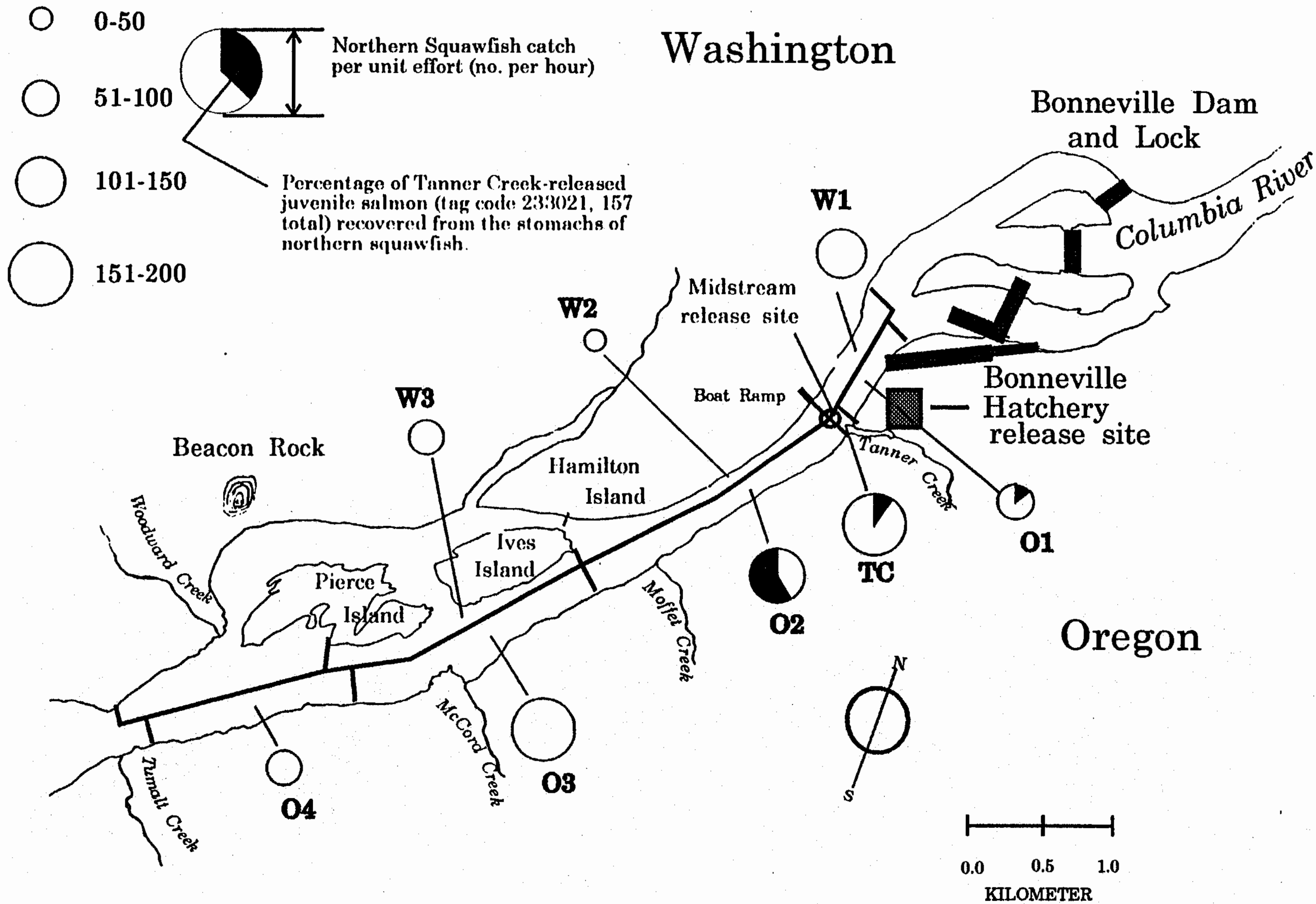

Figure 5. The study area showing the northern squawfish catch per unit effort at each electrofishing transect area and proportion of tags (representing ingested juvenile salmon) from the 21 June Tanner Creek release group recovered in those northern squawfish, 1993.

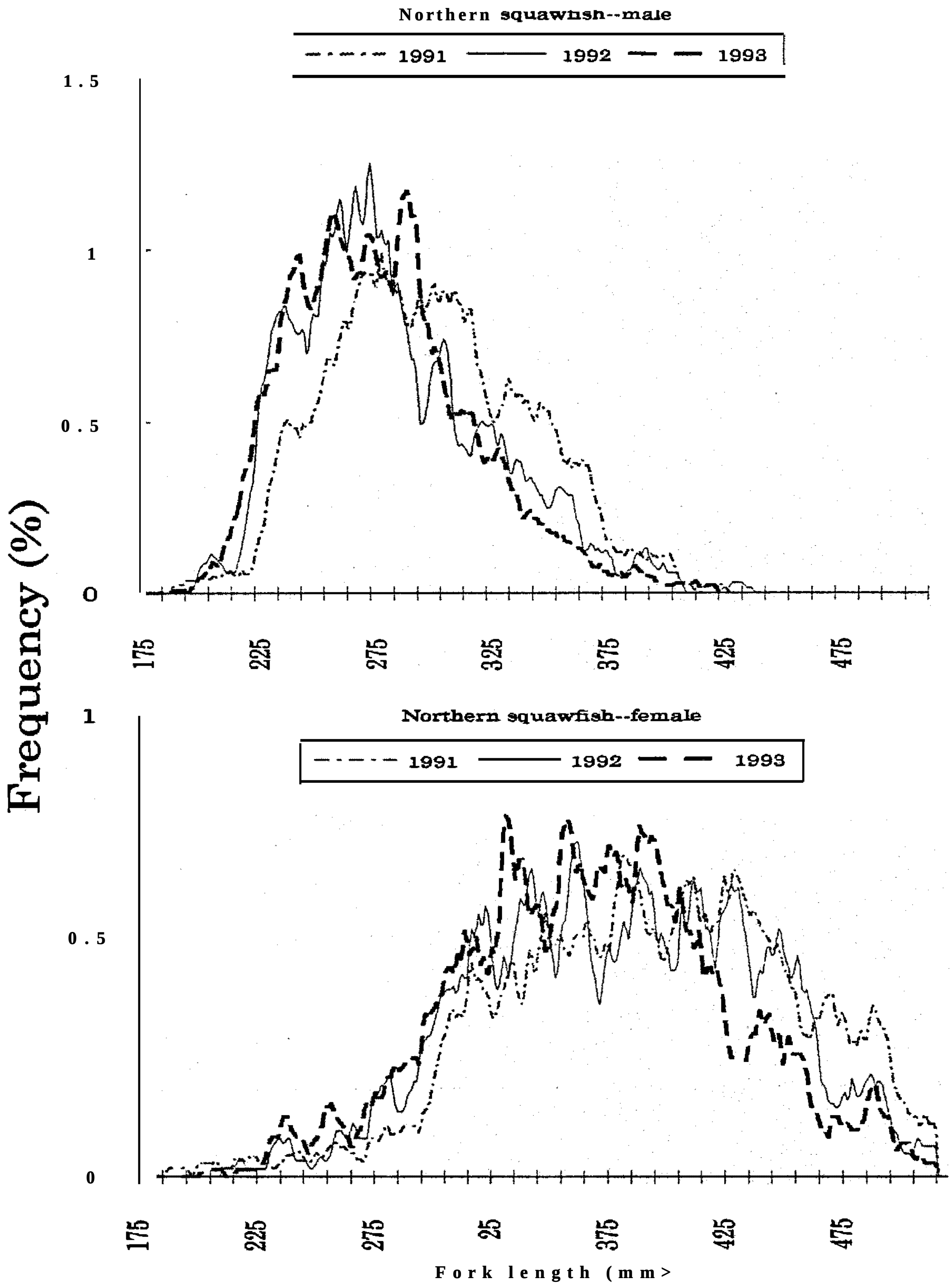

Figure 6. Fork length distributions of northern squawfish removed from the study area by electrofishing, 1991, 1992, and 1993.

Juvenile Salmon Catch Patterns and Movement Rates

There was no evidence from the Jones Beach recovery data to suggest non-homogeneity between treatment recovery distributions of study fish groups released on the same day (α = 0.05; Appendix G-3); 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 G-l .3). Temporal catch distributions of each release group are presented in Figure 7.

Movement rates of study fish between the release site and Jones Beach ranged from 19.6 km/day to 22.4 km/day, similar to movement rates in 1991 and 1992, but faster than movement rates in 1989 or 1990 (Table G-4). Movement rates of fish from the second release groups were slightly slower than those of the first release groups, due perhaps in part to decreased river flow following the second release (Figure 8).

Comparisons of fork length distributions of study fish at release to those captured at Jones Beach suggest that all groups grew about 1 mm per day during the migration period (Figures 9-10). At recovery there were no apparent differences in daily mean lengths among treatment groups (Figure 11). Generally, fish from both pairs of releases showed little change in mean length during the recovery period.

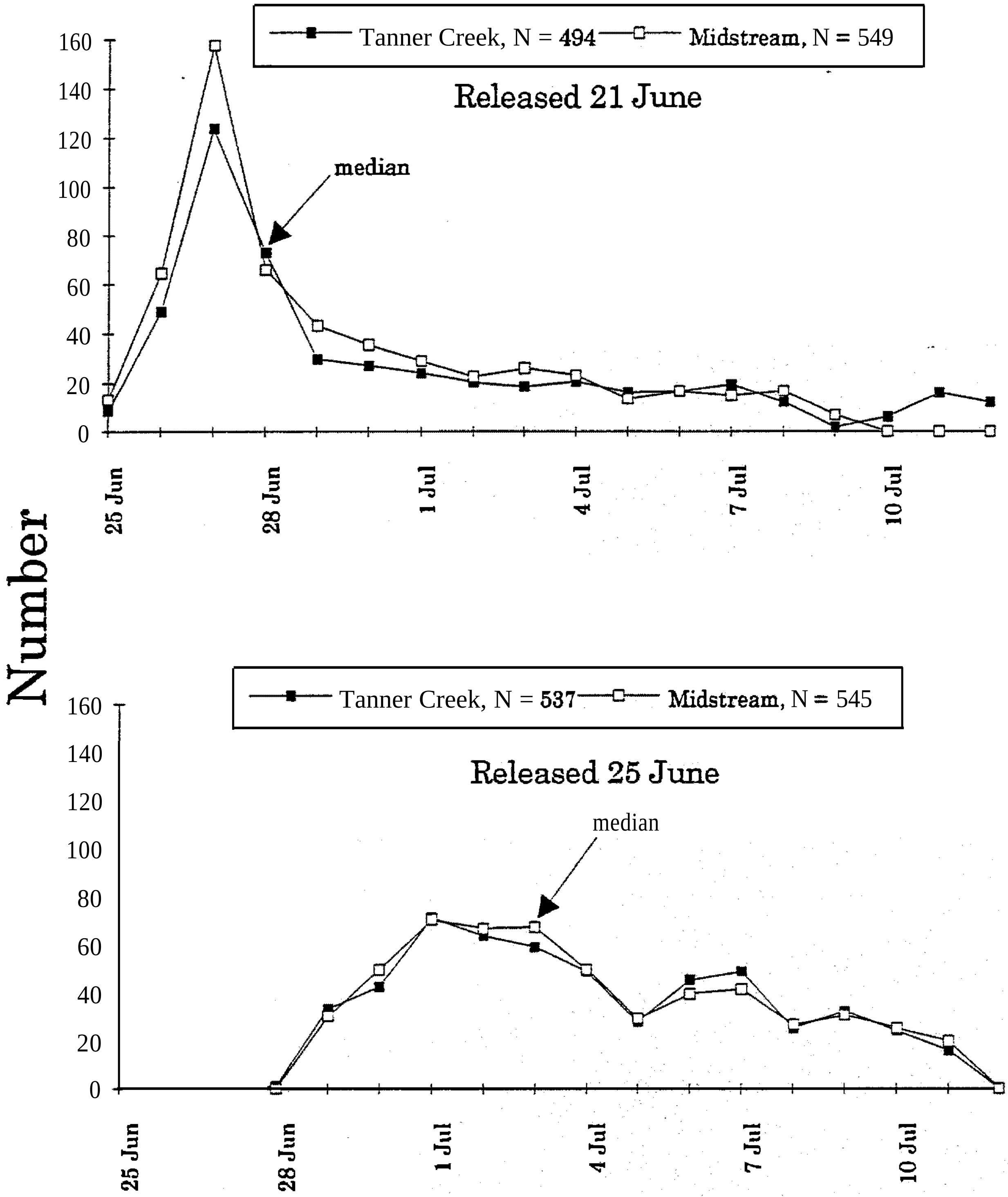

Figure 7. Daily recoveries of test fish at Jones Beach (standardized for effort) comparing midstream Columbia River to Tanner Creek release-groups, 1993.

Table G-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, 1992, and 1993.

Release date	Movement rate (km/day) Midstream Columbia	Tanner Creek	Mean FL (mm)[b]	Flow (kft^3/sec) 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
21 June 1993	22.4	22.4	91	199	186
25 June 1993	19.6	19.6	92	202	175

[a] Movement rate = distance from the midstream Columbia River release site (RKm 232) to recovery site (RKm 75) ÷ time in days from release to median fish recovery. Median fish recovery based on standardized daily effort (Appendix Table G-l .3).

[b] Mean fork length of fish recovered at Jones Beach.

[c] Daily average flow at Bonneville Dam on the day that fish were released.

[d] Four-day average flow at Bonneville Dam within 2 days before and after the date that the median fish was captured; by convention, English units were used for river flow volumes (kft^3/sec = 1,000 ft^3/sec = 28.3 m^3/sec).

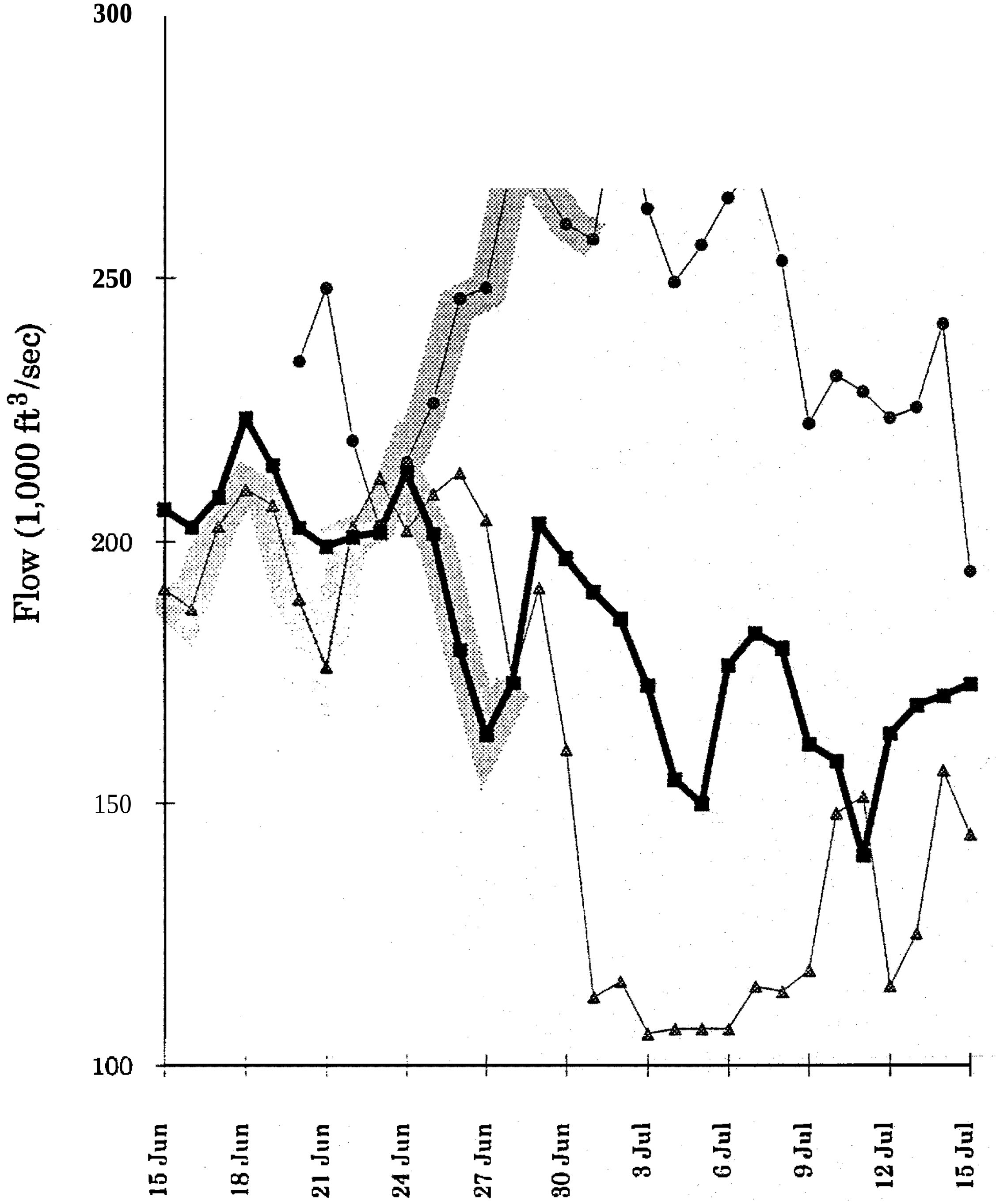

Figure 8. Daily mean flows of the Columbia River at Bonneville Dam during the estuarine **sampling periods,** 1991, 1992, and 1993; flow measurements provided by the U. S. Army Corps of Engineers, Portland, Oregon.

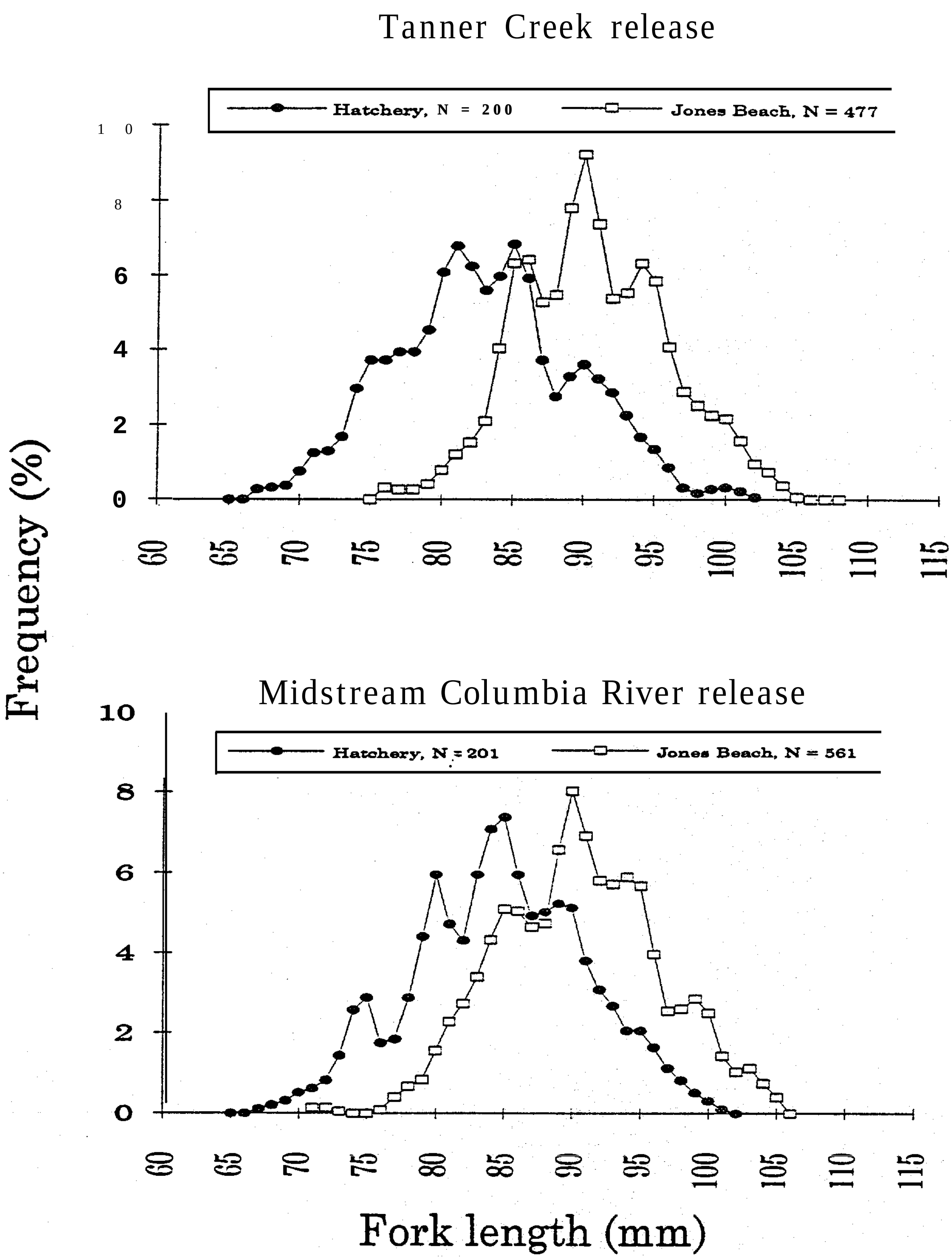

Figure 9. Fork length distributions of study fish at release and after recovery at Jones Beach for fish released on 21 June 1993.

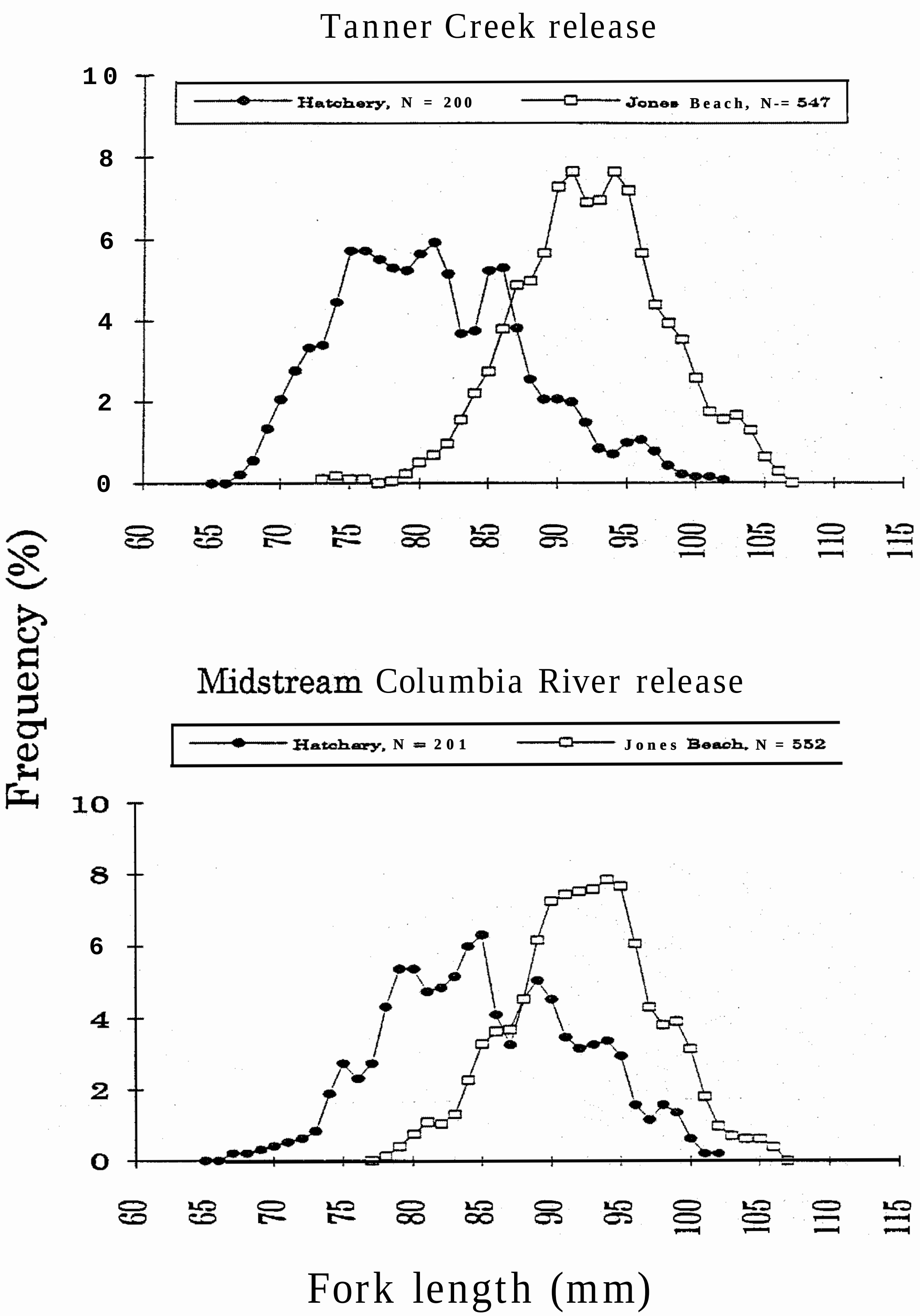

Figure 10. Fork length distributions of study fish at release and after recovery at Jones Beach; fish released on 25 June 1993.

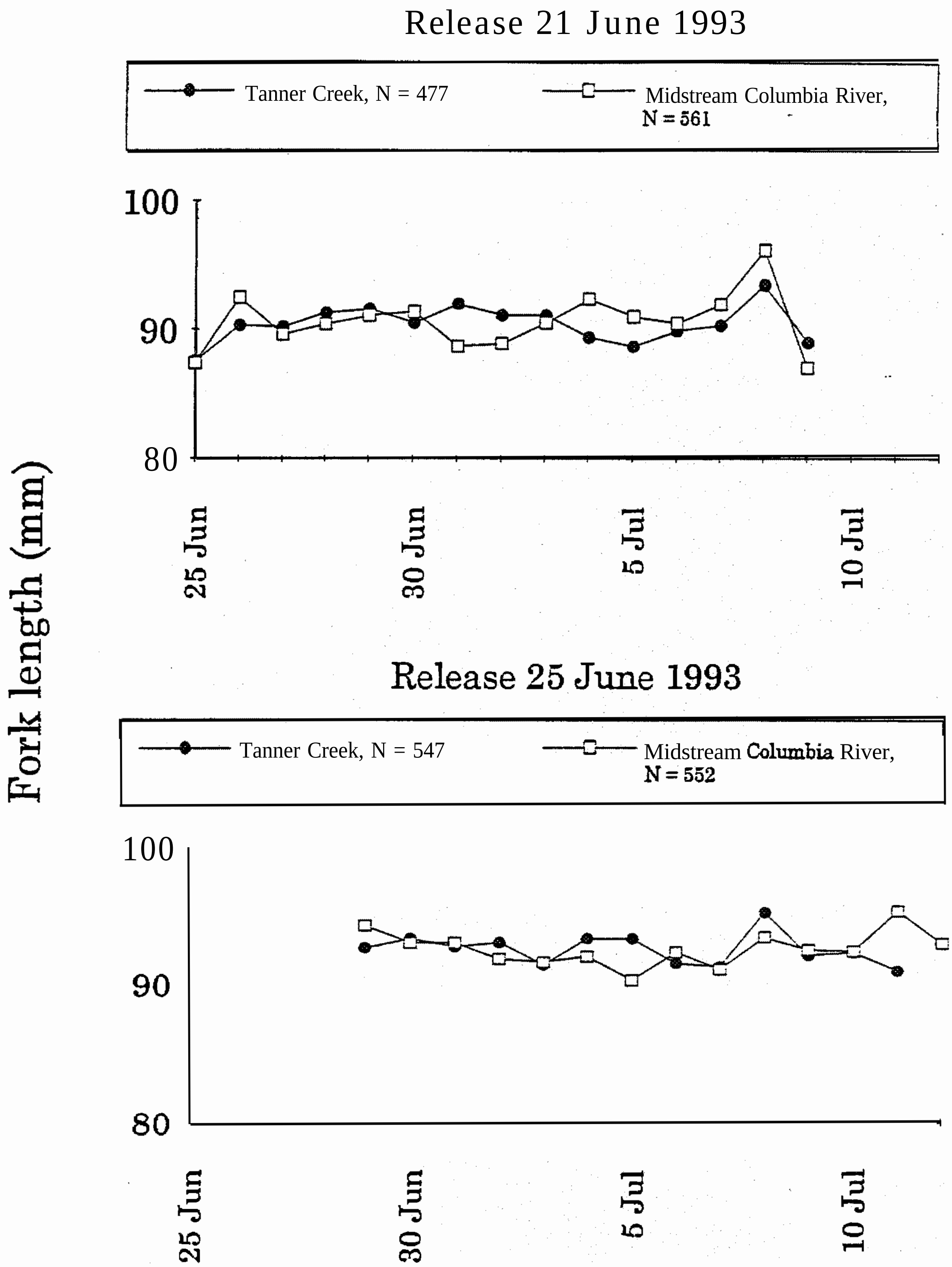

Figure Il. Daily mean fork lengths of subyearling chinook salmon recovered at Jones Beach, comparing midstream Columbia River to Tanner Creek release groups, 1993.

Juvenile Salmon Recovery Differences

Analysis of CWT-fish recoveries at Jones Beach (Appendix G-3) indicated that the recovery percentages for fish released into the midstream Columbia River were significantly higher (P = 0.0023) than for fish released into Tanner Creek for the first release group (0.64 % versus 0.60%). However, for the second pair of release groups, the differences in recovery percentages were reversed, but not significantly different (P = 0.3120), with Tanner Creek recoveries higher than midstream Columbia River recoveries (0.64% versus 0.60%, respectively). Although the relative recovery percentages of the two treatment groups changed between the two release dates (Figure 12), these percentages are not directly comparable because fish releases made on the two different dates were subject to different river conditions, which may affect both migration survival and sampling efficiency, and thus recovery. After the localized removal of northern squawfish, the difference in recovery percentages between the two release sites was reduced from 19.7% to -5.7% (Figure 12; Appendix G-3, Part lc); this 129% reduction in recovery differences ((19.7 - (-5.7) ÷ 19.7) * 100) was significant (P = 0.0041).

To further assess data consistency, we analyzed purse seine recoveries separate from total recoveries (Appendix Table G-l .3, Appendix G-3). 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 c 0.01) than those for fish released into Tanner Creek for the first release pair and insignificant (P = 0.31) for the second release pair. Similarly, there was a significant change (P c 0.01) in the difference 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 2%).

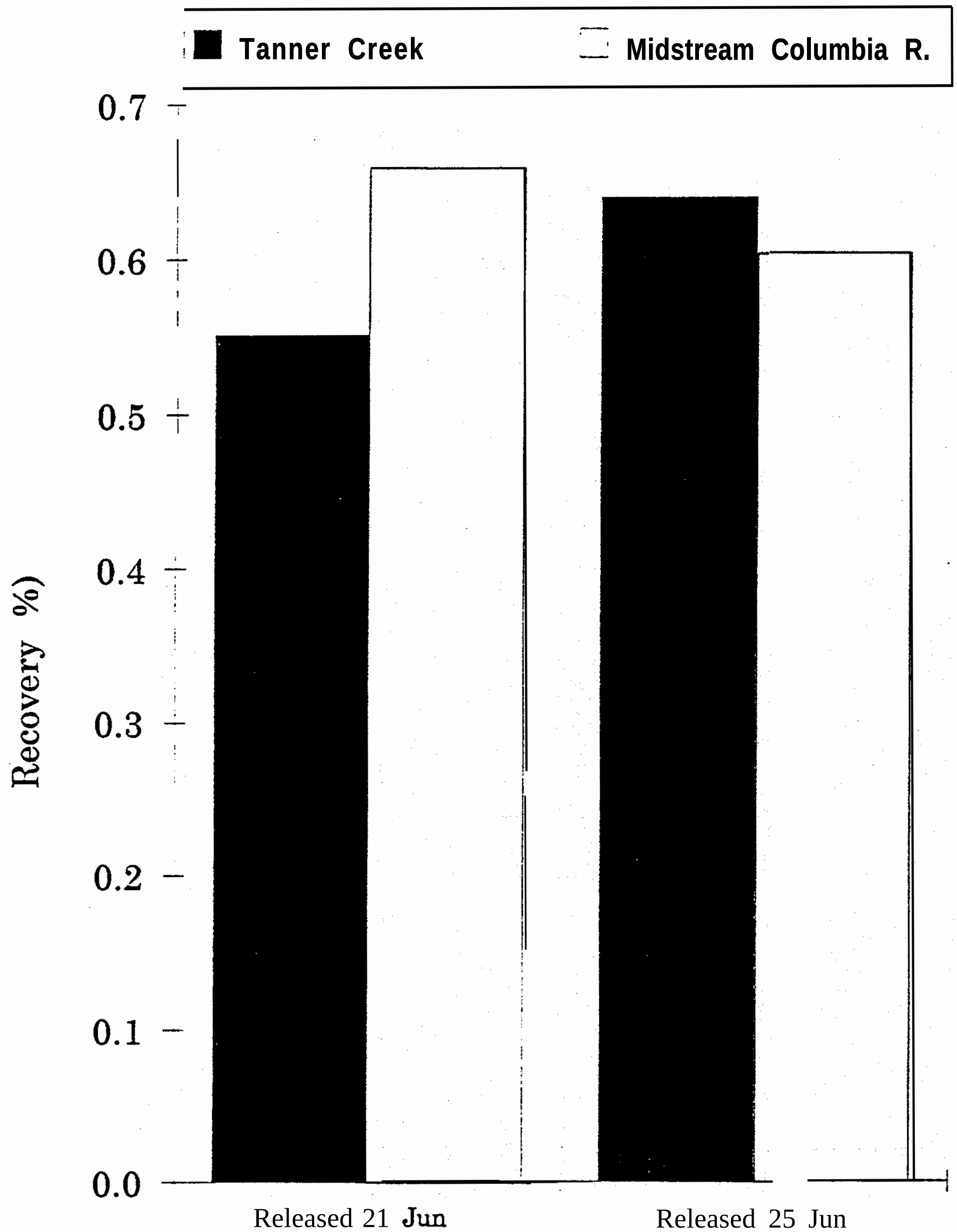

Figure 12. Mean recovery percentages comparing midstream Columbia River to Tanner Creek release groups, 1993. Northern squawfish were removed by electrofishing between the two release dates. Recovery rate for the midstream release group was significantly higher ($P < 0.05$) than for the Tanner Creek release group on 21 June.

DISCUSSION

In 1993, for the first time in eight comparisons over a five-year period, the recovery percentage in the estuary of a marked group of subyearling chinook salmon released into Tanner Creek was higher than the recovery percentage of a similar marked group released into the midstream Columbia River (Table G-5). This exception occurred following electrofishing to remove northern squawfish from the presumed migration route of the Tanner Creek released fish. In all previous marked-group comparisons, dating back to studies in 1989, the midstream Columbia River release groups had significantly higher ($P < 0.05$) recovery percentages after migration to the estuary than groups released directly from Bonneville Hatchery into Tanner Creek.

In 1993, also for the first time, the reduction in benefit for midstream Columbia River release following the electrofishing effort was significant ($P = 0.0041$). In 1991 and 1992, although the benefit for midstream release declined following electrofishing, there remained a significant benefit to releasing subyearling chinook salmon from Bonneville Hatchery at the midstream Columbia River site. We questioned whether the observed declines following electrofishing to remove northern squawfish during 1991 and 1992 were actually a result of electrofishing, or merely responses to changing river flow or other coincidental events occurring between the two release dates each year.

Based on results from studies conducted from 1991 through 1993, we believe that the effectiveness of localized predator removal in protecting juvenile salmon released from Bonneville Hatchery is affected by Columbia River flows at the time of test fish release, as well as the systemwide northern squawfish removal program (Willis and Nigro 1994). We speculate that higher river-flow at the time of release allowed for faster downstream dispersal of Tanner Creek-released fish, resulting in less predation by northern squawfish in the Tanner Creek-Columbia River confluence area and increased survival. We further speculate that the local population of northern squawfish was lower in 1993 than in earlier years of study as a result of the basinwide northern squawfish sport-reward fishery, and this reduced population was more effectively controlled by electrofishing. In total, about 200,000 northern squawfish were removed from the tailrace area of Bonneville Dam between 1991 and 1993 (S. Smith, WDFW, Pullman, pers. comm.).

Table G-5. Recovery percentages of tagged subyearling chinook salmon at Jones Beach for Tanner Creek and midstream Columbia River release groups, 1989, 1990, 1991, 1992, and 1993.

Release date	Midstream Columbia River[b]	Bonneville Hatchery at Tanner Creek[c]	Benefit[a] 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*** post-removal[e]
15 June 1992	0.57	0.42	**35.7***
19 June 1992	0.60	0.51	17.6’ post-removal
21 June 1993	0.66	0.55	20.0’
25 June 1993	0.60	0.64	-6.3 post-removal[e]

[a] The percent benefit for midstream Columbia River release (MC) over Tanner Creek release (TC) is calculated as: [(MC% recovery - TC% recovery) ÷ TC% recovery] X 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 ($P \leq 0.05$).

[e] Benefit for midstream release following 4 days of extensive electrofishing to remove northern squawfish.

In 1991 and 1992, 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. In 1993, flows were almost identical on the two release dates (Table G-4). About 2,000 northern squawfish were removed from the study area between the two release dates in all three years; the difference in survival benefit for midstream Columbia River releases compared to Tanner Creek releases following electrofishing efforts declined through the years (22%, 51%, and 129% decline in survival benefit for 1991, 1992, and 1993, respectively). The effectiveness of localized northern squawfish removal at reducing the survival differences between midstream Columbia River and Tanner Creek releases may also be affected by the dispersal rate of study fish from the area of release. Dispersal rate would affect the period of time that study fish were exposed to the local northern squawfish population.

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 Transects 03 and 04 support the latter explanation (Figure 5). In all three years (1991-1993), CWT recoveries from the stomachs of northern squawfish were concentrated at transects closest to the Tanner Creek release site; nearly all the CWTs recovered were from the Tanner Creek release groups, which suggested 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. In 1993, the CPUE for northern squawfish fluctuated during the removal period, and was lower for the dates following the second pair of juvenile salmon releases, which indicated little influx of northern squawfish into the study area in response to the second release of juvenile salmon. The sharp drop in numbers of CWTs in the digestive tracts of northern squawfish by the final day of electrofishing indicated emigration of the released salmon.

It is difficult to attribute the apparent lack of survival benefit for midstream Columbia River-released fish in 1993 to the removal of only 2,866 northern squawfish. Rather, a general decline in the proportion of the larger-sized northern squawfish in 1992 and 1993 may better explain the decline.

CONCLUSIONS

1) Subyearling chinook salmon from Bonneville Hatchery released into the midstream Columbia River prior to electrofishing efforts exhibited significantly higher survival rates than fish released into Tanner Creek. We believe 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 may be affected by the dispersal rate of study fish from the area of release. More rapid dispersal may be a result of tailwater elevation below Bonneville Dam and consequent hydraulic conditions at the confluence of Tanner Creek, and degree of smoltification .

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) It appeared that the numbers and size of northern squawfish in the study area have declined in recent years and that this general decline in population abundance contributed to the effectiveness of localized predator removal during the 1993 research. Electrofishing to remove northern squawfish from the migration route of juvenile salmon released from Bonneville Hatchery appeared to eliminate the survival difference between midstream Columbia River and Tanner Creek release groups under the conditions in 1993.

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APPENDIX G-1

Juvenile Salmon Marking, Release, and Jones Beach Recovery Information

Appendix Table G-l. 1. Tag loss estimates among marked groups of subyearling chinook salmon after a 30day holding period for Tanner Creek and midstream Columbia River release-groups, 1993.

Release dates	Coded wire tag (AG D1 D2)[a]	NT[b]	Sample"
Tanner Creek releases			
21 June	23 30 21	18	492
25 June	23 30 22	36	489
Midstream releases			
21 June	23 30 23	23	503
25 June	23 30 24	13	482

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.
6 Number of fish checked for the presence of coded wire tags.

Appendix Table G-1.2. Daily purse seine and beach seine fishing effort, water temperatures, and Secchi disk transparency measurements at Jones Beach, 1993.

Date	Number of sets		Temp.	Secchi	Date	Number of sets		Temp.	Secchi
	Purse	Beach	°C	depth (m)		Purse	Beach	°C	depth (m)
18 Jun	2	0	17	--[d]	30 Jun	20	0	18	1.2
19 Jun	0	0	--	--	1 Jul	15	3	18	1.2
20 Jun	0	0	--	--	2 Jul	16	0	17	1.1
21 Jun	3	2	17		3 Jul	13	2	17	1.1
22 Jun	4	2	17	1.1	4 Jul	13	0	17	
23 Jun	8	0	17	1.2	5 Jul	9	0	18	1.2
24 Jun	8	1	16	1.1	6 Jul	13	2	18	1.1
25 Jun	10	0	17	1.2	7 Jul	13	0	18	1.2
26 Jun	13	0	17	1.1	8 Jul	8	2	18	1.1
27 Jun	13	2	17	1.4	9 Jul	7	0	18	1.2
28 Jun	12	1	18	1.1	10 Jul	2	0	18	1.4
29 Jun	15	0	18	1.2	11 Jul	3	0	18	1.2
					12 Jul	1	0	18	--

[d] Dashes indicate data not available.
[e] First recovery of study fish.

Appendix Table G-1.3. 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, 1993.

	Released 21 June											
	Treatments and tag code (AG D1 D2)[a]											
	Tanner Creek 23 30 21						Midstream Columbia 23 30 23					
Date of	Purse		Beach		Total		Purse		Beach		Total	
recovery	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
25 Jun	7	8	NE		7	8	11	13	NE		11	13
26 Jun	53	49	NE	--	53	49	70	65	NE		70	65
27 Jun	134	124	3		137	124	171	158	3		174	158
28 Jun	73	73	3	--	76	73[d]	66	66	3		69	66[d]
29 Jun	37	30	NE	--	37	30	54	43	NE		54	43
30 Jun	45	27	NE	--	45	27	59	35	NE	--	59	35
1 Jul	30	24	6		36	24	36	29	4		40	29
2 Jul	27	20	NE		27	20	30	23	NE		30	23
3 Jul	20	18	1		21	18	28	26	5		33	26
4 Jul	24	22	NE		24	22	27	25	NE		27	25
5 Jul	12	16	NE		12	16	10	13	NE		10	13
6 Jul	18	17	0		18	17	18	17	0	--	18	17
7 Jul	21	19	NE		21	19	16	15	NE	--	16	15
8 Jul	8	12	0	--	8	12	11	17	0	--	11	17
9 Jul	1	2	NE	--	1	2	4	7	NE	--	4	7
10 Jul	1	6	NE		1	6	0	0	NE	--	0	0
11 Jul	4	16	NE	--	4	16	0	0	NE	--	0	0
12 Jul	1	12	NE		1	12	0	0	NE	--	0	0
Total	516	495	13	0	529	495	611	550	15	0	626	550
Recovery (%)	0.54	0.52	0.01	0.00	0.55	0.52	0.64	0.58	0.02	0.00	0.66	0.58
Mvmt rate[e]					*22.4*						*22.4*	

Appendix Table G-1.3. Continued.

