

DEVELOPMENT OF A SYSTEMWIDE PREDATOR
CONTROL PROGRAM: STEPWISE IMPLEMENTATION OF A
PREDATION INDEX, PREDATOR CONTROL FISHERIES, AND
EVALUATION PLAN IN THE COLUMBIA RIVER BASIN
(NORTHERN SQUAWFISH MANAGEMENT PROGRAM)

SECTION I: IMPLEMENTATION

1995 ANNUAL REPORT

Prepared by:

Franklin R. Young

Columbia Basin Fish and Wildlife Authority
Portland, OR 97201

In Cooperation With

Columbia Basin Fish and Wildlife Authority
Columbia River Inter-Tribal Fish Commission
Confederated Tribes of the Umatilla Indian Reservation
Confederated Tribes of the Warm Springs Reservation
National Marine Fisheries Service
Nez Perce Tribe
Oregon Department of Fish and Wildlife
Pacific States Marine Fisheries Commission
S.P. Cramer and Associates, Inc.
Washington Department of Fish and Wildlife
Yakama Indian Nation

Prepared for:

U. S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-362 1

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EXECUTIVE SUMMARY

by Franklin R. Young

We report our results from the fifth 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 John Day Reservoir from 1982 through 1988 indicated that if predator-sized northern squawfish were exploited at a 10-20% rate, the resulting restructuring of their population could reduce their predation on juvenile salmonids by 50%.

To test this hypothesis, we implemented 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 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. The tribal longline fishery has continued on a very limited basis.

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 in catching northern squawfish at specific sites. Consequently, in 1993 we examined a systemwide fishery using floating trap nets, but found this fishery to be ineffective at harvesting large numbers of northern squawfish on a systemwide scale.

In 1994, we investigated the use of trap nets and gill nets at specific locations where concentrations of northern squawfish were known or suspected to occur during the spring season (March through early June). We also initiated a concerted effort to increase public participation in the sport-reward fishery through a series of promotional and incentive activities.

In 1995, promotional activities and incentives were further improved based on the favorable response in 1994. Results of these efforts are subjects of this annual report under Section I, Implementation. In this section, we also report on the system we used to collect and dispose of harvested northern squawfish.

Evaluation of the success of test fisheries in achieving our target goal of a 10-20% annual exploitation rate on northern squawfish is presented in Section II of this report. Overall program success in terms of altering the size and age composition of the northern squawfish population and in terms of potential reductions in loss of juvenile salmonids to northern squawfish predation is also discussed under Section II.

Program cooperators include the Columbia Basin Fish and Wildlife Authority (Authority), the Pacific States Marine Fisheries Commission (PSMFC), Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fish and Wildlife (WDFW), Columbia River Inter-Tribal Fish Commission (CRITFC), and the four lower Columbia River treaty tribes — the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Nez Perce Tribe, and the Yakama Indian Nation. The Authority and PSMFC were responsible for coordination and administration of the program; PSMFC subcontracted various tasks and activities to ODFW, WDFW, CRITFC, and the four lower Columbia River treaty tribes based on the expertise each brought to the tasks involved in implementing the program. Objectives of each cooperator were as follows.

1. WDFW (Report A): Implement a systemwide (Columbia River below Priest Rapids Dam and Snake River below Hells Canyon Dam) sport-reward fishery
2. PSMFC (Report B): Process and provide accounting for reward payments to participants in the sport-reward fishery.
3. CRITFC (Report C): Implement a systemwide angling fishery at eight mainstem dams on the Snake and Columbia rivers.
4. CRITFC (Report D): Implement a fishery for removing northern squawfish near hatchery release sites and at other specific locations where concentrations of northern squawfish are known or suspected to occur.
5. S.P. Cramer and Associates, Inc. (Report E): Implement a private-sector-operated system for collecting and disposing of harvested northern squawfish.
6. ODFW (Report F): Evaluate exploitation rate and size composition of northern squawfish harvested in the various fisheries implemented under the program together with an assessment of incidental catch of other fishes. Estimate reductions in predation on juvenile salmonids resulting from northern squawfish harvest. Evaluate changes in relative abundance, size and age structure, growth, and fecundity of northern squawfish, and consumption rates of juvenile salmonids

by northern squawfish in lower Columbia and Snake River reservoirs and in the Columbia River below Bonneville Dam.

Background and rationale for the Northern Squawfish Management Program study can be found in Report A of our 1990 annual report (Vigg et al. 1990). Highlights of results of our work in 1995 by report are as follows.

Report A
Implementation of the Northern Squawfish Sport-Reward Fishery
in the Columbia and Snake Rivers

1. Objectives for 1995 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, to initiate an incentive and promotional program to increase angler participation and catch, and to report on the dynamics of the fishery and promotional program.
2. The northern squawfish sport-reward fishery was conducted from May 1 through September 24, 1995. Thirteen registration stations were located throughout the lower Snake and Columbia rivers.
3. A total of 199,641 northern squawfish equal to or greater than 11 inches in total length were returned to registration stations for reward vouchers during the 1995 season. These fish were caught during 31,961 successful angler days, which represented 51% of the total number of angler days fished (62,704) by registered anglers. Harvest of northern squawfish was the highest ever — 54% greater than 1994, 6.8% greater than 1992, and 25% greater than 1991. Effort in 1995 was 54% higher than in 1994, 80% higher than in 1993, but 29% lower than 1992, and .7% lower than 1991. Catch per unit effort (CPUE) in 1995 was 3.18 fish per angler day, comparable to 3.17 fish per angler day in 1994. An additional 10,247 northern squawfish under 11 inches were returned to registration stations.
4. We observed a statistically significant ($P < 0.0001$) decrease in mean fork length in northern squawfish greater than 11 inches from 1991 (350 mm) to 1995 (324 mm).
5. Fifty percent of returning anglers were surveyed by questionnaire at the registration stations and 10% of no-returning anglers were surveyed by telephone. Peamouth (*Mylocheilus caurinus*), smallmouth bass (*Micropterus dolomieu*), and white sturgeon (*Acipenser transmontanus*) were the most frequently caught fishes, other than northern squawfish, by both returning and non-returning anglers. Returning anglers released approximately 20% more of their incidental catch than non-returning anglers. Word-of-mouth followed by newspapers were found to be the most effective methods of advertising the northern squawfish sport-reward fishery. Anglers reported that higher rewards, tagged fish drawings, weekly

drawings, and weekly tournaments all increased their participation in the 1995 sport-reward fishery. Returning and non-returning angler satisfaction with the sport-reward fishery is very high (97%).