Date of recovery	Released 25 June — Treatments and tag code (AG Dl D2) — Tanner Creek 23 30 22						Midstream Columbia 23 30 24					
	Purse		Beach		Total		Purse		Beach		Total	
	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
25 Jun	0	0	NE	--	0	0	0	0	NE	--	0	0
26 Jun	0	0	NE		0	0	0	0	NE		0	0
27 Jun	0	0	0		0	0	0	0	0		0	0
28 Jun	1	1	0		1	1	0	0	0	--	0	0
29 Jun	42	34	NE		42	34	38	30	NE		38	30
30 Jun	71	43	NE		71	43	83	50	NE		83	50
1 Jul	89	71	3	--	92	71	88	70	4		92	70
2 Jul	85	64	NE		85	64	89	67	NE		89	67
3 Jul	64	59	4	--	68	59[d]	73	67	0		73	67[d]
4 Jul	53	49	NE	--	53	49	54	50	NE		54	50
5 Jul	21	28	NE	--	21	28	22	29	NE		22	29
6 Jul	49	45	0		49	45	43	40	0		43	40
7 Jul	53	49	NE	--	53	49	45	42	NE		45	42
8 Jul	17	26	1	--	18	26	18	27	0		18	27
9 Jul	19	33	NE		19	33	18	31	NE		18	31
10 Jul	12	24	NE		12	24	10	25	NE		10	25
11 Jul	4	16	NE	--	4	16	5	20	NE	--	5	20
12 Jul	0	0	NE		0	0	0	0	NE		0	0
Total	580	541	8	0	588	541	586	548	4	0	590	548
Recovery (%)	0.63	0.59	0.01	0.00	0.64	0.59	0.60	0.56	0.00	0.00	0.60	0.56
Mvmt rate=						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 12 set per day effort; beach seine effort was limited and not used for data standardization.
[d] Day that the mediin fish was captured (standardized purse seine effort).
[e] Mvmt rate = Movement rate (km/day) = distance traveled (RKm 232 to RKm 75) ÷ travel time (days from release to median fish recovery).

APPENDXX G-2

Northern Squawfiih Electrofiihiig Information

Appendix Table G-2.1. Northern squawfish electrofishing daily effort and catch results, 1993.

Electrofishing period[a]	Electrofishing date	Electrofishing location[b]	Start time'	Effort (sec)[d]	Catch (no.)	CPUE (no./h)[d]
1	22 Jun	01	0326	1,802	27	53.9
2	23 Jun	01	0216	1,271	29	82.1
2	22 Jun	01	2133	970	51	189.3
3	24 Jun	01	0208	1,112	27	87.4
3	23 Jun	01	2115	1,027	25	87.6
4	25 Jun	01	0110	804	29	129.9
4	24 Jun	01	2112	1,104	23	75.0
5	27 Jun	01	0100	1,602	7	15.7
6	28 Jun	01	0155	599	13	78.1
6	27 Jun	01	2107	1,375	31	81.2
6	27 Jun	01	2124	775	32	148.6
Subtotal				12,441	294	
Mean				1,131.0	26.7	93.5
SE				109.0	3.4	14.2
1	22 Jun	02	0408	1,911	60	113.0
2	23 Jun	02	0335	1,738	70	145.0
2	22 Jun	02	2226	1,995	115	207.5
3	24 Jun	02	0304	1,975	64	116.7
3	23 Jun	02	2150	1,861	76	147.0
4	24 Jun	02	2215	2,400	83	124.5
5	27 Jun	02	0309	1,792	26	52.2
5	26 Jun	02	2248	1,901	59	111.7
Subtotal				15,573	553	
Mean				1,946.6	69.1	127.2
SE				71.6	8.9	15.4
1	22 Jun	03	0517	1,866	41	79.1
2	23 Jun	03	0450	1,766	47	95.8
2	22 Jun	03	2313	1,807	223	444.3
3	24 Jun	03	0356	1,242	40	115.9
3	23 Jun	03	2327	1,820	164	324.4
4	25 Jun	03	0412	1,800	51	102.0
4	24 Jun	03	2305	1,800	110	220.0
5	27 Jun	03	0406	1,580	31	70.6
5	26 Jun	03	2336	1,319	78	212.9
6	27 Jun	03	2045	1,750	15	30.9
Subtotal				16,750	800	--
Mean				1,675.0	80.0	169.6
SE				70.2	21.1	41.4

Appendix Table G-2.1. Continued.

Electrofishing period[a]	Electrofishing date	Electrofishing location[b]	Start time’	Effort (sec)[d]	Catch (no.)	CPUE (no. /h)[d]
4	25 Jun	0 4	0300	1,827	29	57.1
Subtotal				1,827	29	--
Mean				1,827.0	29.0	57.1
SE					--	--
1	22 Jun	TC	0506	99	7	254.5
2	23 Jun	TC	0315	231	9	140.3
2	22 Jun	TC	2215	407	33	291.9
3	24 Jun	TC	0325	449	13	104.2
3	23 Jun	TC	2205	250	14	201.6
4	25 Jun	TC	0200	319	12	135.4
4	24 Jun	TC	2200	513	24	168.4
Subtotal				2,268	112	
Mean				324.0	16.0	185.2
SE				54.1	3.5	25.7
1	22 Jun	W1	0315	1,806	84	167.4
2	23 Jun	W1	0238	1,531	132	310.4
2	22 Jun	W1	2058	1,443	57	142.2
3	24 Jun	W1	0202	1,896	68	129.1
3	23 Jun	W1	2058	1,492	11	26.5
4	25 Jun	W1	0200	1,800	78	156.0
4	24 Jun	W1	2100	931	5	19.3
5	27 Jun	W1	0150	1,802	74	147.8
5	26 Jun	W1	2057	1,930	28	52.2
6	27 Jun	W1	2315	1,808	35	69.7
Subtotal				16,439	572	
Mean				1,643.9	57.2	122.1
SE				96.2	12.2	27.3
1	22 Jun	w 2	0645	1,098	15	49.2
2	23 Jun	w 2	0405	1,060	13	44.2
2	22 Jun	w 2	2310	1,800	25	50.0
3	24 Jun	w 2	0413	1,038	7	24.3
3	23 Jun	w 2	2225	1,557	48	111.0
4	25 Jun	w 2	0341	1,265	13	37.0
4	24 Jun	w 2	2241	1,528	25	58.9
5	27 Jun	w 2	0145	1,629	18	39.8
5	26 Jun	w 2	2247	1,130	2	6.4
6	28 Jun	w 2	0245	1,578	24	54.8
6	27 Jun	w 2	2254	1,438	14	35.0
Subtotal				15,121	204	
Mean				1,374.6	18.5	46.4
SE				80.3	3.7	7.8

Appendix Table G-2.1. Continued.

Electrofishing period[a]	Electrofishing date	Electrofishing location[b]	Start time[c]	Effort (sec)[d]	Catch (no.)	CPUE (no. /h)[d]
1	22 Jun	w 3	0643	1,906	19	35.9
2	23 Jun	w 3	0020	1,167	23	71.0
2	23 Jun	w 3	0455	1,802	45	89.9
3	24 Jun	w 3	0445	1,631	63	139.1
3	23 Jun	w 3	2052	1,388	30	77.8
4	25 Jun	w 3	0001	621	5	29.0
4	25 Jun	w 3	0430	1,759	29	59.4
5	27 Jun	w 3	0232	2,311	9	14.0
5	26 Jun	w 3	2330	1,276	14	39.5
6	28 Jun	w 3	0350	1,169	29	89.3
6	27 Jun	w 3	2338	1,057	36	122.6
Subtotal				16,087	302	--
Mean				1,462.5	27.5	69.8
SE				142.5	5.0	11.8
Totals				96,506	2,866	
Mean				1,423.1	40.5	108.9
SE				181.6	8.7	18.1

[a] Sampling periods generally began at 2 100 h and terminated the following morning about 0900 h.
[b] Locations codes (two characters): TC = Tanner Creek transect; other Columbia River transects, where first character 0 = Oregon shoreline and W = Washington shoreline; second character, l-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.

Appendix Table G-2.2. Coded-wire tags from ingested juvenile salmon recovered in the stomachs of northern squawfish during electrofishing efforts, 1993.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
			Data for Tanner Creek release 21 June 1993			
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	4	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	9	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
1	22 Jun	0326	2000	19	01	233021
Subtotal						24
1	22 Jun	0506	2001	1	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	3	TC	233021
1	22 Jun	0506	2001	5	TC	233021
1	22 Jun	0506	2001	5	TC	233021
1	22 Jun	0506	2001	6	TC	233021
Subtotal						10
1	22 Jun	0408	2252	6	02	233021
1	22 Jun	0408	2252	6	02	233021
1	22 Jun	0408	2252	6	02	233021
1	22 Jun	0408	2252	7	02	233021
1	22 Jun	0408	2252	7	02	233021

Appendix Table G-2.2. Continued.

Electrofishing period[b]	Date	Start time'	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
1	22 Jun	0408	2252	7	0 2	233021
1	22 Jun	0408	2252	7	0 2	233021
1	22 Jun	0408	2252	8	0 2	233021
1	22 Jun	0408	2252	8	0 2	233021
1	22 Jun	0408	2252	8	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	9	0 2	233021
1	22 Jun	0408	2252	13	0 2	233021
1	22 Jun	0408	2252	13	0 2	233021
1	22 Jun	0408	2252	13	0 2	233021
1	22 Jun	0408	2252	16	0 2	233021
1	**22 Jun**	0408	2252	18	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	20	0 2	233021
1	22 Jun	0408	2252	21	0 2	233021
1	22 Jun	0408	2252	21	0 2	233021
1	22 Jun	0408	2252	23	0 2	233021
1	22 Jun	0408	2252	27	0 2	233021
1	22 Jun	0408	2252	27	0 2	233021
1	22 Jun	0408	2252	28	0 2	233021
1	22 Jun	0408	2252	28	0 2	233021
1	22 Jun	0408	2252	28	0 2	233021
1	22 Jun	0408	2252	31	0 2	233021
1	22 Jun	0408	2252	31	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	49	0 2	233021
1	22 Jun	0408	2252	50	0 2	233021
1	22 Jun	0408	2252	50	0 2	233021

Appendix Table G-2.2. Continued.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	50	O2	233021
1	22 Jun	0408	2252	52	O2	233021
1	22 Jun	0408	2252	52	O2	233021
1	22 Jun	0408	2252	52	O2	233021
1	22 Jun	0408	2252	54	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 fun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	**22 Jun**	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	22 Jun	0408	2252	55	O2	233021
1	**22 Jun**	0408	2252	55	O2	233021
1	**22 Jun**	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
1	22 Jun	0408	2252	58	O2	233021
Subtotal						80
Total period 1 (all sites)						114
2	22 Jun	2133	2011	22	O1	233021
2	22 Jun	2133	2011	23	O1	233021
Subtotal						2

Appendix Table G-2.2. Continued.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
2	22 Jun	2215	2012	22	TC	233021
2	22 Jun	2215	2012	22	TC	233021
2	22 Jun	2215	2012	27	TC	233021
2	22 Jun	2215	2012	27	TC	233021
2	22 Jun	2215	2012	27	TC	233021
2	23 Jun	0315	2016	6	TC	233021
Subtotal						6
2	22 Jun	2226	2262	6	0 2	233021
2	22 Jun	2226	2262	6	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	8	0 2	233021
2	22 Jun	2226	2262	29	0 2	233021
2	22 Jun	2226	2262	29	0 2	233021
2	22 Jun	2226	2262	29	0 2	233021
2	22 Jun	2226	2262	29	0 2	233021
2	22 Jun	2226	2262	112	0 2	233021
2	23 Jun	0335	2265	7	0 2	233021
2	23 Jun	0335	2265	7	0 2	233021
2	23 Jun	0335	2265	7	0 2	233021
2	23 Jun	0335	2265	7	0 2	233021
2	23 Jun	0335	2265	15	0 2	233021
2	23 Jun	0335	2265	16	0 2	233021
2	23 Jun	0335	2265	16	0 2	233021
2	23 Jun	0335	2265	16	0 2	233021
2	23 Jun	0335	2265	27	0 2	233021
2	23 Jun	0335	2265	27	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	50	0 2	233021
2	23 Jun	0335	2265	57	0 2	233021
2	23 Jun	0335	2265	63	0 2	233021
2	23 Jun	0335	2265	63	0 2	233021
2	23 Jun	0335	2265	63	0 2	233021
Subtotal						33

Appendix Table G-2.2. Continued.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
Total period 2 (all sites)						41
3	24 Jun	0208	2022	1	01	233021
3	24 Jun	0325	2023	5	TC	233021
Total period 3 (all sites-l each for 01 and TC)						2
Grand total this tag number all periods all sites.						157
Data for Midstream Columbia River release 21 June 1993						
1	22 Jun	0408	2252	13	0 2	233023
1	22 Jun	0408	2252	27	0 2	233023
2	22 Jun	2226	2262	8	0 2	233023
Grand total this tag number all periods all sites.					3	
Data for tagged non-study fish						
2	23 Jun	0216	2015	22	01	635003
2	23 Jun	0238	2264	42	W1	076135
2	23 Jun	0238	2264	3	W1	076137
2	23 Jun	0238	2264	108	W1	076137
3	23 Jun	2225	2020	3	w 2	076137
3	23 Jun	2225	2020	3	w 2	076332
4	25 Jun	0200	2280	43	W1	076332
Grand total non-study tags all periods all sites.					7	

[a] Individual specimens of northern squawfish are identified as a combination of collection number and predator number.
[b] Sampling periods generally began at 2100 h and terminated the following morning about 0900 h.
[c] Time that the electrofishing effort began.
[d] Location codes (two characters): TC = Tanner Creek transect; other Columbia River transects, where first character 0 = Oregon shoreline and W = Washington shoreline; second character, l-4, transects located progressively downstream (refer to Figure 3 for precise locations).
[e] CWT code key AG D1D2 = Agency code. Data I code, and Data 2 code.

APPENDIX G-3

Statistical Analysis of Juvenile Salmon Recovery Data

A. Chi-square goodness of fit analysis was used to evaluate differences among observed recoveries (Appendix Table G-1.3) 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_o: There was homogeneity between recovery distributions of treatments.

Release date	Seine type	Chi-sauare	df	P
21 June	purse plus beach	10.33	14	0.7377
25 June	purse plus beach	2.91	12	0.9962

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 preformed on purse-seine plus beach-seine recoveries (section la-lc) 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_{tc1} = true survival to and recovery at Jones Beach of fish released in Tanner Creek before squawfish removal on 21 June.
p_{tc1} = estimate of P_{tc1} = recovery proportion at Jones Beach of fish released at Tanner Creek on 21 June

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 21 June, before squawfish removal
2 denotes releases on 25 June, 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:

$$H_o: (P_{mc1} - P_{tc1}) = 0$$

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} = 626 ÷ 94,938 = 0.006594
p_{tc1} = 529 ÷ 96,013 = 0.005510

Then,

$$z = \frac{(0.006594 - 0.005510)}{\sqrt{\frac{0.006594(0.993406)}{94938} + \frac{0.005510(0.994490)}{96013}}}$$

$$= \frac{0.001084}{0.000355} = 3.053, \ \textbf{\textit{p-value}} = \textbf{\textit{0.0023}}$$

Conclusion: The recovery rate for midstream Columbia River-released fish was significantly higher than for Tanner Creek-released fish; the difference was 19.7 % .

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:

$$H_o: (P_{mc2} - P_{tc2}) = 0$$

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:

$p_{mc2} = 590 \div 97{,}835 = 0.006031$
$p_{tc2} = 588 \div 91{,}926 = 0.006396$

Then,

$$z = \frac{(0.006031 - 0.006396)}{\sqrt{\frac{0.006031(0.993969)}{97835} + \frac{0.006396(0.993604)}{91926}}}$$

$$= \frac{-0.000365}{0.000361} = -1.0111, \text{ \textit{p-value}} = 0.3120$$

Conclusion: The recovery rate for midstream Columbia River-released fish was not significantly higher than for Tanner Creek-released fish; the difference was -5.7%.

c) The null hypothesis for testing whether northern squawfish removal had a significant benefit for Tanner Creek-released fish was:

$$H_o: (P_{mc1} - P_{tc1}) - (P_{mc2} - P_{tc2}) = 0$$

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} = 626 ÷ 94,938 = 0.006594
P_{tc1} = 529 ÷ 96,013 = 0.005510
P_{mc2} = 590 ÷ 97,835 = 0.006031
P_{tc2} = 588 ÷ 91,926 = 0.006396

Then,

$$z = \frac{(0.006594 - 0.005510) - (0.006031 - 0.006396)}{\sqrt{\frac{0.006594(0.993406)}{94938} + \frac{0.005510(0.994490)}{96013} + \frac{0.006031(0.993969)}{97835} + \frac{0.006396(0.993604)}{91926}}}$$

$$= \frac{0.00145}{0.000505} = 2.871 \quad \textbf{\textit{p-value}} = 0.0041$$

Conclusion: The effect of removing northern squawfish from the migration route of Tanner Creek-released fish was significant; the reduction was 128.9% ((19.7% - (-5.7)% ÷ 19.7) * 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,: $(P_{mc1} - P_{tc1}) = 0$; $z = 3.028$; p-value = 0.0025

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:

$$H_o: (P_{mc2} - P_{tc2}) = 0; z = -1.0160; \text{p-value} = 0.3096$$

c) The null hypothesis for testing whether northern squawfish removal had a significant benefit for Tanner Creek-released fish was:

$$H_o: (P_{mc1} - P_{tc1}) - (P_{mc2} - P_{tc2}) = 0; z = 2.7510; \text{p-value} = 0.0059$$

VOLUME II. EVALUATION

Cooperators

Oregon Department of Fish and Wildlife
Research and Development Section

Oregon State University

EXECUTIVESUMMARY

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 larger than 250 mm fork length were exploited at a rate of 10-20%, 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 1993 -- a sport-reward fishery, a dam-angling fishery, and a trap-net fishery, to achieve a 10-20% exploitation rate on northern squawfish. We also began evaluating the response of northern squawfish populations to sustained fisheries. In addition, we gathered information regarding the economic, social, and legal feasibility of sustaining each fishery, and report on the structure and function of the fish collection and distribution system.

The evaluation team included the Oregon Department of Fish and Wildlife (ODFW) and Oregon State University (OSU). ODFW was the lead agency and subcontracted various tasks and activities to OSU based on expertise OSU brings to the evaluation. Objectives of each cooperator were as follows.

1. ODFW (Report H): Continue evaluation of test fisheries in the Columbia River Basin as they are implemented; develop approaches to evaluate relative benefits of the fisheries in terms of juvenile salmonid survival; begin evaluation of systemwide response of northern squawfish to sustained fisheries; and monitor movements of radio-tagged northern squawfish away from dams to test assumptions used in developing an index of northern squawfish abundance.

2. OSU (Report I): Oversee the collection, transportation, storage, and distribution of all northern squawfish removed during the 1993 fishing season; conduct baseline monitoring of dam-angling and sport-reward removal fisheries for northern squawfish; and conduct baseline monitoring of social, regulatory, and enforcement issues related to the predator control program.

Highlights of results of our work by report are as follows.

Report II
Development of a Systemwide Predator Control Program: Indexing and Fisheries Evaluation

1. Systemwide exploitation of northern squawfish was estimated to be 8.5% (all fisheries combined) in 1993. Exploitation was 6.8 % by the sport-reward fishery, 1.3 % by dam angling, and 0.5% by trapnetting. Mean fork length of northern squawfish caught by each fishery was greater than 250 mm. Dam angling was most selective for catching large northern squawfish (406 mm mean fork length). Incidental catch was highest in the trap-net fishery and consisted mostly of cyprinids other than northern squawfish.

2. Modeling results indicated that exploitation of northern squawfish in Snake River reservoirs had little effect on reducing overall predation. However, reducing exploitation in Snake River reservoirs notably increased predation on juvenile salmonids originating upstream from Lower Granite Dam. The goal of reducing overall predation by 50% may be reached by sustaining exploitation at 1991-93 levels. The sport-reward fishery has been two to four times more effective in reducing predation than the dam-angling fishery. However, because of differences in cost and areas fished, the two fisheries are complementary.

3. Proportional stock density, age composition, and sex ratio of northern squawfish populations in the lower Columbia River indicate that the proportion of large individuals has declined in most locations. However, relatively strong recruitment from 1988-90 has increased the proportion of young northern squawfish in most locations.

4. Radio-tagged northern squawfish were rarely found in deep, midchannel areas, supporting our hypothesis that these areas should be excluded when expanding catch indices to abundance indices.

Report I
Economic, Social, and Legal Feasibility of the 1993 Northern Squawfish Removal Fisheries and Fish Distribution System

1. The 1993 handling program was a considerable improvement over previous years; the design of the handling program satisfied all program requirements. An overall atmosphere of cooperation among agencies and fish-handling subcontractors was maintained throughout the season. It is feasible to operate a cost-effective, food-grade collection system in the area between Cascade Locks and The Dalles. At all other areas, the entire catch should be rendered.

2. Results from baseline monitoring of the sport-reward and dam-angling fisheries will be reported when expenditure data become available.

3. Social and regulatory issues associated with the removal fisheries have continued to improve. Enforcement of fishery regulations has been difficult due to large numbers of sport-reward participants, dispersal of registration sites, and difficulties of tracking fish origin. Regulations related to quality of northern squawfish continue to be only marginally enforceable.

REPORT H

Development of a Systemwide Predator Control Program: Indexing and Fisheries Evaluation

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1993 Annual Report

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ABSTRACT

We are reporting progress on evaluation of northern squawfish (*Ptychocheilus oregonensis*) predation and predator control fisheries performance in 1993. Our objectives in 1993 were to (1) evaluate effectiveness of fisheries for northern squawfish by comparing exploitation, size composition and incidental catch among fisheries; (2) develop approaches to compare relative benefits of fisheries in terms of reductions in predation; (3) evaluate changes in relative abundance, consumption, size and age structure, sex ratio, growth, and fecundity of northern squawfish in lower Columbia River reservoirs and Bonneville Dam tailrace; and (4) evaluate movement and distribution of northern squawfish using radiotelemetry.

Systemwide exploitation of northern squawfish in 1993 was 6.8% for sport reward, 1.3% for dam angling, 0.5% for trap nets. Size composition and incidental catch in sport-

reward and dam-angling fisheries was similar to previous years. Incidental catch was very high in the trap net fishery and the majority of northern squawfish harvested were <250 mm fork length.

We developed a spreadsheet to compare reductions in predation among various alternatives for implementation of sport-reward and dam-angling fisheries. Results indicated that exploitation of northern squawfish in Snake River reservoirs had little effect on reducing overall predation. However, reducing exploitation in Snake River reservoirs notably increased predation on juvenile salmonids originating upstream from Lower Granite Dam. The goal of reducing overall predation by 50% may be reached by sustaining exploitation at 1991-93 levels.

We used size-specific reported catch and exploitation of northern squawfish to compare reductions in predation between sport-reward and dam-angling fisheries in 1992 and 1993. Reductions in predation due to the sport-reward fishery ranged from 2.0 to 4.4 times those due to dam angling, depending on the year evaluated and the method used.

We estimated relative abundance and consumption of northern squawfish in Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. Relative abundance in 1993 was similar to or slightly less than in 1990, and relative consumption was considerably lower in 1993 than 1990 in most locations.

Proportional stock density, age composition, and sex ratio of northern squawfish populations in the lower Columbia River indicate that the proportion of large individuals has declined in most locations, particularly in Bonneville Reservoir, and increased in McNary Reservoir. Relatively strong recruitment from 1988-90 has increased the proportion of young northern squawfish in most locations.

Radio-tagged northern squawfish in Bonneville and The Dalles reservoirs were typically found in depths of less than 12 m. More than 80% of the tagged fish moved among different areas (forebay, midreservoir, tailrace, boat-restricted zone) in both reservoirs.

INTRODUCTION

The goal of the predator control program is to reduce in-reservoir mortality of juvenile salmonids to predation by northern squawfish (*Ptychocheilus oregonensis*). From 1990 through 1992, we estimated the relative magnitude of northern squawfish abundance, consumption, and predation in the Columbia River impoundments (1990), Snake River impoundments (1991), and the unimpounded lower Columbia River downstream from Bonneville Dam (1992). Those results established baseline levels of predation and described northern squawfish population characteristics throughout the lower basin before the implementation of sustained predator control fisheries. The 1993 field season represented the third or fourth consecutive year (depending upon area) of predator control fisheries. In this report we describe our activities and findings in 1993, and wherever possible, evaluate any changes from previous years.

Our objectives in 1993 were to (1) evaluate predator control fisheries throughout the lower Columbia River Basin by comparing exploitation, size composition, and incidental catch among fisheries; (2) develop approaches to compare relative benefits of fisheries in terms of losses of juvenile salmonids to predation relative to losses prior to any predator control fisheries; (3) evaluate changes through 1993 in northern squawfish populations, including relative abundance, consumption, size and age structure, sex ratio, growth, and fecundity; and (4) evaluate movement and distribution of radio-tagged northern squawfish outside boat-restricted zones in Bonneville and The Dalles reservoirs to evaluate assumptions associated with abundance indexing and exploitation.

METHODS

Fishery Evaluation

Field Procedures

Three predator control fisheries were conducted in 1993. The sport-reward fishery was implemented by the Washington Department of Wildlife (WDW) from May 3 through September 12 throughout the lower Columbia and Snake rivers. The dam-angling fishery was implemented by Columbia River Inter-Tribal Fish Commission (CRITFC) from May 17 through September 16 at Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose and Lower Granite dams. The trap-net fishery was implemented by Oregon Department of Fish and Wildlife (ODFW), Confederated Tribes of the Warm Springs Reservation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce Tribe from June 1 through August 3 downstream from Bonneville Dam and in Bonneville, The Dalles and John Day reservoirs.

We estimated exploitation of northern squawfish for each fishery based on recovery of fish tagged primarily before implementation of 1993 fisheries. We used electrofishing boats, bottom gill nets and surface gill nets to collect northern squawfish from March 1 to June 17. Sampling effort was randomly allocated in all river kilometers (RKm) from RKm 71 through McNary Reservoir on the lower Columbia River, and in the Snake River from RKm 0 through Lower Granite Reservoir. Fish greater than 225 mm fork length were tagged with a serially numbered spaghetti tag and given a secondary mark (left pelvic fin clip). Tags were recovered from each fishery from May 3 through September 16.

We measured fork lengths of northern squawfish from a subsample of fish harvested in sport-reward and dam-angling fisheries. Fish from each sport-reward check station were sampled at least one weekday per week and one weekend day per month. Fish from each dam were sampled at least one day per week. Fork lengths of fish harvested by the trap-net fishery were collected by ODFW trap-net implementation. Catch composition of each fishery was provided by WDW (sport reward), CRITFC (dam angling), and ODFW Implementation (trap net).

Data Analysis

We used mark and recapture data to compare exploitation rates of northern squawfish among fisheries and reservoirs (Appendix H-2). Exploitation was calculated for one-week periods during predator control fisheries and summed to yield total exploitation for each fishery (Beamesderfer et al. 1987). We adjusted exploitation estimates for tag loss (4.8%) during the season.

We compared mean fork lengths of northern squawfish, length frequency histograms, and incidental catch in 1993 among fisheries. We also compared mean fork lengths of fish harvested by sport-reward and dam-angling fisheries among years (1990-1993).

Relative Benefits of Fisheries

We used a spreadsheet model to compare benefits (reductions in predation by northern squawfish) among various combinations of sport-reward and dam-angling fisheries. Documentation for the “Loss Estimate Spreadsheet” is given in Appendix H-l.

We used age-specific reported catch and age-specific exploitation in 1992 and 1993 to compare reductions in predation due to sport-reward and dam-angling fisheries. For each fishery, we calculated the reduction in predation by each age of northern squawfish as the product of age-specific reported catch or exploitation and age-specific lifetime predation. We summed age-specific reductions to estimate total reduction in predation for each fishery, and determined the ratio of sport-reward to dam-angling reduction.

We used length-at-age analyses from 1990 through 1993 to estimate the age composition of the reported northern squawfish catch for both fisheries. We used Equations 1 through 4 in Appendix H-l to estimate age-specific exploitation for both fisheries. Because calculations using exploitation would give equal weight to each age regardless of age composition, we weighted age-specific exploitation rates by the relative abundance of each age. We used Equation 12 in Appendix H-l to estimate relative age-specific consumption rates for northern squawfish, and then estimated age-specific relative lifetime predation as

$$LC_h = RC_h + (RC_{h+1} \cdot S_{h+1}) + (RC_{h+2} \cdot S_{h+2}) + \cdots + (RC_{h+n} \cdot S_{h+n})$$

where

LC_h = relative lifetime consumption for age h northern squawfish,

RC_h = relative consumption for age h fish, and

S_{h+1} = survival rate of age h fish to age h + 1.

Relative benefits of the fisheries as estimated above depend only upon differences in age (size)-specific catch or exploitation between fisheries. Analysis of observed versus expected recaptures in sport-reward and dam-angling fisheries of northern squawfish tagged inside and outside boat restricted zones indicates that most tagged fish are vulnerable to both fisheries (Appendix Table H-l. 1). Because mixing is relatively complete, only size-related differences in consumption need be considered when evaluating relative benefits of the fisheries.

Biological Evaluation

Field Procedures

To evaluate changes in relative abundance and consumption, we used boat electrofishing, bottom gill nets, and surface gill nets to collect northern squawfish in the Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. Sampling schedules, methods, and gear specifications were as described in previous reports (Vigg et al. 1990; Ward et al. 1991; Parker et al. 1992). Effort in 1993 differed from previous years for two reasons. Abundance indices from 1990 through 1992 were calculated from pooled electrofishing catch and effort data gathered by ODFW and U.S. Fish and Wildlife Service (USFWS). In 1993, John Day Reservoir was the only area sampled by both ODFW and USFWS. As a result, the number of electrofishing runs completed in areas other than John Day Reservoir in 1993 averaged 36% fewer than in 1990. Additionally, high flows in May 1993 prevented sampling in the boat restricted zone (BRZ) of dam tailraces, reducing our total effort in BRZs by approximately 50%. We collected and preserved guts of all northern squawfish ≥250 mm fork length. Details of collection procedures are given in Petersen et al. (1991).

To evaluate changes in population structure, growth, and reproduction, we collected biological data from all northern squawfish collected by electrofishing and gill-net sampling, and from a subsample of northern squawfish caught in the sport-reward and dam-angling fisheries. We measured fork length (mm) and total body weight (g), we determined sex (male, female, undetermined) and maturity (undeveloped or immature, developing, ripe, or spent), and we collected scale samples and gonad samples (ripe females only).

Laboratory Procedures

We examined gut contents of northern squawfish collected by electrofishing to measure relative consumption rates of juvenile salmonids by northern squawfish. Details of laboratory methods are given in Petersen et al. (1991). We pooled ODFW and USFWS data to supplement gut sample size in John Day Reservoir.

We used gravimetric quantification (Bagenal 1968) to estimate fecundity of northern squawfish. Ripe ovaries were preserved in Gilson's solution 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. Only counts of developed eggs, characterized by their relatively large size and yellow or orange color, were used in estimating fecundity and describing fecundity relationships with body weight.

We used scale samples from northern squawfish collected primarily by electrofishing and gill-net sampling for age determinations. We supplemented sample sizes with scales from fish caught in predator control fisheries. For Bonneville Dam tailrace and Columbia River reservoirs, 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

We used the reciprocal of the square root of the proportion of zero catches as an index of northern squawfish density (Ward et al. 1992). In 1993, we were unable to calculate a density index for the tailrace BRZs of Bonneville, John Day, and Ice Harbor dams because the proportion of zero catches equaled zero. The next highest density index value we observed throughout all sampling areas in 1993 was 2.309 (Bonneville Dam tailrace non-restricted zone), which was rounded up to the next whole number (3.000) and assigned to the tailrace BRZs of Bonneville, John Day, and Ice Harbor dams. We assumed an index value of 3.000 was representative of high squawfish density in those areas during 1993. We compared density indices between 1990 and 1993 for all sampling areas in the Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. We calculated indices of northern squawtish abundance (Vigg et al. 1990; Ward et al. 1991; Parker et al. 1992), and compared indices between 1990 and 1993 for the lower Columbia River reservoirs and Bonneville Dam tailrace.

The following formula was developed as a consumption index (CI) by the USFWS (Petersen et al. 1991):

$$CI = 0.0209 \cdot T^{1.60} \cdot MW^{0.27} \cdot (S \cdot GW^{-0.61})$$

where

T = water temperature (°C),
MW = mean predator weight (g),
S = mean number of salmonids per predator, and
GW = mean gut weight (g) per predator.

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). We compared consumption indices between 1990 and 1993 in spring and summer for sampling areas in lower Columbia River reservoirs and Bonneville Dam tailrace.

We used ODFW electrofishing data to compare mean fork lengths and length frequency histograms (50 mm fork length increments) of northern squawfish between 1990 and 1993 for Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. We also compared sex ratio between 1990 and 1993 by summarizing the proportion of females by 50-mm fork length increments, and by calculating the proportion of females among fish $<$ and ≥ 350 mm fork length.

We determined backcalculated fork lengths at formation of annuli to develop age-at-length keys (Appendix H-3) for northern squawfish from Bonneville Dam tailrace, and the four lower Columbia River reservoirs in 1993. We pooled age-at-length data from 1990-93, applied the pooled keys to the size composition of northern squawtish in standardized electrofishing samples in each area, and compared age composition between 1990 and 1993.

After correcting the observed size distributions for bias associated with size selectivity of electrofishing gear (Beamesderfer and Rieman 1988), we calculated proportional stock density (PSD) for all lower Columbia River locations in all years for which standardized electrofishing catch data was available. We defined PSD for northern squawfish as:

$$PSD = \frac{\text{number of quality-sized fish}}{\text{number of stock-sized fish}} \cdot 100$$

We defined stock-size as $\geq$ age 4 in Bonneville, The Dalles, and John Day reservoirs, and $\geq$ age 5 in Bonneville Dam tailrace and McNary Reservoir. We defined quality-size as $\geq$ age 8 in Bonneville Reservoir, and $\geq$ age 9 in the remaining areas. We applied the pooled age-at-length keys to the observed size distribution in each year and area.

To evaluate changes in growth rate after implementation of the predator control program, we compared annual growth increments from 1987 to 1990 for northern squawfish of ages 6-l 1 in 1990 samples with growth increments from 1990 to 1993 for like-aged fish in

1993 samples. We limited analysis to fish of at least age 6 because most 6-year-old fish were "predator-size" (≥ 250mm). We excluded fish older than age 11 because growth increments for older fish were very small, and the accuracy and precision of age determination using scales typically declines for older-age fish. We compared growth for two areas — Bonneville Dam tailrace and the combined lower Columbia River reservoirs.

We calculated mean fecundity (number of developed eggs per female) and mean relative fecundity (number of developed eggs per gram of body weight) in 1991, 1992, and 1993 (fecundity data were not available for 1990) for two areas — Bonneville Dam tailrace and the combined lower Columbia River reservoirs. We determined regression parameters for the regression of log,, (fecundity) on log,,, (weight), and tested slopes for equality among years in each area. If slopes were equal, we used analysis of covariance with weight as the covariate to test for differences among years (a significant difference among slopes prohibited our testing for differences in fecundity among years). If fecundity was similar among years, we pooled data from all three years and calculated a single fecundity estimate.

We used age composition (based on pooled age-at-length keys) of electrofishing catches in successive catch years to calculate relative year-class strength of northern squawfish cohorts by methods described by El Zarka (1959). We plotted the index of relative year-class strength from 1.975 through 1990 for the Bonneville Dam tailrace, and Bonneville and John Day reservoirs based on catch years 1990-1993.

Radiotelemetry

Field Procedures

The USFWS surgically implanted transmitters (3 **V,** 149-150 MHz) in northern squawfish. Transmitters were digitally encoded with up to 13 codes per frequency. Fish were captured, tagged, and released from April 12, 1993, to May 16, 1993, primarily in the tailraces of John Day and The Dalles dams. Seventy-one northern squawfish (340-515 mm fork length) were tagged in The Dalles Reservoir, and 64 northern squawfish (359-550 mm fork length) were tagged in Bonneville Reservoir. In The Dalles Reservoir, 37 fish were released in John Day Dam tailrace BRZ, 28 were released in the tailrace outside the BRZ, and six were released at the mouth of the Deschutes River. In Bonneville Reservoir, 45 fish were released in The Dalles Dam tailrace BRZ, and 19 were released in the tailrace outside the BRZ.

We located tagged fish with a Lotek SRX1C400 receiver, and 3-element and 4-element Yagi antennas. From May through September, we mobile-tracked fish four days per week from a boat, and one day every two weeks from an airplane. Mobile-tracking by boat was conducted primarily outside the BRZs, whereas the USFWS tracked fish primarily from fixed stations within the BRZs. Flights were used to direct boat tracking efforts by identifying general locations of fish away from dams. Individual signals typically could not be decoded from the air. When fish were located during boat tracking, the receiver decoded the transmitters' signals permitting identification of individual fish. When unique signals were decoded, we recorded location (river kilometer to the nearest 0.16 km), distance to each shore (m), and depth (m).

Mobile tracking was conducted primarily during daylight hours, however, one day-per month from June through September, we tracked selected fish during crepuscular and nighttime hours to assess differences in distance to shore, depth, and general activity with time of day.

Data Analysis

We used radiotelemetry to answer two questions: (1) Do northern squawfish occupy areas that are both within 50 m of shore and less than 12.2 m deep?; and (2) Are fish tagged in tailrace restricted zones equally vulnerable to dam-angling and sport-reward fisheries, and conversely, are fish tagged outside boat restricted zones equally vulnerable to each fishery? The first question addresses our assumption that northern squawfish are primarily distributed in littoral zones within midreservoir areas. It tests whether our standardized sampling approach to index northern squawfish abundance was biased by concentrating our sampling efforts in littoral areas, and excluding deep, midchannel areas when indexing northern squawfish abundance in midreservoirs. Our approach was to determine depth and distance to shore of radio-tagged fish in midreservoir areas. Regarding the second question, our approach was to examine the extent of movement of radio-tagged fish among forebay, midreservoir, tailrace, and BRZ areas in each reservoir.

We summarized depth and distance to the nearest shore by reservoir to evaluate the extent to which squawfish utilize near-shore areas. We calculated mean depth and distance to shore, and calculated frequency distributions for depth (3.05-m intervals) and distance to shore (50-m intervals). We also plotted depth and distance to shore versus time for individual fish that were monitored for up to 16 hours in June, July, and August, and for up to 48 hours in September. These records of individual fish movements were used to illustrate any relationships between depth and location in the channel, and to evaluate any consistent patterns of movement associated with time of day.

To evaluate movement of tagged fish throughout reservoirs, we summarized fish locations (farthest area found from release areas) among reaches that corresponded to sampling areas used to index squawfish abundance and consumption. Reaches in river kilometers (RKm) and corresponding areas in Bonneville Reservoir are RKm 234.9-240.7 (forebay), RKm 240.7-302.5 (midreservoir), RKm 302.5-308.1 (tailrace non-restricted zone), and RKm 308.1-310.2 (tailrace restricted zone). Reaches in The Dalles Reservoir are RKm 308.9-316.2 (forebay), RKm 316.2-341.1 (midreservoir), RKm 341.1-347.9 (tailrace non-restricted zone), and RKm 347.9-348.5 (tailrace restricted zone).

RESULTS

Fishery Evaluation

We tagged and released 1,950 northern squawfish throughout the lower Columbia and Snake rivers. A total of 145 marked northern squawfish were recaptured in the three fisheries — 114 by sport-reward anglers, 23 by dam anglers, and 8 by trap-net fishers. Additionally, three tags were recovered during ODFW electrofishing and gill-net sampling, two were recovered by the National Marine Fisheries Service, and two were recovered by other sport anglers not participating in the sport-reward fishery.

Of the 152 marked fish recovered, 139 (91.4%) were recaptured within the reservoir they were originally tagged and released (Table H-l). Northern squawfish movement past dams differed among reservoirs and areas. Only 68.2% of the recaptured fish originally tagged in Bonneville Reservoir were recaptured in Bonneville Reservoir, whereas 100% of recaptured fish tagged in John Day, McNary, and Little Goose reservoirs were recaptured in the reservoir they were originally released.

Table H-l. Percentage of northern sguawfish tagged in a given reservoir recaptured in each reservoir by removal fisheries. DBD = downstream from Bonneville Dam, BON = Bonneville Reservoir, TDA = The Dalles Reservoir, JDY = John Day Reservoir, MCN = McNary Reservoir, ICH = Ice Harbor Reservoir, LMO = Lower Monumental Reservoir, LGO = Little Goose Reservoir and LGR = Lower Granite Reservoir.

Location marked	Number recaptured	Percent recaptured								
		DBD	BON	TDA	JDY	MCN	ICH	LMO	LGO	LGR
DBD	53	96.2	3.8	--	--	--	--	--	--	--
BON	22	13.6	68.2	18.2	--	--	--	--	--	--
TDA	8	12.5	--	87.5	--	--	--	--	--	--
JDY	13	--	--	--	100.0	--	--	--	--	--
MCN	23	--	--	--	--	100.0	--	--	--	--
ICH	0	--	--	--	--	--	--	--	--	--
LMO	5	--	--	--	--	--	--	80.0	--	20.0
LGO	4	--	--	--	--	--	--	--	100.0	--
LGR	17	--	--	--	--	--	--	--	11.8	88.2

The sport-reward fishery had the highest exploitation of northern squawfish among fisheries in nearly all areas in 1993 (Table H-2). Compared to exploitation rates in 1992, sport-reward exploitation was lower in 1993 than 1992 in all locations except The Dalles, McNary, and Lower Monumental reservoirs. Dam angling exploitation was lower in 1993 relative to 1992 in all areas where tags were recovered both years. No tagged fish were recaptured by dam angling in 1993 in the Bonneville Dam tailrace and The Dalles, Lower Monumental, and Lower Granite reservoirs. The trap-net fishery contributed relatively little to total exploitation below Bonneville Dam and in Bonneville Reservoir. No tagged fish were recovered in trap nets in The Dalles and John Day Reservoir. Reservoir-specific exploitation estimates are conservative because they exclude fish that were recaptured in reservoirs other than where marked, whereas systemwide exploitation estimates include northern squawfish caught in reservoirs other than those in which they were originally tagged. Total exploitation (all fisheries combined) of northern squawfish ≥250 mm during 1993 was 8.5 % , which was lower than in previous years (Table H-3). Reservoir-specific exploitation was lower in 1993 than 1992 in all locations except McNary Reservoir. There are no estimates of exploitation in Ice Harbor Reservoir in 1992 and 1993 because no northern squawfish were tagged.