Report B

Northern Squawfish Sport-Reward Fishery Payments

1. During 1995, a total of \$861,339 was paid for 196,878 northern squawfish harvested in the sport-reward fishery.
2. A total of 21,253 vouchers were processed of which 19,965 were standard vouchers representing a harvest of 196,668 fish and 210 vouchers for tagged northern squawfish (one tagged fish per voucher). Non-tagged fish were processed with an award payment of \$3 per fish while tagged fish were processed with an award value of \$50 per fish. Not all vouchers issued to anglers were submitted for reward payment.
3. The mean catch was 9.9 northern squawfish per voucher.
4. Voucher processing proceeded smoothly with checks being cut and mailed to the angler within five days of receipt of the voucher.
5. Vouchers that had missing or incomplete information were returned to anglers for completion, causing delay in payment. Vouchers that were not returned, or for which missing information was not provided, were rejected for payment.
6. The number of vouchers that were rejected totaled 58 with a combined potential reward of \$174 to \$290. There were a variety of reasons for vouchers being rejected, the most common being failure to complete the required questionnaire and failure to submit the voucher prior to the end of season deadline.
7. In addition to voucher processing, awards for weekly tournaments (195 prizes; \$48,750) two week extension tournaments (12 prizes; \$3,000) special tag drawings (37 prizes; \$9,250) G.I. Joes tournaments (21 prizes; \$5,950) and upper river tournaments (18 prizes; \$5,100) were processed. Voucher payments and program award payments totaled \$861,339 in 1995.

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

1. Dam angling at eight dams on the lower Snake and Columbia rivers during 1995 resulted in a catch of 5,299 northern squawfish from May through August, combined with another 189 northern squawfish caught using longlining gear. This was 33% of the 1994 catch.
2. Overall catch per angler hour (0.7) was less than half of that for 1994 (1.6). The boat angling effort was increased over that of 1994 (943 angler hours in 1995 vs. 771 angler hours in 1994) with better success than-dam-angling.
3. Overall dam-angling effort was reduced from 10,002 angler hours in 1994 to 7,289 angler hours in 1995 in response to the decline in catch rates at all dams. These declines were likely caused by a change in the distribution of juvenile salmonids and northern squawfish brought about by heavy spills and previous removals.
4. Incidental species caught as compared to the total catch increased significantly from 2.3% in 1994 to 8.3% in 1995. White sturgeon accounted for 55% of the bycatch. Five juvenile and no adult salmonids were caught in 1995.
5. We recommend that dam-angling efforts be reduced to mobile crews in response to expected high spill levels again in 1996 and that efforts be focused at times and in areas that are most productive. We also recommend continuing to test longlining and other angling techniques and maintaining volunteer angling at the current level (10- 12 groups).

Report D
**Site-Specific Removal of Northern Squawfish Aggregated to Feed on
Juvenile Salmonids During the Spring in the Lower Columbia and Snake Rivers**

1. Small-meshed gill nets were used to catch 9,484 predator-sized northern squawfish during April through June 1995. Most of the fish were caught at locations in Bonneville Pool (91%). The mouth of the Klickitat River was the most productive fishing location, The most productive location outside of Bonneville Pool was Levey Landing in Ice Harbor Pool.
2. The total incidental catch was 10,248 fish, with suckers (*Catostomus* spp.) being the most common incidentally caught species. Salmonid bycatch was reduced by 33%, largely due to the elimination of Merwin trapping in 1995.
3. We recommend continuation of the site-specific fishery using gill nets only. We propose to focus the majority of our effort at locations in Bonneville Pool. We

also plan to investigate new locations where we have evidence to suggest catch rates of northern squawfish would be high.

Report E

Handling and Transportation of Northern Squawfish Harvested Under the Columbia River Northern Squawfish Management Program in 1995

1. Approximately 214,572 northern squawfish were harvested under the three fisheries implemented in 1995. We continued the private-sector-operated fish handling system established in 1994 to collect and transport harvested northern squawfish to end users, and we successfully coordinated activities among end users and fishery managers.
2. The 1995 fish handling system included a food-grade fish collection network located in the lower Columbia River. These fish were packaged and sold frozen to Stoller Fisheries, Inc. in Spirit Lake, Iowa. Fish caught in other areas were rendered or killed and returned to the river.
3. The total spent for the fish handling system in 1995 was \$142,164. With cost recovery from sale of food-grade fish, the net cost for the fish handling system was \$133,450.

Report F

Development of a Systemwide Predator Control Program: Indexing and Fisheries Evaluation

1. Objectives in 1995 were to (1) evaluate incidental catch of non-target species and the exploitation rate and size composition of northern squawfish captured in the various fisheries, and estimate reductions in predation on juvenile salmonids since implementation of the Northern Squawfish Management Program; and (2) evaluate changes through 1995 in relative abundance, smolt consumption rate, size and age structure, growth, and fecundity of northern squawfish in lower Columbia and Snake River reservoirs and in the Columbia River downstream from Bonneville Dam.
2. Systemwide exploitation of northern squawfish in 1995 was 13.5% for sport-reward, 0.5% for dam-angling, and 1.9% for site-specific fisheries. Subsamples from each fishery indicated that the mean fork length was 327 mm in the sport-reward fishery, 367 mm in the dam-angling fishery, and 411 mm in the site-specific gill-net fishery. Bycatch of salmonids was relatively low in all fisheries and was lowest in the dam-angling fishery.

3. In general, relative abundance of northern squawfish in 1995 decreased from previous years in the Columbia River downstream from Bonneville Dam, in John Day Reservoir, and in the Snake River. Relative abundance in Bonneville and The Dalles reservoirs was similar to previous years.
4. We estimated that potential predation on juvenile salmonids in 1996 will be reduced 36% from pre-program levels. Eventual reductions in potential predation varied depending on estimates of sustained exploitation. However, it appeared feasible to reduce overall northern squawfish predation by at least 41%. Smolt consumption by northern squawfish declined downstream from Bonneville Dam and increased in Lower Granite Reservoir relative to previous years. Consumption indices in the remaining areas were generally similar to previous years. Predation indices in 1995 were lower than previous years in nearly all areas,
5. Proportional stock density (PSD) of northern squawfish collected from the Bonneville Dam tailrace was lower in 1995 than in previous years. Estimates of PSD from 1991-95 were generally below levels that would have been expected without implementation of the Northern Squawfish Management Program. Variations in recruitment from 1989-91 and in exploitation in 1995 should result in decreased PSD estimates in 1996 for the Bonneville Reservoir and the Columbia River downstream from Bonneville Dam, whereas PSD in the John Day Reservoir should remain similar to 1995,

SECTION I. IMPLEMENTATION

Cooperators

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

Report A

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

Prepared by

**John S. Hisata
Marc R. Petersen
Dennis R. Gilliland
Eric C. Winther
Scott S. Smith
Janice Suarez-Pena**

**Washington Department of Fish and Wildlife
600 Capitol Way N., Olympia, WA 98501-1091**

1995 Annual Report

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ABSTRACT

Northern squawfish (*Ptychocheilus oregonensis*) harvest in 1995 totaled 199,788 fish returned to the registration stations for payment. Northern squawfish harvest was the highest ever and 54.4% greater than in 1994 (129,434) 91.1% greater than in 1993 (104,536) 6.9% greater than in 1992 (186,904) and 25.5% greater than in 1991 (159,162). A total of 62,725 angler days were spent fishing for northern squawfish in 1995 and 5.1% (31,985) of the registered anglers returned to registration stations for an exit interview. Effort in 1995 was higher than in 1994 (40,783 angler days) and 1993 (34,879 angler days), but lower than in 1992 (88,495 angler days) and 1991 (67,384 angler days). Catch per unit effort was 3.19 (fish/angler day) and comparable to 1994 (3.17).