As was the case in previous years, the sport-reward and dam-angling fisheries harvested a disproportional number of large northern squawfish (Figure H-l). Mean fork length was 335 mm in the sport-reward fishery and 406 mm in the dam-angling fishery. In contrast, the trap-net fishery harvested a wide size range of northern squawfish, with the majority (83.9%) of fish <250 mm. A representative sample of fork lengths was not obtained for small fish, and excluding fish < 250 mm fork length, the mean size of fish harvested in the trap-net fishery was 318 mm (N=493). If small fish had been measured, the mean fork length would be much lower.

Table H-2. Exploitation rates (%) of northern sguawfish ≥250 mm among fisheries in 1993.

Location	Sport reward	Dam angling	Trap net	Total
Downstream from Bonneville Dam	6.1	--	1.0	7.1
Bonneville	2.1	2.2	0.3	4.6
The Dalles	7.0	--	--	7.0
John Day	2.4	8.1	--	10.5
McNary	16.0	0.5	--	16.5
Ice Harbor	--	--	--	--
Lower Monumental	3.1	--	--	3.1
Little Goose	3.3	3.3	--	6.6
Lower Granite	12.6	--	--	12.6
Systemwide	6.8	1.3	0.5	8.5

Table H-3. -Total exploitation rates (all fisheries combined) of northern aquawfish 2250 mm in 1991, 1992 and 1993.

Location	1991	1992	1993
Downstream from			
Bonneville Dam	8.1	11.8	7.1
Bonneville	15.2	6.8	4.6
The Dalles	10.5	7.2	7.0
John Day	13.3	14.3	10.5
McNary	5.2	5.6	16.5
Ice Harbor	17.5	--	
Lower Monumental	27.0	7.7	3.1
Little Goose	18.4	18.1	6.6
Lower Granite	16.8	14.6	12.6
Systemwide	11.3	12.2	8.5

Mean size of northern squawfish harvested in each reservoir by dam angling in 1993 was generally within the range for previous years (Table H-4). The significance of apparent increases in size in 1993 in McNary, Ice Harbor, and Lower Monumental reservoirs is uncertain because mean fork lengths in 1993 were based on relatively small sample sizes. The size of fish harvested in 1993 by sport-reward anglers declined downstream from Bonneville Dam and in Bonneville Reservoir, but did not change appreciably in other Columbia River reservoirs (Table H-4). The size of fish harvested in 1993 appeared to differ from previous years in Snake River reservoirs, but sampling was limited in the Snake River in 1993.

Incidental catch varied among fisheries (Table H-5). Relative to the total number of fish caught, the sport-reward fishery had the lowest percentage (1.8 %) of incidental catch. Dam-angling incidental catch was also relatively low (5.7%) and consisted mostly of smallmouth bass (*Micropterus dolomieui*) and channel cattish *Ictalurus punctatus*. Incidental catch in the trap-net fishery was 77.0%, and included 2,511 adult and juvenile anadromous salmonids. The proportion of predator-size northern squawfish (≥ 250 mm fork length) relative to total number of squawfish harvested was very low (16.1%) in the trap-net fishery. In contrast, predator-sized fish comprised 93.1% of northern squawfish harvested by sport-reward anglers and 99.0% of northern squawfish harvested by dam anglers.

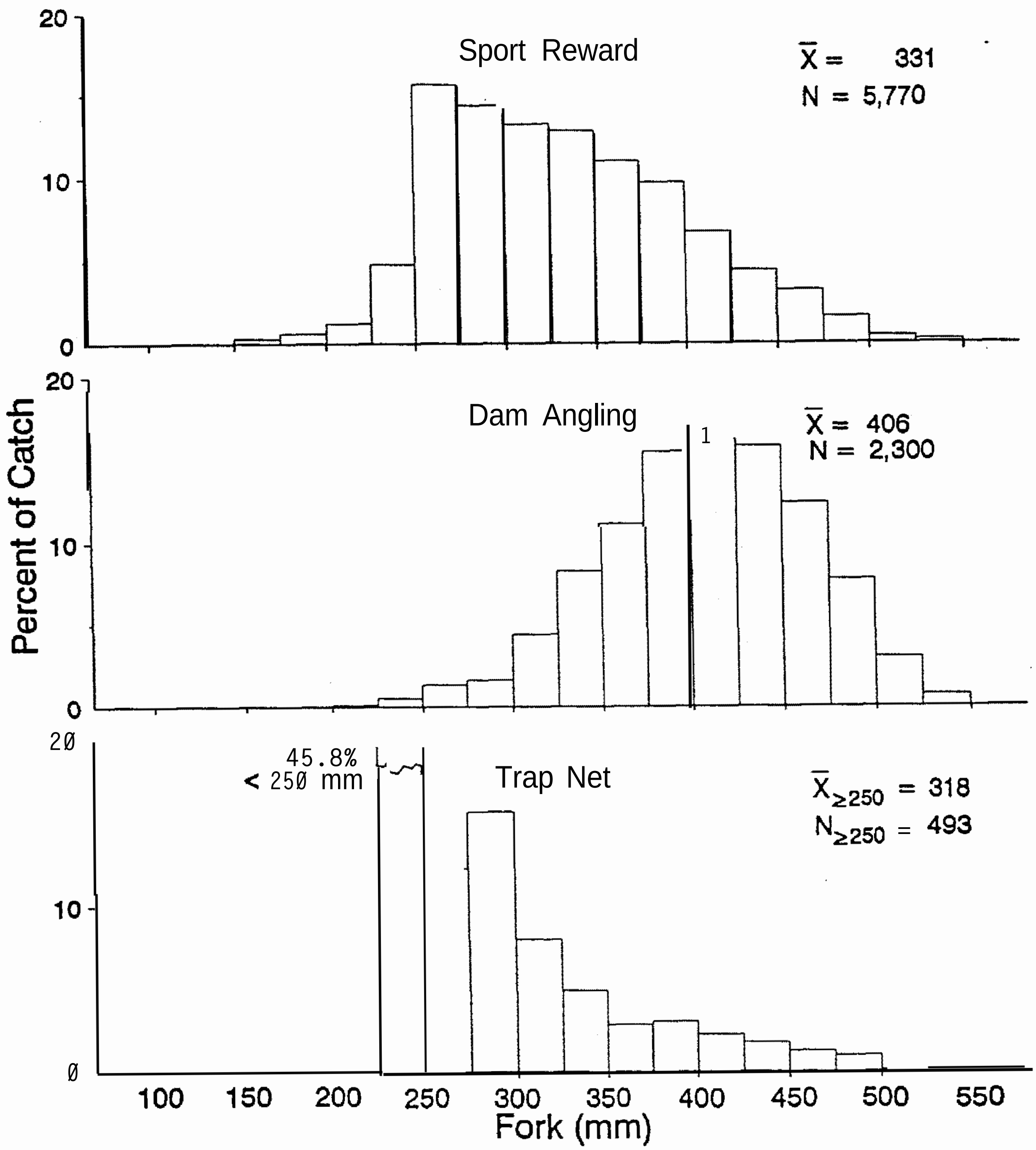

Figure H-1. Size composition and mean fork length of northern squawfish in subsamples of fish harvested system-wide in sport-reward, dam-angling, and trap net fisheries in 1993. N = subsample size.

Table H-4.. Mean fork length (mm) of northern squawfish harvested from 1990 through 1993 in each fishery downstream from Bonneville Dam (DBD), and in each lower Columbia River and lower Snake River reservoir.

Fishery: location	Mean fork length (mm)			
	1990	1991	1992	-1993
Dam angling:				
Bonneville Dam Tailrace	414	417	388	390
Bonneville Reservoir	407	417	416	415
The Dalles Reservoir	421	404	380	420
John Day Reservoir	416	414	417	416
McNary Reservoir	393	393	375	408
Ice Harbor Reservoir	--	375	369	414
Lower Monumental Reservoir	--	325	309	341
Little Goose Reservoir	--	380	346	373
Lower Granite Reservoir	--	--	--	377
Sport reward:				
Downstream from Bonneville Dam	--	332	337	316
Bonneville Reservoir	--	343	347	312
The Dalles Reservoir	--	344	369	369
John Day Reservoir	377	370	367	370
McNary Reservoir	--	354	356	358
Ice Harbor Reservoir	--	357	360	317
Lower Monumental Reservoir	--	338	330	307
Little Goose Reservoir	--	312	347	344
Lower Granite Reservoir	--	343	345	362

Table H-5.. Number of northern sguawfish and incidentally caught fish by species or family in each fishery in 1993.

Species or family	Sport reward	Dam angling	Trap net
Northern sguawfish:			
≥ 250 mm fork length	104,506	17,210	1,684
< 250 mm fork length	7,786	170	8,754
Channel catfish	202	366	74
Smallmouth bass	493	394	45
Walleye'	121	32	13
White sturgeon[a]	11	138	8
American shad' (adult)	28	57	1,500
Salmonidae':			
Chinook (adult)	5	0	36
Chinook (juvenile	0		2
Sockeye (adult)	0	00	319
Coho (adult)	1	0	0
Steelhead (adult)	23	1	657
Steelhead (juvenile)	9	3	71
Unknown (adult)	0	2	26
Unknown (juvenile)	0	0	1,400
Catostomidae[b]idae[b]	1,105 80	::	23,724 2,650
Other	65	49	4,308
Total (all species)	114,385	18,422	45,298

[a] Walleye = *Stizostedion vitreum vitreum*, white sturgeon = *Acipenser transmontanus*, american shad = Alosa *sapidissima*, salmonids = *Oncorhynchus* spp.

[b] All "non-game" fish caught by dam-angling are classified as "Other."

Relative Benefits of Fisheries

Eventual reductions in predation vary depending on in which reservoirs fisheries are implemented (Table H-6). The number of years required to reach maximum annual benefit also varies. The goal of reducing predation by 50% appears possible if systemwide exploitation is sustained at 1991-93 levels. Eliminating exploitation in Snake River reservoirs will have little effect on overall predation. However, eliminating exploitation in Snake River reservoirs will notably increase predation on juvenile salmonids originating upstream from Lower Granite Dam.

The sport-reward fishery has had more effect on reducing predation than dam angling (Table H-7). Estimates of sport-reward benefits in 1992 were highest when using reported catch. However, sport-reward catch may include fish caught outside program boundaries. This is reflected by differences in ratios between reported catch and exploitation rate.

Biological Evaluation

Density (Table H-8) and relative abundance (Figure H-2) of northern squawfish ≥250 mm in John Day Reservoir were nearly identical between 1993 and 1990. The percent change from 1990 to 1993 in abundance indices for other areas ranged from -36.1% in Bonneville Reservoir to + 16.7% in Bonneville Dam tailrace.

Northern squawfish consumption indices in 1993 were lower in most sampling areas than in 1990, particularly in summer (Table H-9), which translated into lower indices of predation in 1993 (Figure H-3). The percent change from 1990 to 1993 in predation indices during spring was -37.6% for Bonneville Dam tailrace, -75.4% for Bonneville Reservoir, -35.0% for The Dalles Reservoir, +14.9% for John Day Reservoir, and -90.5% for McNary Reservoir. The change in predation indices during summer was -42.3% for Bonneville Dam tailrace, -82.3% for Bonneville Reservoir, -96.2% for The Dalles Reservoir, -54.5% for John Day Reservoir, and -49.2% for McNary Reservoir. Combining spring and summer predation indices, predation in 1993 was 40-50% lower than in 1990 in Bonneville Dam tailrace, and John Day and McNary reservoirs, and an order of magnitude lower in Bonneville and The Dalles reservoirs.

Table H-6.. Comparison of predicted annual losses of juvenile salmonids (expressed as percent of loss prior to exploitation of northern sguawfish) to northern sguawfish predation among various alternatives for distribution of fishing effort. Exploitation rates in each reservoir beyond 1993 were assumed to equal the mean 1991-93 rate (from Table H-3). Reservoirs are: l-Downstream from Bonneville Dam, 2-Bonneville, 3-The Dalles, 4-John Day, 5-McNary, 6-Ice Harbor, 7-Lower Monumental, 8-Little Goose, and 9-Lower Granite.

	Reservoirs fished		Overall predation		Predation on fish originating upstream from Lower Granite Dam	
Fisheries alternative	Sport reward	Dam angling	% of pre-exploitation	Year reached	% of pre-exploitation	Year reached
1	l-9	1-8	50	2004	45	2001
2	1-5,8,9	1-4,7,8	52	2000	50	1999
3	1-5	l-5	55	1998	84	2004
4	1-5	1-4	55	1999	84	2004
5	1-4	1-4	61	2002	84	2004
6	1-4	1,4	63	2002	84	2004
7	1,2,4	1,4	65	2004	84	2004
8	1,2	1,4	67	2004	84	2004
9	1,4	1,4	71	2002	84	2004
10	1,8,9	1,7,8	76	2003	51	1998
11	1	1	80			
12	8,9	7,8	96	2004 2003	84 69	2003 2003

Table H-7. Ratio of sport-reward fishery to dam-angling fishery for reported catch, estimated exploitation rate, and reduction in losses of juvenile salmonids to northern sguawfish predation.

			Reduction in predation	
Year	Reported catch	Exploitation rate	Based on age-specific reported catch	Based on age-specific exploitation
1992	6.7-1.0	3.5-1.0	4.4-1.0	2.0-1.0
1993	6.1-1.0	5.1-1.0	3.1-1.0	3.1-1.0

Table H-8.- Indices of northern sguawfish density in 1990 and 1993 for sampling zones within Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. (N) = number of electrofishing runs. BRZ = boat restricted zone.

Location, zone	Density index (N) 1990	Density index (N) 1993
Bonneville Dam tailrace		
Dam tailrace		
Tailrace	1.732 (27)	2.309 (16)
Tailrace BRZ	3.464 (12)	3.000 (9)
Bonneville Reservoir		
Forebay	4.847 (47)	1.414 (32)
Mid-reservoir	1.961 (50)	1.414 (28)
Tailrace	1.609 (37)	1.387 (25)
Tailrace BRZ	3.250 (13)	1.225 (6)
The Dalles Reservoir		
Forebay	[illegible] (62)	1.434 (37)
Mid-reservoir	[illegible] (34)	1.233 (38)
Tailrace	2.812 (45)	1.271 (21)
Tailrace BRZ	3.317 (11)	3.000 (5)
John Day Reservoir		
Forebay	1.183 (56)	1.254 (44)
Mid-reservoir	1.116 (61)	1.078 (43)
Tailrace	1.275 (39)	1.217 (37)
Tailrace BRZ	1.789 (16)	1.732 (9)
McNary Reservoir		
Forebay	[illegible] (64)	1.032 (33)
Mid-reservoir	[illegible] (60)	1.036 (29)
Tailrace	[illegible] (38)	1.195 (30)
Tailrace BRZ	[illegible] (14)	3.000 (5)
Upper-reservoir	1.279 (54)	1.128 (42)

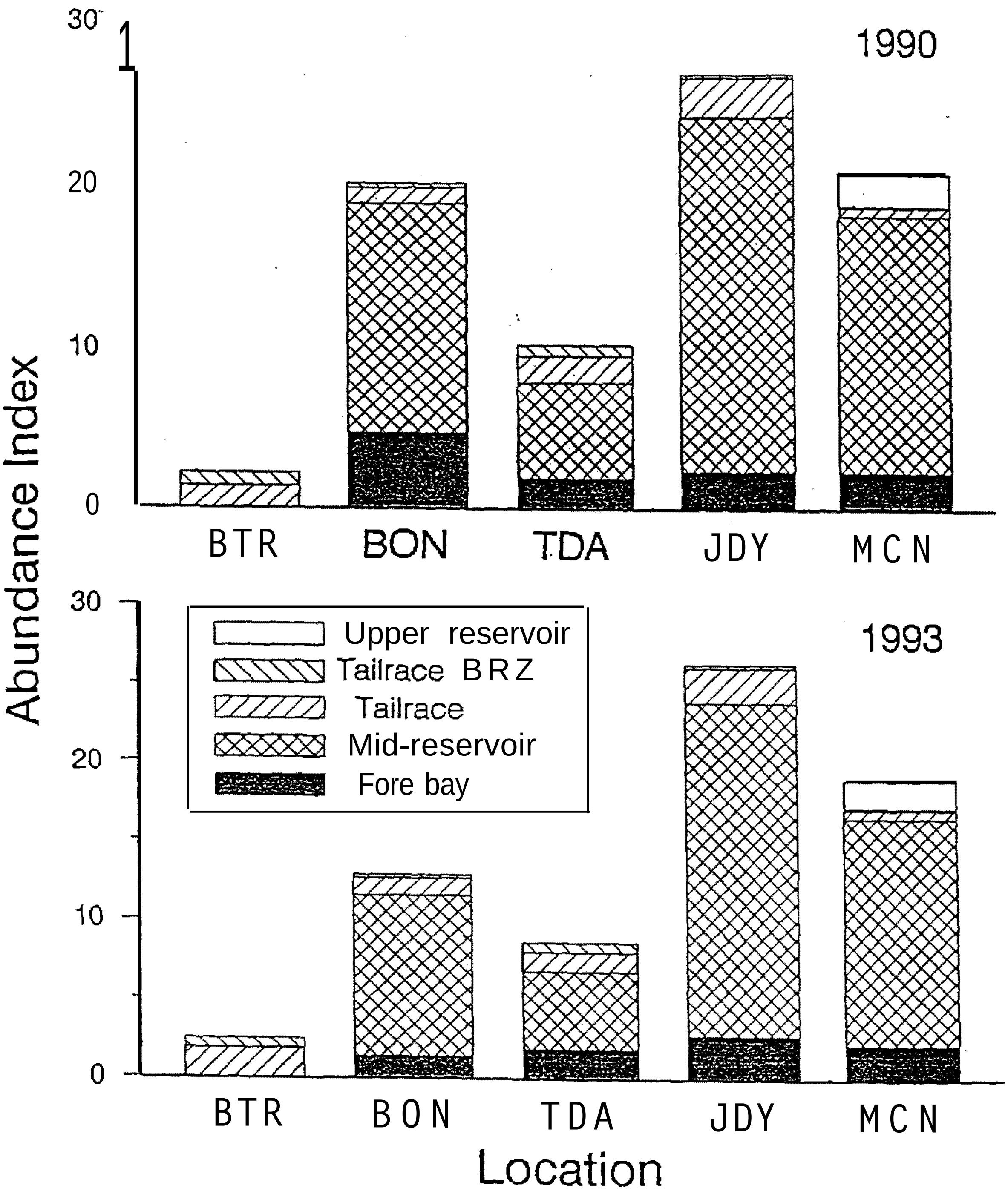

Figure H-2. Index of northern squawfish abundance in 1990 and 1993 in Bonneville Dam **tailrace (BTR),** and Bonneville (BON), The Dalles (TDA), John Day (JDY), and **McNary** (MCN) reservoirs,

Table H-9. . Indices of northern squawfish consumption of juvenile salmonids in 1990 and 1993 in sampling zones within Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. BRZ = boat restricted zone. N = the number of northern eguawfieh digestive tracts examined.

	Consumption index (N)							
	1990				1993			
Location, zone	Spring		Summer		Spring		Summer	
Bonneville Dam tailrace								
Dam tailrace								
Tailrace	1.2	(61)	0.5	(45)	0.8	(74)	1.2	(81)
Tailrace BRZ	2.7	(86)	5.5	(109)	1.1	(64)	1.0	(61)
Bonneville Reservoir								
Forebay	0.6	(153)	1.8	(139)	0.7	(20)	0.5	(95)
Mid-reservoir	0.0	(39)	0.0	(42)	0.0	(14)	0.0	(31)
Tailrace	0.3	(7)	0.0	(4)	0.0	(18)	0.0	(14)
Tailrace BRZ	2.3	(41)	0.8	(61)	--		1.0	(23)
The Dallee Reservoir								
Forebay	0.8	(38)	1.0	(50)	0.1	(19)	0.0	(28)
Mid-reservoir	0.0	(15)	0.1	(46)	0.4 0.0	(12)	0.0	(13)
Tailrace	0.7	(27)	0.0			(8)	0.0	(9)
Tailrace BRZ	0.9	(50)	6.4	(50)	0.0	(1)	0.5	(117)
John Day Reservoir				)				
Forebay	1.5	(38)	2.4	(16)	0.0 1.5	(11)	0.6	(40)
Mid-reservoir	0.0	(6)	0.9	(7		(2)	0.6	(10)
Tailrace	1.5	(17)	2.6	(25)	2.0	(15)	0.0	(8)
Tailrace BRZ	2.5	(60)	11.7	(50)	--		0.6	(119)
McNary Reservoir								
Forebay	1.3	(24)	2.4	(9)	0.0	(1)	8.6	(3)
						(1)	0.0	(1)
Tailrace / Mid-reservoir	0.1 -	(9)	1.8 / 0.6	(13 / 14)	0.0 / 0.6	(2)	0.0	(21)
Tailrace BRZ	2.4	(14)	0.9	(79)	--		0.0	(27)
Upper-reservoir	1.5	(33)	1.5	(36)	0.2	(15)	0.0	(1)

Size composition of northern squawfish in standardized electrofishing samples was quite different between 1990 and 1993 (Figure H-4, H-5, and H-6). Mean fork length in 1993 was lower than 1990 in all locations except McNary Reservoir. Mean fork length decreased by more than 50 mm in the Bonneville Dam tailrace and The Dalles reservoir, and by nearly 100 mm in Bonneville Reservoir, primarily due to an increase in the proportion of northern squawfish < 250mm. Mean fork length in John Day Reservoir was only 16 mm lower in 1993 than 1990.

Northern squawfish < 250 mm were primarily of undetermined sex, whereas fish > 400 mm were nearly all females (Figure H-4 through H-6). Sex ratio differed in most locations between 1990 and 1993 (Table H-10). The percent of female northern squawfish in electrofishing catches declined in 1993 in Bonneville Dam tailrace and Bonneville Reservoir, primarily due to a decline in the percent of females among fish *c* 350 mm fork length. In contrast, the percent of females was similar or increased in The Dalles, John Day, and McNary reservoirs. The < 350 mm fork length category excludes most small (<200 mm) fish because their gonads were typically immature and we could not determine their sex (Figures H-4 through H-6).

Proportional stock density (PSD) differed among years and locations (Table H-11). Proportional stock density was lower in 1993 than 1990 in all areas except McNary Reservoir. The proportion of large fish fluctuated widely from 1990 to 1993 in the Bonneville Dam tailrace and Bonneville Reservoir, whereas the range of PSD estimates was narrower in John Day Reservoir. Differences in PSD between 1990 and 1993 were consistent with differences in mean fork length (Figures H-4, H-5, and H-6), even though PSD estimates excluded fish <250mm fork length.

Age composition of northern squawfish differed between years and among locations (Figures H-7, H-8, and H-9). The proportion of fish younger than age 5 was considerably higher in 1993 than 1990 in the Bonneville Dam tailrace, and Bonneville and The Dalles reservoirs, and to a lesser extent in John Day Reservoir, whereas the proportion of young fish was similar between years in McNary Reservoir.

Growth of northern squawfish from ages 6-11 has not increased since the implementation of predator control fisheries (Figure H-10 and H-11). Annual growth increments from 1990 to 1993 were generally similar to (Bonneville Dam tailrace) or less than (Columbia River reservoirs) increments for like-aged fish from 1987 to 1990.

The pattern of variation in year-class strength of northern squawfish was similar in Bonneville Dam tailrace, and Bonneville and John Day reservoirs (Figure H-12). The magnitude of variation was smaller in John Day Reservoir than in Bonneville Dam tailrace and Bonneville Reservoir. In general, year-class strength declined from 1980 to 1987, and increased in the years since 1987.

Fecundity of northern squawfish has not changed appreciably from 1991 through 1993 (Table H-12). Slopes for the regression of $\log_{10}$(fecundity) on $\log_{10}$(body weight) were similar among years ($P=0.09$) for northern squawfish in the Bonneville Dam tailrace. Analysis of covariance revealed no difference ($P=0.26$) in fecundity (adjusted for any differences in weight) among years. The estimate (pooled among years) of fecundity for fish in Bonneville Dam tailrace was 30,396. Slopes for the regression of $\log_{10}$(fecundity) on log&body weight) for the Columbia River reservoirs were different ($P=0.05$), therefore, we could not use analysis of covariance to test for differences among years and could not pool data from 1991-1993. Mean fecundity was very similar in 1991, 1992, and 1993.

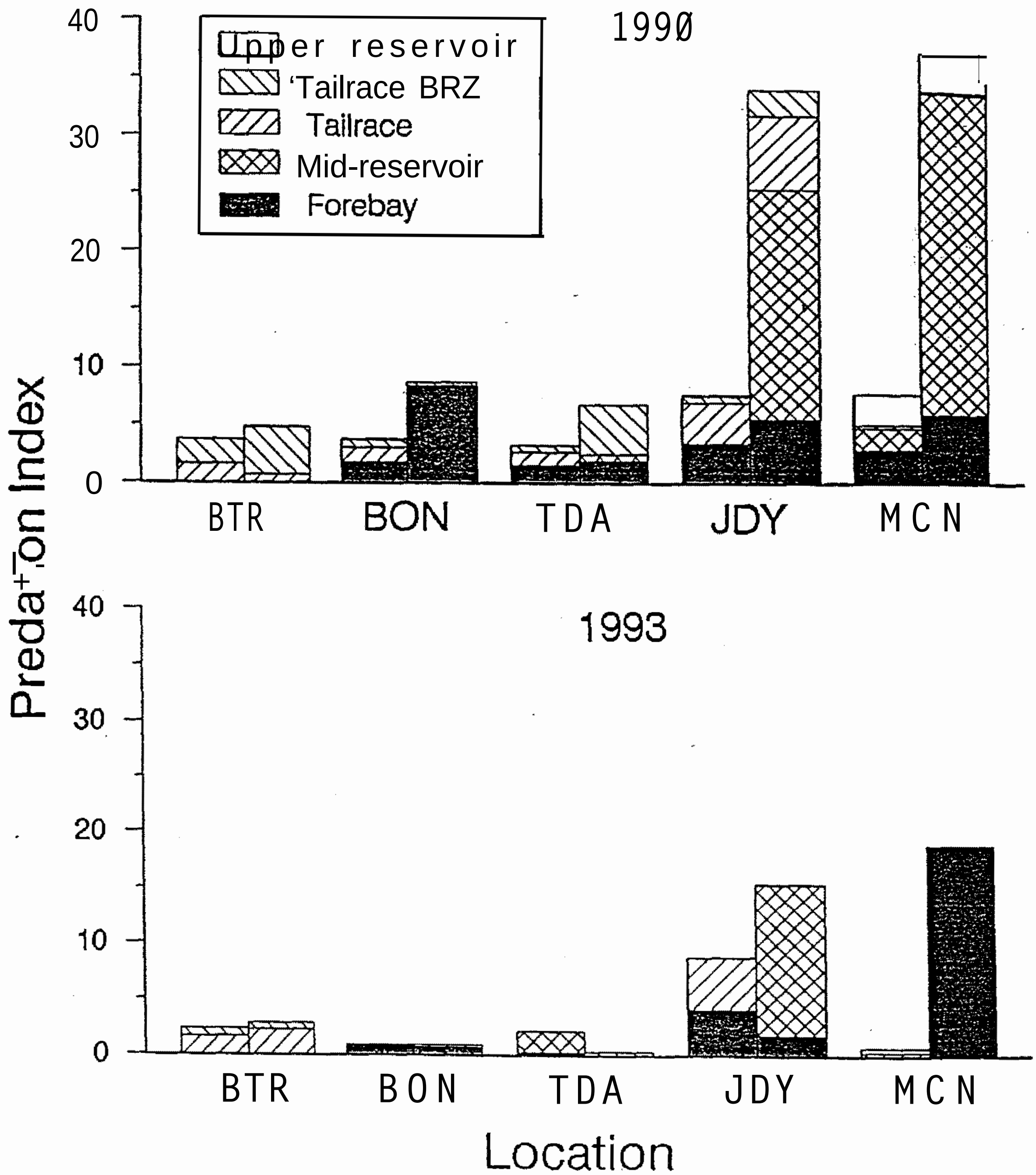

Figure H-3. Index of northern squawfish predation in 1990 and 1993 in Bonneville Dam tailrace (BTR), and Bonneville (BON), The Dalles (TDA), John Day (JOY), and McNary (MCN) reservoirs. The bar on the left represents spring and the bar on the right represents summer.

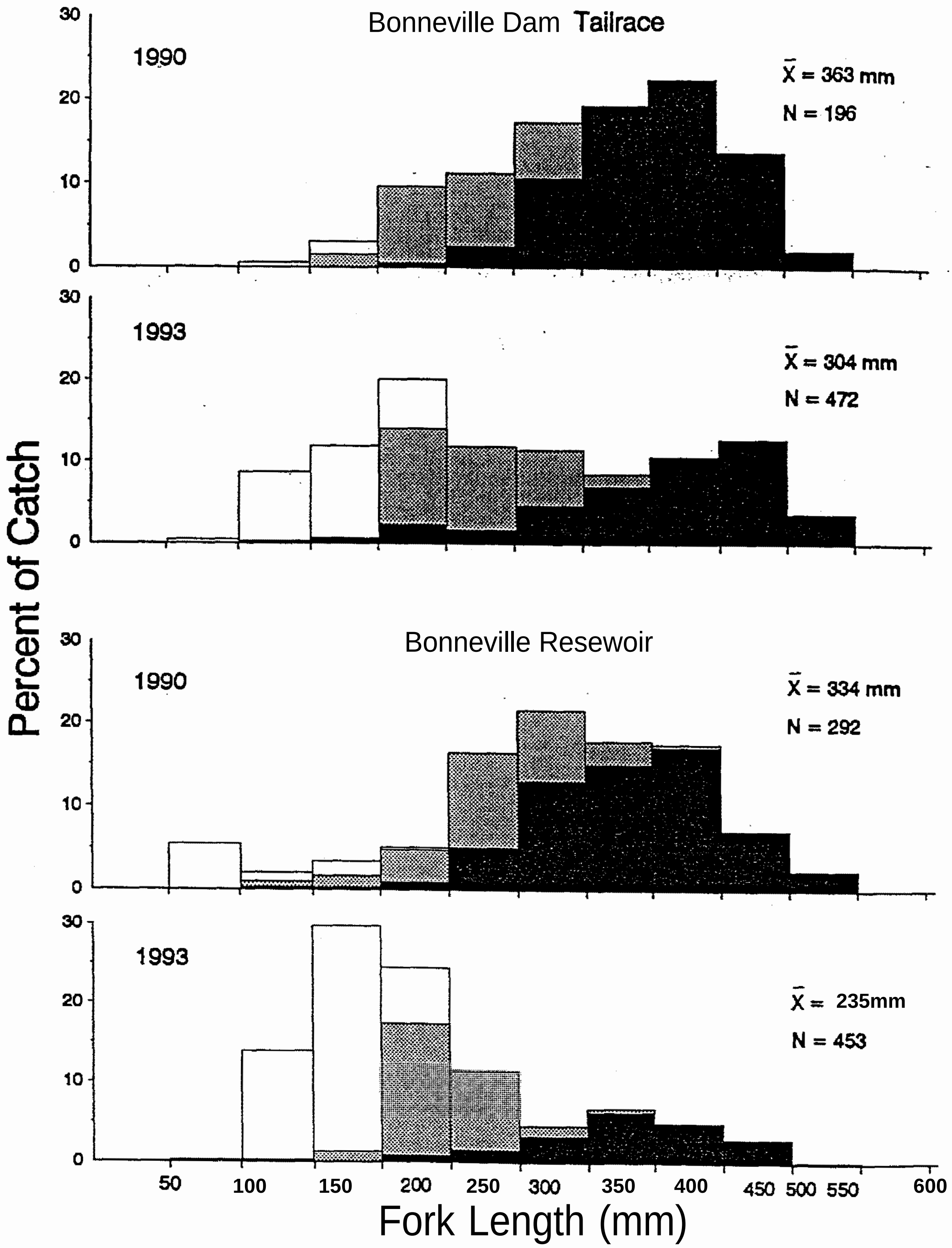

Figure H-4. Size and sex composition of northern squawfish in electrofishing samples from Bonneville Dam tailrace and Bonneville Reservoir in 1990 and 1993. Unshaded portion of bars is undetermined sex, stippled portion is males, and darkened portion is females.

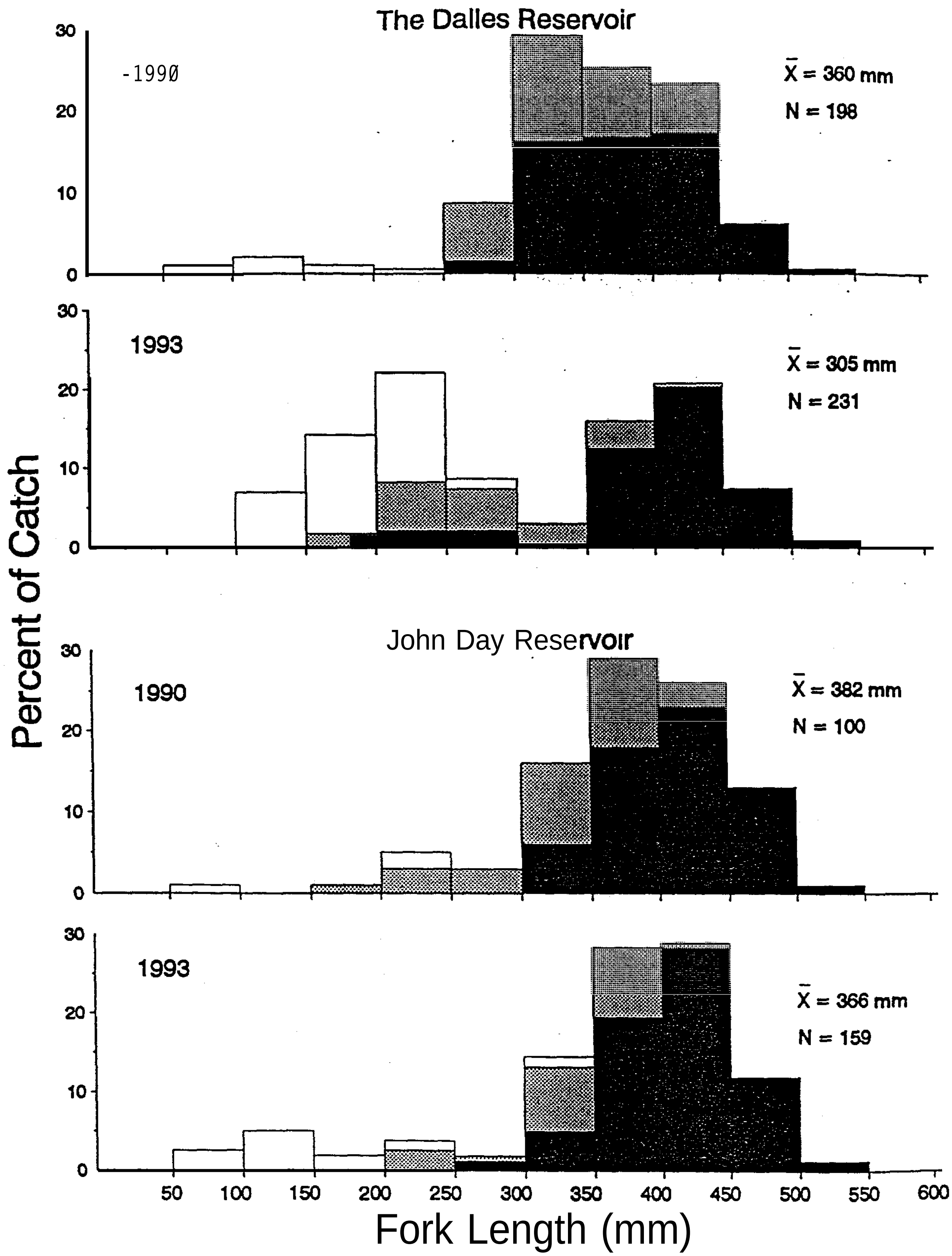

Figure H-5. Size and sex composition of northern squawfish in electrofishing samples from The Dalles and John Day reservoirs in 1990 and 1993. Unshaded portion of bars is undetermined sex, stippled portion is males, and darkened portion is females.

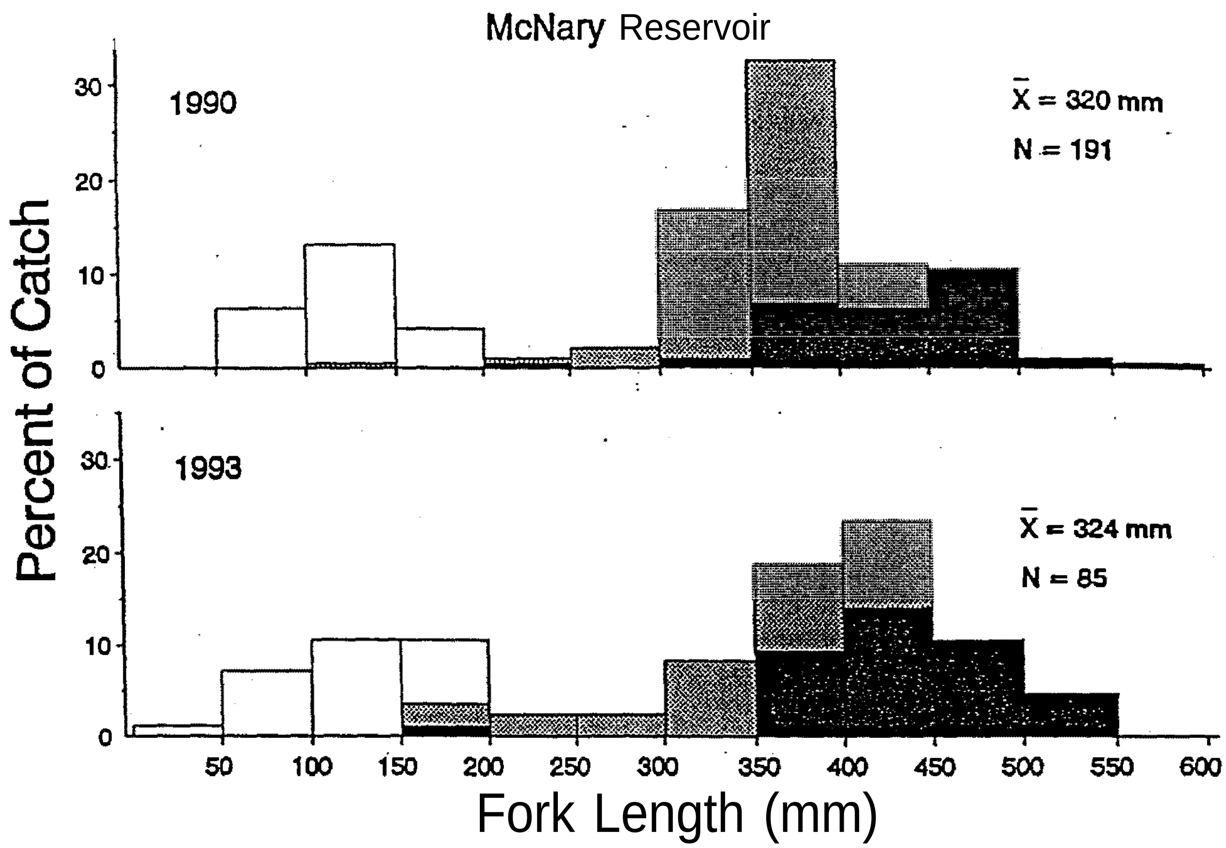

Figure H-6. Size and sex composition of northern squawfish in electrofishing samples from McNary Reservoir in 1990 and 1993. Unshaded portion of bars is undetermined sex, stippled portion is males, and darkened portion is females.

Table H-10. Percent of female northern sguawfish in electrofishing samples from Bonneville Dam tailrace and lower Columbia River reservoirs in 1990 and 1993.

	Percent females					
	<350 mm		≥350 mm		All sizes	
Location	1990	1993	1990	1993	1990	1993
Bonneville Dam tailrace	33.8	23.6	99.1	95.3	72.9	58.5
Bonneville Reservoir	43.6	15.8	93.1	97.1	68.2	40.8
The Dalles Reservoir	44.3	23.4	73.7	91.3	62.5	70.2
John Day Reservoir	27.3	38.5	78.6	85.1	66.3	76.4
McNary Reservoir	7.9	7.7	44.9	66.0	35.2	54.0

Table H-11. Proportional stock density (PSD) of northern sguawfish in electrofishing samples from Bonneville Dam tailrace and lower Columbia River reservoirs from 1990 to 1993.

Location	1990	1991	1992	1993
Bonneville Dam tailrace	30	42	28	22
Bonneville Reservoir	29	49	38	10
The Dalles Reservoir	28	--	--	18
John Day Reservoir	51	49	48	41
McNary Reservoir	41	--	--	59

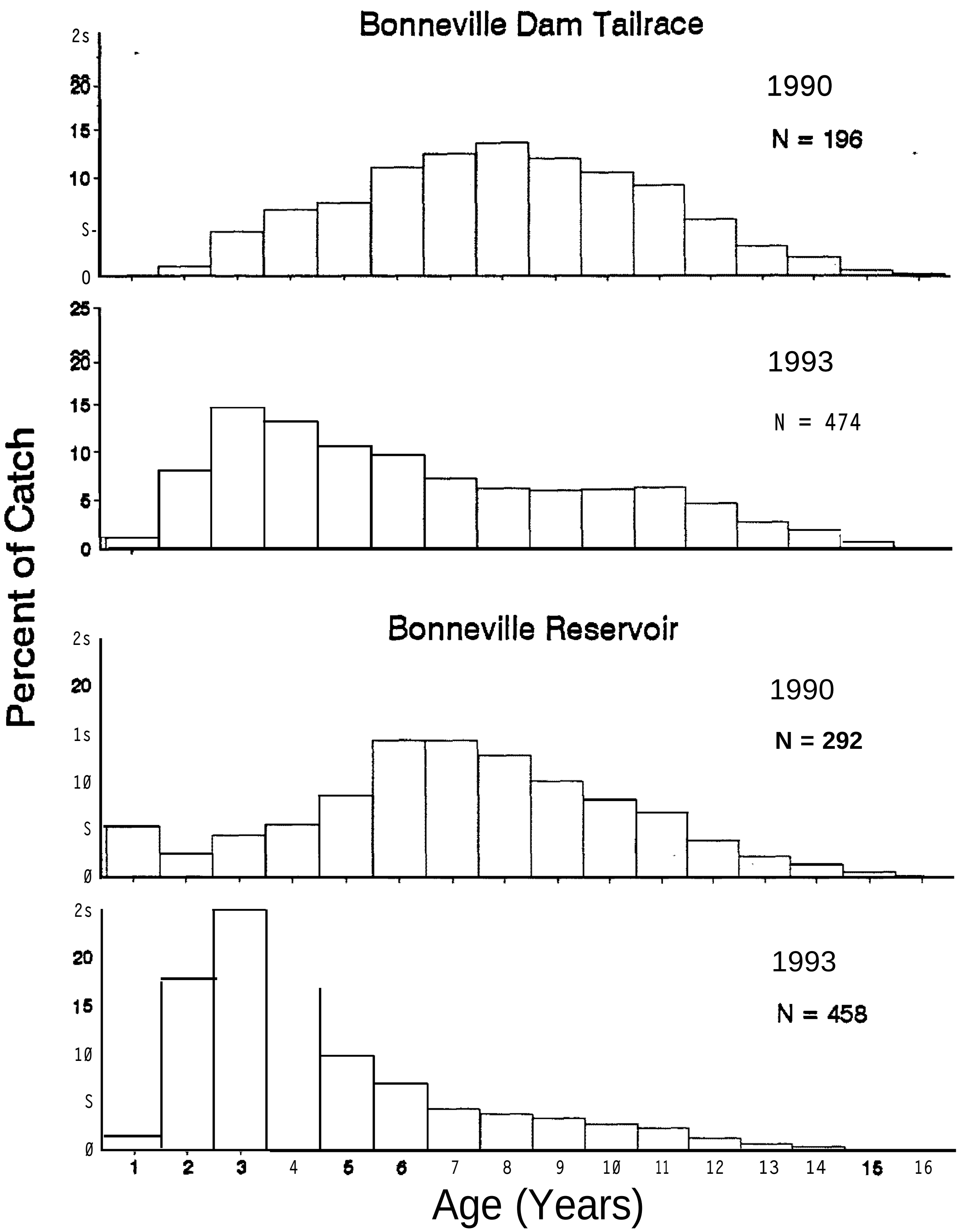

Figure H-7. Age composition in Bonneville Dam tailrace and Bonneville Reservoir in 1990 and 1993.

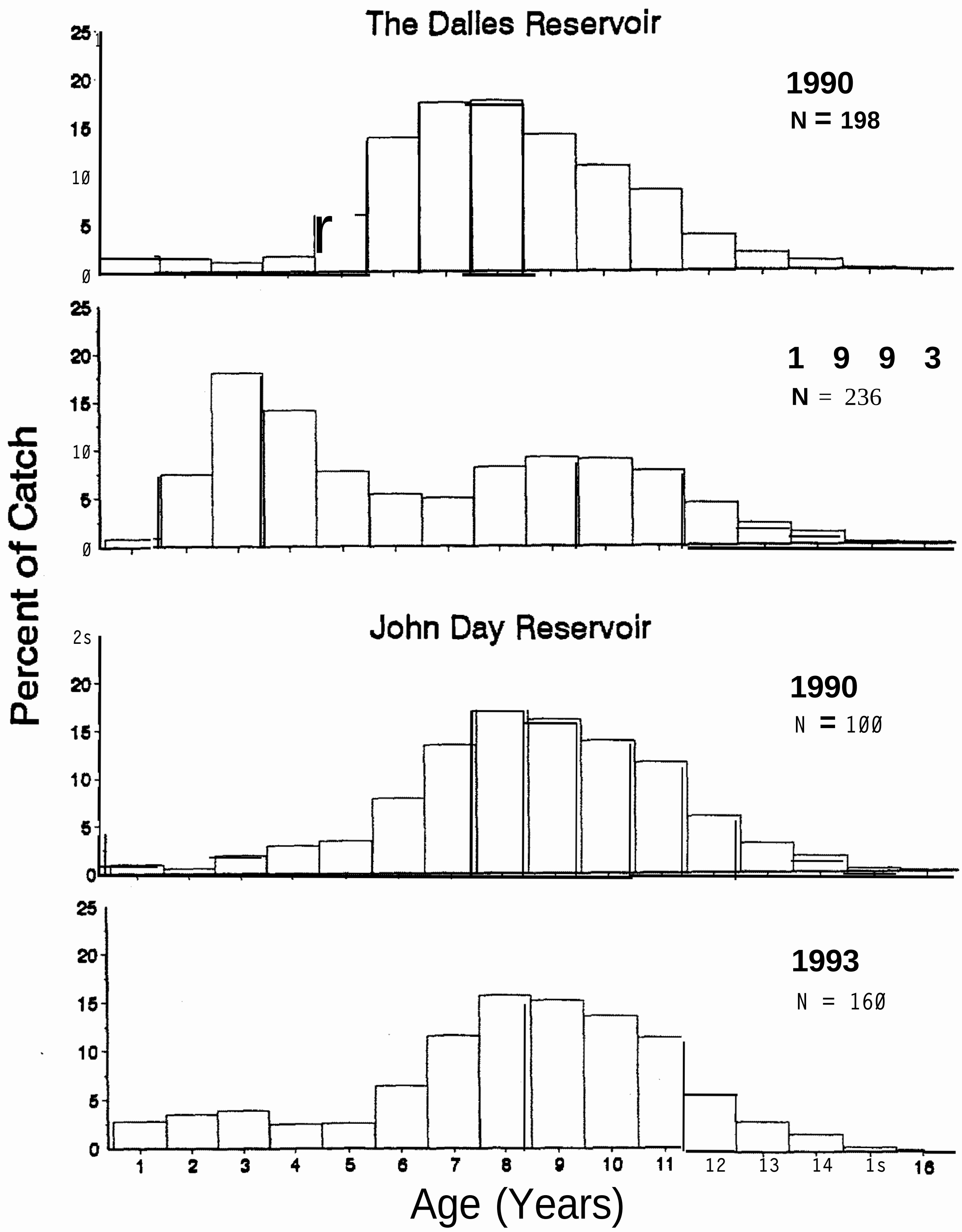

Figure H-8. Age composition in The Dalles and John Day reservoirs in 1990 and 1993.

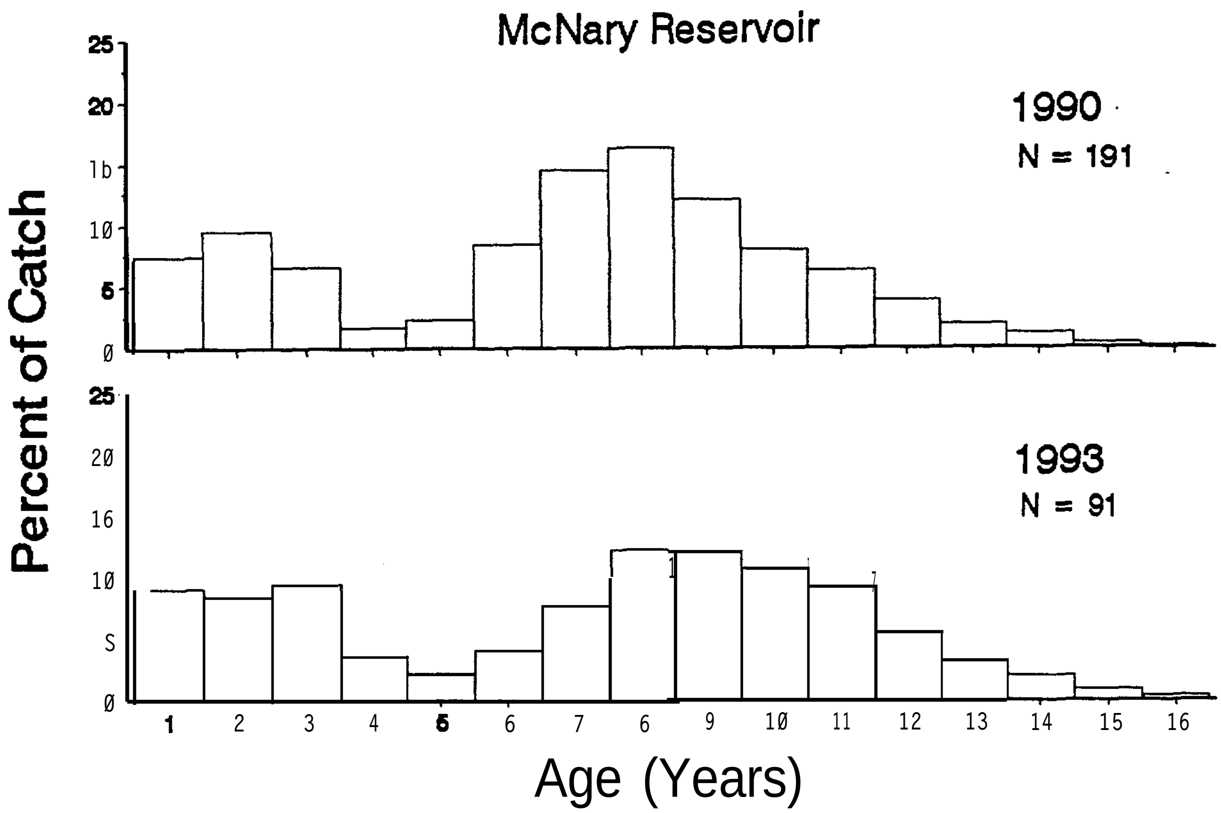

Figure H-9. Age composition in McNary Reservoir in 1990 and 1993.

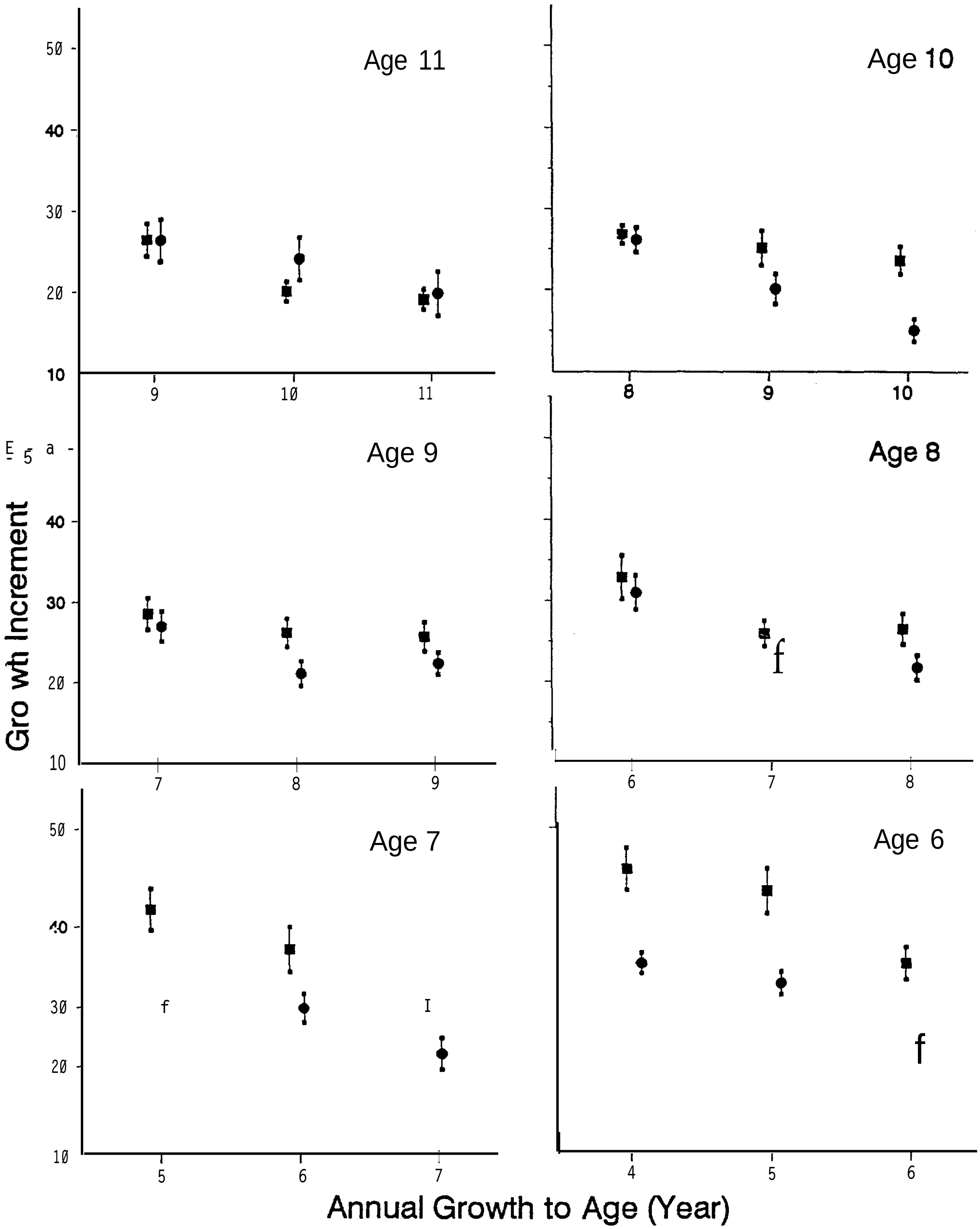

Figure H-1Ø. Mean annual growth increments (mm) from 1987 to 199Ø (closed squares) versus 199Ø to 1993 (closed circles) for northern squawfish aged 6-11 in Bonneville Dam tailrace. Bars are standard errors. An asterisk indicates a significant difference ($P \leq Ø.Ø5$) between pairs.

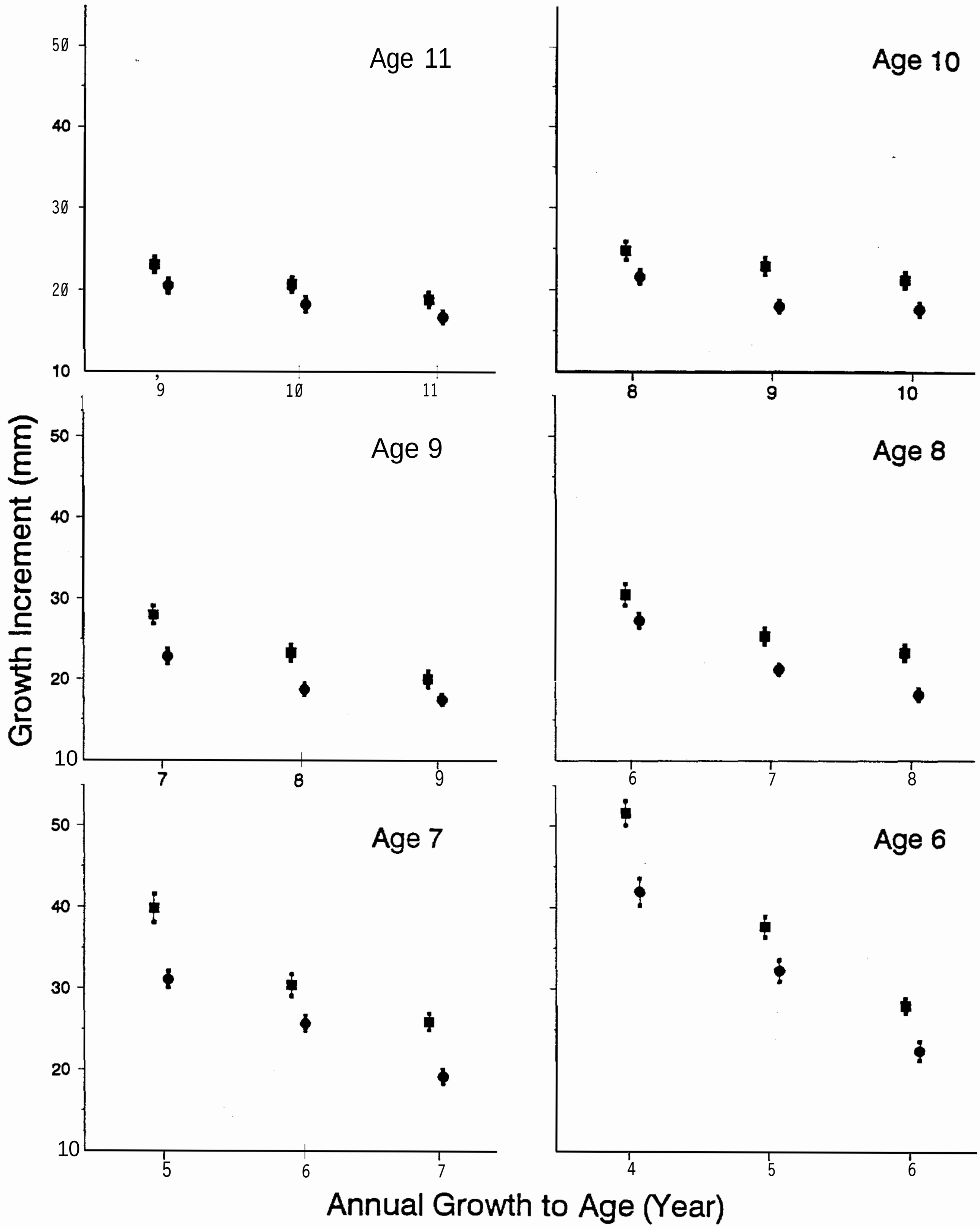

Figure H-11. Mean annual growth increments (mm) from 1987 to 1990 (closed squares) versus 1990 to 1993 (closed circles) for northern squawfish aged 6-11 in Columbia River reservoirs. Bars are standard errors. An asterisk indicates a significant difference ($P \leq 0.05$) between pairs.

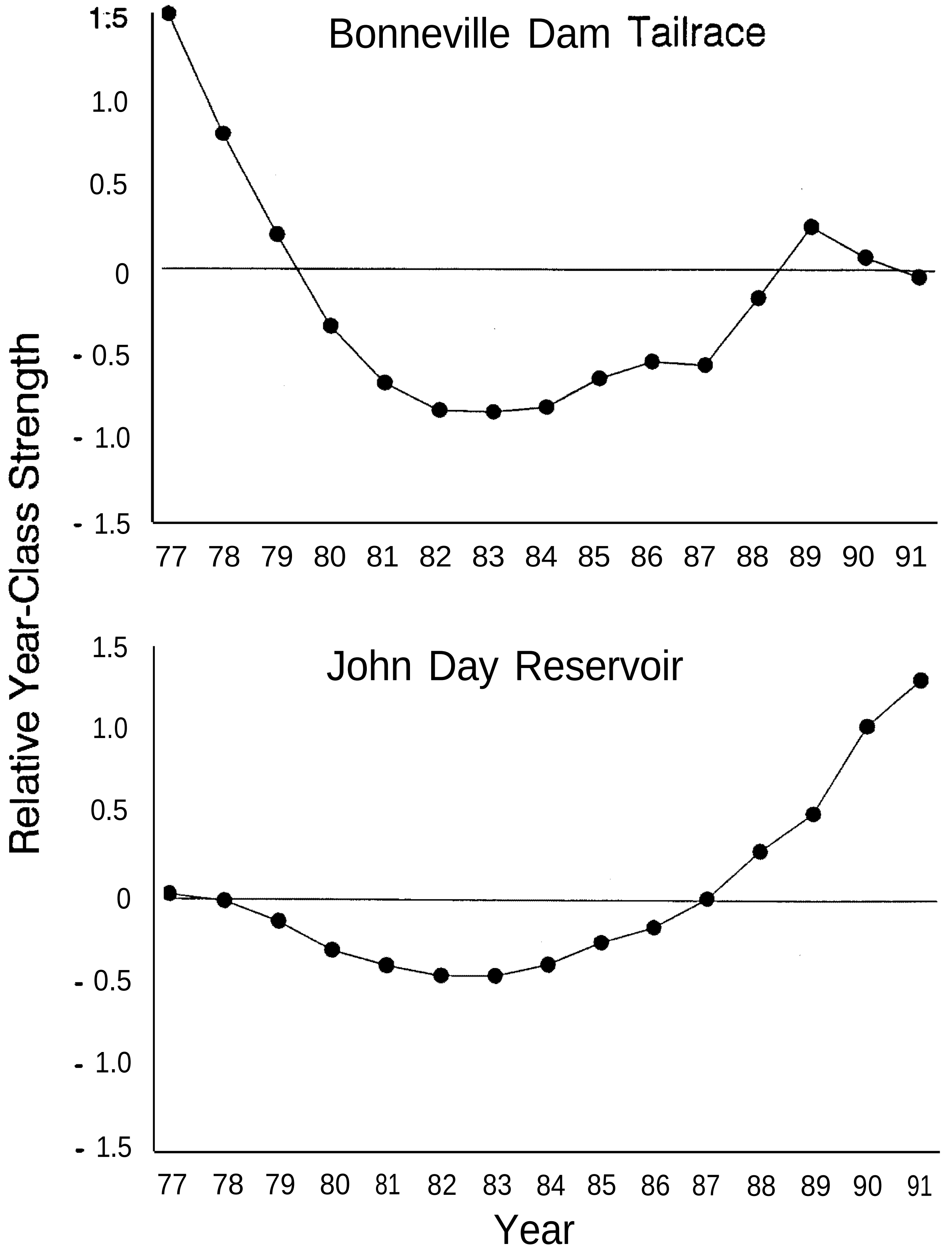

Figure H-12. Index of relative year-class strength of northern squawfish in Bonneville Dam tailrace and John Day Reservoir.

Table H-12.. Mean fecundity (number of developed eggs per female), mean relative fecundity (number of developed eggs per gram of body weight), and slope, intercept, and coefficient of determination (R^2) for the linear regression of $\log_{10}$(fecundity) on $\log_{10}$(body weight) for northern squawfish in Bonneville Dam tailrace and the combined lower Columbia River reservoirs.

Location, parameter	1991	1992	1993	Pooled 1991-1993
Bonneville Dam tailrace				
Mean fecundity	34,807	33,136	23,235	30,396
Mean relative fecundity	36.58	38.44	33.18	35.59
Slope	1.09	0.86	0.62	0.95
Intercept	1.27	1.96	2.57	1.65
R^2	0.60	0.59	0.25	0.50
Columbia River reservoirs				
Mean fecundity	30,376	29,805	29,418	--
Mean relative fecundity	31.74	32.19	30.59	--
Slope	0.57	0.67	0.49	--
Intercept	2.74	2.47	2.99	--
R^2	0.22	0.37	0.17	--

Radiotelemetry

The USFWS and ODFW crews combined located 70 (98.6% of total) of the northern squawfish released in The Dalles Reservoir at least once, and 61 (95.3 %) of the fish released in Bonneville Reservoir. Excluding USFWS in and near the BRZs, ODFW crews located 51 (71.8 %) fish released in The Dalles Reservoir at least once, and 49 (76.6%) fish released in Bonneville Reservoir at least once.

Mean depth of fish located in the midreservoir of Bonneville Reservoir was 3.4 m, and all fish were located at depths less than 12.2 m (Table H-13). Mean depth of fish located in midreservoir of The Dalles Reservoir was 7.4 m, and 83.5% of the observations were at depths of less than 40 m. Although fish were mainly found at relatively shallow depths in midreservoirs, they were frequently found in areas greater than 50 m from either the Washington or Oregon shore (Table H-13). Mean distance to shore was 75.2 m in Bonneville Reservoir and 182.2 m in The Dalles Reservoir. However, nearly all fish that occupied areas distant from shore were along shorelines of islands.

There was no consistent relationship between depth, distance to shore, and time of day based upon records of individual fish movements (Figures H-13 through H-16). Four fish were tracked June 17-18 at Miller Island in The Dalles Reservoir (Figure H-13), four fish were tracked July 15-16 in the same area (Figure H-14), three fish were tracked August 23-24 in The Dalles Reservoir forebay (Figure H-15), and five fish were tracked September 21-24 between The Dalles Dam forebay and Miller Island (Figure H-16). Behavior among fish was highly variable, with some exhibiting little movement (e.g., Figure H-15; frequency

149900, code 57), and others exhibiting extensive movement (e.g., Figure H-16; frequency 149860, code 65). There were no consistent patterns of movement associated with day, night, or crepuscular hours.

Table H-13. Number of observations of radio-tagged northern sguawfish at various intervals of depth and distance to shore in the midreservoirs of Bonneville and The Dalles reservoirs.

	Number of observations (%)	
Interval	Bonneville Reservoir	The Dalles Reservoir
Depth (m)		
<3.0	15 (46.9)	40 (21.3)
3.0- 6.1	13 (40.6)	70 (37.2)
6.1- 9.1	4 (12.5)	38 (20.2)
9.1-12.2	0 (0)	9 (4.8)
>12.2	0 (0)	31 (16.5)
Distance to shore (m)		
<50	7 (26.9)	68 (39.8)
50-100	15 (57.7)	17 (9.9)
100-150	2 (7.7)	14 (8.2)
150-200	(7.7)	10 (5.8)
200-250	0 2 (0)	7 (4.1)
250-300	0 (0)	11 (6.4)
>300	0 (0)	44 (25.7)

The vast majority of fish were found outside their release area at some time in both The Dalles and Bonneville reservoirs (Table H-14). Only 15 (11.4 %) of 13 1 fish apparently remained within their area of release. Of fish released in the tailrace BRZ in The Dalles Reservoir, four moved as far as forebay, 13 moved to the midreservoir, and 17 were found in the tailrace outside the restricted zone. Of the 29 fish released in the non-restricted portion of the tailrace in The Dalles Reservoir, 13 fish moved downstream and 14 fish moved upstream. One fish crossed The Dalles Dam into Bonneville Reservoir, and two fish moved past John Day Dam into John Day Reservoir. Fish released at the mouth of the Deschutes River were subsequently found in the tailrace restricted zone. Two-way movement between the tailrace and midreservoir of The Dalles Reservoir was particularly common, with most fish using the mouth of the Deschutes River or Miller Island in the mid-reservoir. Most fish occupying the Deschutes River remained near the river mouth, but three fish were found 24-64 km upriver. Exchange was extremely common between the non-restricted and restricted portions of the tailrace, where many fish were logged alternately in both areas throughout the summer.

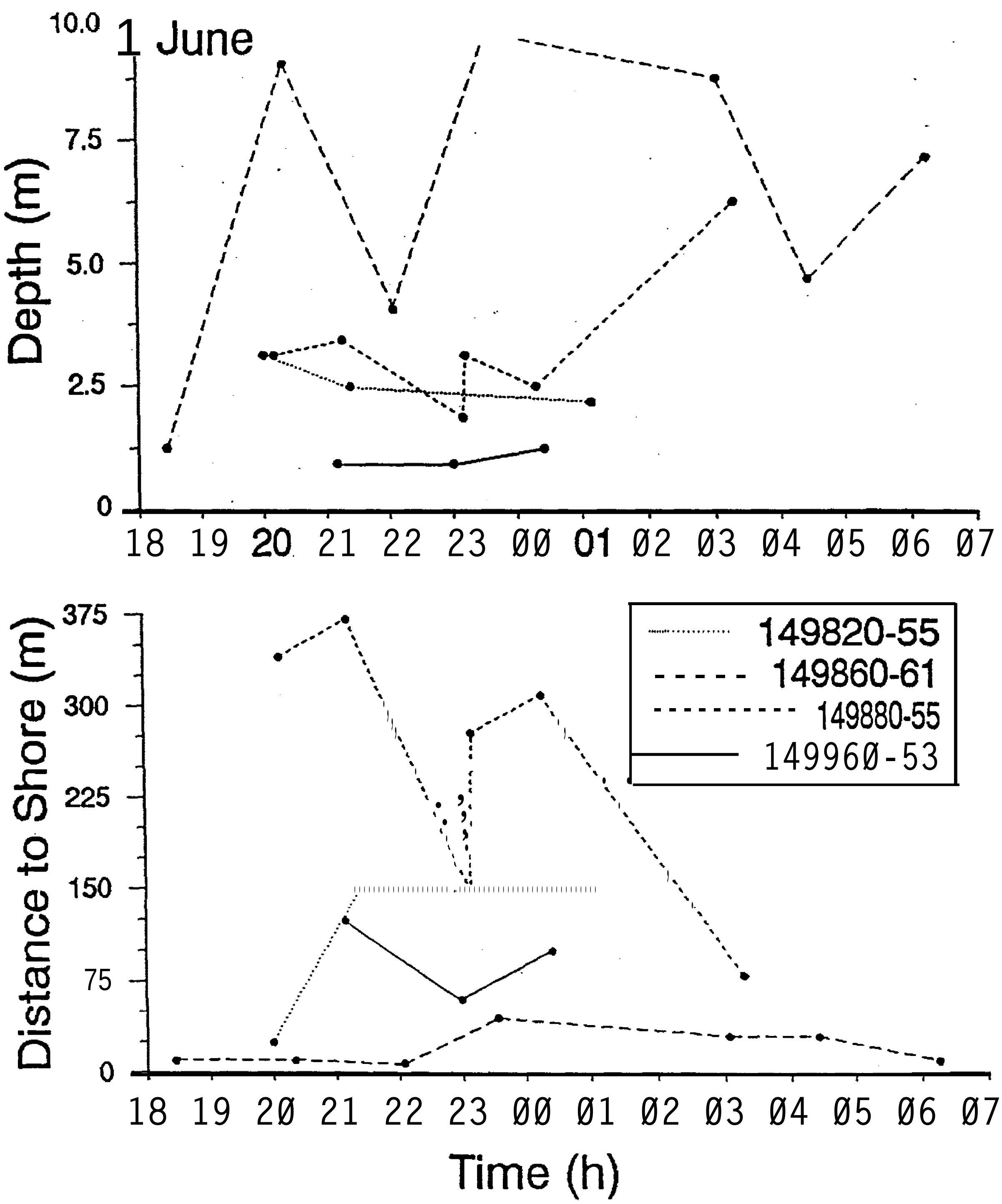

Figure H-13. Depth (m) and distance to shore (m) versus time (h) for 4 fish tracked from 2230 on 17 June to 1300 on 18 June around Miller Island (RKm 328.2-334.7) in The Dalles Reservoir. The 6-digit frequency and 2-digit code for each fish is provided in the key.

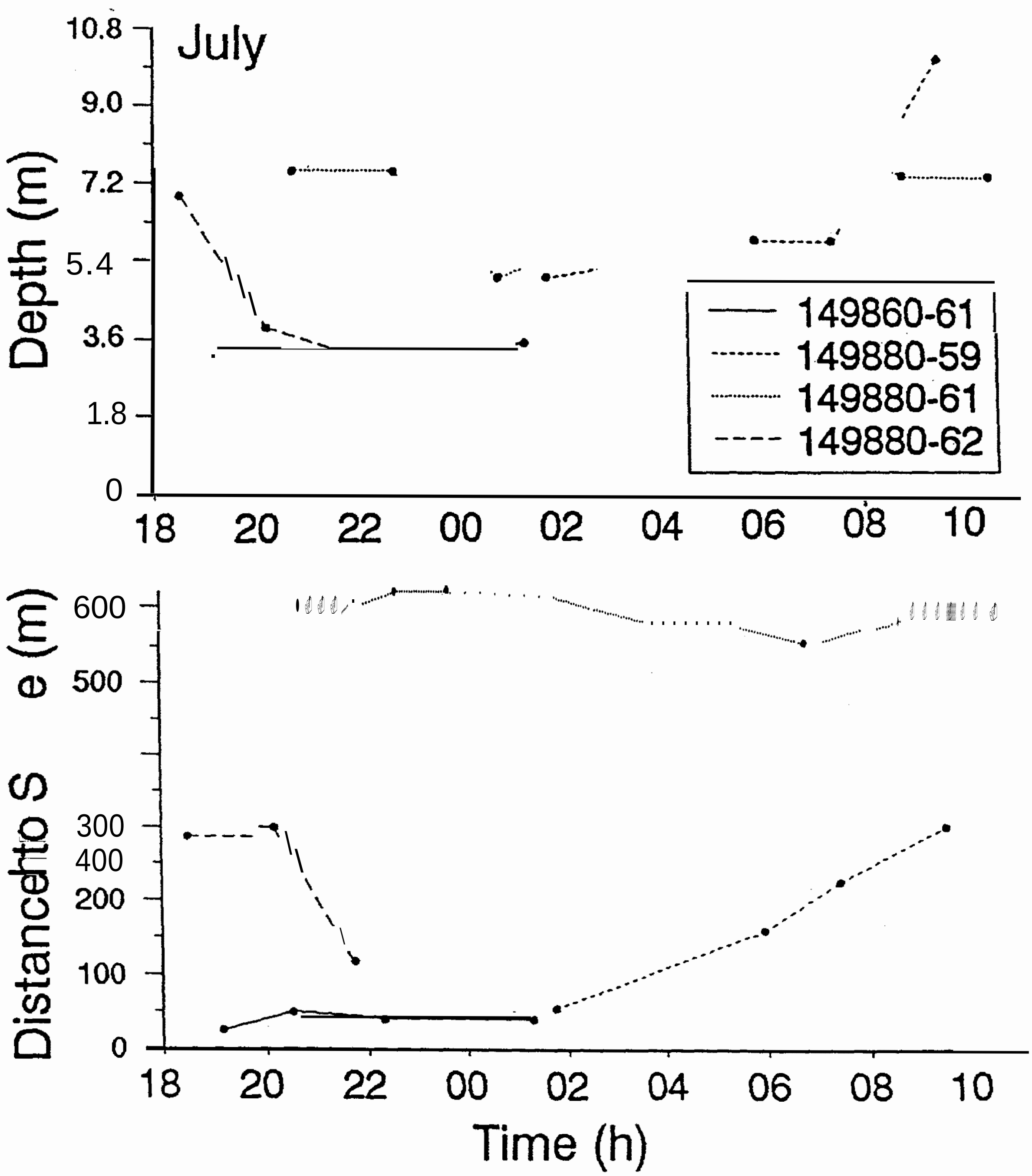

Figure H-14. Depth (m) and distance to shore (m) versus time (h) for 4 fish tracked from 1800 on 15 July to 1000 on 16 July around Miller Island (RKm 328.2-333.1) in The Dalles Reservoir. The 6-digit frequency and Z-digit code for each fish is provided in the key.

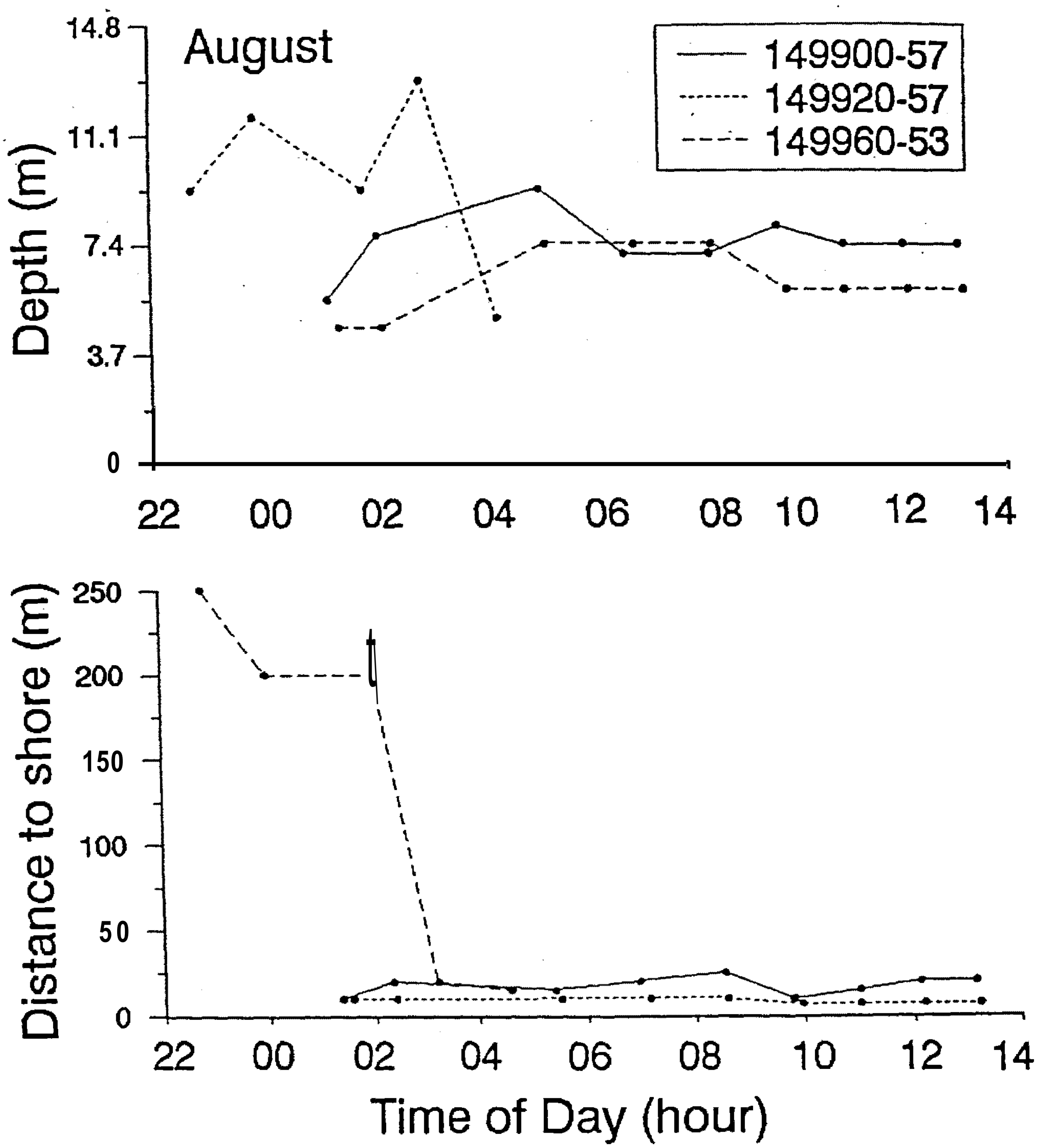

Figure H-15. Depth (m) and distance to shore (m) versus time (h) for 3 fish tracked between 2200, 23 August and 1300, 24 August in the forebay (RKm 310.5-317.0) of The Dalles Reservoir. The 6-digit frequency and 2-digit code for each fish is provided in the key.

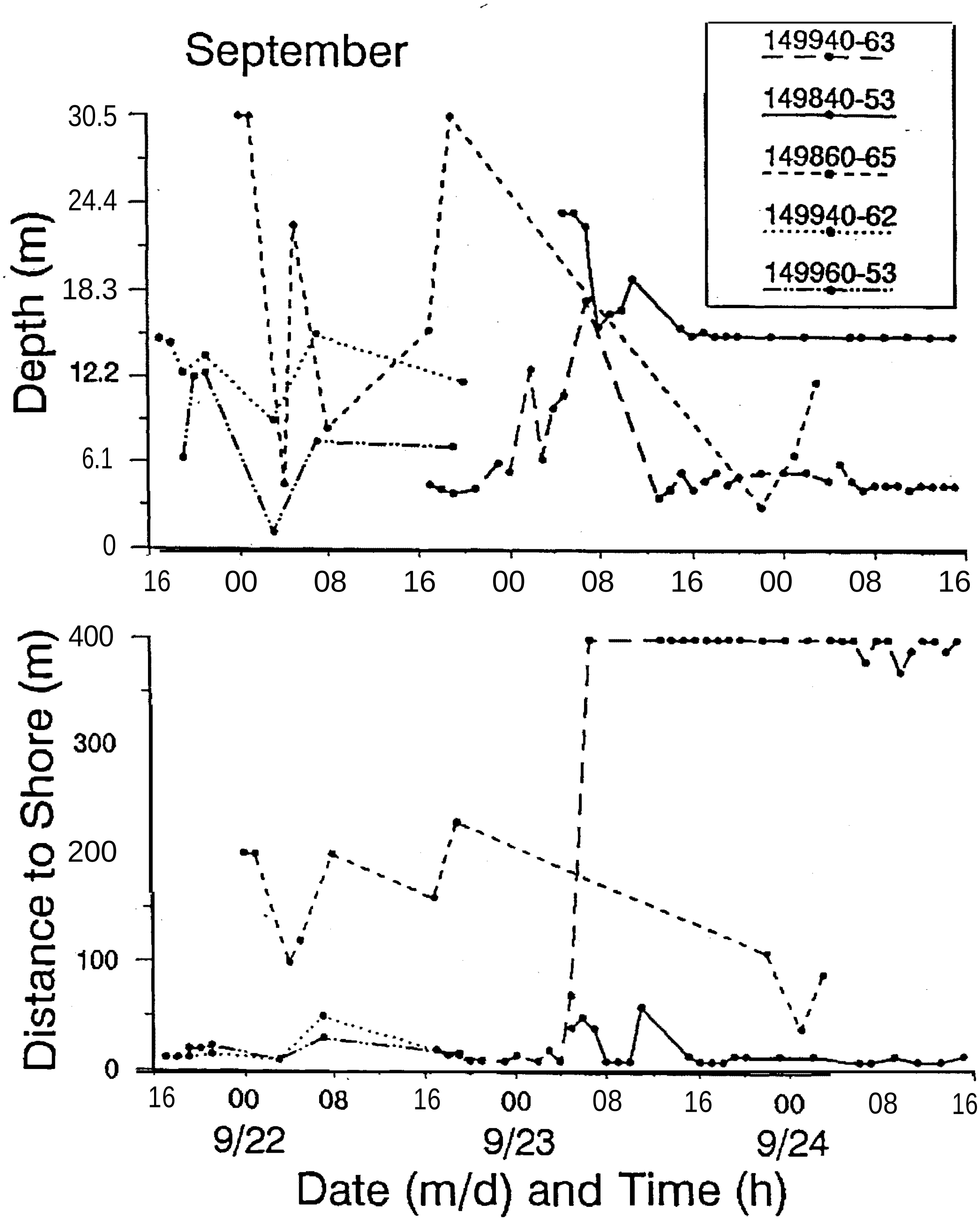

Figure H-16. Depth (m) and distance to shore (m) versus time (h) for 5 fish tracked between 1600, 21 September and 1600, 24 September in The Dalles deservoir (RKm 310.5-329.8). The 6-digit frequency and 2-digit code for each fish is provided in the key.

Table H-14, Number and percent (in parentheses) of fish located in various areas of Bonneville (BON), The Dalles (TDA), and John Day (JDY) reservoirs relative to the release site. Numbers in bold-face indicate the number of fish that were never located outside their release site. Reservoir areas are forebay (FOR), midreservoir (MID), non-restricted tailrace (TRN), and restricted zone of tailrace (BRZ). For each release area, the total represents the number of radio-tagged fish that were located at least once.

Farthest distance travelled	Number of fish by release area (percent)				
	BON TRN	BON BRZ	TDA MID	TDA TRN	TDA BRZ
BON FOR	--	1 (2.3)	--	--	
MID	1 (5.6)	5 (11.6)	--	--	--
TRN	1 (5.6)	15 (34.9)	--	--	--
BRZ	12 (66.7)	9 (20.9)	--	1 (3.5)	--
TDA FOR	1 (5.6)	1 (2.3)	--	3 (10.3)	4 (10.8)
MID	--	1 (2.3)	--	9 (31.0)	13 (35.1)
TRN	1 (5.6)	--	--	2 (6.9)	17 (46.0)
BRZ	2 (11.1)	11 (25.6)	4 (100)	12 (41.4)	3 (8.1)
JDY FOR		--	--	1 (3.5)	--
MID		--	--	1 (3.5)	
Total	18 (100)	43 (100)	4 (100)	29 (100)	37 (100)

Fish released in the non-restricted tailrace in Bonneville Reservoir generally moved upriver. Most (66.7%) moved only as far as the restricted zone, but four fish passed The Dalles Dam into The Dalles Reservoir. While most fish released in the tailrace BRZ moved downstream, 13 moved upstream into The Dalles Reservoir. Eleven of those fish were found as far upstream as the tailrace BRZ in The Dalles Reservoir, and many of those lingered in the midreservoir around the Deschutes River or Miller Island. As an indication of how far northern squawfish can move in a four-month period, six of the 17 fish that moved from Bonneville Reservoir upstream to The Dalles Reservoir later returned to Bonneville Reservoir.