Fork lengths were measured from 86,923 northern squawfish of which 81,752 had fork lengths greater than or equal to 250 mm (approximately 11 inches total length). We observed a statistically significant ($P < 0.0001$) decrease in mean fork length of northern squawfish ≥ 11 inches from 1991 (350mm) to 1995 (324mm).

Fifty percent of returning anglers were surveyed by questionnaire at the registration stations; 10% of non-returning anglers were surveyed by telephone. Other than northern squawfish, peamouth (*Mylocheilus caurinus*), smallmouth bass (*Micropterus dolomieu*) and white sturgeon (*Acipenser transmontanus*) were the most frequently caught fishes by both returning and non-returning anglers. Word-of-mouth followed by newspapers were the most effective methods of advertising the northern squawfish sport-reward fishery (NSSRF). Surveyed anglers reported that higher rewards, tagged fish drawings, weekly drawings and weekly tournaments all increased their participation in the 1995 NSSRF. Returning and non-returning angler satisfaction with the NSSRF was very high (97%).

Electrophoresis was used to identify 73 F₁ hybrids between northern squawfish and chiselmouth (*Achrocheilus alutaceus*) in Lower Granite Reservoir. The hybrids were found to be as piscivorous as northern squawfish and were recommended for inclusion in the reward program.

INTRODUCTION

Northern squawfish (*Ptychocheilus oregonensis*) are the primary predator of juvenile salmonids (*Onchorhynchus* spp.) in the lower Columbia and Snake River systems (Beamesderfer and Rieman 1991). Rieman and Beamesderfer (1990) demonstrated that predation on juvenile salmonids could be reduced by 50% with limited (10-20%) but sustained exploitation of northern squawfish greater than 275 mm fork length. The Columbia River Northern Squawfish Management Program began in 1990 with the goal of achieving a 10-20% annual exploitation of northern squawfish. The northern squawfish sport-reward fishery has the highest rate of exploitation within the program (Knutsen et al. 1995). The sport-reward fishery encourages recreational anglers to catch northern squawfish by offering cash rewards for northern squawfish \geq 11 inches in total length.

Thirteen registration stations and 16 satellite registration sites were operated on the Columbia and Snake rivers from May 1 through September 24, 1995. The purposes of the registration stations were to register anglers, issue pay vouchers for northern squawfish \geq 11 inches, conduct exit interviews, provide program information, and collect biological data on a subsample of fish. Satellite sites were similar to registration stations, but with limited hours of operation. They were operated in conjunction with a parent registration station with the goal of increasing the efficiency of the parent station by increasing angler participation and northern squawfish harvest at minimal additional cost.

An exit interview questionnaire for returning anglers and a telephone survey for non-returning anglers were used to solicit the opinion of anglers participating in the sport-reward fishery regarding the management of the program and to estimate incidental catch from anglers targeting northern squawfish. Angler satisfaction with the sport-reward fishery is necessary for the continued success of the program. Catch data were also recorded in the surveys to assist the Oregon Department of Fish and Wildlife (ODFW) in evaluating the effect of the sport-reward fishery on fishes other than northern squawfish.

The objectives of the exit interview questionnaire and telephone survey were to (1) estimate angler catch and harvest of northern squawfish, peamouth (*Mylocheilus caurimus*), smallmouth bass (*Micropterus dolomieu*), white sturgeon (*Acipenser transmontanus*), walleye (*Stizosfedion vitreum*) and channel catfish (*Ictalurus punctatrrs*) while targeting northern squawfish; (2) estimate catch of adult and juvenile salmonids (*Oncorhynchus* spp.) while anglers targeted northern squawfish; (3) determine angler satisfaction with new promotional and incentive programs; (4) determine if anglers were satisfied with the sport-reward fishery, and (5) evaluate angler satisfaction with sport-reward fishery technicians (non-returning anglers only).

A new incentive for the 1995 season was a tiered reward system designed to increase harvest in the early pre-spawn period and retain more successful anglers in the late, postspawn season. The reward was \$3 for the first 100 northern squawfish, \$4 for 101-400 northern squawfish, and \$5 for each not-them squawfish in excess of 400 during the season. Past seasons have shown a drop in participation as catch rates declined after midseason. Our assumptions were that the tiered reward would encourage anglers to increase harvest in the early season while catch rates were high to reach the higher tiers as soon as possible, and that the higher tiers of \$4 and \$5 would keep anglers who successfully reached these levels fishing later into the season. Promotional activities for the northern squawfish sport-reward fishery are reported in Appendix C. Additionally, the Bonneville Power Administration (BPA) continued to aggressively pursue promotional opportunities for the program to increase participation by the general public.

We continued evaluating the cost of registration station and satellite station operation (Appendix D) to continue to control and reduce operating costs. We made every effort to ensure that our method of figuring costs was comparable to the method used by Susan Hanna (Hanna et al. 1994) in her cost analysis conducted following the 1992 season.