DISCUSSION

Exploitation declined in most locations in 1993 relative to 1992. Since exploitation rates in 1991 and 1992 were already at the lower end of the 10-20% target range, every effort should be made to increase harvest of northern squawfish in 1994.

Our analyses indicate that a reduction in the scope of fisheries may not result in a significant increase in predation. Eliminating sport-reward exploitation in Ice Harbor and Lower Monumental reservoirs, and eliminating dam-angling exploitation in Ice Harbor and

McNary reservoirs resulted in an eventual predation increase of only 2% overall, and only 5% on juvenile salmonids originating upstream from Lower Granite Dam. It is obvious that management alternatives will affect individual stocks of juvenile salmonids differently. Eliminating fisheries from Columbia River reservoirs resulted in a decrease in overall benefits of 25%, but benefits to fish originating upstream from Lower Granite Dam were- unchanged.

Although results varied among years and methods, benefits of the sport-reward fishery have been greater than that of dam angling. However, the greater cost of the sport-reward fishery, and differences in the areas fished by the two fisheries, result in fisheries being complementary and make both fisheries important components of a program designed to remove 10-20% of northern squawfish ≥275 mm annually.

Relative abundance of northern squawfish was similar between 1990 and 1993, but relative consumption was lower in 1993, particularly in summer. While a decline in predation was anticipated based on predator control efforts to date, lower consumption estimates in 1993 may also be attributable to annual variation in temperature, flow regime, and differences in the timing of sampling to estimate relative consumption of juvenile salmonids by northern squawfish. Predation in John Day Reservoir differed each year from 1990 through 1993, with predation in 1993 intermediate between the low levels seen in 1992 and the higher levels seen in 1990 and 1991. The "indices" of relative abundance, consumption, and predation were intended to detect order-of-magnitude differences among locations or years, and any decrease in sample sizes might further compromise the precision of the indices. Since ODFW is now the only agency collecting abundance and consumption data in all locations throughout the lower Columbia Basin, we will refine our sampling schedule in 1994 such that sample sizes for electrofishing effort and northern squawfish gut samples are comparable to those in 1990-92.

Northern squawfish population structure, as characterized by mean fork length, size composition, PSD, and sex ratio has changed to varying degrees, depending upon location, from 1990 to 1993. Changes in mean fork length and the proportion of small (< 250 mm) fish reflected changes throughout the entire population, whereas changes in PSD and sex ratio reflected changes primarily among predator-sized fish. The proportion of small individuals increased markedly in the Bonneville Dam tailrace, and Bonneville and The Dalles reservoirs. Consequently, declines in mean fork length were greatest in those three areas. The increase in the proportion of small fish in all locations suggests that 1988-1990 were good recruitment years for northern squawfish throughout the lower Columbia River, and these fish will be recruited into lower end of the "predator size range" (≥250 mm) in 1994.

The change in sex ratio from 1990 to 1993 differed among locations, with the greatest decline (14%) in Bonneville Reservoir and the greatest increase (19%) in McNary Reservoir. These changes were generally consistent with changes in PSD, which declined by 19% in Bonneville Reservoir and increased by 18% in McNary Reservoir. Declines in the proportion of large, predominantly female northern squawfish are consistent with variation in year-class strength for reservoirs downstream from McNary Dam. In contrast, the recruitment history in McNary Reservoir is apparently quite different.

The current structure of northern squawfish populations in the lower Columbia River probably reflects variation in recruitment and the effects of three or four years of exploitation. Low levels of exploitation may be contributing to the changes outlined above, but since they would be occurring anyway, it is difficult to separate the effects of squawfish harvest from age-structured population dynamics. Most populations in the lower Columbia River have shifted toward fewer old and many more young individuals. Both dam-angling and sport-reward fisheries are selective for large (> 350 mm) northern squawfish, and catch rates and harvest may decline over the next 2-3 years, except perhaps in McNary Reservoir. Meanwhile, it will take several years for the strong 1988-1990 cohorts to grow into the size range that fisheries exploit most heavily. The challenge will be to maintain effort and interest in the fisheries through a few lean years until the strong cohorts are fully recruited.

We believe that our estimates of year-class strength of northern squawfish in lower Columbia River reservoirs were not greatly affected by different rates of size-specific exploitation in different years because exploitation rates have been relatively low and similar among years. However, estimates of year-class strength based on size and age composition may be biased in the future as northern squawfish fisheries are sustained. Although we are not currently aware of alternative methods to reconstruct the recruitment histories of northern squawfish populations throughout the lower Columbia Basin, we propose to investigate alternatives during 1994.

We found no evidence of compensation among northern squawfish, either in growth or fecundity. Compensation may be unlikely after only 3-4 years of relatively low exploitation rates.

Movement of radio-tagged northern squawfish supported our approach to estimate relative abundance. While we often found fish long distances from either shore, fish typically occurred in depths of less than 12.2 m. Tagged fish therefore occupied areas that we defined as potential squawfish habitat for purposes of expanding density indices to relative abundance We also found that most fish tagged and released in tailrace BRZs subsequently moved outside BRZs and would therefore be vulnerable to fisheries occurring outside BRZs. Similarly, most fish tagged outside BRZs subsequently moved into BRZs for at least some time and would be vulnerable to dam angling. This indicates that fisheries are for the most part harvesting northern squawfish from a single population rather than two subpopulations composed of large, highly predaceous fish in BRZs, and smaller, less predaceous fish outside BRZs. The implication is that fish harvested by sport anglers are no less important than fish harvested by dam angling because sport-caught fish have a reasonably high probability of residing in BRZs at some time.

Movement of radio-tagged fish past dams was consistent with tag recovery data in 1993 (Table H-3) and 1992 (Parker et al. 1992), which showed that interreservoir movement was far more prevalent at Bonneville and The Dalles dams than at other projects.

Interreservoir movement could confound attempts to characterize population structure in the Bonneville Dam tailrace, and Bonneville and The Dalles reservoirs, particularly if the degree of mixing differs among years. Mixing among the three areas may have also contributed to similar trends in population structure that were summarized in this report.

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APPENDIX H-l

Documentation for Spreadsheet Used to Compare Relative Losses of Juvenile Salmonids Among Various Management Alternatives

Introduction

Our objective is to estimate losses of juvenile salmonids to predation by northern squawfish relative to losses that occurred prior to implementation of northern squawfish removal fisheries. The user enters any combination of exploitation estimates among reservoirs and years for sport-reward and dam-angling fisheries in the "Loss Estimate Spreadsheet" (Appendix Figure H-l. 1). The effects of exploitation on predation are presented as "Losses as a percent of pre-exploitation." Steps involved in estimating losses are (1) exploitation in year j is estimated for each age of northern squawfish, (2) the effect of exploitation and natural mortality in year j on the age distribution of northern squawfish in year j+l is calculated, (3) an index of losses of juvenile salmonids in year j+ 1 is calculated as the product of abundance and consumption rate for each age, and (4) the loss index for year j + 1 is presented as the percent of the loss index prior to northern squawfish removals. Calculations through Step 3 are made for each reservoir (the Columbia River downstream from Bonneville Dam is treated as a reservoir); results are summed to yield a "systemwide" estimate for Step 4.

Northern squawfish population structure prior to removals is expressed in an equilibrium or mean state. Although this equilibrium state rarely, if ever, actually occurs in a given year, it is a good representation of the average population status over a number of years. By presenting population structure in this manner, variations in factors such as year-class strength are eliminated, and changes in northern squawfish population structure (and therefore predation) are related directly to removals. This, in effect, allows us to estimate what the effects of removals would be if we were somehow able to hold all variables except exploitation constant.

Because of differences in diet, consumption (Vigg et al. 1991), and vulnerability to fisheries among sizes of northern squawfish, information is summarized for each age. Northern squawfish less than 250-mm fork length were not considered because few juvenile salmonids are consumed by these fish. Northern squawfish do not reach 250-mm fork length until age 5 in most reservoirs (Rieman and Beamesderfer 1990; Parker et al., in review). Therefore, we evaluate predation only by fish $\geq$ age 5.

Exploitation

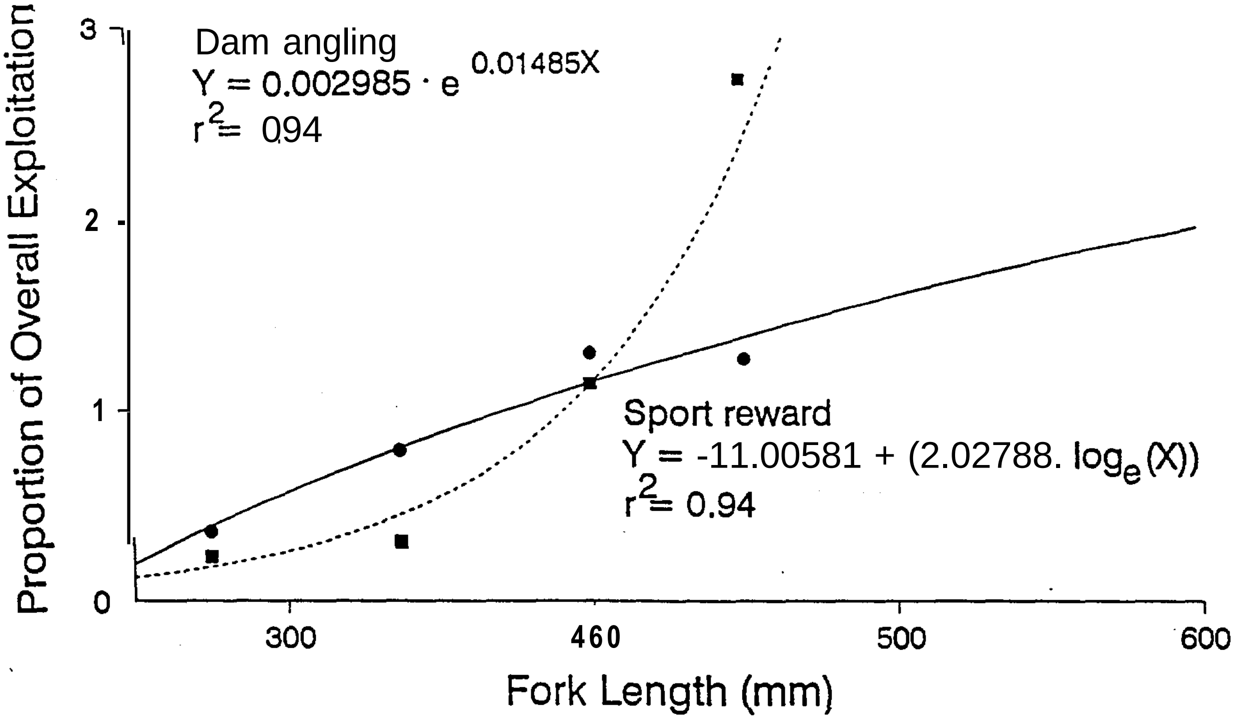
Exploitation estimates in future years are entered by the user in the "Loss Estimate Spreadsheet" (Appendix Figure H-l. 1). Only sport-reward and dam-angling fisheries are presently included, however, the spreadsheet can be modified if other fisheries are found to be effective, Exploitation estimates entered by the user are used to estimate age-specific exploitation rates. From 1990 through 1993, overall exploitation increased with northern squawfish size, however, the relationship between exploitation and size differed between the sport-reward and dam-angling fisheries (Appendix Figure H-l .2).

Relative benefits of the sport-reward and dam-angling fisheries are based on the assumption that all fish in a reservoir are available to both fisheries. For this to be true, fish tagged outside of boat restricted zones must be available to dam anglers, and fish tagged within boat restricted zones must be available to sport-reward anglers. Information from 1992 and 1993 indicated that an assumption of complete mixing is much more realistic than an assumption of no mixing (Appendix Table H-l. 1).

LOSS ESTIMATE SPREADSHEET

Reservoir	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Below Bonneville																	
sport	0.000	0.079	0.108	0.058													
Dam	0.000	0.002	0.001	0.009													
Bonneville																	
sport	0.000	0.134	0.099	0.020													
Dam	0.012	0.018	0.029	0.024													
The Dalles																	
Sport	0.000	0.061	0.051	0.067													
Dam	0.013	0.044	0.031	0.000													
John Oey																	
sport	0.045	0.043	0.034	0.023													
Oam	0.042	0.090	0.079	0.078													
McNary																	
sport	0.000	0.033	0.097	0.153													
Dam	0.014	0.019	0.004	0.005													
Ice Harbor																	
Sport	0.000	0.039	0.245	0.000													
Dam	0.000	0.136	0.018	0.000													
Lower Monumental																	
Sport	0.000	0.100	0.052	0.030													
Dam	0.000	0.170	0.083	0.000													
Little Goose																	
Sport	0.000	0.050	0.123	0.032													
Dam	0.000	0.134	0.064	0.032													
Lower Granite																	
Sport	0,000	0.168	0.171	0.120													
Oam	0.000	0.000	0.000	0.000													
losses (% of pre-exploitation)	100	W	88	80	79	83	87	91	94	96	98	99	100	100	100	100	100

Appendix Figure H-l.1. Loss Estimate Spreadsheet used to enter exploitation estimates.



Appendix Figure H-1.2. Relationship between exploitation rate and northern squawfish fork length for sport-reward and dam-angling fisheries.

Appendix Table H-1.1. Expected catch of tagged northern squawfish in the sport-reward and dam-angling fisheries assuming no mixing and complete mixing of fish tagged within and outside boat restricted zones (BRZs), and observed catch. Numbers in parentheses indicate expected catch after adjusting for differences in size-related vulnerability between fish tagged within and outside BRZs. Sport-reward effort is limited to areas outside BRZs, whereas dam angling is limited to BRZs.

Year, catch distribution	Sport reward		Dam angling	
	Tagged in BRZ	Tagged outside BRZ	Tagged in BRZ	Tagged outside BRZ
1992				
Expected (no mixing) (complete mixing)	110 (124)	235 (225)	103 (37)	0 69 (66)
Observed	134	215	86	17
1993				
Expected (no mixing) (complete mixing)	10 (11)	100 (99)	24 (2)	0 22 (22)
Observed	13	97	5	19

For the sport-reward fishery, the preliminary exploitation rate on each age northern squawfish in a given year is computed as:

$$PE_{s,h,i,j} = E_{s,i,j} \cdot (-11.00581 + (2.02788 \cdot \log\&J) \cdot (RP_{h,0} / RP_{h,j}) \quad (1)$$

where

$PE_{s,h,i,j}$ = preliminary sport-reward exploitation rate on age h fish in reservoir i in year j,

$E_{s,i,j}$ = overall sport-reward exploitation rate in reservoir i in year j,

$L_{h,i}$ = mean fork length of age h fish in reservoir i,

$RP_{h,0}$ = proportion of reservoir population aged h in 1990, and

$RP_{h,j}$ = proportion of reservoir population aged h in year j.

Although Equation 1 addresses the relationship between exploitation and northern squawfish size, the sum of the age-specific exploitation rates may not equal the overall exploitation rate. Age-specific exploitation rates are therefore corrected as:

$$E_{s,h,i,j} = PE_{s,h,i,j} \cdot (E_{s,i,j} / \sum_h PE_{s,h,i,j}) \qquad (2)$$

where

$E_{s,h,i,j}$ = sport-reward exploitation rate on age h fish in reservoir i in year j,

$PE_{s,h,i,j}$ = preliminary sport-reward exploitation rate on age h fish in reservoir i in year j, and

$E_{s,i,j}$ = overall sport-reward exploitation rate in reservoir i in year j.

For the dam angling fishery, the preliminary exploitation rate on each age in a given year is computed as:

$$PE_{d,h,i,j} = E_{d,i,j} \cdot e^{(0.01485 \cdot L_{h,i})} \cdot (RP_{h,0} / RP_{h,j}) \qquad (3)$$

where

$PE_{d,h,i,j}$ = preliminary dam-angling exploitation rate on age h fish in reservoir i in year j,

$E_{d,i,j}$ = overall dam-angling exploitation rate in reservoir i in year j,

$L_{h,i}$ = mean fork length of age h fish in reservoir i,

$RP_{h,0}$ = proportion of reservoir population in size group h in 1990, and

$RP_{h,j}$ = proportion of reservoir population in size group h in year j.

Age-specific dam-angling exploitation rates are also corrected as:

$$E_{d,h,i,j} = PE_{d,h,i,j} \cdot (E_{d,i,j} / \sum_h PE_{d,h,i,j}) \qquad (4)$$

where

$E_{d,h,i,j}$ = dam-angling exploitation rate on age h fish in reservoir i in year j,

$PE_{d,h,i,j}$ = preliminary dam-angling exploitation rate on age h fish in reservoir i in year j, and

$E_{d,i,j}$ = overall dam-angling exploitation rate in reservoir i in year j.

Total exploitation for each age is calculated as the sum of sport-reward and dam-angling exploitation rates:

$$E_{h,i,j} = E_{s,h,i,j} + E_{d,h,i,j} \qquad (5)$$

where

$E_{h,i,j}$ = total exploitation rate on age h fish in reservoir i in year j,

$E_{s,h,i,j}$ = sport-reward exploitation rate on age h fish in reservoir i in year j, and

$E_{d,h,i,j}$ = dam-angling exploitation rate on age h fish in reservoir i in year j.

The maximum exploitation rate for any age is 1.0. If calculations result in exploitation exceeding 1.0, the result is changed to 1.0. If realistic exploitation estimates are entered, this will occur rarely, and only for the oldest ages. This may result in overall exploitation being less than the rate originally entered. However, if populations have been restructured so that total harvest of large fish is possible, overall exploitation rates will probably be lower than if more large fish were available. This is because small fish are less vulnerable to exploitation than larger fish (Appendix Figure H-l .2).

Size and Age Structure

An index of abundance of northern squawfish ≥250 mm fork length in each reservoir prior to removals was estimated from boat electrofishing data (Ward et al., in review). Data was collected from Columbia River reservoirs in 1990, Snake River reservoirs and John Day Reservoir in 1991, and the Columbia River downstream from Bonneville Dam and John Day Reservoir in 1992. Abundance was indexed for each reservoir forebay, midreservoir, tailrace, tailrace restricted zone (BRZ), and upper reservoir where applicable. Indices from these areas were summed to yield a reservoir-wide index. To simplify comparisons, the mean 1990-92 index of abundance for John Day Reservoir was assumed to equal 100,000 fish (Appendix Table H-1.2). It is important to note that the index should not be used to estimate actual numbers of fish; its proper use is as an indicator of relative differences among reservoirs.

Size and age structure of northern squawfish populations were estimated from boat electrofishing data collected while sampling to estimate relative abundance. Catches were used to generate length-frequency histograms for each reservoir, and scale analyses were used to estimate mean length at age of northern squawfish in each reservoir. Unadjusted age frequencies were then estimated by multiplying the number of fish in each 25-mm length interval by the proportion of fish of each age in a subsample from that length interval.

Appendix Table H-1.2. Indices of abundance and estimates of natural mortality for northern squawfish prior to implementation of removal fisheries.

Reservoir	Year(s) indexed	Abundance index for year sampled	Abundance index at equilibrium	Recruitment to age 5	Natural mortality (%)
Downstream from Bonneville Dam	1992	235,745	176,290	60,351	34
Bonneville	1990	74,707	73,163	18,889	25
The Dalles	1990	37,893	38,408	9,235	23
John Day	1990-92	100,000	99,284	16,620	14
McNary	1990	77,397	75,213	14,917	18
Ice Harbor	1991	23,233	22,494	6,632	29
Lower Monumental	1991	16,857	16,414	7,882	48
Little Goose	1991	24,973	24,683	5,935	23
Lower Granite	1991	23,812	23,178	7,270	31

Because different sizes of northern squawfish are differentially vulnerable to capture even when samples from different gears are pooled (Beamesderfer and Rieman 1988), the following formula was used to index the relative vulnerability of northern squawfish:

$$Y = 0.0112 \cdot e^{-(408.1 - L)^2 / 12261.8} \qquad (6)$$

where

Y = index of vulnerability to capture, and

L = fork length of northern squawfish.

Age composition for each reservoir was adjusted by dividing the unadjusted proportion of fish at each age by the index of vulnerability for the mean length at that age.

We used the adjusted age composition to estimate an equilibrium or average age composition for each reservoir prior to removals. For each reservoir, we used linear regression on a catch curve constructed from adjusted age frequencies (Ricker 1975) to estimate (1) annual mortality rate, and (2) mean recruitment of fish to age 5 (Appendix Table H-1.2). Because data was collected prior to or coinciding with full implementation of fisheries in each reservoir, we assumed all estimated mortality to be natural. We calculated the equilibrium abundance index for each age northern squawfish in a reservoir as

$$AI_{h,i} = AI_{5,i} \cdot ((1 - M_i) \cdot (h - 5)) \qquad (7)$$

where

$AI_{h,i}$ = equilibrium abundance index of age h fish in reservoir i,

$AI_{5,i}$ = abundance index (mean recruitment) of age 5 fish in reservoir i (from Appendix Table H-1.2), and

M_i = annual natural mortality rate in reservoir i prior to exploitation (from Appendix Table H-l .2).

Age structure of northern squawfish populations after removals change as a function of exploitation and natural mortality:

$$AI_{h,i,j} = AI_{h-1,i,j-1} \cdot (1 - ((M_i \cdot (1 - E_{h-1,i,j-1})) + E_{h-1,i,j-1})) \quad (8)$$

where

$AI_{h,i\,j}$ = abundance index of age h fish in reservoir i in year j,

$AI_{h-1,i,j-1}$ = abundance index of age h-l fish in reservoir i in year j-l (in the first year of exploitation this equals $AI_{h,i}$),

M_i = annual natural mortality rate in reservoir i prior to exploitation, and

$E_{h-1,i,j-1}$ = exploitation rate of h-l fish in reservoir i in year j-l.

This assumes that natural mortality occurs after fishing ends and that the forces of natural mortality remain constant (Picker 1975). The recruitment of fish to age 5 remains constant at the equilibrium level.

Consumption

An index of consumption of juvenile salmonids by northern squawfish in each reservoir prior to removals was estimated by examining digestive tracts of northern squawfish collected by electrofishing (Petersen et al. 1990; Ward et al., in review). Sampling was concurrent with that for indexing northern squawfish abundance and size structure. A consumption index was calculated for each reservoir area in both spring and summer:

$$CI_{l,m} = 0.0209 \cdot T^{1.60} \cdot MW^{0.27} \cdot (S \cdot GW^{-0.61}) \quad (9)$$

where

$CI_{l,m}$ = consumption index for area 1 in season m, T = water temperature (°C),

MW = mean weight (g) of northern squawfish in sample,

S = mean number of juvenile salmonids per northern squawfish in sample, and

GW = mean total gut weight (g) of northern squawfish in sample.

Although sampling for consumption was timed to coincide with peak densities of juvenile salmonids, predicting highest passage densities was difficult. We therefore used linear regression to evaluate the relationship between salmonid densities and northern squawfish consumption indices for each area and season. To approximate the number of fish in tailraces and upper reservoirs, we summed estimates of passage at the nearest upstream dam or collection facility and releases directly into the area from hatcheries, and subtracted estimates of fish removed at collection facilities and later transported downstream. We used similar information adjusted for rate of juvenile salmonid migration to approximate number of fish in midreservoirs. We used estimates of passage at the nearest downstream dam to approximate the number of fish in forebays. Salmonid density was approximated as mean daily passage for days sampled divided by surface hectares.

We found no significant relationship between consumption indices and juvenile salmonid density except in tailrace areas (both non-BRZs and BRZs) in summer. The functional response of northern squawfish consumption to salmonid density has been described by exponential or sigmoid models (Petersen and DeAngelis 1992), however, the linear model we used explained much of the variability in consumption indices among tailraces in summer (non-BRZ r^2 = 0.77; BRZ r^2 = 0.60). Relationships in the spring, and in non-tailrace areas in summer was poor (r^2 = 0.01 - 0.26), and would not fit any functional response model well. We therefore used observed consumption indices in subsequent analyses except that indices in tailrace non-BRZs in summer were calculated as

$$CI_{l,s} = -0.40 + (0.075 \cdot D_{l,s}) \qquad (10a)$$

and indices in tailrace BRZs in summer were calculated as

$$CI_{l,s} = 1.55 + (0.015 \cdot D_{l,s}) \qquad (10b)$$

where

$CI_{l,s}$ = consumption index in area 1 (tailrace non-BRZ or tailrace BRZ) in summer, and

$D_{l,s}$ = density of juvenile salmonids (mean daily passage during days sampled divided by surface hectares) in area 1 in summer.

Consumption indices were converted to consumption rates (juvenile salmonids per northern squawfish per day) by the formula from Petersen et al. (1990):

$$Log_{10}\ (MC_{l,m}) = -0.41 + (1.17 \cdot Log_{10}\ (CI_{l,m})) \qquad (11a)$$

or,

$$Log_{10}\ (MC_{l,m}) = -0.41 + (1.17 \cdot Log_{10}\ (CI_{l,s})) \qquad (11b)$$

where

$MC_{l,m}$ = consumption rate for mean size (age) northern squawfish in sample from area 1 in season m,

$CI_{l,m}$ = consumption index for area 1 in season m, and

$CI_{l,s}$ = consumption index for area 1 (tailrace non-BRZ or BRZ) in summer.

Size of northern squawfish used in estimates of consumption is important because consumption rates generally increase with northern squawfish length (Vigg et al. 1991). Consumption rates were therefore adjusted to reflect differences in mean size of northern squawfish in samples. The relationship between consumption rate and northern squawfish fork length was based on consumption rates observed in John Day Reservoir (U.S. Fish and Wildlife Service, unpublished data):

$$RC_{h,l,m} = 0.0016149 \cdot (e^{(F_{h,l} \cdot 0.0130939)}) \qquad (12)$$

where

$RC_{h,l,m}$ = relative consumption rate for age h fish in area 1 and season m, and

$F_{h,l}$ = mean fork length of age h fish in area 1.

After the mean age of northern squawfish used in developing a consumption index (and therefore calculating $MC_{l,m}$) for each area was determined, a consumption rate for each age calculated as

$$CR_{h,l,m} = MC_{l,m} \cdot (RC_{h,l,m} / MRC_{l,m}) \qquad (13)$$

where

$CR_{h,l,m}$ = consumption rate for age h fish in area 1 and season m,

$MC_{l,m}$ = consumption rate for mean age fish in sample from area 1 in season m,

$RC_{h,l,m}$ = relative consumption rate for age h fish in area 1 and season m, and

$MRC_{l,m}$ = relative consumption rate for mean age fish in sample from area 1 in season m.

The relative abundance of each age of northern squawfish in each reservoir area Was then used to develop a reservoirwide consumption rate for each age for each season:

$$CR_{h,i,m} = \sum_{l} (CR_{h,l,m} \cdot RP_{h,l}) \qquad (14)$$

where

$CR_{h,i,m}$ = consumption rate for age h fish in reservoir i in season m,

$CR_{h,l,m}$ = consumption rate for age h fish in area 1 and season m, and

RP_h = proportion of reservoir population of age h fish in area 1.

Loss Estimates

Estimates of the relative loss of juvenile salmonids to northern squawfish predation in each reservoir are calculated as the product of northern squawfish abundance and consumption rates. Seasonal predation by each age of northern squawfish is calculated and summed to yield annual predation by each age:

$$L_{h,i,j} = \sum_{m} (AI_{h,i,j} \cdot CR_{h,i,m} \cdot D_m) \qquad (15)$$

where

$L_{h,i,j}$ = loss of juvenile salmonids to age h northern squawfish in reservoir i in year j,

$AI_{h,i,j}$ = abundance index of age h fish in reservoir i in year j,

$CR_{h,i,m}$ = consumption rate of age h fish in reservoir i in season m, and

D_m = number of days in season m.

Total annual predation in each reservoir is calculated as the sum of the seasonal losses:

$$RL_{i,j} = \sum_{h} L_{h,i,j} \qquad (16)$$

where

$RL_{i,j}$ = total loss of juvenile salmonids to northern squawfish in reservoir i in year j, and

$L_{h,i,j}$ = loss of juvenile salmonids to northern squawfish of age h in reservoir i in year j.

Predation is summed for all reservoirs then divided by the predation estimate for 1990 **to** yield "Losses as a percent of pre-exploitation" (Appendix Figure H-l. 1):

$$TL_j = (\sum_i RL_{i,j}) / (\sum_i RL_{i,0}) \cdot 100 \qquad (17)$$

where

TL_j = total loss of juvenile salmonids to northern squawfish in year j expressed as a percentage of losses prior to exploitation,
$RL_{i,j}$ = total loss of juvenile salmonids to northern squawfish in reservoir i in year j, and

$RL_{i,0}$ = total loss of juvenile salmonids to northern squawfish in reservoir i in 1990.

Appendix H-l References

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APPENDIX H-2

Exploitation by Reservoir and Fishery in 1993

Appendix Table H-2.1. Exploitation of northern squawfish downstream from Bonneville Dam.

		Recaptures					Exploitation		
P	T	Sport	Dam	Net	Misc.	M	Sport	Dam	Net
1	783	--	--	--		---	--	--	
2	--	5	--	--		783	0.0064		--
3		1	--	--		778	0.0013		
4			--	--		777	--	--	
5	--	2	--	--	--	777	0.0026	--	--
6	--	3	--	--	1	775	0.0039	--	--
7	--	3	--	1	--	771	0.0039	--	0.0013
8	--	7	--	--	--	767	0.0091	--	--
9	--	5	--	--	1	760	0.0066	--	--
10	--	6	--	2	--	754	0.0080	--	0.0027
11	--	2	--	1	1	746	0.0027	--	0.0013
12	--	--	--	2		742	--	--	0.0027
13		2	--	1	1	740	0.0027	--	0.0014
14		1	--	--	1	737	0.0014	--	--
15	--	2	--	--	--	735	0.0027	--	--
16	--	1	--	--	1	733	0.0014	--	--
17	--	2	--	--	--	732	0.0027	--	--
18	--	1	--	--	--	730	0.0014	--	--
19	--	--	--	--		729	--	--	--
20	--	1	--	--	--	729	0.0014		--
21		--	--	--	--	728	--		--
22	--	--	--	--		728	--	--	--
Total	783	44	0	7	4	---	0.0580	0.0000	0.0093
Adjusted for tag loss							0.0608	0.0000	0.0098

Appendix Table H-2.2. Exploitation of northern squawfish in Bonneville Reservoir.

P	T	Recaptures				M	Exploitation		
		Sport	Dam	Net	Misc.		Sport	Dam	Net
1	333	--	--	--	--	---	--	--	--
2	18	--	--	--	--	333	--	--	--
3	--	--	--	--	--	351	--	--	--
4	--	1	--	--	--	351	0.0028	--	--
5	--	1			1	350	0.0029	--	--
6	--	--	--		1	348	--	--	--
7	--	--	2	--	--	347	--	0.0058	--
8	--	4	--	--	2	345	0.0116	--	--
9	a -	--	2	--	1	339	--	0.0059	--
10	--	1	1	--	1	336	0.0030	0.0030	--
11	--		--		1	333	--		--
12	--		2	1		332	--	0.0060	0.0030
13	--		--	--	--	329	--		--
14	--	--	--	--	--	329	--	--	--
15	--	--	--	--	--	329	--	--	--
16	--	--	--	--	--	329	--	--	--
17	--		--	--		329	--	--	--
18	--	--	--	--	--	329	--	--	--
19	--	--	--	--	--	329	--	--	--
20	--	--	--	--	1	329	--	--	--
21	--	--	--	--	--	328	--	--	--
22	--	--	--	--	--	328	--	--	--
Total	351	7	7	1	8		0.0203	0.0207	0.0030
Adjusted for tag loss							0.0212	0.0217	0.0032

Appendix Table H-2.3. Exploitation of northern squawfish in The Dalles Reservoir.

		Recaptures					Exploitation		
P	T	Sport	Dam	Net	Misc.	M	Sport	Dam	Net
1	92		--	--	--	---	--	--	
2			--	--	--	92		--	--
3	18		--	a-	--	92	--	--	--
4	--		--	--	2	110	--	--	--
5	--	--	--	--	--	108		--	--
6	--	1	--	--	--	108	0.0093	--	
7	--	1	--	--	--	107	0.0093	--	
8	--	2	--	--	--	106	0.0189	--	--
9	--	1	--	--	--	104	0.0096	--	--
10	--		--	--	--	103	--	--	--
11	--	--	--	--	--	103	--	--	
12	--	--	--	--	1	103		--	--
13	--	--	--	--	--	102	--	--	
14	--	2	--	--	--	102	0.0196	--	--
15	--		--	--	--	100	--	--	--
16	--	--	--	--	--	100	--	--	--
17	--	--	--	--	--	100	--	--	
18	--	--	--	--	--	100	--	--	
19	--	--	--	--	--	100	--	--	
20	--	--	--	--	--	100		--	--
21	--	--	--	--	--	100	--	--	--
22			--	--	--	100		--	--
Total	110	7	0	0	3		0.0667	0.0000	0.0000
Adjusted for tag loss							0.0669	0.0000	0.0000

Appendix Table H-2.4. Exploitation of northern squawfish in John Day Reservoir.

		Recaptures					Exploitation		
P	T	Sport	Dam	Net	Misc.	M	Sport	Dam	Net
1	66	--	--	--	--	---	--	--	--
2	--	--	--	--	--	66	--	--	--
3	--	--	--	--	--	66	--	--	--
4	--	--	--	--	--	66	--	--	--
5			--	--	--	66	--	--	--
6	53	1	--	--	--	66	0.0152	--	--
7	8	--	--	--	--	118	--	--	--
8	9	--	--	--	--	126	--	--	--
9	--	--	--	--	--	135	--	--	--
10	--		2	--	--	135	--	0.0148	--
11	26	1	4	--	--	133	0.0075	0.0301	--
12	--		2	--	--	154	--	0.0130	--
13	--	--	--	--	--	152	--	--	--
14	--	--	2	--	--	152	--	0.0132	--
15	--	--	1	--	--	150	--	0.0067	--
16	--	--	--	--	--	149	--	--	--
17	--		--	--	--	149	--	--	--
18	--		--	--	--	149	--	--	--
19	--		--	--	--	149	--	--	--
20	--	--	--	--	--	149	--	--	--
21	--	--	--	--	--	149	--	--	--
22	--	--	--	--	--	149	--	--	--
Total	162	2	11	0	0	---	0.0227	0.0777	0.0000
Adjusted for tag loss							0.0238	0.0814	0.0000

Appendix Table H-2.5. Exploitation of northern squawfish in McNary Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	50	--	--	--	---	--	--
2	--	--	--	--	50	--	--
3	--	--	--	--	50	--	--
4	--	--	--	--	50	--	--
5	3	--	--	--	50		--
6		--		--	53	--	--
7	157	3	--	--	53	0.0566	--
8	--	1	--	--	207	0.0048	--
9	--	1		--	206	0.0049	--
10	--	4	--	--	205	0.0195	
11	--	1	1	--	201	0.0050	0.0050
12	--	1	--	--	199	0.0050	--
13	--	2	--	--	198	0.0101	--
14		3			196	0.0153	--
15	--	1	--	--	193	0.0052	
16	--	2	--	--	192	0.0104	--
17	--	--	--	--	190	--	--
18	--	1	--	--	190	0.0053	--
19	--	1	--	--	189	0.0053	--
20		1	--	--	188	0.0053	
21		--	--	--	la7	--	--
22	--		--	--	187	--	
Total	210	22	1	0	---	0.1527	0.0005
Adjusted for tag loss						0.1600	0.0052

Appendix Table H-2.6. Exploitation of northern squawfish in Lower Monumental Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	97	--	--	--		--	--
2	--	--	--	--	97	--	--
3		--		--	97	--	--
4	21	--	--		97		--
5	17	--	--		118		--
6	--	1	--	--	135	0.0074	--
7	--	--	--	--	134	--	--
8	2	1	--	--	134	0.0075	--
9		1	--	--	135	0.0074	--
10		--	--	--	134		--
11		--		1	134	--	--
12	--	--		--	133	--	--
13	--	--	--	--	133	--	--
14	--	--	--	--	133	--	--
15	--	--	--	--	133	--	--
16	--	--	--	--	133	--	--
17	--	--	--	--	133	--	--
18			--	--	133	--	--
19		1		--	133	0.0075	--
20	--	--		--	132		--
21	--	--	--	--	132	--	--
22	--	--	--	--	132	--	--
Total	137	4	0	1	---	0.0298	0.0000
Adjusted for tag loss						0.0312	0.0000

Appendix Table H-2.7. Exploitation of northern equawfish in Little Goose Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	4	--	--	--	---	--	--
2	1	--	--	--	4	--	--
3	3	--	--	--	5	--	
4	37	--		--	8	--	--
5				--	45		--
6	--	--	--	--	45		--
7	--	--	--	--	45	--	--
8	20	--	--	--	45	--	--
9	--	--	--	--	65		
10	--		--		65	--	
11	--			--	65	--	
12	--		1	--	65	--	0.0154
13	--	1	--	--	64	0.0156	--
14	--	--	--	--	63	--	--
15	--	--	--	--	63	--	
16	--	1	--	--	63	0.0159	
17	--		1		62	--	0.0161
18	--		--	--	61	--	--
19	--	--	--	--	61	--	--
20	--	--	--	--	61	--	--
21	--	--	--	--	61	--	--
22	--	--	--	--	61	--	
Total	65	2	2	0		0.0315	0.0315
Adjusted for tag loss						0.0330	0.0330

Appendix Table H-2.8. Exploitation of northern squawfish in Lower Granite Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	45	--	--	--	---	--	--
2	87	--	--	--	45	--	--
3	--	3	--	--	132	0.0227	--
4	--	--	--	--	129	--	--
5	--	3	--	--	129	0.0233	--
6	--	3	--	--	126	0.0238	--
8 --	--	2 1	.. --	.. --	123 121	0.0163 0.0083	.. ..
9	--	--	--	--	120	--	--
10	--	--	--	--	120	--	--
11							
12 --	--	.. 2	.. ..	.. 1	120 119	0.0168 --	.. ..
13	--	--	--	1	117	--	--
14	--	1	--	--	116	0.0086	--
15	--	--	--	--	115	--	--
16	--	--	--	--	115	--	--
17	--	--	--	--	115	--	--
18	--	--	--	--	115	--	--
19	--	--	--	--	115	--	--
20	--	--	--	--	115	--	--
21	--	--	--	--	115	--	--
22	--	--	--	--	115	--	--
Total	132	15	0	2	---	0.1197	0.0000
Adjusted for tag loss						0.1255	0.0000

Appendix Table H-2.9. Exploitation of northern squawfish systemwide.

		Recaptures					Exploitation		
P	T	Sport	Dam	Net	Misc.	M	Sport	Dam	Net
1	1,470	--	--	--	--	--	--	--	--
2	106	5	--	--	--	1,470	0.0034	--	--
3	21	4	--	--	--	1,571	0.0025	--	--
4	58	1	--	--	2	1,588	0.0006	--	--
5	20	6	--	--	1	1,643	0.0037	--	--
6	53	11	--	--	--	1,565	0.0066	--	--
7	165	9	2	1	--	1,698	0.0053	0.0012	0.0006
8	31	18	--	--	--	1,851	0.0097	--	--
9	--	9	2	--	1	1,864	'0.0048	0.0011	--
10	--	12	3	2	--	1,852	0.0065	0.0016	0.0011
11	26	8	5	1	--	1,835	0.0044	0.0027	0.0005
12	--	4	5	3	--	1,847	0.0022	0.0027	0.0016
13	--	5	1	1	1	1,835	0.0027	0.0005	0.0005
14	--	7	2	--	1	1,828	0.0038	0.0011	--
15	--	3	1	--	--	1,818	0.0017	0.0006	--
16	--	4	--	--	1	1,814	0.0022	--	--
17	--	2	1	--	--	1,810	0.0011	0.0006	--
18	--	2	--	--	--	1,807	0.0011	--	--
19	--	2	--	--	--	1,805	0.0011	--	--
20	--	2	1	--	--	1,803	0.0011	0.0006	--
21	--	--	--	--	--	1,800	--	--	--
22	--	--	--	--	--	1,800	--	--	--
Total	1,950	114	23	8	7	--	0.0646	0.0126	0.0044
Adjusted for tag loss							0.0677	0.0132	0.0045

APPENDIX H-3

Backcalculated Lengths and Age-at-Length Keys for 1593

Appendix Table H-3.1. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from Bonneville Dam tailrace, 1993.

Year Class	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1992	96														
1991	44	132													
1990	41	125	183												
1989	32	113	164	207											
1988	33	126	178	214	245										
1987	33	146	199	235	268	296									
1986	33	141	202	244	279	309	335								
1985	35	148	194	237	271	305	328	354							
1984	33	145	208	253	298	335	363	385	408						
1983	35	157	217	265	304	336	366	394	415	434					
1982	35	147	209	250	291	324	355	384	412	435	458				
1981	37	157	220	268	312	346	373	400	428	452	471	497			
1980	35	152	215	262	301	329	352	377	402	422	444	462	477		
1979	35	136	181	224	263	302	334	367	391	415	438	455	475	497	
1978	37	154	191	231	280	312	336	354	373	392	420	443	464	490	520
N	256	244	212	179	159	128	100	65	55	35	26	16	7	3	1
Mean	39	136	194	237	277	316	349	382	412	436	459	482	479	494	520
SD	16	24	27	32	33	31	31	29	29	26	24	29	21	7	--
Increment	39	97	58	43	40	39	33	33	30	24	23	23	--	--	--

Appendix Table H-3.2. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from Bonneville Reservoir, 1993.

Year Class	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1992	68															
1991	33	111														
1990	32	107	169													
1989	32	123	184	230												
1988	33	127	193	238	271											
1987	30	134	183	223	262	293										
1986	29	137	204	248	280	306	329									
1985	32	137	199	250	287	314	335	354								
1984	30	138	206	251	285	314	339	359	375							
1983	33	138	203	253	293	324	350	373	394	414						
1982	31	127	198	254	295	329	356	379	399	416	435					
1981	31	145	208	264	312	345	373	403	426	447	467	485				
1980	31	144	206	261	299	337	364	388	416	437	459	480	501			
1979	28	142	205	268	325	356	387	410	430	453	475	492	511	526		
1978	39	115	168	222	235	281	325	364	392	420	442	460	475	492	512	
1977	39	90	154	191	232	255	298	320	341	357	392	417	441	458	472	505
N	293	289	259	209	157	139	126	101	78	63	41	25	13	5	2	1
Mean	32	126	190	244	286	318	346	373	399	425	451	481	497	506	492	505
SD	8	25	27	28	27	30	32	33	33	35	31	25	27	31	28	--
Increment	32	94	64	54	42	32	28	27	26	26	26	30	16	9	--	--

Appendix Table H-3.3. Mean backcalculated fork lengths (mm) at the end of each year of life for northern sguawfish from The Dalles Reservoir, 1993.