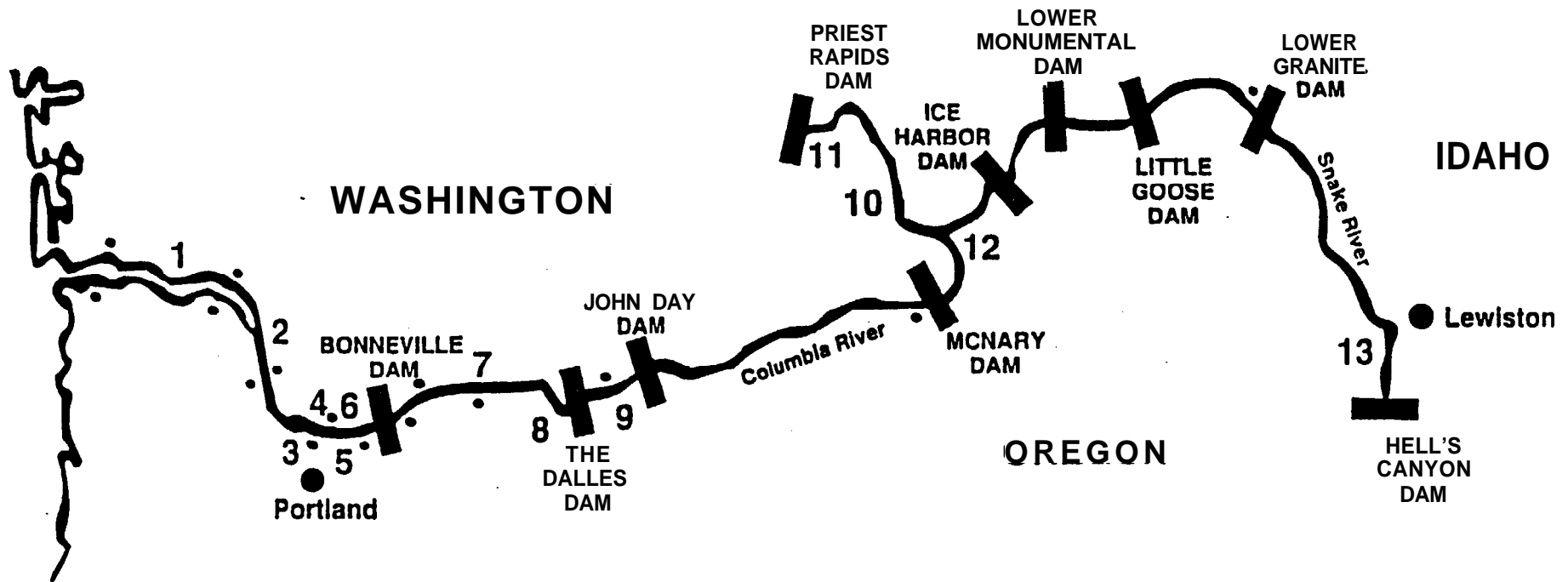
Putative hybrids between northern squawfish and chiselmouth (*Acrocheilus alutaceus*) were sampled from Lower Granite Reservoir. Electrophoretic, MtDNA, principal component and stomach contents analyses were used to provide a comprehensive understanding of the hybrids' genetic makeup, morphometric differences and feeding behavior (Appendix E).

METHODS

Study Area

The northern squawfish sport-reward fishery 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 mouths of tributaries along these reaches of these two rivers were also open for harvest of northern squawfish for reward payment. Thirteen registration stations (Figure 1 a) and 16 satellite sites (Figure 1 b) were located on these river reaches.

A "tailrace" was defined as the section of river immediately below a dam. A "reservoir" was defined as the section of river from the tailrace of an upstream dam to the next downstream dam. The only exception to this is the section of river from below Bonneville Dam to the mouth, which is referred to as the Bonneville tailrace.



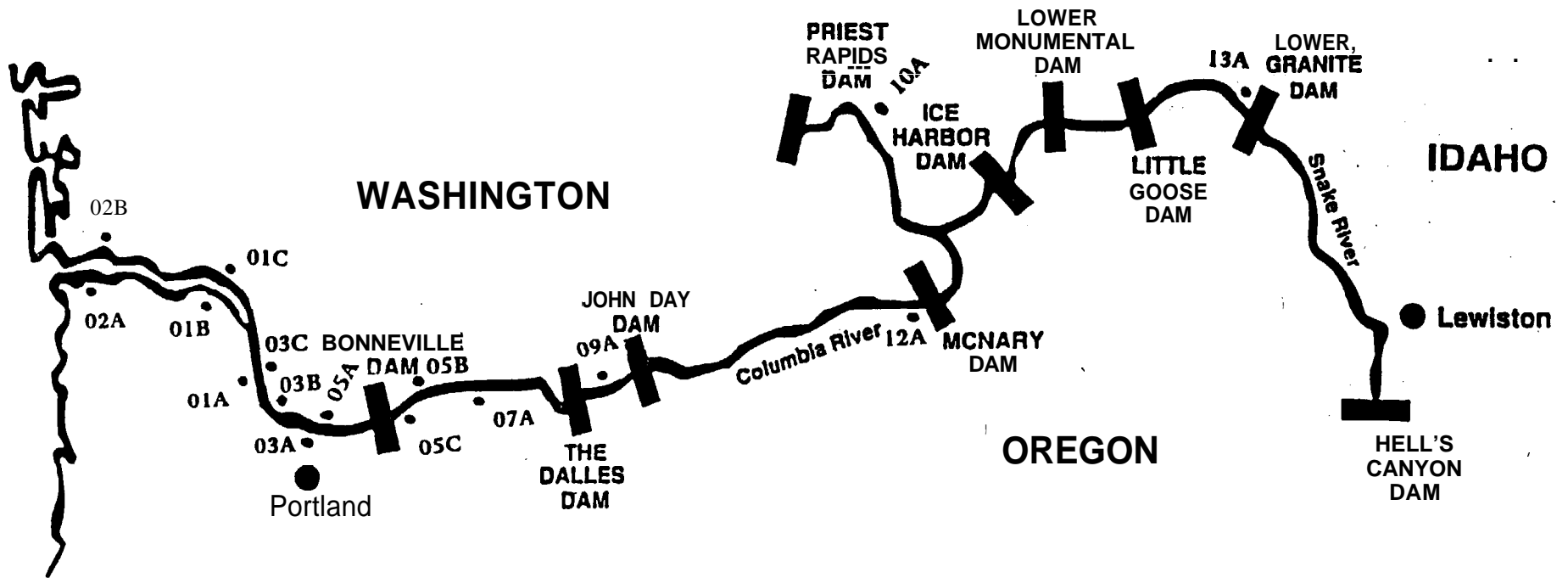
Access Sites:

- 1. Cathlamet Marina
- 2. Kalama Marina
- 3. M. James Gleason Boat Ramp
- 4. Washougal Boat Ramp/Port of Camas

- 5. The Fishery at Covert's Landing
- 6. Hamilton Island
- 7. Bingen Marina
- 8. The Dalles Boat Ramp
- 9. Giles French Boat Ramp

- 10. Columbia Point Park
- 11. Veinita Bridge Rest Area
- 12. Hood Park
- 13. Greenbelt Boat Ramp

Figure 1 a. Location of the Northern Squawfish Sport-Reward Fishery registration stations on the Columbia and Snake rivers during the 1995 field season.



Satellite Sites:

- | | | | |
|--------------------------|---------------------------------|----------------------------------|---------------------------|
| 01A. Scappose | 02A. John Day Ramp | 03A. Chinook Landing | OSA. Beacon Rock |
| 01B. Rainier | 02B. Deep River | 03B. Marine Park (Portco) | 05B. Home Valley |
| 01C. Willow Grove | | 03C. Ridgefield Marina | 05C. Cascade Locks |
| 07A. Hood River | 09A. Maryhill State Park | 10A. Ringold | 12A. Umatilla |
| | 13A. Boyer Park | | |

Figure 1 b. Location of the Northern Squawfish Sport-Reward Fishery satellite registration stations on the Columbia and Snake rivers during the 1995 field season.

Participation Requirements

Angler participation compliance rules for 1995 were adopted as follows.

- A) Prior to fishing, each angler must register at one of the registration sites 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 must exchange, in person, their eligible northern squawfish for a payment voucher at the same registration site where the angler registered between 1 p.m. and 9 p.m. during the same fishing day.
- C) To be eligible for payment, each northern squawfish must be 11 inches or greater in total length and be presented in fresh condition or alive.
- D) Anglers shall provide information regarding their catch as requested by WDFW personnel at the registration site.
- E) Anglers shall have a current Washington, Oregon or Idaho state fishing license to fish for northern squawfish and must comply with the angling regulations for the licensing state.

Registration Stations and Satellite Sites

Washington Department of Fish and Wildlife (WDFW) technicians were present to register anglers from 1 p.m. to 9 p.m. daily at registration stations and during hours of operation at satellite sites. Outside of operating hours, anglers could also self-register daily at a registration box near the sites. A short registration form was completed to record information pertinent to the angler's fishing day.

Satellite sites were staffed by intermittent technicians using the existing vehicles for registration station operation and were operated in conjunction with a parent registration station. Anglers could register and turn in fish for payment vouchers during the operation of the satellite sites. Satellite sites were evaluated during the early season; those that did not produce a reasonable harvest were terminated to reduce overall operating costs. The satellite sites' operation schedules were based on the site location on a road route from the parent registration station and on time limitations for practical operation while trying to provide for angler convenience. Registration was possible at these sites during off-hours through self-registration boxes.

Exit Interview

Anglers were required to return to the same registration station where they registered to turn in their northern squawfish catch. WDFW technicians retrieved the angler's registration form and conducted an exit interview, which included stop time, actual hours fished, location fished and number of northern squawfish ≥ 11 and < 11 inches harvested. The technicians recorded northern squawfish harvested and asked anglers if any other fish species were caught or harvested while targeting northern squawfish. Other fish caught or harvested were recorded on the angler questionnaire. Biological data were taken on other fish species if the fish were available and if time permitted. Biological data consisted of fork length, weight, scale sample, tags, secondary marks, and sex (determined by opening the fish). Other fish species brought to the site were processed for biological data (except sex) and returned to the angler. Biological data on tagged northern squawfish were recorded by the technician and the tags with data were sent to ODFW by the angler. Upon completion of the interview, a payment voucher was issued to the angler. The angler was required to mail the voucher to the Pacific States Marine Fisheries Commission (PSMFC) for payment.

Northern Squawfish Processing

All reward-sized northern squawfish were tail-clipped to indicate processing by a WDFW technician. Northern squawfish were graded according to guidelines provided by S.P. Cramer and Associates to determine whether a fish would be processed as "food-grade" or "fertilizer-grade."

Graded fish were placed on ice in insulated coolers marked "good" for food-grade or "poor" for fertilizer-grade northern squawfish. At the end of each shift, technicians delivered the fish to a designated facility for processing or storage by facility personnel. Food-grade registration stations included Washougal, Gleason, The Fishery, Hamilton Island, Bingen, The Dalles and Giles French.

Fertilizer-grade fish were placed in insulated coolers and delivered to designated storage facilities at the end of each shift to ultimately be delivered to rendering facilities. Fertilizer-grade only registration stations included Cathlamet, Kalama, Columbia Point, Vernita, Hood Park and Greenbelt.

Returning Angler Sampling

Approximately 50% of returning anglers were surveyed by technicians at each registration station using a systematic random sample (one in two; Table 1). Returning anglers and exit interview questionnaires were summed each week by registration location. The accuracy of the sample size was monitored.

Non-Returning Angler Sampling

Non-returning anglers were surveyed by telephone (Table 1). Ten percent of all non-returning anglers were surveyed each week, except Weeks 9 through 12, in which 5% were surveyed. A 50% systematic random sample (one in two) of non-returning angler registration forms was taken from all registration stations each week. The samples were shuffled to randomize registration dates and times, Telephone survey personnel called anglers from the random sample until they completed the 10% sample. If the sample (10%) was not reached during the first pass through the registration forms, survey personnel would re-call anglers that weren't reached during the first attempt until the goal was met.

Returning and Non-Returning Angler Estimates

“Caught” is defined as those fish harvested or returned to the water alive. For a fish to be considered caught, the angler must have touched, released or landed the fish. “Harvest” is defined as those fish caught and not returned to the water alive.

The data were checked with computer programs designed to detect non-relevant responses in each field. Except Question 3, returning and non-returning angler estimates were reported as a percentage of the total anglers that chose each of the possible multiple choice answers for a given question. Catch data were derived from Question 3 and the total catch estimates for returning and non-returning anglers were calculated for each species using simple estimators. Incidental salmonid catch ratios were created by dividing the number of salmonids caught by the number of northern squawfish caught (salmonid/squawfish) and the number of salmonids caught by angler effort (salmonid/effort). The precision of our returning angler catch estimates were tested by estimating the number of northern squawfish ≥ 11 inches harvested and comparing that estimate to the actual harvest recorded on the registration forms,

Table 1. 1995 Northern Squawfish Sport-Reward Fishery exit questionnaire and telephone survey.

Interviewer Initials D a t e _____ **Doc No.** _____

Registration Location Code _____ Reservoir Code _____

Fishing Location Code _____

1. Did you specifically fish for northern **squawfish** at anytime during your fishing trip? If “no”, go to question 4.

Y N

2. While targeting northern **squawfish**, did you catch any fish? If “no”. go to question 4.

Y N

3. please tell me how many of each type of **fish** you caught while you were specifically fishing for northern squawfish (“Caught” is the **total** number of fish that the angler touched) and how many were released.

	Species	Caught	Released
Squawfish > 11 inches		# _____	# _____
Squawfish < 11 inches		# _____	# _____
Other (specify)		# _____	# _____
		# _____	# _____
		# _____	# _____

4. How did you **find** out about the 1995 Northern Squawfish Sport-Reward Fishery?

- A. Newspaper c. T.V. E. Printed Material/Brochure
 B. Radio D. **Word** of Mouth F. Other(specify)_____

5. Would you have taken this fishing trip if the sport-reward fishery did not exist?

Y N

6. For Anglers at Satellite Stations: Would you have registered with the Northern Squawfish Sport-Reward Fishery today if this satellite station did not exist?