Year Class	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1992	--															
1991	46	121														
1990	41	120	182													
1989	41	123	180	226												
1988	41	136	192	233	267											
1987	41	152	211	259	290	314										
1986	41	151	222	266	295	318	338									
1985	42	144	210	261	295	322	342	361								
1984	41	133	203	256	293	323	345	364	384							
1983	40	144	217	268	301	331	356	376	393	413						
1982	44	134	210	263	302	331	358	381	402	422	441					
1981	42	132	202	253	291	321	344	367	387	407	425	446				
1980	43	143	212	260	301	335	362	388	408	428	448	464	484			
1979	42	169	226	270	309	343	373	396	415	433	452	467	479	494		
1978	39	163	215	265	300	329	358	377	401	425	446	458	474	488	504	
1977	45	161	198	239	279	306	341	367	396	313	434	453	469	483	490	511
N	277	277	262	214	167	145	127	102	85	61	46	36	27	12	8	2
Mean	42	135	199	251	292	324	349	373	395	420	441	458	480	489	500	511
SD	6	24	30	29	23	21	25	26	26	25	27	28	30	34	24	35
Increment	42	93	64	52	41	32	25	24	22	25	21	17	22	9	11	11

Appendix Table H-3.4. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from John Day Reservoir, 1993.

Year Class	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1992	86															
1991	66	97														
1990	63	136	187													
1989	65	164	218	258												
1988	68	144	209	256	279											
1987	68	166	233	269	297	320										
1986	66	171	226	266	296	320	341									
1985	69	167	232	274	304	328	347	364								
1984	69	173	237	278	313	340	360	379	399							
1983	68	184	244	285	313	340	361	382	398	415						
1982	67	154	223	279	317	349	370	393	410	423	438					
1981	67	189	252	290	322	349	376	403	424	446	467	486				
1980	67	170	228	268	304	331	354	381	400	421	440	455	471			
1979	66	202	244	278	306	330	347	361	375	399	429	453	465	479		
1978	70	156	206	249	283	314	335	358	381	405	428	446	465	477	494	
1977	68	122	175	224	247	275	295	322	348	365	390	420	444	465	478	525
N	167	160	156	148	139	133	118	93	70	49	29	22	16	9	9	1
Mean	68	166	228	271	303	330	352	376	399	418	440	459	466	476	492	525
SD	7	32	33	29	29	29	30	28	28	27	24	25	19	18	22	--
Increment	68	98	62	43	32	27	22	24	23	19	22	19	7	10	16	33

Appendix Table H-3.5. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from McNary Reservoir, 1993.

Year Class	Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1992	68															
1991	62	120														
1990	63	123	175													
1989	59	133	172	203												
1988	61	134	197	236	263											
1987	60	139	199	243	274	298										
1986	61	142	196	240	273	300	320									
1985	61	153	213	259	294	318	338	357								
1984	60	157	218	258	291	317	339	357	376							
1983	62	161	226	269	309	338	362	383	401	420						
1982	65	163	232	276	308	333	357	377	396	412	428					
1981	65	179	235	281	320	349	370	390	412	433	449	468				
1980	67	175	223	262	295	327	353	382	405	432	450	467	486			
1979	59	147	205	240	285	320	344	363	377	403	416	436	447	459		
1978	59	133	199	243	284	323	352	379	400	419	442	456	477	494	508	
1977	60	153	201	236	260	293	323	351	366	384	410	425	440	453	467	486
N	187	182	168	163	156	140	123	98	74	49	33	18	11	6	4	1
Mean	62	148	209	253	288	318	343	369	392	419	436	460	472	475	498	486
SD	6	27	27	28	26	26	27	28	28	29	32	24	29	30	34	--
Increment	62	86	61	44	35	30	25	26	23	27	17	24	12	3	23	--

REPORT I

Economic, Social, and Legal Feasibility of the 1993 Northern Squawfish Removal Fisheries and Fish Distribution System

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1993 Annual Report

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ABSTRACT

We report on our research conducted from April 1, 1993, through September 30, 1993, to analyze the economic, social and legal feasibility of northern squawfish (*Ptychocheilus oregonensis*) removal fisheries. We also report on the structure and function of the fish collection and distribution system.

Northern squawfish were provided to this project from two removal fisheries — a sport-reward fishery and a dam-angling fishery. We performed baseline monitoring of the two removal fisheries and assessed cost-effectiveness of removals. We evaluated the removal fisheries for social, regulatory, and enforcement issues related to their conduct.

We developed and administered an extensive collection, transportation, storage and delivery system for northern squawfish landed by the sport-reward and dam-angling fisheries. We provided northern squawfish for both food and non-food uses.

We analyzed the angler participation segment of the sport-reward fishery through responses to a survey administered to all anglers returning northern squawfish to check stations. We surveyed creel clerks for further information on angler response and fishery

operations. We assessed several social issues related to the operation of the sport-reward fishery through surveys of fishery participants, fishery staffs, and enforcement personnel.

We make several specific recommendations concerning fish collection and distribution in subsequent fishing seasons.

INTRODUCTION

The 1993 season concluded our research of the feasibility of alternative fisheries for northern squawfish (*Ptychocheilus oregonensis).* The research was first begun in February 1989. This report summarizes our research activities and results during the first half of the performance period from April 1, 1993, until September 30, 1993. The 1993 project has three objectives related to the evaluation of the feasibility of northern squawfish removal fisheries. These three objectives are listed below.

1. Oversee the collection, transportation, storage, and distribution of all northern squawfish removed during the 1993 fishing season.

2. Conduct baseline monitoring of dam-angling and sport-reward removal fisheries for northern squawfish.

3. Conduct baseline monitoring of social, regulatory, and enforcement issues related to the predator control program.

This report presents results of research activities conducted through September 30 under the three project objectives. Discussions are presented in four subject areas — fishery operations, distribution of catch, catch utilization, and social and regulatory issues.

METHODS

Fishery Operations

Northern squawfish were harvested by two types of fisheries in 1993 — sport reward and dam angling. The number of harvest sites in the sport-reward and dam-angling fisheries continued as in 1992, but the mix of harvest locations changed. Harvest sites included eight mainstem dams and sport-reward locations ranging from Longview, Washington, east to Clarkston, Washington.

Staggered opening times in the two fisheries meant that northern squawfish were provided to the Oregon State University (OSU) project during different time periods. The dam-angling fishery was conducted between May 17 and September 19. As in the 1992 season, opening times varied for different dams. The sport-reward fishery operated between May 3 and September 12.

Operations of the two northern squawfish removal fisheries were monitored by this project for logistics of operations, characteristics of sport anglers, and the effectiveness of fish collection and distribution systems. Catch and effort per site, agency expenditures, and conflicts will be evaluated in the second half of the performance period. Because funding interest in the economic and social components of the fishery has waned, the 1993 monitoring level was reduced to a much lower level than in 1992.

Five sources of data provided monitoring of the sport-reward fishery — reward voucher questionnaires, registration forms, catch weight, a survey of creel clerks, and agency expenditures.

Consistent with the lower level of monitoring, the survey instrument used to collect data from the sport-reward fishery was revised to include fewer questions. The 1993 angler survey included questions on amount of time spent fishing, reason for the fishing trip, fishing methods, reasons for participation in the northern squawfish program, distance traveled to fish, frequency of recreational fishing throughout the year, age, and home state. Questions on angler expenditures, accommodations, information sources, and education were eliminated. Responses in the previous two years were similar enough to indicate that no new information would be generated by their continuance.

The survey was administered to every participant in the sport-reward fishery returning to a check station. The design of the survey instrument was coordinated with the Washington Department of Wildlife (WDW) and the Pacific States Marine Fisheries Commission (PSMFC). The 1993 sport-reward fishery survey form is presented in Appendix Figure I-l. 1. As in 1992, the payment voucher certifying 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. The list of 1993 sport-reward fishery check stations and their numerical codes is presented in Appendix Table I-l. 1.

Survey data were entered throughout the 1993 fishing season; 9,357 survey forms were coded and processed. A total of 10,251 survey forms were returned, but 894 of these forms (8.7%) were returned after the data entry position was terminated and so were not entered. The distribution of both analyzed and not analyzed survey forms is presented in Appendix Table I-1.2. The percent of each check station's total surveys not analyzed ranged from a low of 2.4% for The Dalles to a high of 19.9% for Columbia Park. These percentages are consistent with the distribution of analyzed surveys across sites.

The cost-effectiveness of sport-reward fishery operations in terms of total expenditures and average expenditures per fish removed is awaiting data to be provided by cooperators in the Washington Department of Fisheries and Wildlife. Cost-effectiveness summaries appear in Appendix Tables I- 1.3 and I- 1.4.

Dam-angling fishing operations were monitored using two sources of data — catch data and agency expenditures. Further assessments of dam-angling fishery operations were made through a survey of dam supervisors and enforcement personnel. The major questions of interest to the feasibility project concerning the dam-angling removal method are the effectiveness per unit cost and the interactions with other project components, dam operations, and the general public. Effectiveness is measured in terms of northern squawfish removals per dollar spent to plan, operate and manage the fishery. Data elements required for the feasibility analysis are catch, effort, incidental catch, gear, bait, time spent fishing, labor costs, and equipment costs. These data were provided by CRITFC, which oversaw dam-angling operations. The results are presented in Appendix I-2.

Distribution of Catch

The 1993 harvest of northern squawfish was approximately 142,500 lb. This quantity was harvested by the two removal fisheries. The northern squawfish were used in minced-food production and rendered for fish meal and oil. Of the total, Stoller Fisheries Inc. received approximately 99,000 lb of frozen, food-grade northern squawfish for the production of minced fish and fishmeal/oil. The remaining 43,500 lb was rendered for conversion to fish meal and fish oil.

Seventy-eight percent of the 1993 northern squawfish catch that was handled in food-grade collection areas was food-grade quality. Oversight and quality control of the handling program increased in effectiveness in 1993 because food-grade handling was limited to three locations, as opposed to five locations in 1992. Two of the locations, Tri-River Smelt in Kelso and the Cascade Locks facility, were operated by subcontractors who worked with the program in 1992. Desert Cold Storage in Pasco, Washington, was a new participant in 1993. All three handlers have performed very well during their involvement with the program.

Good handling practices by both sport-reward creel clerks and the dam anglers allowed for the collection of a high proportion of food-grade northern squawfish. Coolers containing fish, with very few exceptions, were properly labeled, iced and drained when received by the processors. The good field handling practices made the job of grading individual fish easier. Stoller Fisheries trucks picked up the frozen squawfish promptly when minimum quantities were accumulated, eliminating the need for temporary cold storage.

The 1993 northern squawfish collection, handling and distribution program was designed to accomplish four tasks associated with our first project objective. Objective 1 is to oversee the collection, transportation, storage, and distribution of all northern squawfish collected during the 1993 fishing season. Tasks associated with Objective 1 are listed below:

1. Set up a network for receiving, handling and shipping of northern squawfish operated principally by the private sector.

2. Design and develop a program to facilitate the transfer of virtually all handling responsibilities to the private sector in 1994.

3. Develop a quality control plan with the goal of 75% food-grade collection. Include a plan for the complete transfer of fish handling responsibilities and handling equipment to participating agencies that operate in remote, relatively unproductive areas (e.g., Snake River dams, Lyons Ferry).

4. Establish a mechanism for northern squawfish purchase by private sector users.

The collection, handling and distribution system was designed and implemented with several key components. Equipment to facilitate the handling and distribution of northern squawfish was distributed to participating agencies and subcontractors for their maintenance and use. The equipment included chest freezers, commercial fishing totes and coolers purchased by the OSU project between 1990 and 1992. Distribution of the equipment to the various projects handling northern squawfish was done to simplify its oversight, maintenance and protection.

Two companies, Tri-River Smelt in Kelso, Washington, and Desert Cold Storage in Pasco, Washington, were contracted to receive and process food-grade northern squawfish. The food-grade fish were harvested by the sport-reward and dam-angling fisheries. The fish were packaged and frozen at the two facilities.

A fish processing facility in Cascade Locks, Oregon, served as the headquarters for the handling program and processed about 60% of harvested squawfish in 1993. The facility was rented fully equipped with an ice machine, freezer, cooler, fork lift, and other processing equipment. Three fish-handling technicians were hired to staff the facility. Storage spaces were rented in Portland, Oregon, and Dallesport, Washington, to serve as pickup locations for squawfish harvested in these areas.

Three businesses were subcontracted in eastern Washington to provide disposal services. Dayton Cut and Wrap, Finch's Market, and Height's Meat market transferred northern squawfish for rendering. The disposal service arrangement was established to accommodate fishing areas logistically unsuited for the collection of food-grade northern squawfish.

A 30,000-lb truck was rented to provide the principal transportation needs for the lower river collection area. This area extended from Longview to The Dalles. The truck was equipped with a lift gate for delivering totes of ice and picking up northern squawfish.

A quality control program was implemented at sport-reward check stations and dam fishing sites in areas with food-grade fish handling services. The program resulted in the collection of food-grade northern squawfish representing 78% of the total catch weight in these areas. As in 1992, packaged food-grade northern squawfish were made available to Stoller Fisheries in Spirit Lake, Iowa. The frozen northern squawfish were delivered by Stoller Fisheries trucks to their Iowa plant for processing into minced-fish products.

A summary of northern squawfish collection and distribution by area follows.

Longview: Tri-River Smelt in Kelso, Washington, provided food-grade fish handling services for the Cathlamet, Rainier, and Kalama sport-reward sites. The facility, located at 804 Westside Highway in Kelso was well suited for the purpose of boxing and freezing squawfish, but was not able to provide ice. Ice was provided by the Cascade Locks facility, delivered weekly by an OSU employee. One employee hired by Tri-River Smelt processed fish and cleaned coolers daily. At the end of each sport-reward check station shift, creel clerks delivered coolers containing iced squawfish to the walk-in cooler in the facility. The Tri-River Smelt facility also served as the WDW sport-reward field office.

Portland: A storage space was rented from Brattain Ideal lease, 13101 N.E. Whitaker Way, Portland, Oregon. Northern squawfish from the M. James Gleason and Camas sport-reward check stations were delivered daily to this facility by WDW creel clerks. Coolers containing the iced northern squawfish were picked up daily by an OSU employee dispatched from the Cascade Locks facility. As needed, OSU employees delivered clean coolers and insulated totes containing ice to sport-reward check stations for use by WDW. Northern squawfish collected from the storage site were processed at the Cascade Locks facility.

Cascade Locks: The Cascade Locks facility was located at 100 Herman Creek Dr., Cascade Locks, Oregon. It processed squawfish received from several fishery locations. The sport-reward fishery locations served by the Cascade Locks facility included M. James Gleason, Camas, The Fishery, Hamilton Island, Cascade Locks, Bingen Marina, The Dalles, and LePage Park. Dam-angling fishing sites served by the facility included Bonneville Dam, The Dalles Dam, and John Day Dam.

As was mentioned earlier, sport-reward fish from M. James Gleason and Camas were delivered by WDW to the Portland storage location and later picked up by OSU employees for transport to Cascade Locks. OSU employees also transported ice, coolers and northern squawfish to and from Bonneville and The Dalles dams. Northern squawfish from The Fishery, Hamilton Island and Cascade Locks Marina were delivered directly to the Cascade Locks facility by WDW technicians. Squawfish from Bingen Marina, The Dalles, and Lepage Park were delivered to the Dallesport field office by WDW and then picked up daily by OSU technicians and transported to Cascade Locks. Squawfish caught by dam anglers on John Day Dam were bagged and frozen in chest freezers on site and picked up as needed by OSU.

The Cascade Locks facility provided all equipment necessary for the fish handling needs of the program. The equipment included a fork lift, a -5°F freezer, cooler, conveyer line, steam cleaner and a standard-height loading dock. This facility also served as the office for the handling and distribution program office.

Northern squawfish received at the facility were sorted into food grade and industrial grade. Food-grade northern squawfish were boxed, frozen and stored in the freezer. Industrial-grade northern squawfish were dropped into a tote and picked up weekly by Darling Delaware, a renderer from Portland, Oregon. Boxes of frozen northern squawfish were picked up by Stoller Fisheries from Cascade Locks and Pasco when a total of 45,000 lb was accumulated.

The Dalles: A storage space at HWY 197 and Tidyman Rd., Dallesport, Washington, was rented from Gilmore Fish. This facility served as a drop-off location for Bingen, The Dalles, and LePage Park sport-reward sites. An OSU technician picked up full coolers daily for transport to Cascade Locks and delivered ice and clean coolers as needed. WDW also rented office space at this location.

Tri-Cities: Desert Cold Storage at Pasco Airport, Building E, Pasco, Washington, was subcontracted to supply food-grade handling services. This facility served as a receiving area for fish from the Umatilla, Columbia Point, Vemita, and Hood Park sport-reward sites and also from McNary Dam. Desert Cold Storage subcontracted for both ice supplies and rendering services, and also rented office space to WDW.

WDW creel clerks delivered full coolers daily to Desert Cold Storage. McNary Dam anglers delivered their daily catch to the Umatilla sport-reward site and exchanged filled coolers for clean coolers and ice. WDW technicians then delivered these coolers from the Umatilla check station to Desert Cold Storage in Pasco.

Lyons Ferry: Northern squawfish landed at the Lyons Ferry sport-reward check station were bagged and frozen in a chest freezer located at the Lyons Ferry Marina. WDW technicians delivered the frozen bags weekly to Dayton Cut and Wrap, 406 Main St., Dayton, Washington. The northern squawfish were ultimately rendered.

Pullman: Northern squawfish landed at the Boyer Park sport-reward check station were delivered daily by WDW technicians to Finch's Market, 850 S. Grand, Pullman, Washington. The fish were picked up occasionally from Finch's Market by a Spokane rendering company.

Clarkston: Northern squawfish landed at the Greenbelt Park check station were delivered daily by WDW to Height's Meat Market, 2454 Appleside - 15th S., Clarkston, Washington. Squawfish from the Snake River dam-angling fishery were also periodically delivered to this location by CRITFC. The fish delivered by CRITFC had been previously bagged and frozen in chest freezers on the dams, and were ultimately rendered.

Social and Regulatory Issues

The 1993 assessment of social and regulatory issues associated with the conduct of the sport-reward and dam-angling fisheries for northern squawfish is based on information from the operation of the two fisheries. Information on conflicts occurring either on the water or on shore during the 1993 season was collected through surveys of sport anglers, creel clerks, dam anglers, and enforcement personnel.

The creel clerks' perspective on fishery operations and suggestions for improvement were assessed through a written survey. The survey was distributed to creel clerks at the end of the season and asked to assess the program in terms of the number of angler complaints they heard about boat ramps, fishing, registration, operating hours, data forms, fish check-in, data collection, staffing and equipment. Creel clerks were also asked to identify any areas of needed change in the operations of the sport-reward fishery. The 1993 creel clerk survey form is presented in Appendix Figure I-l .2.

Information summarizing social and coordination issues in the dam-angling fishery was acquired from CRITFC personnel. Enforcement issues related to both the dam-angling fishery and the sport-reward fishery were identified through interviews with enforcement personnel from all geographic areas of the predator control program. Enforcement personnel were also asked for their recommendations for change in operations of either the sport-reward or dam-angling fishery.

RESULTS

Fishery Operations

Sport-Reward Fishery

The sport-reward fishery began on May 3 and encompassed 18 check stations along the Columbia and Snake rivers, two fewer than in 1992. We again used a combined voucher-survey form to collect information from participating anglers. Information collected included fishing time and methods, distance traveled, fishing experience, reasons for participating in the program, and various demographic variables. The 1993 survey-voucher form is included in Appendix Figure I-l. 1. Sport-reward fishery check stations and station codes are listed in Appendix Table I-l. 1.

The sport-reward fishery involved agency expenditures for creel clerk wages, reward payments, uniforms, vehicles, fuel, oil, and miscellaneous equipment. Data on costs in the sport-reward fishery were provided to this project by the Washington Department of Fish and Wildlife. Sport-reward fishery expenditures are summarized by registration check station in Appendix Tables I-l .3 and I-l .4. Expenditure data represents only station-specific expenditures and includes no apportionment of administrative costs. The most cost-effective check stations were those that caught the most fish for the expenditures allocated. Costs per fish removed ranged from a low of $6.87 at Covert's Landing to a high of $66.19 at Umatilla. The five most cost-effective check stations were, in order of least-cost per fish removed, Covert's Landing, Greenbelt Park, LePage Park, Vemita Bridge, and Hamilton Island. The five least cost-effective check stations were, in descending order from the least cost-effective, Umatilla, Boyer Park, Rainier, Kalama, and Lyon's Ferry.

A total of $1,425,273 was spent in the 1993 sport-reward fishery to remove 104,616 fish. On average over all sites, $13.62 was spent per northern squawfish removed from the rivers.

Analysis of angler survey data reveals several areas in which angler participation varied among check stations. A summary of characteristics by site is presented in the "Discussion" section. Residence of anglers varied according to the location of the check station (Appendix Figure I-l .3). Not surprisingly, anglers tended to use check stations closest to their homes. Oregon residents dominated at Gleason (4), The Fishery (6), Cascade Locks (8), The Dalles (10), LePage Park (1 1), and Umatilla (12). Washington residents dominated at Cathlamet (1), Camas (5), Hamilton Island (7), Columbia Park (13), Vernita (14), Hood Park (15), Lyons Ferry (16), and Boyer Park (17). Idaho residents dominated at Greenbelt (18).

Anglers varied in age from 14 to over 60, with the largest proportion of anglers in the 30-50 age bracket (Appendix Figure I-1.4). Greenbelt (18) was the exception, with anglers in the 41-50 and > 60 age groups dominating.

At all check stations, the majority of participants fished frequently, with most making over 25 trips per year (Appendix Figure I-l .5). This pattern of angler experience is similar to 1992. With the exception of Cathlamet (1), the majority of anglers at all check stations had participated in the sport-reward fishery in 1992 (Appendix Figure I- 1.6). However, some sites attracted large numbers of new participants, notably Cathlamet (1), Rainier (2), Kalama (3), Umatilla (12), Vemita (14), and Lyons Ferry (16).

Sites are distinguished by the distances anglers traveled to fish at them. Sites at Cathlamet, Rainier, Kalama, Gleason, Camas, Hamilton Island, Cascade Locks, Bingen, The Dalles, Umatilla, and Greenbelt attracted a majority of anglers from distances of less than 20 miles. At LePage Park, The Fishery, Columbia Park, Vemita, Hood Park, Lyons Ferry, and Boyer Park, the majority of anglers traveled greater distances to fish. Anglers fishing out of LePage Park and Lyons Ferry typically traveled distances of over 100 miles.

For the majority of participating anglers, fishing for northern squawfish was the primary reason for the fishing trip (Appendix Figure I-l .8). Exceptions are at The Dalles (10), Umatilla (12), and. Lyons Ferry (16) check stations, where the majority of anglers said they would have taken the trip even without the northern squawfish fishery.

The number of anglers represented on a single survey form varied very little across check stations. Most people filled out surveys as single anglers (Appendix Figure I-1.9). Similarly, the average number of hours fished also varied little, ranging from 4.5 hours to 7 hours per day (Appendix Figure I-l. 10). The number of northern squawfish caught per trip did vary across check stations. The lowest average catches were at Camas (5) and Umatilla (12). The highest at Vemita (14) and Hood Park (15) (Appendix Figure I-1.11). Very high maximum catch levels were reported at Gleason (4), The Fishery (6), Bingen (9), Vemita (14), and Hood Park (15). Average catch per hour did not vary much by check station, ranging from a low of .69 at Rainier (2) to a high of 2.34 at Hood Park (15; Appendix Figure I-1.12).

At most check stations, the primary fishing target was northern squawfish. The exception was at Lyons Ferry (16), where other target species were the primary objective for the majority of anglers (Appendix Figure I-l. 13).

Anglers were asked about their motivations for participating in the northern squawfish fishery. One survey question 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 I-l. 14 to I-l. 17. Receiving. a payment for squawfish was very important to the majority of anglers at all check stations, but Camas (5), Umatilla (12), and Lyons Ferry (16) were similar in having a larger proportion of anglers to whom payment was only somewhat important than did other check stations (Appendix Figure I- 1.14).

Having access to a recreational fishing opportunity was very important to a majority of anglers fishing out of Kalama (3), Gleason (4), Camas (5), Bingen (9), The Dalles (10) and Boyer Park (17), but less important at others. The recreational fishing opportunity element of fishing for northern squawfish was least important to anglers fishing at Vemita (14) and Greenbelt (18; Appendix Figure I-l. 15). Vemita (14) and Greenbelt (18) are also the two check stations where the majority of anglers named payment for northern squawfish as a very important factor in their participation. The majority of anglers said the opportunity to cover fishing expenses was either very or somewhat important at all check stations except Cathlamet (1). For other check stations, between 20-40% of anglers said covering fishing expenses was not important (Appendix Figure I-l. 16). The opportunity to participate in a salmon enhancement activity was very important to the majority of anglers at all check stations, repeating patterns of 1992 (Appendix Figure I-l. 17).

Fishing methods used by anglers varied by check station (Appendix Table I-1.5). Anglers fishing at Kalama (3), Camas (5), Hamilton Island (7), Cascade Locks (8), Bingen (9), The Dalles (10), LePage Park (11), Umatilla (12), Lyons Ferry (16), and Greenbelt (18) had a stronger preference for fishing from shore. In contrast, more anglers fishing at Rainier (2), Gleason (4), The Fishery (6), Columbia Park (13), Vemita (14), and Hood Park (15) fished from boats. Other methods, for example the type of boat fishing and the type of angling, varied as well.

Bait and tackle used by anglers also varied by check station (Appendix Table I-1.6). Overall, worms were the most commonly used bait. Hook and line with a single hook was the most commonly used tackle at most check stations.

The results of the sport-reward creel clerk survey indicated that check station operation has improved in several areas since 1992. The majority of creel clerks evaluated the adequacy of station operating hours, the registration process, data forms, the data collection process, staffing, and station security as "good" (Appendix Table I-1.7). These results are indicative of improvement in data forms, staffing, station security and the registration process, which had received several "fair" or "poor" ratings in 1992. Equipment at check stations continues to be evaluated as less than adequate; only 47% of creel clerks evaluated the equipment as "good," while 42 % judged it to be "fair," and 11% thought it was "poor."

Registration time at check stations, an area of frequent angler complaint in 1992, was the source of few complaints in 1993 according to 90% of responding creel clerks. The paperwork required at registration was still the source of some complaint. Fish quality requirements, which dictated fish handling practices by anglers, was still the most common source of complaint; 28% of the creel clerks reporting said they had received some complaints in this area. Also a fairly common source of complaint were the activities of other water users, resulting in complaints about speeding boats, jet skiers, and water skiers (Appendix Table I- 1.8).

According to the creel clerks, anglers were pleased, as in previous years, with the opportunity to earn money fishing and to participate in salmon enhancement activities. Several anglers also noted the benefit of the northern squawfish fishery as a fishing opportunity for children.

Dam-Angling Fishery

The 1993 dam-angling fishery was conducted by seven fishing crews fishing Columbia and Snake River dams — Lower Granite and Little Goose, Ice Harbor and Lower Monumental, McNary, John Day, Bonneville and The Dalles. In addition to crews assigned to these dams, fishing was also conducted by a mobile crew and a volunteer crew. Management and oversight of the dam-angling fishery was provided by the Columbia River Inter-Tribal Fish Commission (CRITFC), 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, labor and equipment.

Data on total agency expenditures and expenditure per fish removed by fishing crew in the dam-angling fishery were provided by CRITFC. Expenditures include subcontractor costs plus costs incurred by CRITFC specific to each dam's operation, plus costs incurred by CRITFC common to all operations (e.g., data handling, coordination, reporting).

Total agency (CRITFC) expenditures and expenditure per fish removed by fishing operation in the dam-angling fishery are presented in Appendix Table I-2.1. Expenditures include all expenditures dedicated to the operation and oversight of seven fishing crews — crews located at Bonneville and The Dalles, John Day, McNary, Ice Harbor and Lower Monumental, Little Goose and Lower Granite, the mobile crew and a volunteer angling group. Most angling crews were supervised through subcontractors. Most crews were associated with dams, but some were not. Catch figures in Appendix Table I-2.1 represent each operation's catch and may therefore not exactly correspond to catches reported for each dam.

Total expenditure figures reported for each fishing crew in Appendix Table I-2.1 include costs of project administration common to all operations. Administrative costs associated with the dam-angling fishery not directly allocable to a particular operation were distributed among the crews on a proportional basis. Proportions of common administrative costs assigned to each crew ranged from .09 for the volunteer angling crew to .22 to the mobile crew. Examples of common administrative costs apportioned among fishing crews include centrally procured supplies, data handling, coordination, and reporting. Crews that were supervised directly by CRITFC and crews that required extra oversight attention accounted for a higher proportion of total administrative costs.

The costs of handling fish are included in total costs. These costs were subtracted from total costs in 1992, but since fish handling responsibilities were shared by the removal fishery projects in 1993, handling costs are included as a part of each fishery operation.

A total of $638,480 was spent in the 1993 dam-angling fishery to remove 16,949 fish. On average over all dam operations, $38 was spent per northern squawfish removed from the rivers. Expenditures per fish removed by dam operation ranged from a low of $20 per fish for the McNary operation to a high of $134 per fish for the Little Goose and Lower Granite operation. Because most operating costs are fixed, cost per fish depends on the size of the catch for the paid crews; 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. Therefore, McNary Dam, with its high levels of catch, represents the lowest expenditures per fish removed, followed by the mobile crew operation at $29 per fish removed. The volunteer crew, although accounting for small total numbers caught, accounted for expenditures of $26 per fish removed. The relatively low expenditure per fish removed by the volunteer crew is possible because crew time is not reimbursed and costs are limited to those required for administration and oversight.

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.

Distribution of Catch

Fish Collection and Distribution

The 1993 collection and distribution system operated smoothly and efficiently. The experience in 1992 allowed us to ensure that mechanisms were in place from the season's beginning to anticipate and resolve problems. One measure of the system's success is that the pre-season goal of collecting 75% food-grade squawfish was exceeded because mechanisms were in place to handle any problems.

Of the total 142,500 lb caught in 1993, 126,300 lb, or 89%, was handled by the system set up to provide food-grade fish. Out of the food-grade handling system, 99,000 lb was food-grade, 78 % . Out of the same handling system, 27,300 lb was industrial-grade. Industrial-grade fish results from several factors. Biological sampling requires cutting open the fish, making them unsuited for food processing. Northern squawfish are sometimes in poor condition when anglers bring them in to the check station. Poor handling on site at the check station also can contribute to degraded quality. Finally, some fish, although > 11 inches, may be too small to process, and for that reason are graded for industrial use.

Overall, fish handling by the packaging subcontractors, WDW and CRITFC was excellent. However, lower than expected catch rates and smaller squawfish from the sport-reward fishery resulted in a relatively low yield in 1993. All food-grade northern squawfish were picked up by Stoller Fisheries and processed in Spirit Lake, Iowa. Stoller Fisheries indicated that the quality of the fish received was very high. All industrial-grade squawfish were processed by regional rendering facilities.

Collection and Distribution by Area

Longview: Tri-River Smelt in Kelso, Washington, provided excellent service at a suitable facility. The same company provided office space for WDW in 1992 and 1993. Only 7,839 lb were handled at this facility in 1993. The low volume combined with fixed costs of operation resulted in very high handling costs ($2.14/lb). We are looking into the possibility of Tri-River Smelt supplying rendering services for a greatly reduced cost in the future.

Portland: A small warehouse space was rented from Brattain Ideal Lease, a truck rental business. The warehouse space served as a transfer station for northern squawfish caught in the Portland area sport-reward fishery. Conflicts between OSU and Brattain Ideal lease concerning use of the space resulted in an assessment that the space was not compatible with the program. In future, northern squawfish caught in the Portland area should probably be rendered.

Cascade Locks: The Cascade Locks facility is owned by Bomstein Seafood in Seattle. This facility served the handling program very well in 1993. This building was equipped to meet all handling and packaging needs. Most of the equipment used in the sport-reward fishery, dam fishery, and the collection and distribution system is currently stored in this space. Provided this facility is available in 1994, it should again be rented for handling purposes.

Once it became apparent that 1993 catch would not be at large as in 1992, OSU began laying off handling staff at the Cascade Locks facility. The season started with three employees. One employee was laid off in mid-July. A second employee converted to half-time in early August. The 1993 season provided insight on labor requirements for operating this facility.

The Cascade Locks facility handled 86,512 lb of squawfish and packaged 68,200 lb of food-grade fish at a direct cost of $0.53/lb. Considering the modest harvest in 1993, the unit cost of processing food-grade fish at this facility was reasonable.

The Dalles: Gilmore fish in Dallesport, Washington, provided a building to serve as a fish transfer station and WDW field office. Because the facility has functioned as a fish-buying station, it has water, a loading dock, and other attributes that served the collection and distribution program well. The facility should be considered for the 1994 program.

Tri-Cities: Desert Cold Storage provided food-grade handling services to the collection and distribution program. Office space for WDW was also provided. In previous years it was difficult to find qualified subcontractors in the Tri-Cities area. The service provided by Desert Cold Storage was of high quality. The facility handled a total of 31,964 lb of northern squawfish in 1993. Of this total, 24,600 lb of food-grade fish were packaged at a cost of $0.57/lb. The facility should be subcontracted in 1994 for office space and to serve in some fish handling capacity.

Lvons Ferrv: Dayton Cut and Wrap provided adequate rendering services for this low volume area. The facility should be subcontracted in 1994 if the Lyons Ferry sport-reward site is retained.

Pullman: Finch's Market provided adequate rendering services for northern squawfish returned to the Boyer Park sport-reward check station. The facility should be considered for subcontracting in 1994.

Clarkston: Height's Meat Market provided various services to the collection and distribution program. In both 1992 and 1993, a cooler cleaning station was provided for the use of creel clerks at the Greenbelt Park sport-reward check station. Rendering services were also provided in the same time period. Rendering services for northern squawfish harvested in the Snake River dam-angling fishery were provided in 1993. Height's rendered 13,130 lb of northern squawfish in 1993. Height's rendering services are charged at $0.31 per lb, a low unit cost for a medium volume area.

Collection and Distribution Volume and Cost

Fish handling costs are summarized in Appendix I-3. All costs associated with handling operations in each area are included in the summary. Cost items include personnel, rental (building and equipment), supplies (packaging and ice), and transportation (vehicle rental). Administration and other fixed costs were not included when handling costs by area were calculated because they do not directly influence the efficiency of individual operations. These cost, however, are itemized and included in the total budget summary for 1993. Appendix Table I-3.1 summarizes the yield, costs by handling area, and total handling program costs for the first half of the 1993 performance period.

The 1993 collection and distribution program handled 142,480 lb of squawfish at a total cost of $113,925. Average direct handling costs were $0.80 per lb. Of the total direct costs, about $24,000 ($0.17 per lb) was spent for logistical arrangements associated with the program's large geographic scope. The program covers 26 collection sites over a 350-mile wide area. In absence of the costs associated with geographic scope, direct fish handling costs are reduced to $89,925, $0.63 per lb.

Height's Meat Market in Clarkston provided the handling and distribution program the least expensive rendering services ($0.31/lb) for a medium volume area (13,135 lb). A programwide rendering system probably could not have operated for less than $0.40 - $0.45/lb. Rendering for the squawfish program is expensive because of the labor and space rental associated with a demand for daily services for 4.5 months. Rendering costs increase with volume because labor and equipment requirements also increase. Higher volumes require more frequent pickups. Large volumes of northern squawfish require additional labor for fish handling. In addition, large volumes of fish must be chilled in the field and remain chilled until pickup to prevent spoilage. Per-ton rendering costs at $30-$50/ton do not decrease as volume increases. Finally, the odor of rotting fish would surely cause public concern and a poor perception of the handling program.

Provided reimbursement for northern squawfish in the range of $. 11 to $. 15 is possible, food-grade handling becomes cost-effective as the volume handled at one location increases. For example, a food-grade operation at Cascade Locks can be operated as inexpensively as a rendering program in the same area (about $0.45/lb after sale of fish at $0.15/lb), provided the volume handled is large. With some streamlining, a cost-effective food-grade program may be possible for the Tri-Cities area as well.

Catch Utilization

Minced Food Product

Stoller Fisheries again processed northern squawfish into a minced food product in 1993. A total of 103,010 lb of northern squawfish were received by this firm. The quality of fish received by Stoller Fisheries was very high. Fish was freshly frozen and well-packaged. Of the total received by Stoller Fisheries, 96.3% of the fish were large enough - over 13 inches long - and of high enough quality to be processed as deboned product. The mince was processed by itself and not mixed with other species. Yield rates for deboned mince were 32.43%. The remaining 3,820 lb (3.7%) were processed into fish meal.

The exvessel value of food-grade northern squawfish collected in 1993 ranged between $6,600 to $12,000 depending on assumed exvessel price ($. 11 - $. 15) and recovery yields (9-15%). Recovery yields vary with size of fish. Sale of northern squawfish within this price range represents a substantial potential cost-recovery for the handling and distribution program.

In 1991 and 1992, research on the food qualities of northern squawfish and its suitability for processing was supported by this project. A Masters of Science thesis on this subject was completed in 1993 (Lin 1993). Findings are consistent with Stoller Fisheries evaluations of northern squawfish characteristics. Production of deboned minced fish was found to be an effective method of utilizing northern squawfish. Textural qualities of minced flesh were found to be robust to lack of washing or washing, as well as to different temperature settings. Cryoprotectants were found to be effective for maintaining texture during frozen storage. Minced flesh maintained good qualities with respect to oxidation (Lin 1993).

Northern squawfish flesh was also tested for its suitability for surimi. Surimi yield from whole fish ranged between 15.5-21.6%. Freshness of flesh was positively associated with surimi quality and negatively associated with frozen storage life. Experimental results indicated that it was feasible to produce surimi from northern squawfish stored on ice for up to nine days (Lin 1993).

Renderers

The 43,500 lb of industrial-grade northern squawfish delivered to renderers was combined with other protein sources and eventually processed into animal feed.

Social and Regulatory Issues

Sport-Reward Fishery

Continuing conflict with other on-water users is evident in the sport-reward fishery. "Some" to "many" angler complaints about crowding from other anglers were received by 21% of creel clerks in 1993. A percentage of creel clerks also reported "some" to "many" complaints about speeding boats (24%), jet skiers (28%), water skiers (22%), and litter on banks (19%). Very few complaints were heard about commercial fishermen or gear damage in 1993, an improvement over 1992 (Appendix Table I-1.7). Other complaints made by anglers to creel clerks often enough to take note include questions about fish quality requirements, the need for registration paperwork, and check-in times.

Creel clerks were asked to make note of the most frequent complaints heard from anglers about the sport-reward fishery. A recurring complaint from anglers concerns the lack of payment for fish < 11 inches. Many making this complaint suggest a small reward for undersized fish. It is notable, however, that unlike previous years, no complaints about the size of the reward payment were registered. In fact, some complaints about the reward payment being too large were noted. Other complaints center on the requirement to fish in the mainstem rather than tributaries and the need to register every day. Still others complained that the entire program was a waste of public money.

Creel clerks were also asked to record frequently heard compliments about the sport-reward fishery. The most frequent compliment was about the income opportunities associated with the program. Anglers like participating in salmon enhancement activities, and also liked the ability to pre-register.

Creel clerks were asked for their evaluation of several aspects of sport-reward check station operations — operating hours, registration process, check-in process, data forms, data collection, staffing, equipment, and station security. Results of this evaluation are summarized in Appendix Table I-1.6.

Operating hours were evaluated to be "good" by 79% of reporting creel clerks and "fair" by 21%. Most creel clerks responding to the survey made suggestions for improvement. One suggestion was to vary the opening hours by check station, scheduling the longest opening hours at the most productive check stations. Another suggestion was to arrange opening hours to enable only one shift per site. A related suggestion was to allow self-registration in the morning and extend the check station hours into the evening.

The registration process received exactly the same evaluation as did operating hours — 79% "good" and 21% "fair." One suggestion for improvement made by several creel clerks was to allow anglers to register only once. Others suggested that registration boxes be placed at boat ramps, that registration paperwork be streamlined, and that anglers be allowed to register the previous day.

The check-in process received very high ratings by creel clerks, with 97% rating it "good." The only suggestion for change was a single suggestion to take complete biological data on fish under 10 inches and continue to use the current protocol on fish > 11 inches.

Data forms were also rated highly, with 92% of the responding creel clerks evaluating them as "good." Suggestions for improvement included eliminating the overlapping data on the OSU survey form, placing the last name first, and requiring registration proof for fishing in waters closed to trout or steelhead.

The data collection process was evaluated as "good" by 89% of responding creel clerks and "fair" by 11%. Creel clerk suggestions included improving the scale cards and envelopes, to use the same protocol for all fish, and to decrease the number of early-season scale samples required.

Staffing received a "good" rating by 82% of responding creel clerks, and was rated only "fair" by 18%. Several comments suggested that check stations were overstaffed. One suggestion was that a single employee is enough for check stations that process fewer than 500 fish per day.

Equipment received the worst rating of all check station elements evaluated. Only 47% of responding creel clerks gave the equipment a good rating; 42% rated it "fair," and 11% rated it "poor." The major complaint was about the scales used at check stations. The scales were characterized as old and inaccurate. Additional comments were made about dull knives and the need to have battery operated lights instead of Coleman lanterns.

Although 89% of responding creel clerks thought station security was good, several concerns were also expressed. Major concerns were that remote stations needed phone or radio communication and that stations should either have two creel clerks on duty in the evening or be closed after dark.

The existence of the sport-reward and dam-angling fisheries for northern squawfish has increased the burden on limited enforcement resources. The survey of enforcement personnel identified several regulatory issues related to the sport-reward fishery. These issues fall into the categories of enforceability of program boundaries, "allowable fish," fishing without licenses, closed fishing areas, and coordination of enforcement considerations with project planning.

Enforceability ofprogram boundaries: There is a mismatch between Oregon state law that allows the take of northern squawfish from any area and the predator control program boundaries, which restrict the area from which northern squawfish can be taken for reimbursement. A similar problem in Washington state was resolved with the reclassification of northern squawfish as game fish, which can be restricted in area of catch. Taking fish from beyond the specified boundaries of the program represents fraud when those fish are presented for reimbursement under the predator control program, but is not a violation of fish and wildlife code. It is difficult for enforcement entities to justify devoting limited enforcement resources to this issue while other code violations are demanding their attention. Anglers turning in fish caught outside the program area has been a source of complaint to enforcement from other anglers. Enforcement personnel suspect that fishing outside the program area remains a common practice, with estimates of up to 10% 'of total catch coming from outside program boundaries.

Allowable fish": In addition to the cases mentioned above of landed fish that are illegal by area of catch, a few incidents of fish caught with illegal gear were reported. Some fish with obvious gill-net marks were accepted by check stations. Other fish in poor condition were accepted.