Y N 0
(not at sat.station)

7. Please tell me how the following activities have affected your participation in the sport-reward fishery.

ACTIVITY	1 INCREASED	2 NOT CHANGED	3 DECREASED	4 NOT AWARE
A.) Satellite Stations	_____	_____	_____	_____
B.) Higher reward	_____	_____	_____	_____
C.) \$50 Tagged Fish	_____	_____	_____	_____
D.) Weekly Tournaments	_____	_____	_____	_____
E.) BPA Tournament	_____	_____	_____	_____
F.) Random Drawings	_____	_____	_____	_____

8. Are you satisfied with the Northern Squawfish Sport-Reward Fishery?

Y N

If "no" (please explain) _____

(Phone Survey Only!!)

9. How would you rate your interaction with the technicians at the registration station?

- A. Very Good
- B. Good
- C. Poor (If "C" record why in "Additional Comments" section)
- D. No Interaction

additional comments: _____

RESULTS AND DISCUSSION

Northern Squawfish Harvest

The 1995 sport-reward fishery harvest of northern squawfish ≥ 11 inches totaled 199,788. In addition, 10,237 northern squawfish < 11 inches were turned in at registration stations. Harvest of northern squawfish ≥ 11 inches was the highest ever and was 54.4% greater than the 1994 harvest of 129,434 (Smith et al. 1995), 91.9% greater than the 1993 harvest of 104,536 (Klaybor et al. 1995), 6.9% greater than the 1992 harvest of 186,904 (Burley et al. 1994) and 25.5% greater than the 1991 harvest of 159,162 (Burley et al. 1992). Harvest by reservoir ranged from a low of 252 northern squawfish in Ice Harbor Reservoir to a high of 66,151 northern squawfish in the Bonneville tailrace (Figure 2). Exploitation for the 1995 sport-reward fishery was the highest ever for the first five years of the program at 13.6% (D. Ward, ODFW, personal communication). The increased harvest for 1995 can be attributed to the tiered reward system and to strong year classes as reported by Zimmerman et al. (1997) entering the reward eligible size range of ≥ 11 inches. Six registration stations (Cathlamet, Gleason, The Fishery, Giles French, Vernita and Greenbelt) along with six satellite sites (Rainier, Chinook, Washougal, Hamilton Island, Cascade Locks and The Dalles) remained open for an additional two weeks beyond the scheduled (September 10) end of the season, yielding an additional harvest of 8,302 northern squawfish. These stations remained open due to favorable river and weather conditions, and increasing catch per unit effort.

The systemwide mean weekly harvest in 1995 was 9,513 northern squawfish and ranged from 3,930 to 17,874 fish (Figure 3). Harvest varied by week from 1991-95, but peak harvest occurred prior to the end of the 29th week of the year (approximately July 15) in all years (Figure 4). The timing of peak northern squawfish harvest demonstrates the importance of angler participation early in the sport-reward season. However, river conditions can affect harvest early in the season. High flows and murky water in May and early June hindered harvest on the Snake River.

Mean harvest of northern squawfish by registration station in 1995 was 15,368 fish and ranged from 2,724 at the Kalama Marina to 45,790 at the Giles French boat ramp (Figure 5). Even with the season's record harvest, not all areas contributed to this record. Only nine of the 13 registration stations showed an increase in harvest over the 1994 season. All stations except Kalama, Washougal, Hamilton Island and Hood Park showed an increase. The Giles French boat ramp showed the greatest increase in catch over the previous year (3.4 times greater), followed by The Dalles boat basin (3.2 times greater), Bingen Marina (2.3 times greater) and Columbia Point Park (2 times greater; Table 2).

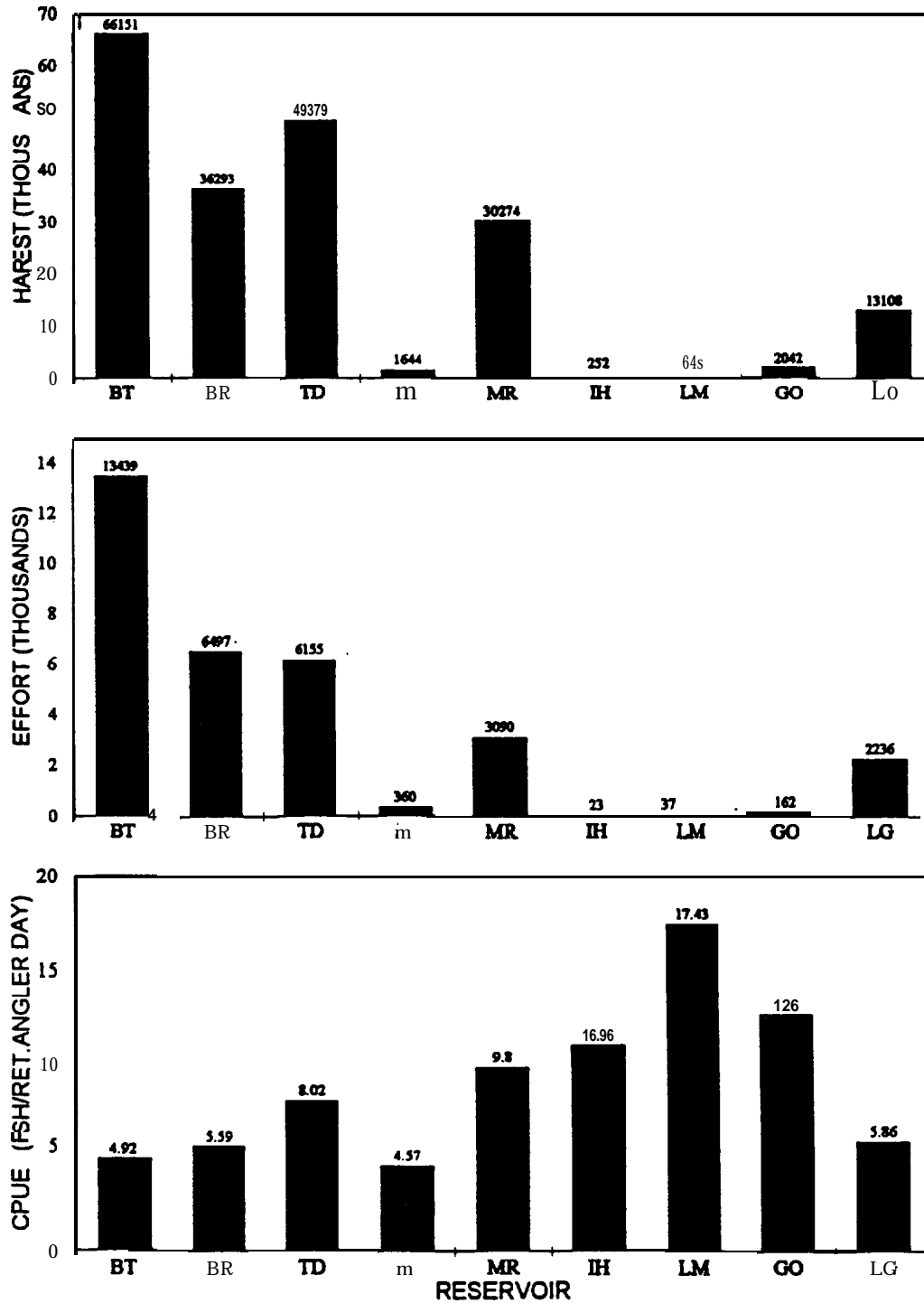


Figure 2. Northern squawfish harvest, effort (returning angler day) and CPUE (fish/returning angler day) by reservoir in 1995. BT - Bonneville Tailrace, BR - Bonneville Reservoir, TD - The Dalles Reservoir, JD - John Day Reservoir, **MR - McNary** Reservoir, LM - Lower Monumental Reservoir, GO -Little Goose Reservoir, LG - Lower Granite Reservoir.

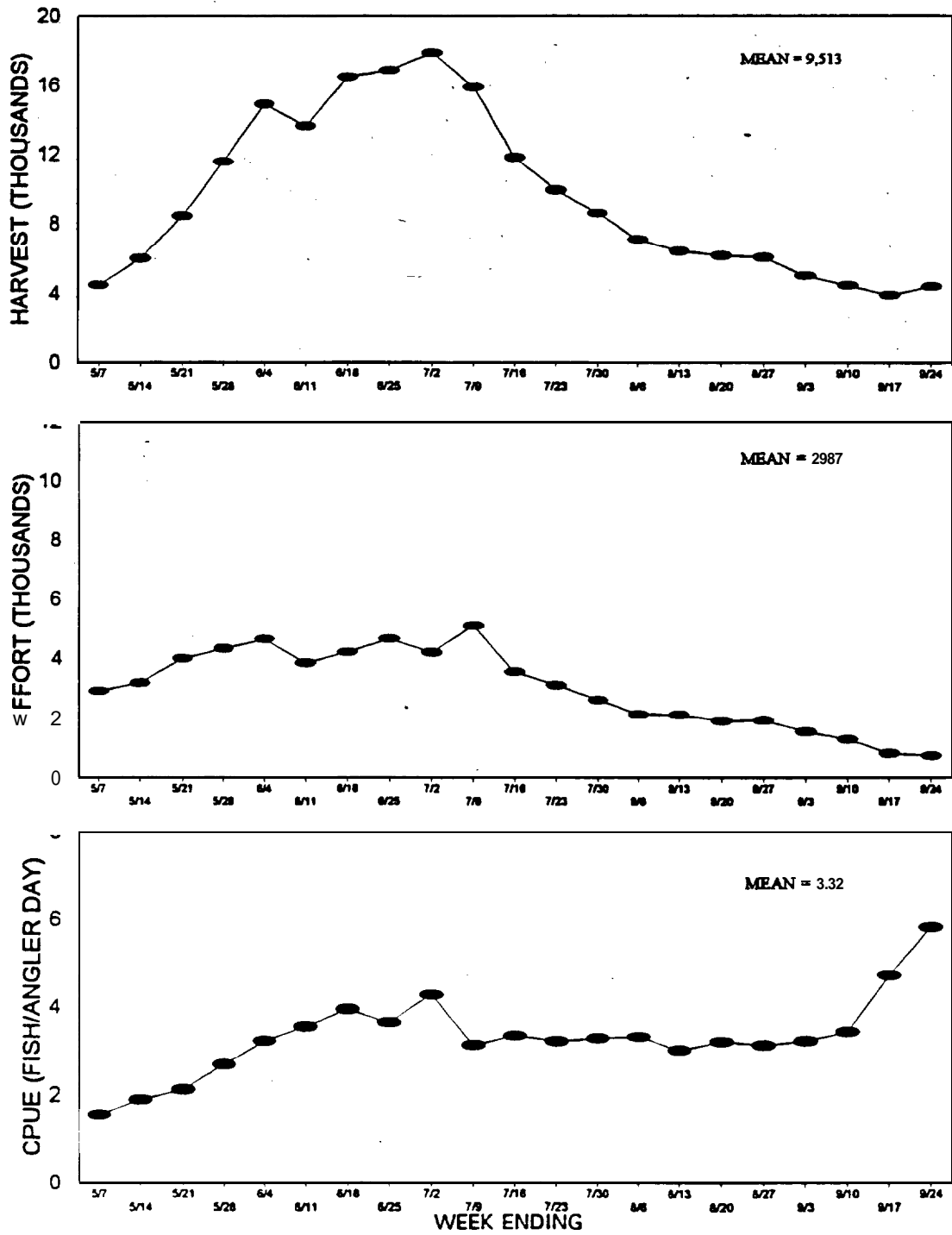


Figure 3. Northern squaw-fish harvest, effort (angler day) and CPUE (fish/angler day) by week in 1995.