Fishing without licenses: A few cases were reported of anglers with revoked Washington fishing licenses attempting to purchase Oregon fishing licenses to fish for northern squawfish. This problem is not specific to the predator control program and is not thought to be widespread.

Closed fishing areas: The reclassification of northern squawfish as game fish in Washington state has allowed the state to impose closed areas and gear restrictions for management purposes. These changes have eased the enforcement burden somewhat. Problems persist in areas that are closed to other sport fishing, but open to northern squawfish fishing. A specific example involves two reaches along the Columbia River, one below Priest Rapids Dam and the other below McNary Dam, that are closed to spring fishing to protect nesting waterfowl, but are not closed to northern squawfish fishing.

Coordination of enforcement efforts with program planning: Enforcement personnel mentioned the continuing need to improve the coordination between predator control program operations and enforcement needs. Program design and rules have enforcement implications that are often not considered by program planners. As a consequence, enforcement burdens are sometimes higher than necessary and compliance is sometimes not as high as it could be. The general assessment was that coordination is improving, but further improvements are needed.

Dam-Angling Fishery

The assessment of dam-angling operations by both CRITFC and enforcement personnel indicate a continued improvement in dam-angling interactions with other program participants and with the public.

The volunteer angling program, in which members of the public participate in dam angling, was reported by CRITPC to be producing intangible benefits of cooperation between tribal members and non-tribal recreational anglers, between the predator control program and members of the public, and between fishery management organizations and the public. Additional benefits are realized through interactions between visitors to dams and members of dam-angling fishing crews.

Relationships between dam angling crews and Army Corps of Engineers personnel are generally good, and are continuing to improve in areas that were problematic in the past.

Enforcement personnel report very few social or regulatory problems with the dam-angling fishery. There do continue to be complaints form the public concerning dam anglers fishing in the boat restricted zones around dams. Although dam anglers are not in violation while fishing in these areas, the public is generally not aware of this exception to general angler regulations.

DISCUSSION

Fishery Operation

Sport-Reward Fishery

The sport-reward fishery was far less cost-effective in 1993 than in 1992. Average cost per fish removed increased by almost $4 per fish, a 29% increase. The primary reason for the decrease in cost-effectiveness was a large decline in the number of fish removed. Compared to 1992, total catch in the sport-reward fishery declined by 79,670 fish, a decrease of 43%. Total per-site expenditures declined 20% compared to 1992, but the larger proportional decrease in catch overwhelmed the potential cost savings. Continuation of sport-reward fishery operations that are based on fixed per-site costs will continue the fishery's per-fish cost vulnerability to variations in catch.

Anglers are satisfied with the reward payment in 1993, although some still request payment for northern squawfish < 11 inches. Large numbers of anglers still see the recreation opportunity provided by northern squawfish fishing and the contribution to salmon enhancement as important motivations for their participation. An increased reward level is not necessary for continued participation of repeat anglers.

The continued use by anglers of check stations nearest their homes indicates the importance of continuing to locate check stations near large population centers and at sites that have involved the most anglers in the past. Angler response to check station hours combined with the expense of operating extended or double shifts at check stations indicates that cost savings could be realized through a combination of shorter hours with more flexible anglers registration systems. The predominant age group attracted to a given check station may serve as a guide for custom-tailoring station hours.

Most anglers in the sport-reward fishery continue to be repeat from earlier seasons. However, new participants are being attracted at new check stations. For continued project operations, it will be important to decide whether to encourage more effort by repeat, experienced anglers or whether to locate check stations to attract new anglers.

Angler motivations remain consistent with earlier seasons. Payment for northern squawfish is important, as is having a recreational opportunity. Even more important to most anglers is the opportunity to participate in salmon enhancement activities. Unlike previous years, creel clerks registered few if any complaints about the size of the reward payment. There is no evidence to suggest that an increase in the reward payment is warranted. However, the program may want to consider a reduced reward payment for northern squawfish < 11 inches, suggested by many anglers.

Processing of anglers at check stations has clearly improved with time. However, complaints about poor equipment are still being received from creel clerks.

The patterns of participation and operation continue to vary by site. Site characteristics were summarized from the angler voucher survey data to characterize "typical" patterns at each site. These summaries are listed below. "Typical" characteristics are determined by the modal, or most frequent, response for each variable and are expressed as the typical angler at each site. These characteristics may be used to plan for future program planning and site configuration.

Cathlamet: Washington angler, 30-50 years old, new participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent over five hours fishing in the trip, and caught about five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

Rainier: Washington or Oregon angler, 51-60 years old, new participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent almost six hours fishing for northern squawfish, and caught about four fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with a single hook-and-line.

Kalama: Washington angler, 41-50 years old, takes over 25 fishing trips per year, could be either a new or repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than five hours fishing for northern squawfish, and caught about four fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

Gleason: Oregon angler, 3 l-40 years old, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about six hours fishing for northern squawfish, and caught about eight fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with a single hook-and-line.

Camas: Washington angler, 21-40 years old or >60, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent between five and six hours fishing for northern squawfish, and caught about five fish.

Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

The Fishery: Oregon angler, 31-50 years old, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 40 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about seven hours fishing for northern squawfish, and caught about 12 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with a single hook-and-line.

Hamilton Island: Washington angler, any age, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than five hours fishing for northern squawfish, and caught about eight fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

Cascade *Locks:* Oregon angler, 21-50 years old, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent over six hours fishing for northern squawfish, and caught about five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing *expenses.* Preferred bottom angling from shore, and used worms with a single hook-and-line.

Bingen: Washington angler, any age, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than six hours fishing for northern squawfish, and caught about 10 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

The Dalles: Oregon angler, 41-60 years old, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for species other than northern squawfish. Spent about five hours fishing for northern squawfish, and caught about five fish.

Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

LePage Park: Oregon angler, any age, takes a varying number of fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled more than 100 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about six hours fishing for northern squawfish, and caught about eight fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred shore fishing or boat trolling, and used worms with a single hook-and-line.

Umatilla: Oregon angler, any age, takes over 25 fishing trips per year, could be either a new or repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was either to fish for northern squawfish or to fish for other species. Spent about five hours fishing for northern squawfish, and caught about five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred shore fishing or boat trolling, and used worms with spinners.

Columbia Park: Washington angler, any age, takes over 25 fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled up to 40 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than six hours fishing for northern squawfish, and caught about 10 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with a single hook-and-line.

Vemita: Washington angler, any age, takes over 25 fishing trips per year, either a new or repeat participant in the northern squawfish fishery in 1993. Traveled between 41-60 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about seven hours fishing for northern squawfish, and caught about 18 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with spinners.

Hood Park: Washington angler, 31-50 years old, takes over 25 fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled varying distances to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about six hours fishing for northern squawfish, and caught about 18 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from a drifting boat, and used worms with a single hook-and-line.

Lyons Ferry: Washington angler, any age, takes a *varying* number of fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled over 100 miles to fish, and the primary reason for the trip was to fish for a combination of northern squawfish and other species. Spent less than six hours fishing for northern squawfish, and caught less than five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, recreational opportunity, payment for northern squawfish, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

Boyer Park: Washington angler, 41-50 years old, takes over 25 fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled between 81-100 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent more than five hours fishing for northern squawfish, and caught about five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred boat trolling with worms.

Greenbelt: Idaho angler, 31-40 years old or over 60, takes over 25 fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than five hours fishing for northern squawfish, and caught less than 10 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used cutfish with a single hook-and-line.

Data to evaluate cost-effectiveness of sport-reward site operations have not been provided to this project.

Dam-Angling Fishery

Operations of the 1993 dam-angling fishery proceeded smoothly for the most part. The cost effectiveness of dam angling *operations* varied considerably across fishing sites. Costs to remove northern squawfish through dam angling varied from a low of $20 per fish at McNary Dam to a high of $134 per fish at Little Goose and Lower Granite dams. Because the cost of maintaining crews on dams is fixed for a fishing season, the per-fish cost of removal is obviously very sensitive to volumes caught. In 1993, high volumes corresponded to low per-fish costs and vice versa. The volunteer angler program is a method to reduce operating costs to administrative costs through the elimination of labor costs. An increase in the size of the volunteer effort would result in lower per-fish removal costs by averaging fixed administrative costs over a larger effort.

The dam-angling fishery caught fewer fish at higher cost per fish in 1993 than in 1992. Average cost per fish removed increased from $28 to $38, a large increase even after adjustment for a change in accounting procedures between the two years. The increase in expenditures per fish removed is attributable to lower volumes of fish handled.

Harvest Collection and Distribution

Aside from a smaller than expected harvest, the 1993 squawfish handling program was a considerable improvement over previous years. This success can be attributed principally to conscientious fish handling by sport-reward creel clerks and CRITFC dam anglers. An overall atmosphere of cooperation among WDW, CRITFC, ODFW, and OSU was maintained throughout the season. The performance of fish-handling subcontractors was also excellent.

The design of the handling program satisfied all program requirements. The program provided the necessary services for the agencies and subcontractors operating the removal fisheries. The food-grade handling facilities packaged, froze and shipped to Stoller Fisheries 78% of the volume they handled. The exceptional care taken by all parties handling fish demonstrated that a food-grade quality control program is possible. Costs of rendering compared to costs of food-grade handling show that cost-effective food-grade processing is possible when medium to large volumes of fish are sold at prices ranging between $. 11 and $.15 per pound.

The 1993 harvest was collected, processed and distributed to various end uses for an average of $0.80/lb. Of the $.80 per lb, $0.17/lb represented unavoidable logistical costs associated with the geographic scope of the program. At an estimated $0.15/lb exvessel price for the packaged squawfish, the overall direct handling cost of operating the 1993 food-grade/rendering system ($0.63/lb) was not cost-effective. However, based on information and experience gained in 1993, we conclude that it is feasible to operate a cost-effective food-grade collection system in the area between Cascade Locks and The Dalles, the most concentrated removal area. Limiting food-grade collection to the Cascade Locks-The Dalles area would reduce direct handling costs to about $0.40 - $0.50/lb (net sale at $0.15/lb).

A programwide rendering handling system probably cannot be operated at for less than $0.40 - $0.50/lb for several reasons. Rendering is inexpensive only for areas of low volume because small amounts of labor and handling equipment are required. Per unit costs rise as volumes increase due to the need for additional equipment, labor, more frequent pickups and higher rendering fees. Because of the high volumes processed, rendering in the Cascade Locks area would require most of the equipment, ice, and some of the labor necessary for food-grade handling. An additional consideration is that rendering costs in western Oregon and Washington are twice as high as those in eastern Oregon and Washington. The reason for this price discrepancy is unknown.

Large volumes of fish require some level of attention to prevent spoilage while awaiting rendering pickup. The potential for public complaint or failing Department of Agriculture inspections would make a cut-rate rendering program risky. A rendering system would not provide the services provided by the 1993 food-grade handling system — cooler steam cleaning, cooler repair, full cooler pickups, and ice deliveries in some areas. Without a food-grade handling system in place, costs of these services would be passed on to the agencies responsible for the two fisheries, WDW and CRITFC.

Collection and Distribution Recommendations

A least-cost squawfish handling system that accommodates the overall removal program should be implemented in 1994. This system should not only be cost-conscious, but also represent an awareness of overall logistics, public perception of the program, public nuisance and health issues. The handling program could include limited food-grade collection in areas where this can be accomplished cost-effectively ($0.40 - $0.50/lb) compared to rendering. The following recommendations are for a system that satisfies all of the objectives listed above.

1. Operate a food-grade collection system that receives squawfish from all harvest locations between The Fishery and Lepage Park sport-reward check stations. Do not include John Day Dam in this system. This area handled 53% of the total catch in 1993. The Cascade Locks facility used in 1993 should be rented again for 1994.

2. Render the entire catch at all other areas, with the possible exception of the Tri-Cities area.

3. At rendering-only locations, WDW and CRITFC technicians should be responsible for overall cleaning and sanitation of all equipment at their work sites. Employee time should be budgeted to help with rendering pickups from field office locations, probably once or twice a week. Involvement of WDW and CRITFC personnel in fish handling activities will reduce overall labor costs to the program.

4. Maintain the quality-control requirements for anglers in the sport-reward fishery.

5. Sell food-grade squawfish to Stoller Fisheries or other interested processors.

6. Consolidate sport-reward field stations where possible to reduce logistical costs.

7. Evaluate the possibility of renting dam-angling field offices in areas that accommodate both the dam angling crews and fish handling logistics.

Social and Regulatory Issues

Social and regulatory issues associated with the removal fisheries for northern squawfish have continued to improve.

The most prominent issues continue to be related to the large numbers of anglers participating in the sport-reward fishery. Large number 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.

Enforcement personnel had the following recommendations for changes in the sport-reward and dam-angling fisheries. Oregon should reclassify northern squawfish as a game fish to ensure that regulations affecting its capture arc consistent with other sport fish and with Washington. Regulations managing northern squawfish should be coordinated with other existing fish and wildlife management efforts. More pre-season coordination should exist between the sport-reward fishery and enforcement personnel.

Because of the difficulties caused by limits on the source of origin of qualifying fish, enforcement personnel recommended that the sport-reward fishery remove its restrictions on origin of fish and accept all fish delivered. Alternatively, if the fishery needs to continue to restrict source of origin, the program should hire its own criminal investigator to pursue possible sources of fraud rather than rely on existing law enforcement personnel. A half-time officer might be sufficient to this task. It was noted that most violations occur early in the season when tributary squawfish are easier to catch in warmer water. An alternative approach to hiring a criminal investigator would be for WDFW squawfish biologists to assume some enforcement responsibilities as field observers. This function is now performed by ODFW biologists during big game seasons.

Enforcement personnel made two additional recommendations about sport-reward fishery operations. The first is to reconsider the self-registration procedure, which allows anglers to falsify actual registration time and provides them the opportunity to fish at greater distances from the registration site. The second recommendation is to carefully consider the effect of incentive programs such as tags and drawings. These programs encourage anglers to report violations, but also encourage more fraud.

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.

REFERENCES

Lin, D. 1993. Characteristics of northern squawfish (Ptychocheilus oregonensis) and feasibility for utilization as human food. Unpublished M.S. Thesis. Oregon state University, Department of Food Science and Technology, Corvallis.

APPENDIX I-l

Sport-Reward Fishery Information

Appendix Figure I-l. 1. Sport-reward fishery survey form, 1993.

Both voucher and questionnaire must be completed before payment will be made. An incomplete voucher or questionnaire will be returned to sender for completion. This will delay processing and payment.

PLEASE CIRCLE OR FILL IN THE APPROPRIATE ANSWER

1. Number of anglers reporting catch on this form: ___ anglers

2. Number of hours each angler reporting on this form spent fishing: a n pgr l e r

3. Primary reason for this fishing trip **(circle only one):**
   1. Squawfish
   2. Other fish
   3. Combination of squawfish/other

4. Would you have taken this fishing trip if there were no squawfish reward fishery?
   1. Yes
   2. No
   3. **Don't know**

5. Fishing methods used this trip **(Circle any that apply):**
   1. Boat, anchored
   2. Boat, drifting
   3. Boat, trolling
   4. Fished from shore
   5. Angling, surface
   6. Angling, bottom
   7. Other (specify) ______________

6. Bait or tackle used this trip (Circle **any that apply):**
   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 (specify) ______________

7. Did you fish in the squawfish reward fishery last year?
   1. Yes
   2. No

8. How important are the following factors in your participation in the squawfiih reward fishery? (Circle **the number that applies: 1=very important; 2= somewhat important; 3=not important)**

A. Payment for squawfish	1	2	3
B. Recreationalopportunity	1	2	3
C. Covering expenses for other target species	1	2	3
D. Participating in salmon enhancement program	1	2	3

9. Miles traveled (one way) to this location:

1. ≤20	4.61-80
2. 21-40	5. **81-100**
3. 41-60	6. **>100**

10. Number of fishing trips (for any species) you usually take per **year:**

1.0	5. 16-20
2. l-5	6.21-25
3. 6-10	7. **>25**
4. 11-15	

11. Your age:

1. ≤20	4. **41-50**
2. 21-30	6. 51-60
3. 31-40	7. **>60**

12. Home state:
   1. Oregon
   2. Washington
   3. Idaho
   4. Other (specify) ______________

SPORT REWARD VOUCHER

LAST NAME

FIRST NAME

MI

STREET

CITY

STATE

ZIP

MO DAY YR

DOCUMENT #

SOCIAL SECURITY # - -

NUMBER OF QUALIFYING SQUAWFISH

SITE

NUMBER OF QUALIFYING SQUAWFISH: (print)

VOUCHER #:

CREEL CLERK SIGNATURE

ANGLER SIGNATURE (Signed in presence of Creel Clerk)

I have followed all program rules. All northern squawfii exchanged for this voucher of payment were legally obtained.

Keep record of voucher #. To receive payment voucher mast be postmarked no later than 10/15/93.

-------------------------------- fold here --------------------------------

Place
Stamp
Here

SQUAWFISH SPORT-REWARD PROGRAM
POBOX683
'OREGON CITY, OR 97045

Appendix Table I-l. 1. Sport fishery check station codes, 19%.

Check Station	Code
Cathlamet	1
Rainier	2
Kalama	3
Gleason	4
Camas/Washougal	5
Covert's Landing	6
Hamilton Island	7
Cascade Locks	8
Bingen Marina	9
The Dalles	10
LePage Park	11
Umatilla	12
Columbia Park	13
Vernita Bridge	14
Hood Park	15
Lyons Ferry State Park	16
Boyer Park	17
Greenbelt	18

Appendix Table I-1.2. Number of angler surveys per check station, 1993.

Check Station	Analyzed		Not Analyzed		
	N	(%) Total	N	(%) Total	% Station Total
Cathlamet	430	4.6	32	3.6	6.9
Rainier	242	2.6	33	3.7	12.0
Kalama	231	2.5	45	5.0	16.3
Gleason	795	8.5	71	7.9	8.2
Camas	902	9.6	112	12.5	11.0
The Fishery	1052	11.2	89	10.0	7.8
Hamilton Island	1066	11.4	47	5.3	4.2
Cascade Locks	282	3.0	19	2.1	6.3
Bingen	546	5.8	51	5.7	8.5
The Dalles	577	6.2	14	1.6	2.4
LePage Park	728	7.8	72	8.1	9.0
Umatilla	214	2.3	25	2.8	10.5
Columbia Park	277	3.0	69	7.7	19.9
Vemita	447	4.8	39	4.4	8.0
Hood Park	215	2.3	24	2.7	10.0
Lyons Ferry	191	2.0	35	3.9	15.5
Boyer Park	149	1.6	11	1.2	6.9
Greenbelt	1011	10.8	106	11.9	9.5

Appendix Figure I-1.2. Sport-reward fishery creel clerk survey form, 1993.

Creel Clerk Questionnaire
1993 Sport-Reward Fishery

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
Boat Ramps					
overcrowding on boat ramps	___	___	___	___	___
size of boat ramps	___	___	___	___	___
time waiting to launch	___	___	___	___	___
other (specify)					
____________________	___	___	___	___	___
____________________					
Fishing					
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)					
____________________	___	___		___	___
____________________	___	___	___	___	___
Registration and Check-In					
registration processing time	___	___	___	___	___
registration processing paperwork	___	___	___	___	___
problems with other anglers	___	___	___	___	___
check-in time	___	___	___	___	___
check-in paperwork	___	___	___	___	___
fish quality requirements	___	___	___	___	___
other (specify)					
____________________	___	___	___	___	___
____________________	___	___	___	___	___

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: good ___ fair ___ poor ___

recommendations: ______________________________

____

g. equipment: good ___ fair ___ poor ___

recommendations: ______________________________

____

h. <u>interaction with public</u>: good ___ fair ___ poor ___

recommendations: ____

____

i. <u>station security</u>: good ___ fair ___ poor ___

recommendations: ____

____

j. <u>other recommendations</u>: ____

____

____

____

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 <u>compliments</u> about the operation of the sport-reward fishery? YES ___ NO ___ If yes, please specify:

____

____

____

____

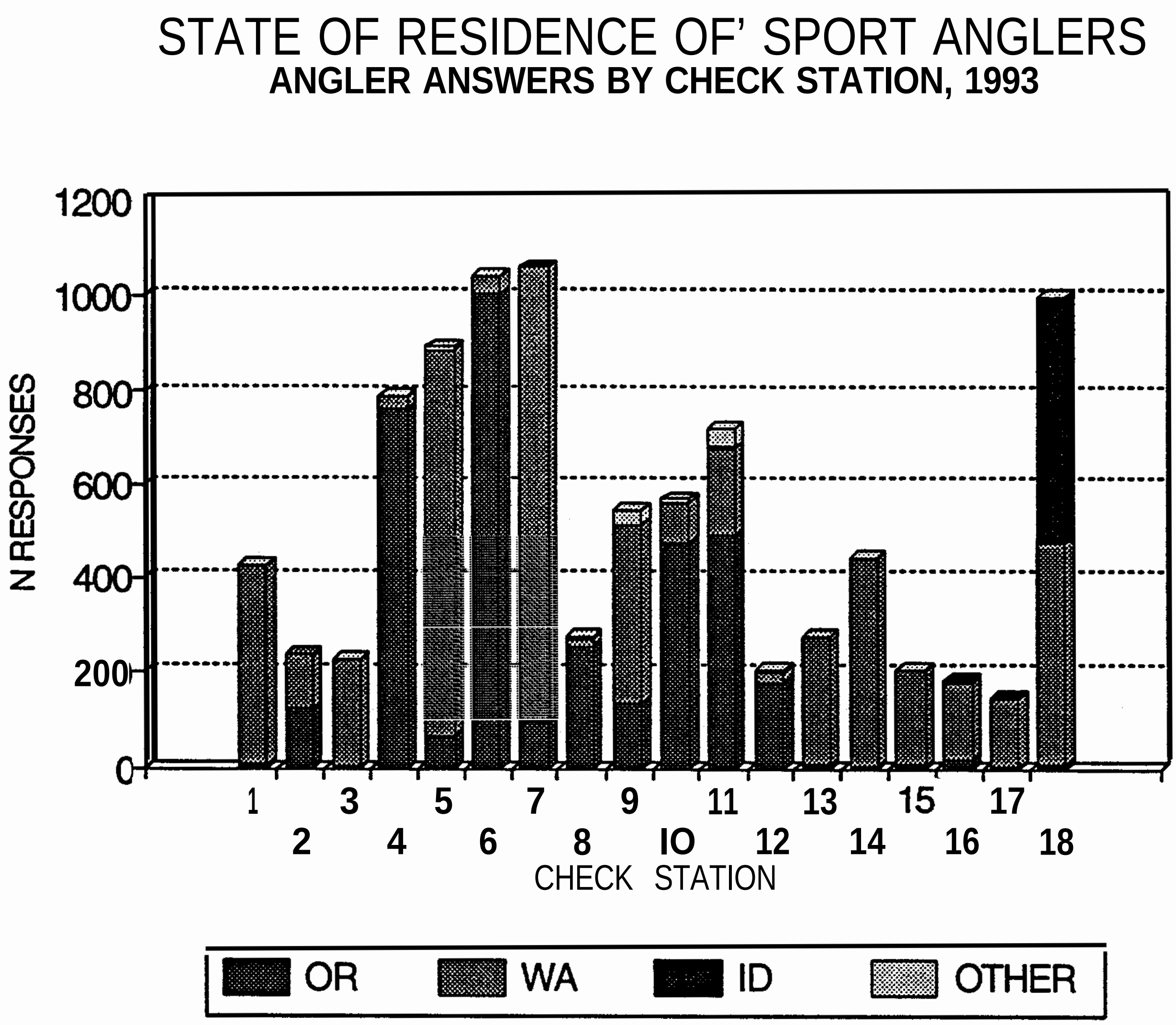
THANK YOU FOR YOUR HELP.

Appendix Table I-l .3. Agency **total** expenditures and expenditure per fish removed for the sport-reward fishery by check station, station-specific expenditures only.

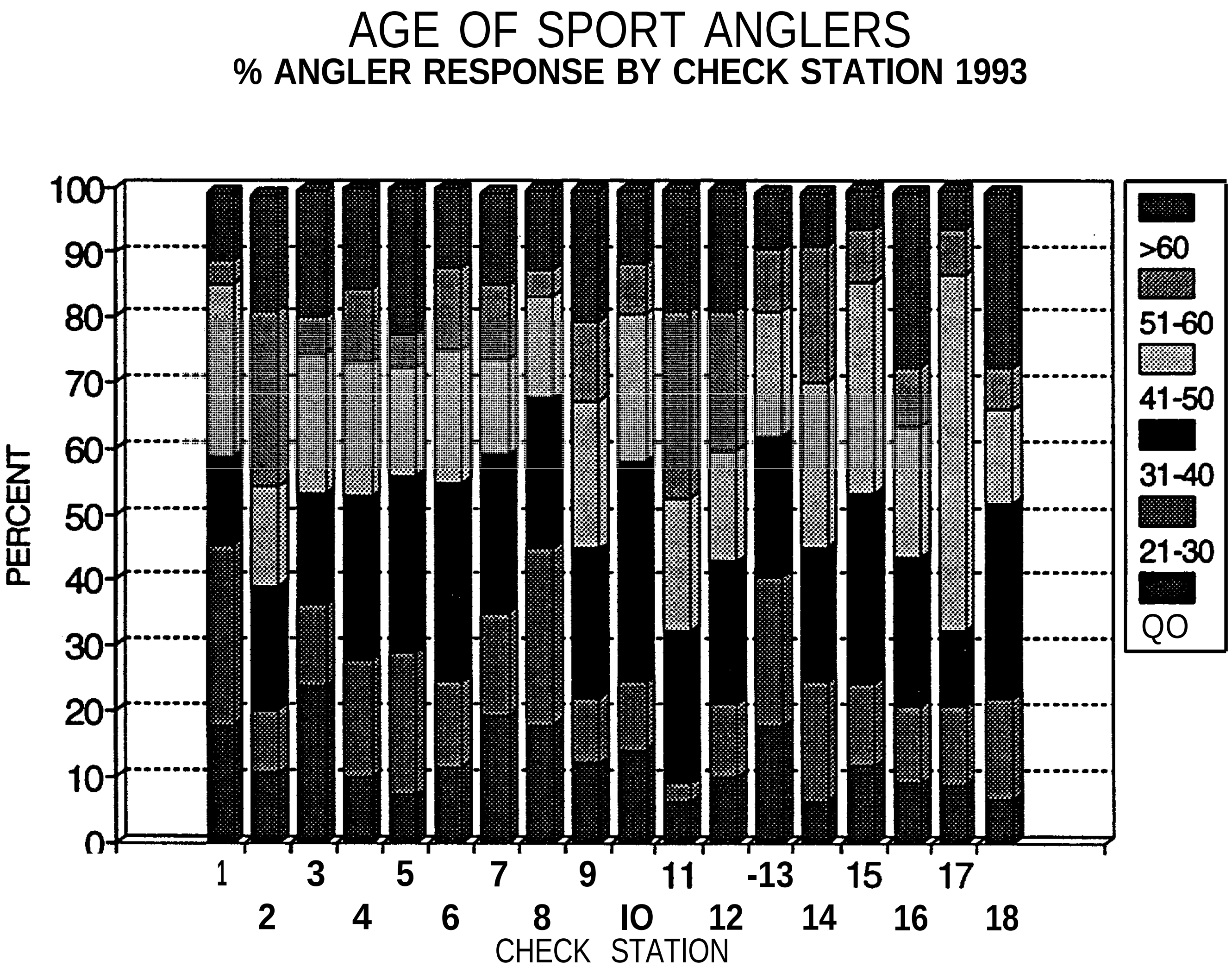
Check Station	**Total** Expenditure (including payment per fish)	Total Catch	Expenditure Per Fish Removed
Cathlamet	$60,278	3,960	$15.22
Rainier	73,398	1,561	47.02
Kalama	74,237	1,605	46.25
M. James Gleason	105,776	9,719	10.88
Camas/Washougal	90,460	5,920	15.28
Covert s Landing	112,057	16,308	6.87
Hamilton Island	92,055	9,126	10.09
Cascade Locks	58,070	1,881	30.87
Bingen Marina	79,335	6,408	12.38
Dalles	72,332	4,338	16.67
LePage Park	*95,772*	10,643	9.00
Umatilla	66,194	**1,000**	66.19
Columbia Park	80,209	5,192	15.51
Vemita Bridge	90,857	9,765	9.30
Hood Park	62,086	4,119	15.07
Lyons Ferry State Park	62,362	1,466	45.54
Boyer Park	63,887	1,296	49.30
Greenbelt	85,917	10.309	**8.33**
TOTAL	**$1,425,273**	104,616	$13.62

Appendix Table I-1.6. Agency expenditure per fish removed for the sport-reward fishery by check station, station-specific expenditures only.

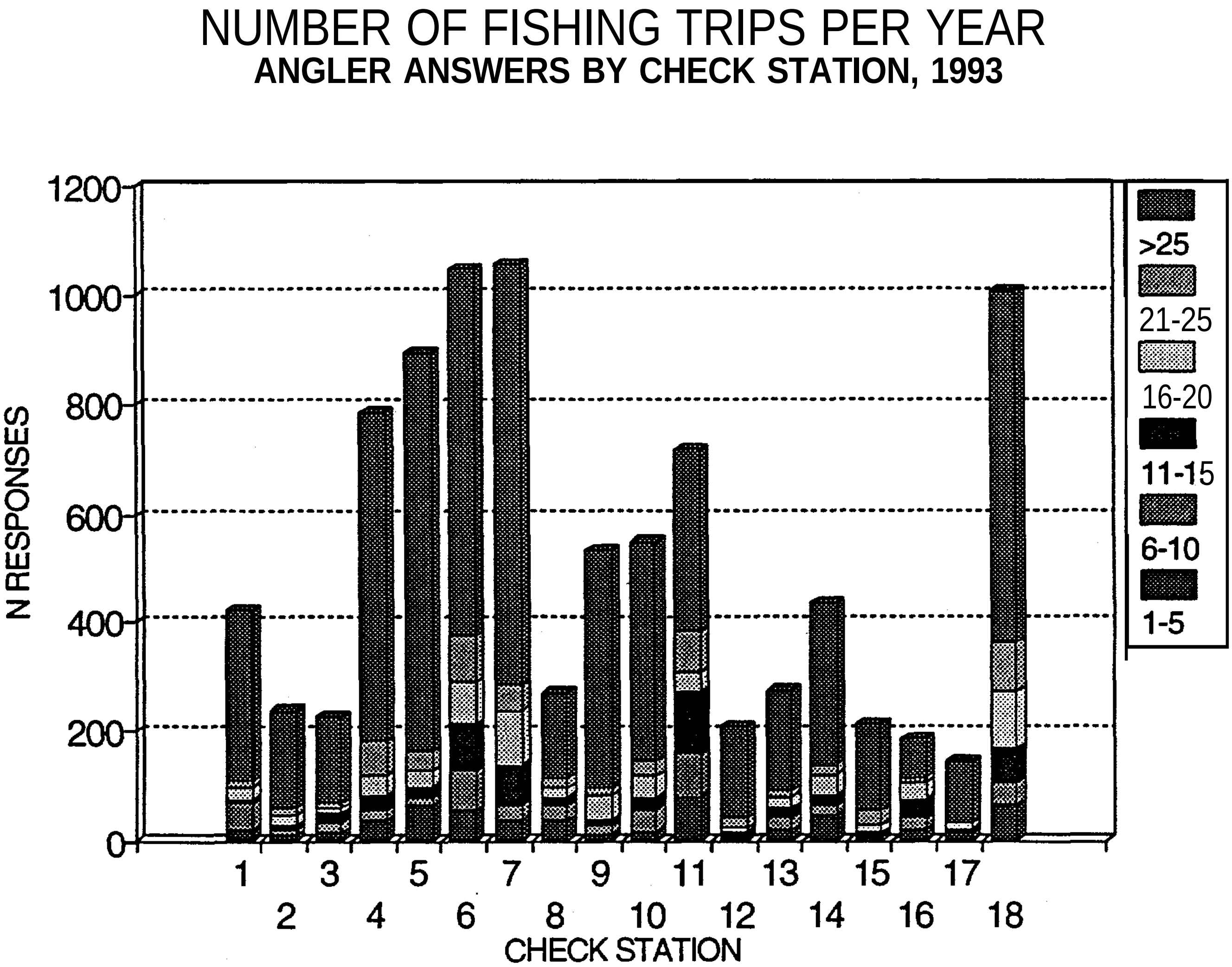
Check Station	Expenditure Per Fish Removed (excluding administrative expenditures)
Cathlamet	$15.22
Rainier	47.02
Kalama	46.25
M. James Gleason	10.88
Camas/Washougal	15.28
Covert s Landing	6.87
Hamilton Island	10.09
Cascade Locks	30.87
Bingen Marina	12.38
Dalles	16.67
LePage Park	9.00
Umatilla	66.19
Columbia Park	15.51
Vernita Bridge	9.30
Hood Park	15.07
Lyons Ferry State Park	45.54
Boyer Park	49.30
Greenbelt	8.33
TOTAL	$13.62



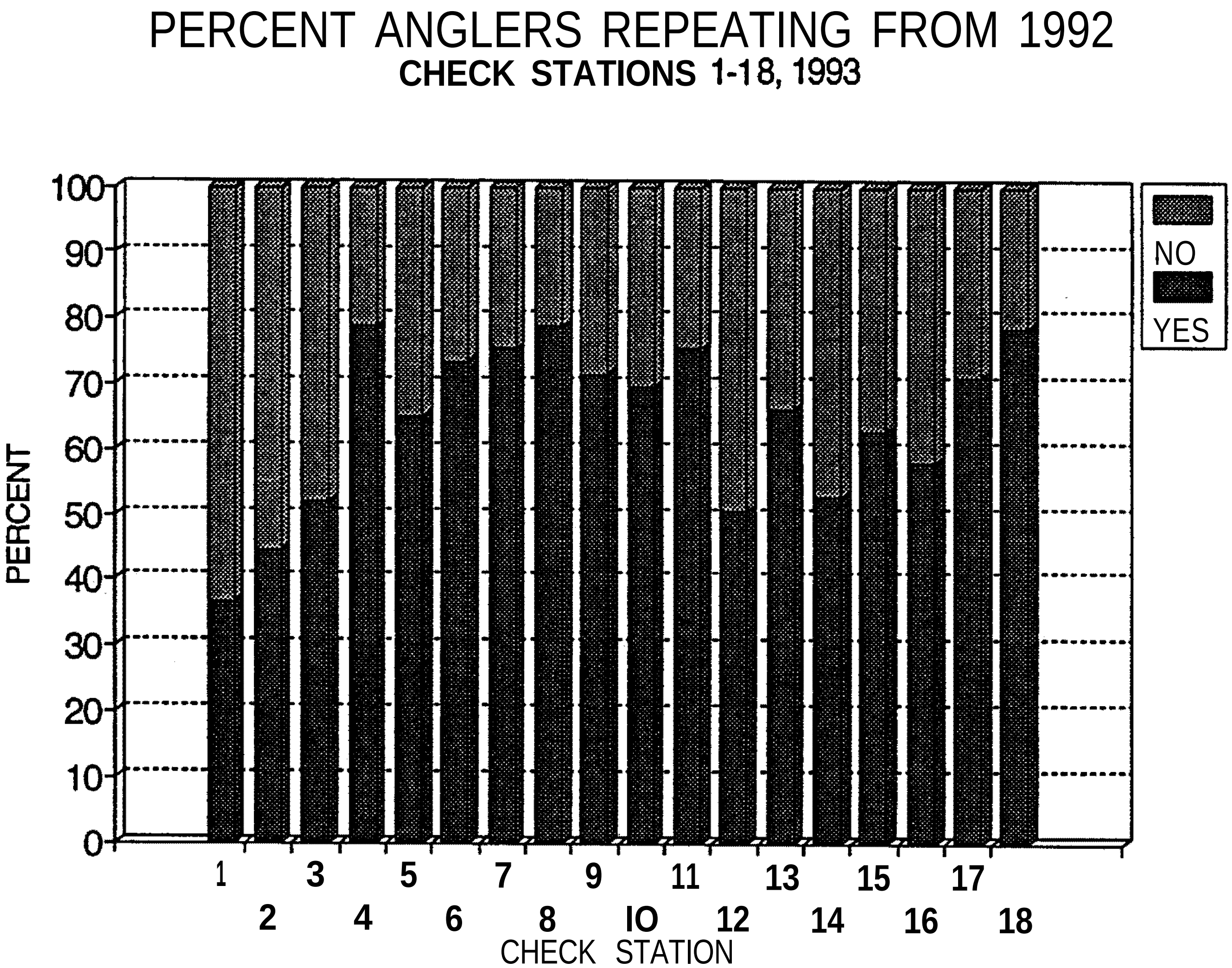
Appendix Figure I-l. 3. State of residence of sport anglers, 1993.



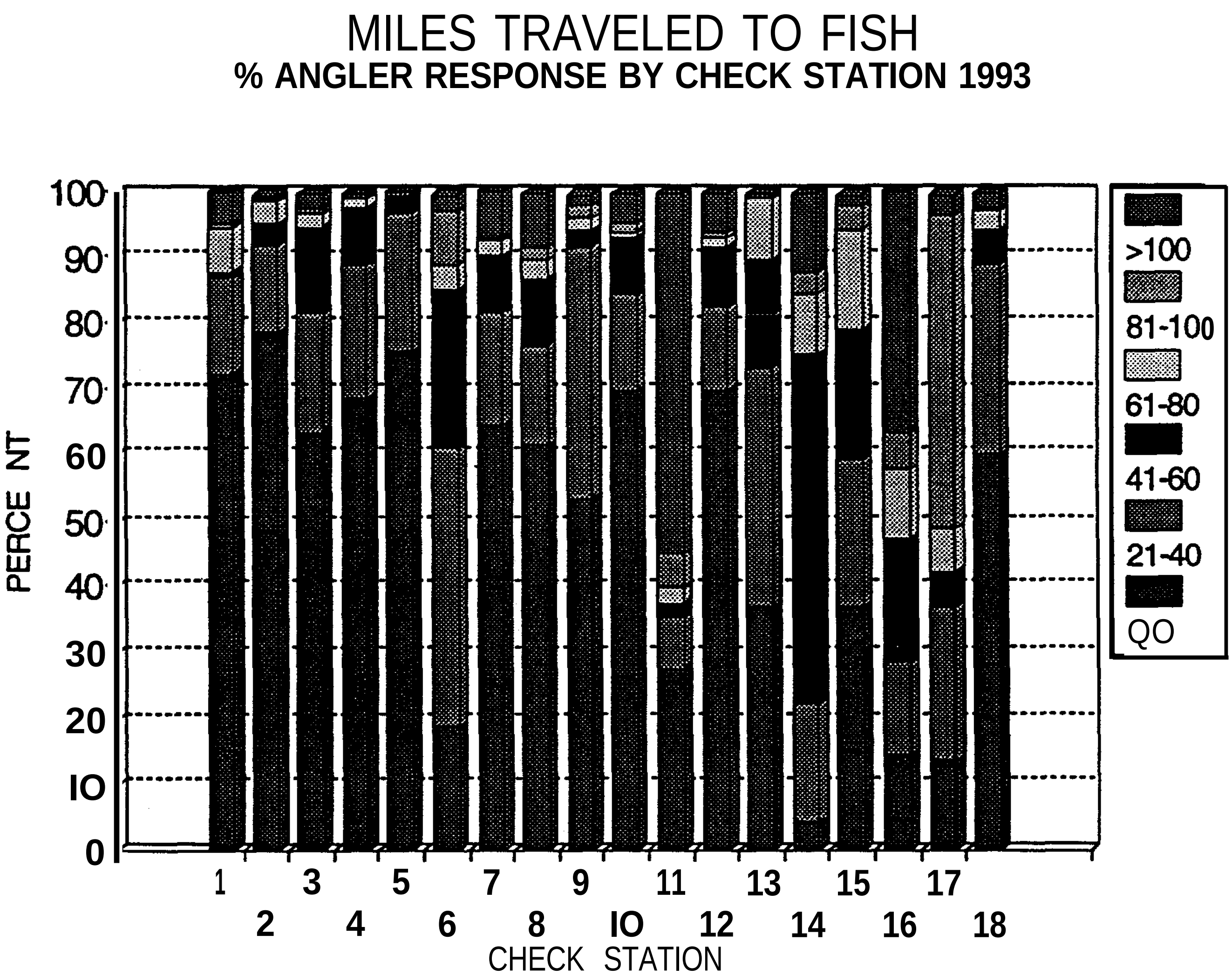
Appendix Figure I-1.4. Age of sport anglers, 1993.



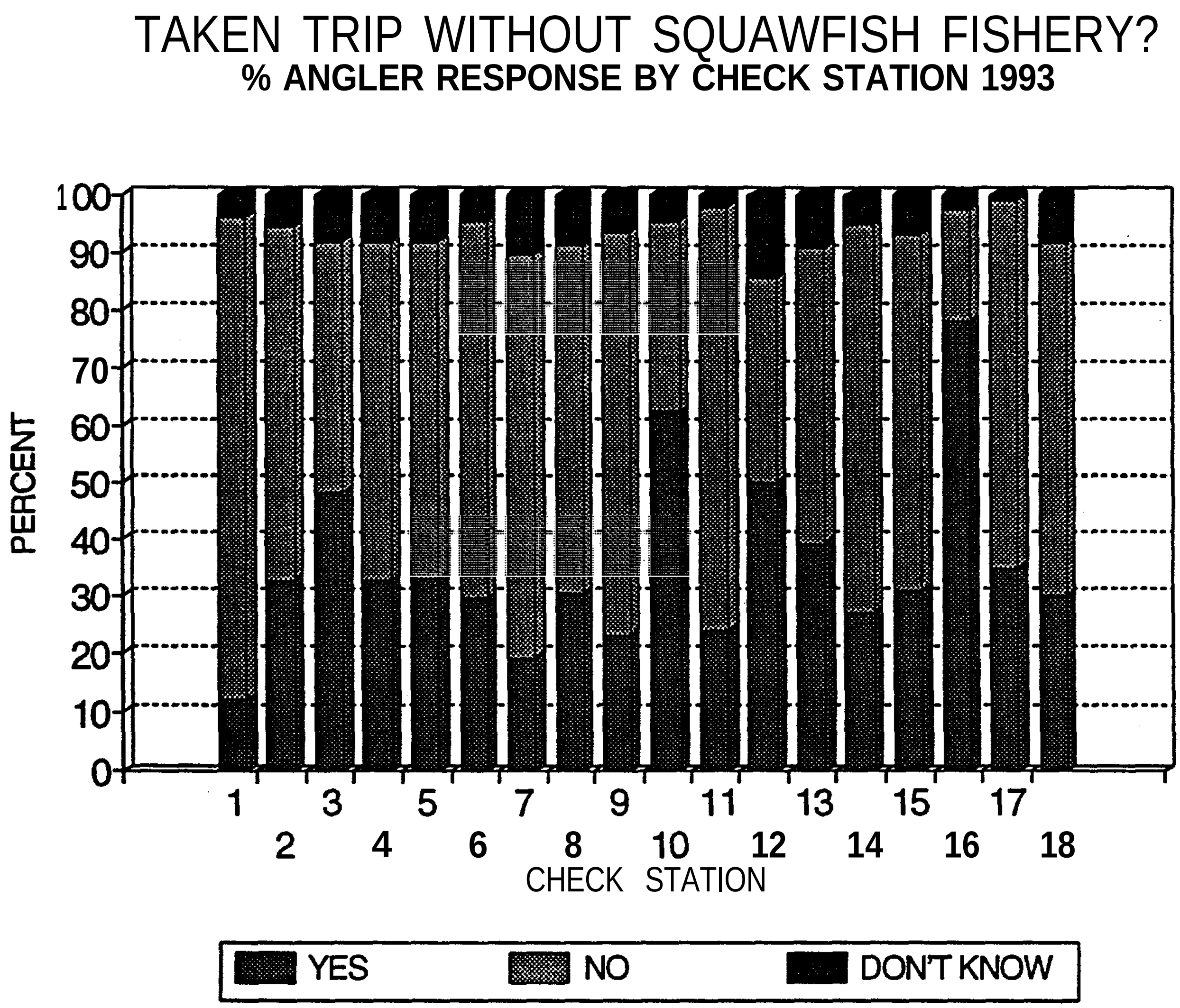
Appendix Figure I-1.5. Number of sport-fishing trips made by anglers per year, 1993.



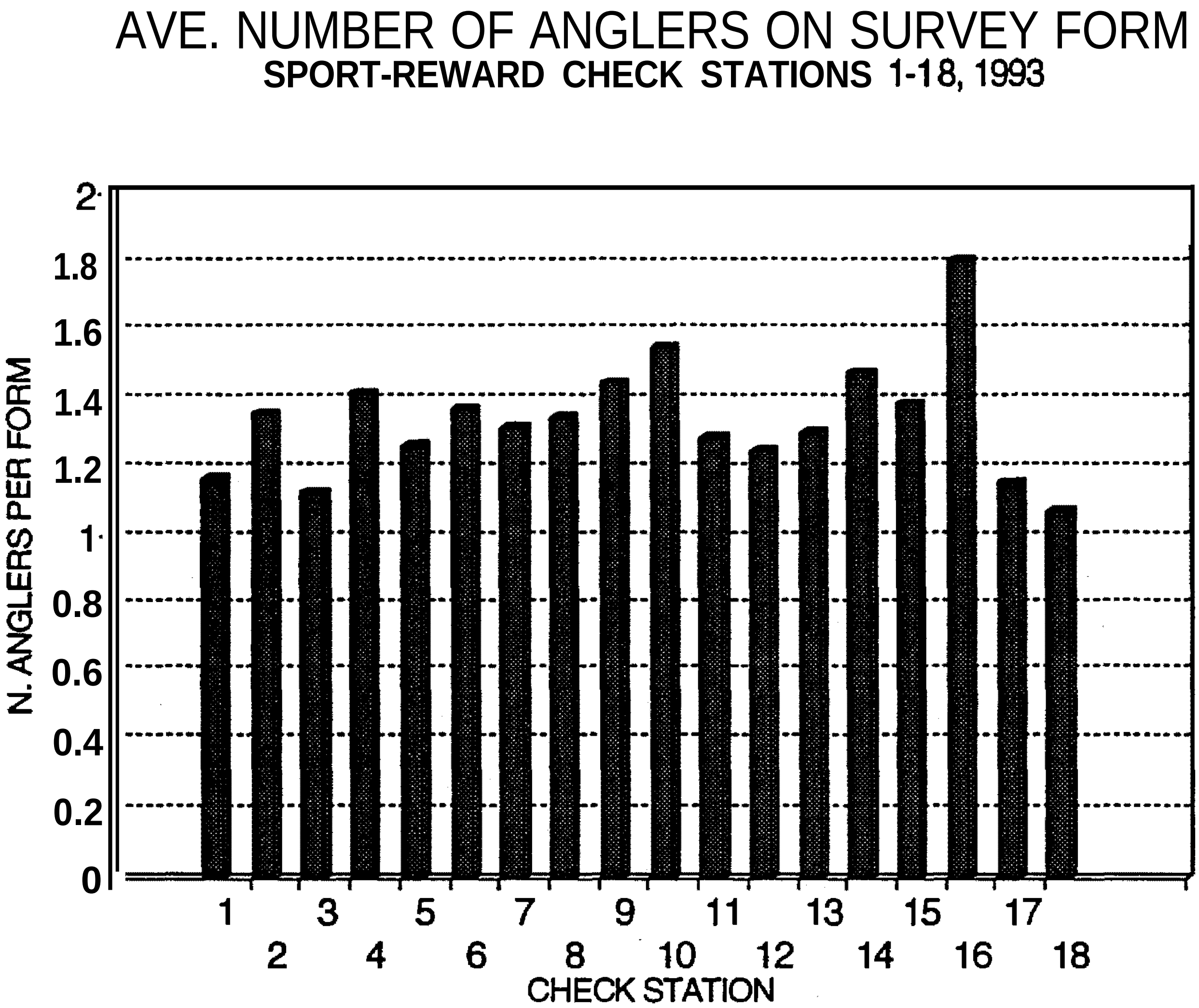
Appendix Figure 1-1.6. Percent anglers repeating from 1992.



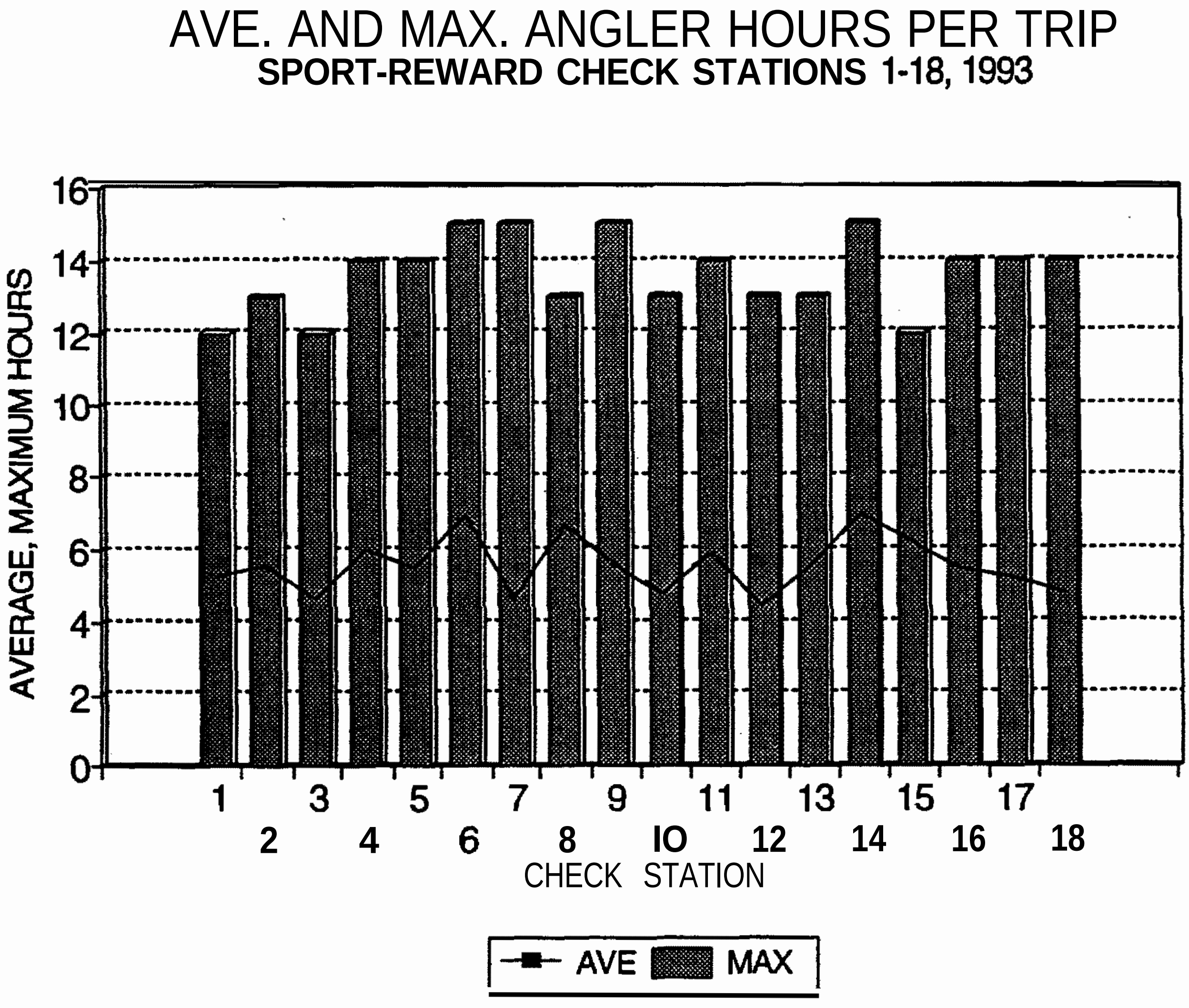
Appendix Figure I-l .7. Miles traveled to fish, 1993.



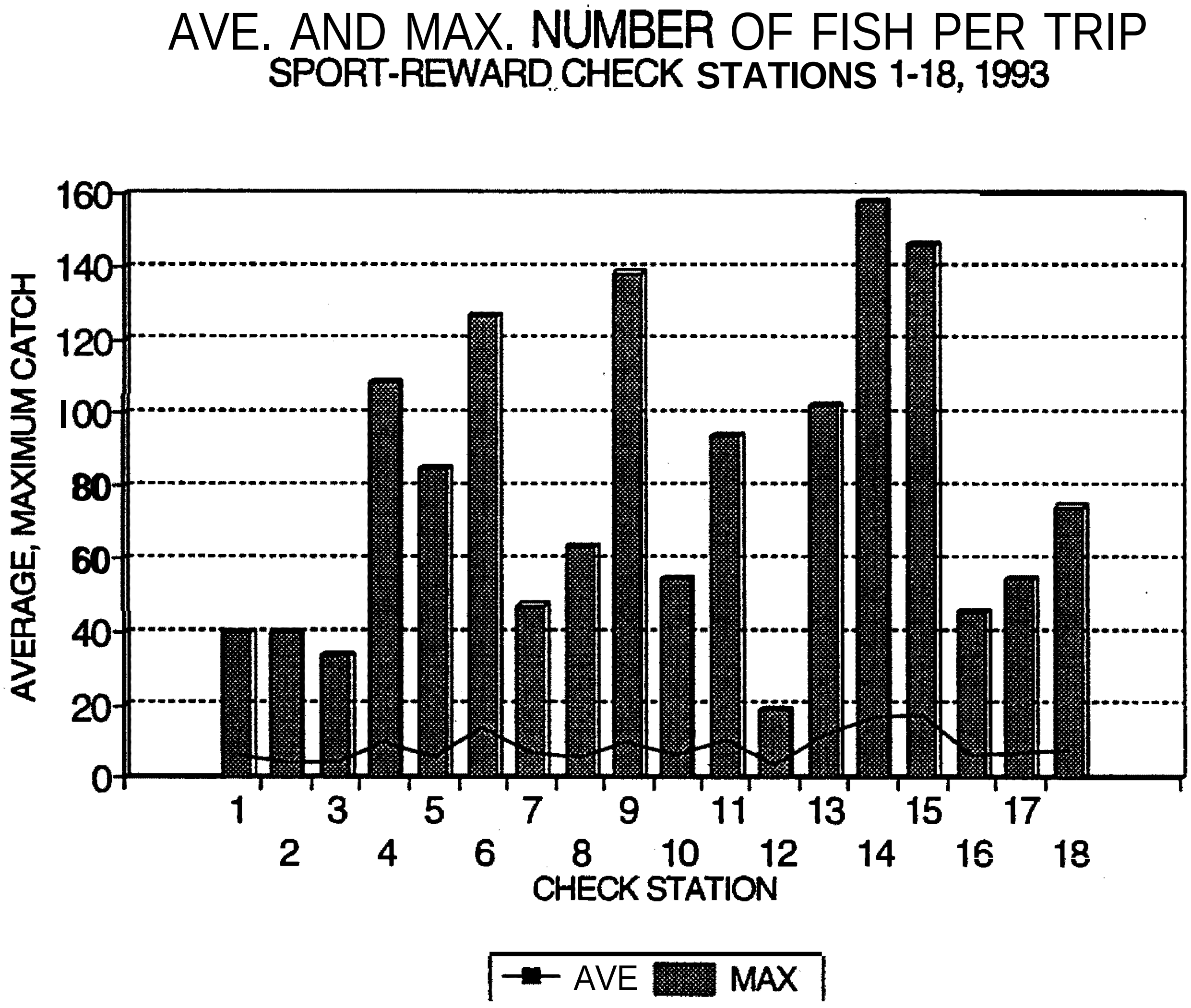
Appendix Figure I-l .8. Taken trip without the squawfish fishery?



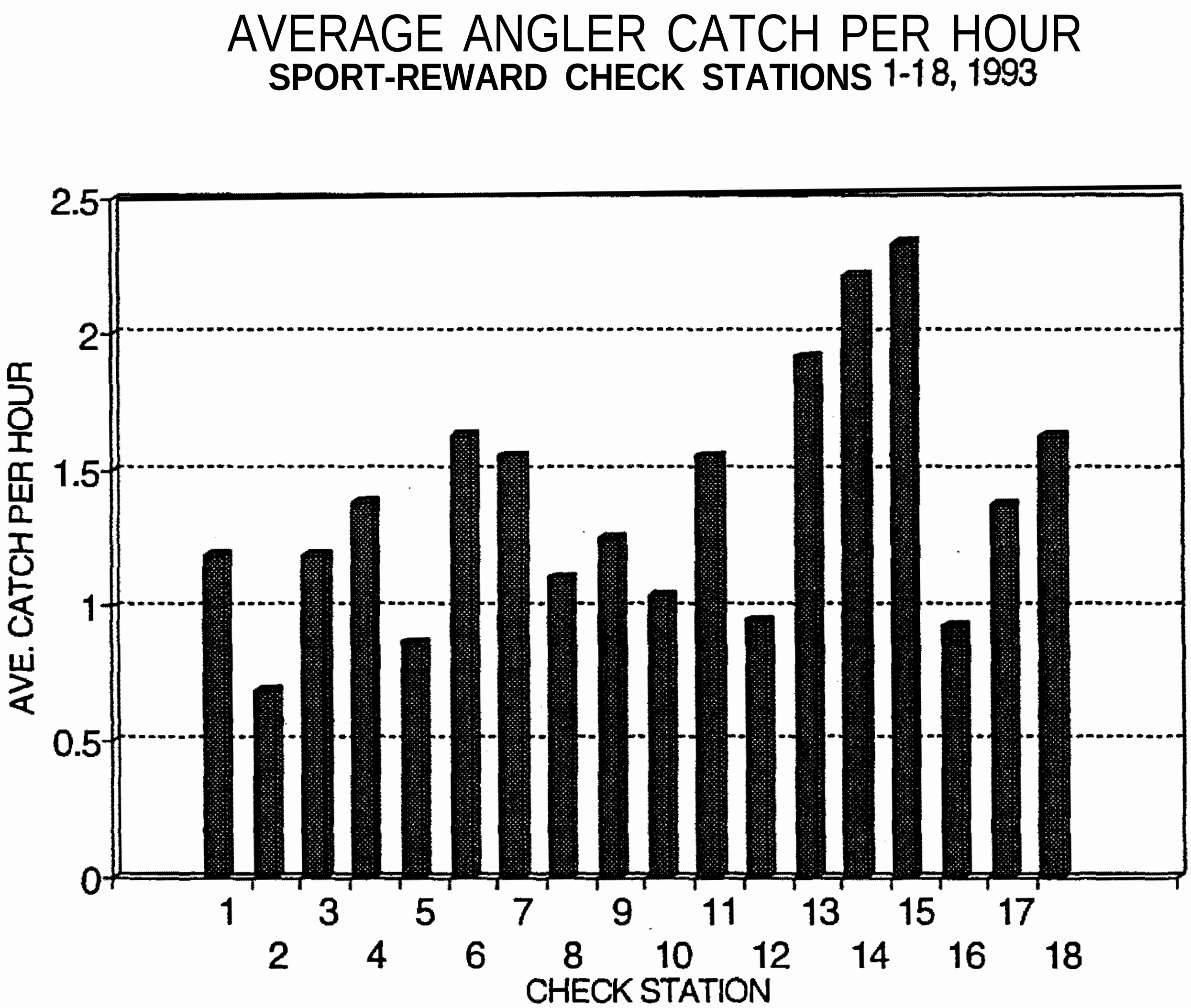
Appendix Figure I- 1.9. Average number of sport anglers on survey form, 1993.



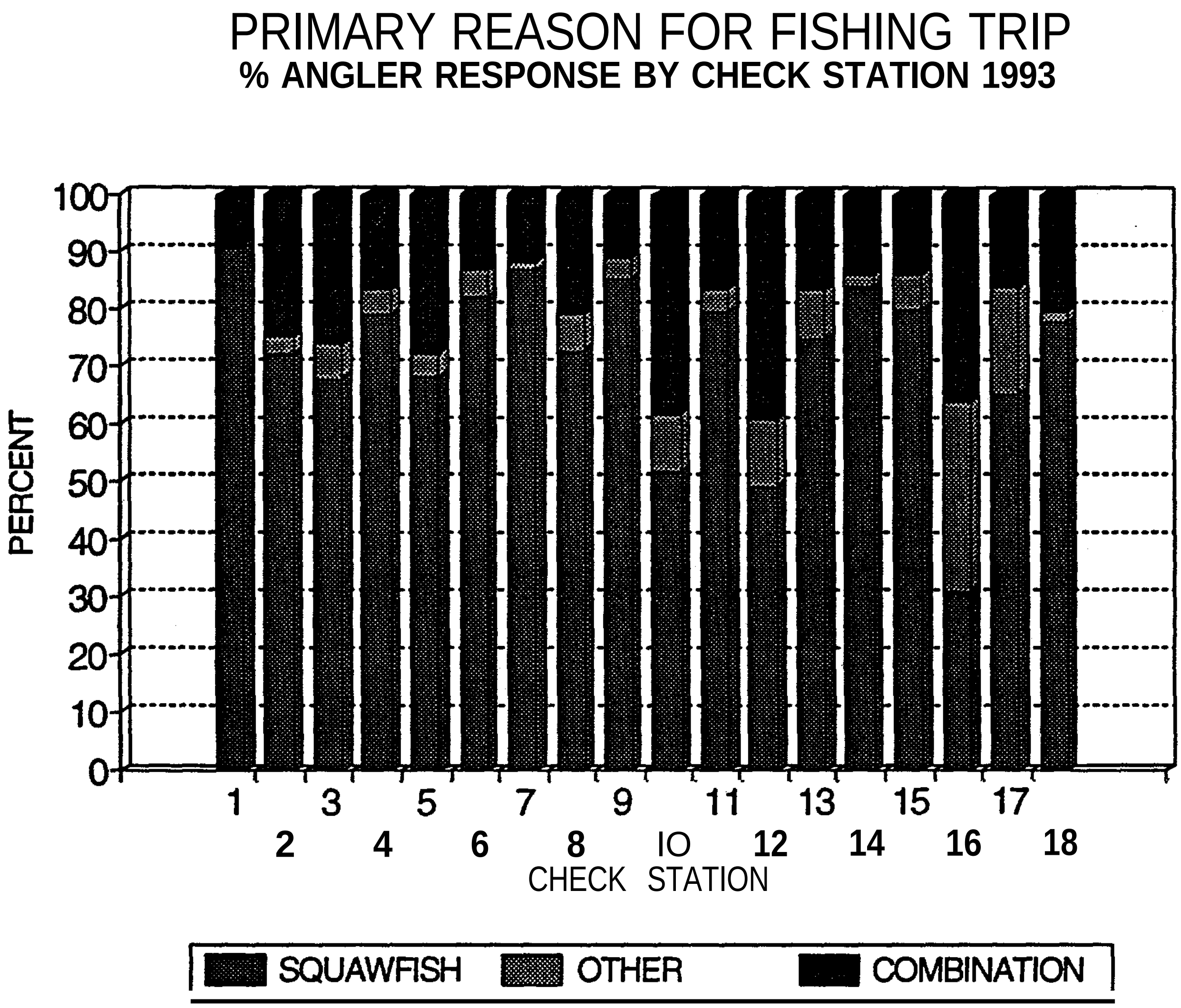
Appendix Figure I-l. 10. Average and maximum angler hours per trip, 1993.



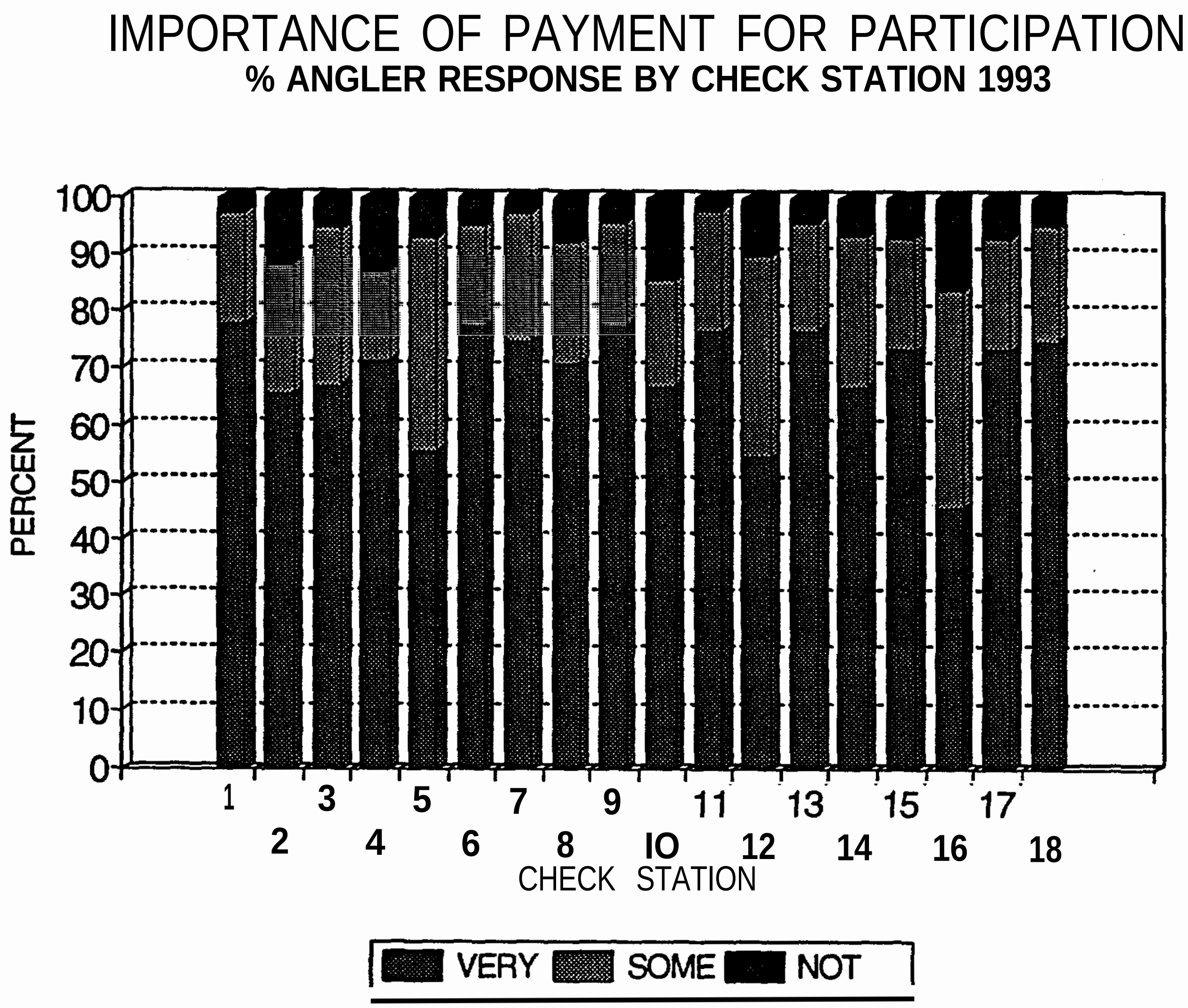
Appendix Figure I-l. 11. Average and maximum number of fish per trip, 1993.



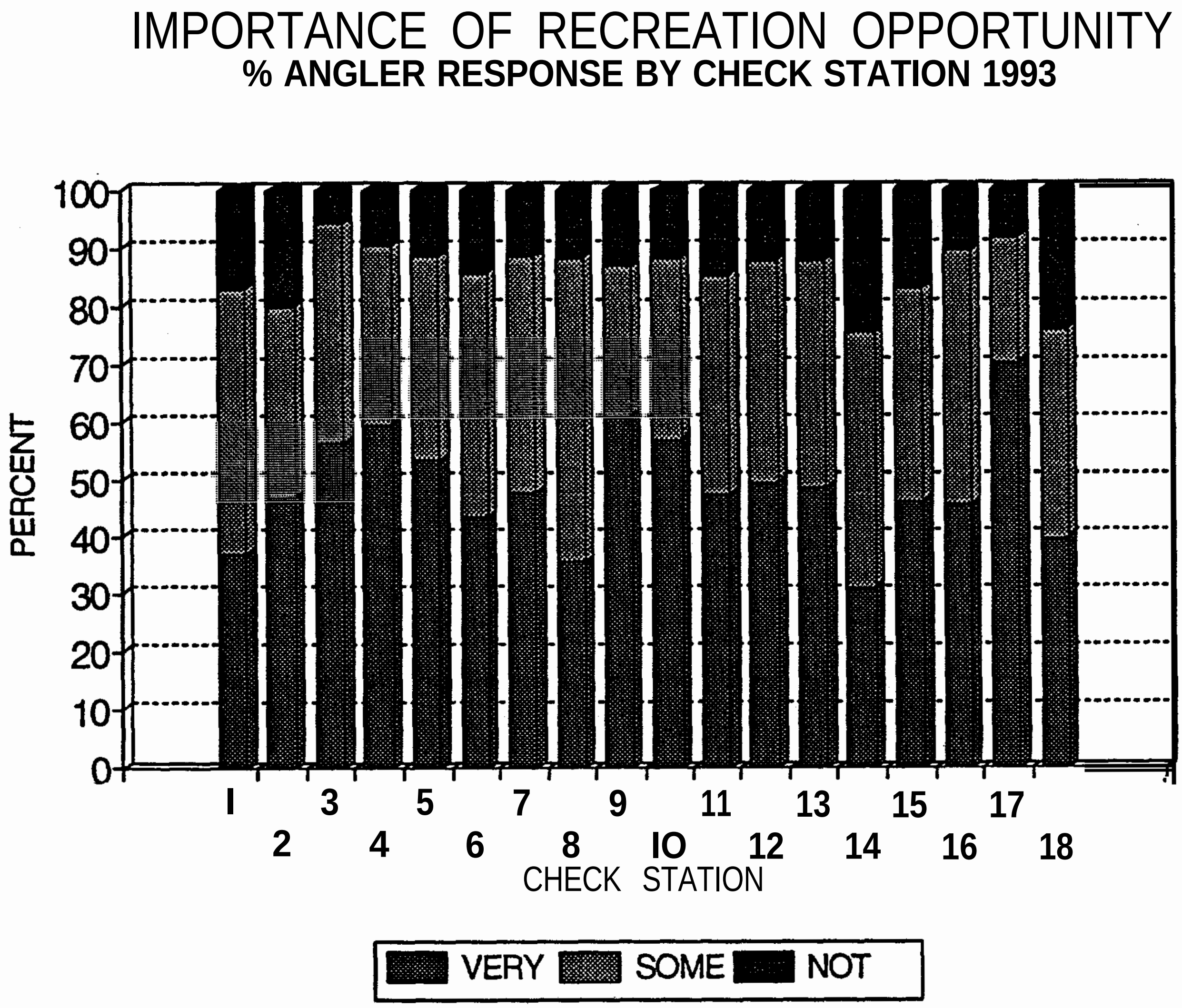
Appendix Figure I-l. 12. Average angler catch per hour, 1993.



Appendix Figure I-l. 13. Primary reason for fishing trip, 1993.

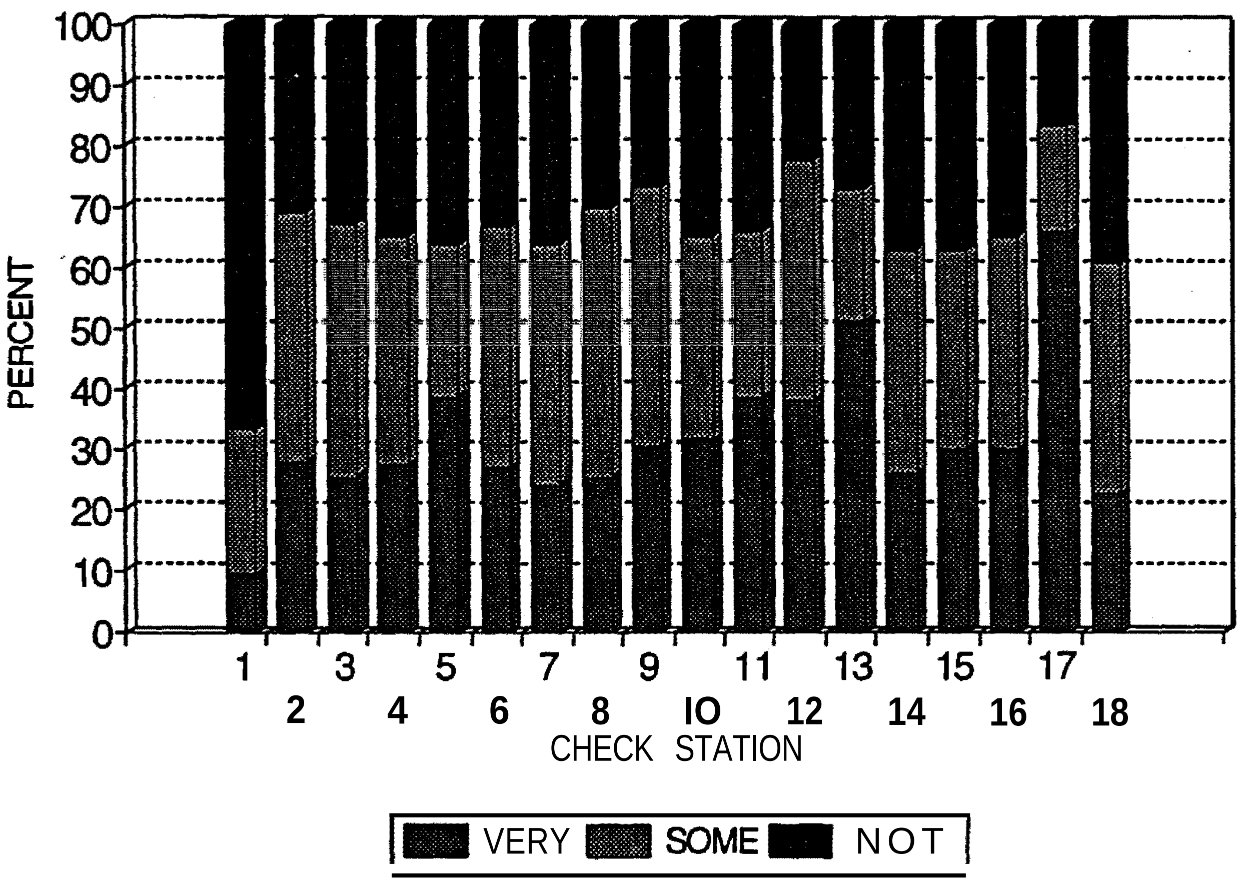


Appendix Figure I-l. 14. Importance of payment for participation, 1993.

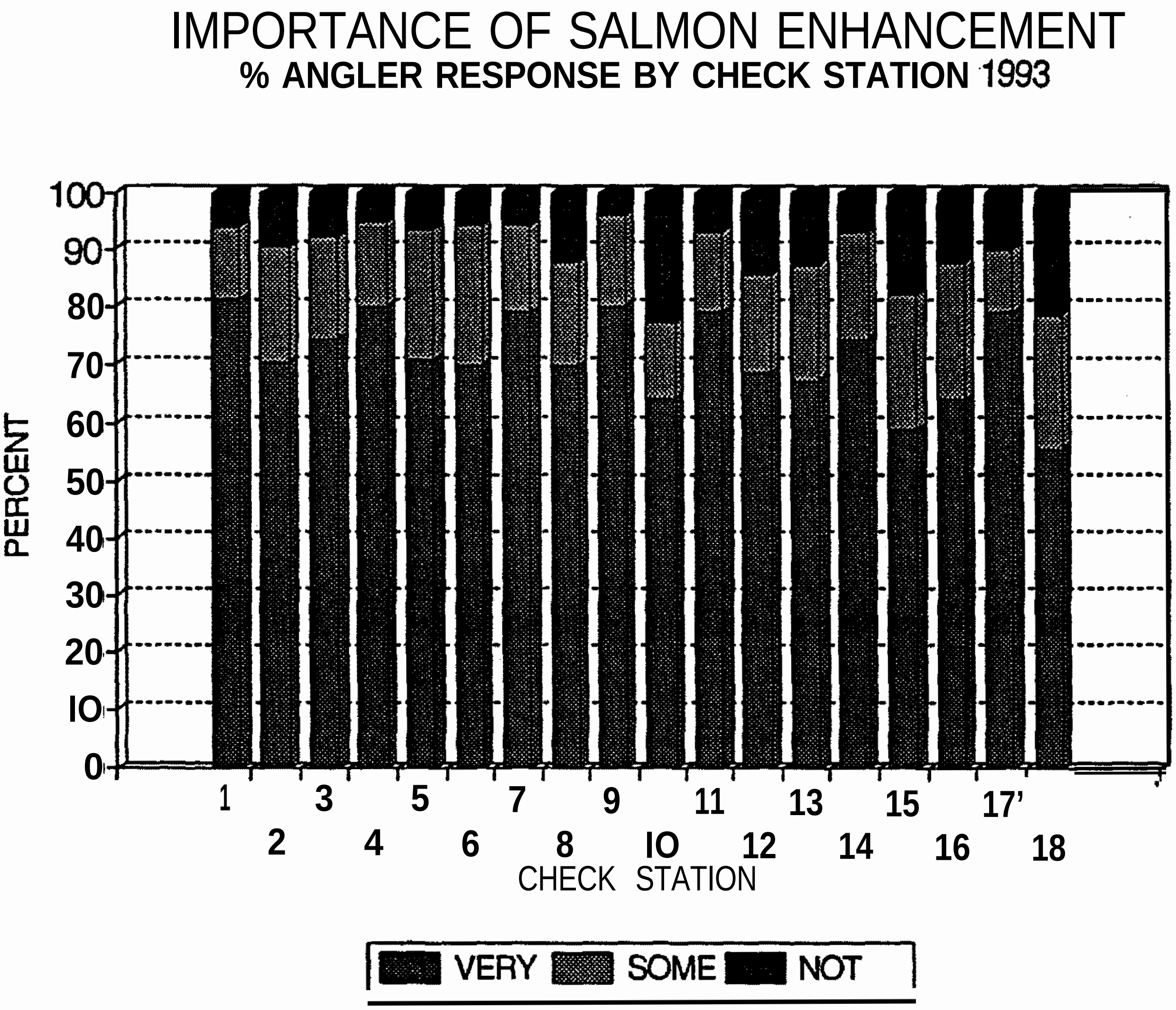


Appendix Figure I-l. 15. Importance of the recreation opportunity to anglers, 1993.

IMPORTANCE OF COVERING FISHING EXPENSES
% ANGLER RESPONSE BY CHECK STATION 1993



Appendix Figure I-l. 16. Importance of covering fishing expenses to anglers, 1993.



Appendix Figure I-l. 17. Importance of salmon enhancement to anglers, 1993.

Appendix Table I-1.5. Distribution of fishing methods by check station, 1993.

Station	Boat Anchored	Boat Drifting	Boat Trolling	Shore	Angling Surface	Angling Bottom	Other
1	71	12	7	153	11	176	1
2	88	6	5	59	7	77	0
3	55	18	5	80	9	62	1
4	254	40	121	125	18	225	13
5	161	55	67	341	34	237	6
6	384	82	108	182	52	238	7
7	90	25	24	759	32	133	2
8	33	10	5	132	11	90	0
9	66	24	20	276	38	122	0
10	56	32	95	239	21	133	1
11	28	41	261	315	12	71	0
12	27	7	31	103	18	29	0
13	90	56	22	58	1	50	1
14	139	96	46	87	12	68	0
15	40	78	32	31	5	29	0
16	35	16	30	58	14	37	1
17	11	19	53	39	6	21	0
18	149	56	12	528	22	241	2

Appendix Table I-1.6. Distribution of bait and tackle used by check station, 1993.

Station	Worms	Cut-fish	Spin-ners	Spoon	Flat-fish	Surface plugs	H&L 1 hook	H&L >1 hook	Other
1	160	26	8	10	1	8	164	28	23
2	104	24	4	2	4	8	50	28	18
3	100	17	14	11	5	9	40	11	24
4	214	70	57	31	32	34	225	41	86
5	324	87	43	14	10	48	201	58	116
6	324	163	70	32	32	85	209	42	88
7	332	96	26	20	7	42	253	22	267
8	101	56	21	5	2	4	74	7	10
9	256	19	49	22	12	12	126	9	40
10	258	6	70	10	24	46	110	7	45
11	165	4	31	32	29	57	197	38	176
12	71	8	34	40	6	5	28	6	15
13	108	18	34	1	5	4	53	6	47
14	167	41	56	27	13	23	55	12	51
15	91	9	35	6	7	9	38	4	15
16	58	19	18	4	5	14	33	14	25
17	34	9	8	1	10	5	13	4	63
18	224	236	29	14	7	14	327	23	127

Appendix Table I-1.7. Creel clerk evaluation of the 1993 sport-reward program (N=38).

Program Component	Good N (%)	Fair N (%)	Poor N (%)	NA N (%)
Operating Hours	30 (79)	8 (21)	0 (0)	0 (0)
Registration Process	30 (79)	8 (21)	0 (0)	0 (0)
Check-in Process	37 (97)	1 (3)	0 (0)	0 (0)
Data Forms	35 (92)	3 (8)	0 (0)	0 (0)
Data Collection	34 (89)	4 (11)	0 (0)	0 (0)
Staffing	31 (82)	7 (18)	0 (0)	0 (0)
Equipment	18 (47)	16 (42)	4 (11)	0 (0)
Station Security	34 (89)	4 (11)	0 (0)	0 (0)

Appendix Table I-1.8. Frequency of angler complaints about various aspects of the 1993 sport-reward fishery, as reported by creel clerks (N=38).

Type of Complaint	Many N	Many (%)	Some N	Some (%)	Few N	Few (%)	None N	None (%)	NA N	NA (%)
Boat Ramps										
overcrowding	4	(11)	3	(8)	10	(27)	20	(54)	0	(0)
size	0	(0)	6	(15)	8	(20)	24	(60)	2	(5)
wait time to launch	2	(6)	4	(11)	9	(26)	20	(57)	0	(0)
Fishing										
angler crowding	1	(3)	7	(18)	14	(36)	16	(41)	1	(3)
corn. fish. crowding	4	(1)	0	(0)	4	(11)	22	(59)	7	(19)
gear damage/anglers	0	(0)	1	(3)	10	(26)	26	(68)	1	(3)
gear damage/commer.	0	(0)	1	(3)	2	(5)	28	(76)	6	(16)
speeding boats	5	(13)	4	(11)	14	(37)	15	(39)	0	(0)
jet skiers	5	(13)	6	(15)	9	(23)	18	(46)	1	(3)
water skiers	4	(11)	4	(11)	8	(21)	21	(55)	1	(3)
litter in water	1	(3)	4	(11)	10	(26)	23	(61)	0	(0)
litter on banks	1	(3)	6	(16)	6	(16)	25	(66)	0	(0)
Registration/Check-In										
regis. time	0	(0)	4	(10)	9	(23)	26	(67)	0	(0)
regis. paperwork	1	(3)	8	(22)	12	(32)	16	(43)	0	(0)
other anglers	0	(0)	4	(10)	9	(23)	26	(67)	0	(0)
check-in time	3	(8)	5	(13)	12	(32)	17	(45)	1	(3)
check-in paperwork	1	(3)	6	(16)	15	(39)	15	(39)	1	(3)
fish quality require.	2	(6)	8	(22)	16	(44)	10	(28)	0	(0)

APPENDIX I-2

Dam-Angling Fishery Expenditures

Appendix Table I-2.1. Agency total expenditures and expenditure per fish removed for the 1993 dam-angling fishery, by fishing crew.

Fishing Operation	Total Expenditure (components explained in text)	Total Catch	Expenditure Per Fish Removed
Bonneville + The Dalles	$188,659	5,879	$32.00
John Day	106,309	1,743	61.00”
McNary	95,381	4,685	20.00
Ice Harbor + Lower Monumental	33,946	325	104.00
Little Goose + Lower Granite	115,654	861	134.00[b]
Mobile Crew	84,375	2,906	29.00
Volunteers	14.157	550	26.00
Total	$638,480	16,949	$38.00

[a] Number is net of 261 fish reportedly caught before July 11. If the 261 fish are added to the total catch, $/NSF declines to $53.
[b] Total costs and $/NSF are high due to cost of boat angling at dams.

APPENDIX I-3

Collection and Distribution of Northern Squawfish

Appendix Table I-3.1. Collection and distribution budget summary, 1993.

Area	Total Lb	Lb Fd-grd.	% Fd-grd.	Total cost	cost /lb.
Longview	7,839	6,200	79	$16,800	$2.14
Portland	17,170	--	--	**$13,000[3]**	$0.76
c. Locks	45,897	**68,200[2]**	79	$46,000	$0.53
T. Dalles	23.445	--	--	**$14,200[3]**	$0.61
	86,512[1]				
Tri-Cities^	31,964	24,600	77	$18,325	$0.57
L. Ferry”	1,607	--	--	**$1,000(est)**	$0.62
Pullman”	1,423	--	--	$400	$0.28
Clarkston	13.135	--	--	$4,200	$0.31
Subtotal	142,480	99,000	78	$113,925	$0.80
Other Costs (applying to all areas)		Administration		$30,500	
		Travel		$12,300	
		Op. and Maint.		$11,700	
		Ind. Costs @ 15%		$25.200	
Total Costs Through Nov. 1993				**$193,625[4]**	

[1] Squawfish from the Portland, C. Locks, and The Dalles areas were processed in C. Locks. This figure is the total for these areas.
[2] Volume of food-grade squawfish processed in Cascade Locks.
[3] These cost reflect rent, personnel, and transportation only because squawfish were not processed at these locations.
[4] This total includes all FY 1993 salaries associated with the handling program.
^ Rendering only locations.