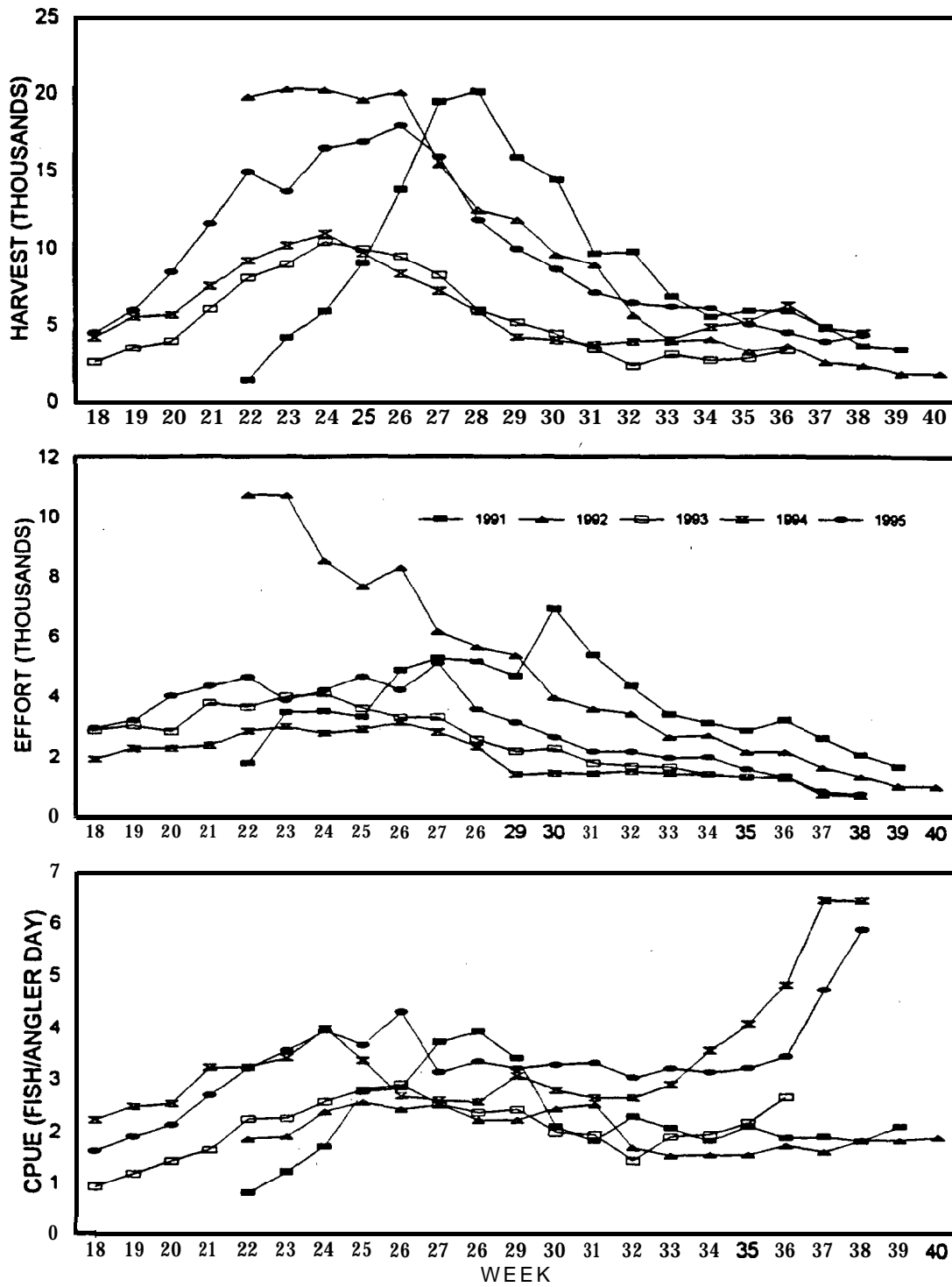


Figure 4. Comparison of northern squawfish harvest, effort (angler day), and CPUE (fish/angler day) by week, 1991 - 1995.

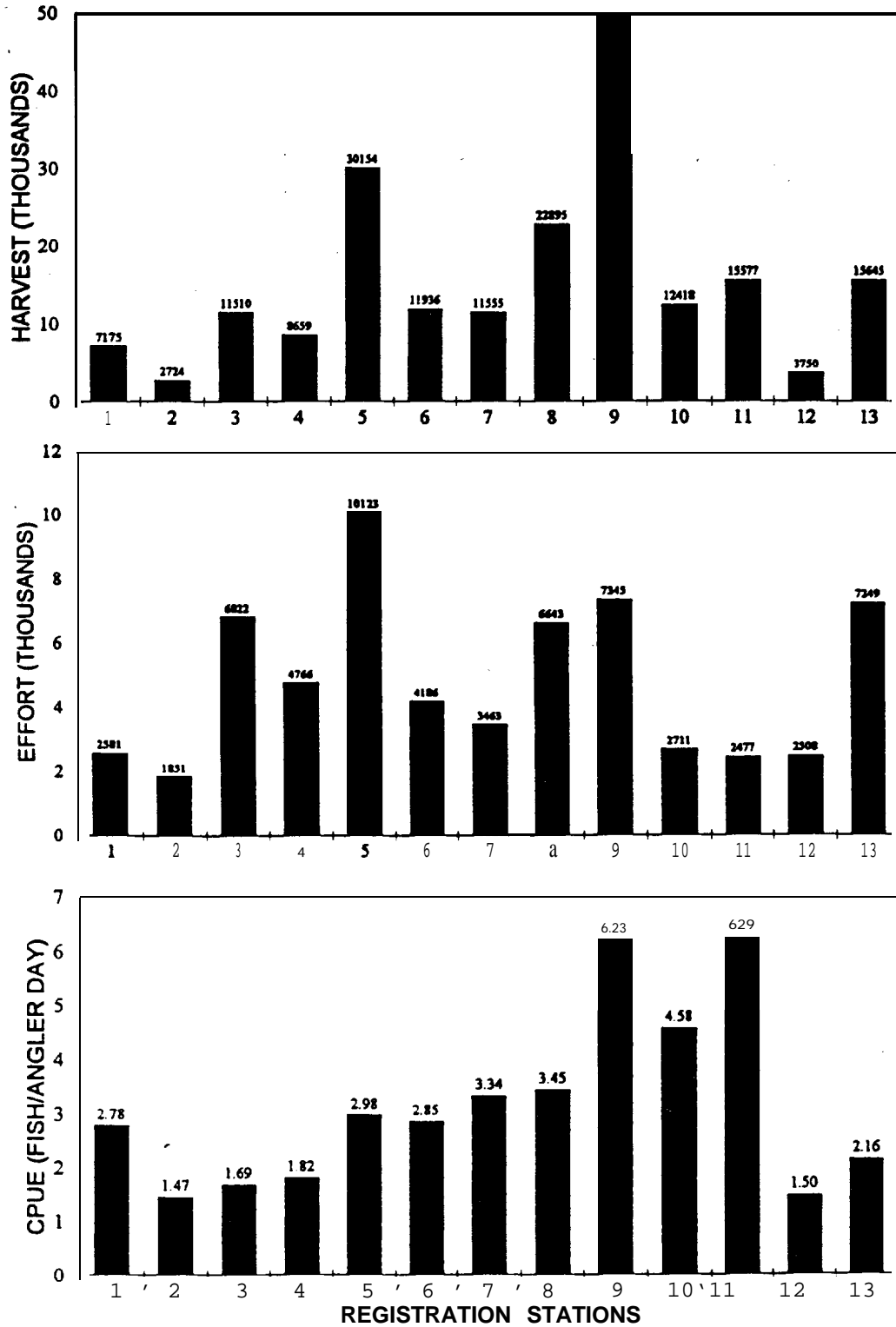


Figure 5. Northern squawfish harvest, effort and CPUE (fish/angler day) by registration location in 1995. 1 - Cathlamet, 2 - **Kalama**, 3 - Gleason, 4 - Washougal, 5 - The Fishery, 6 - Hamilton Island, 7 - Bingen, 8 - The Dalles, 9 - Giles French, 10 - Columbia Point, 11 - Vernita, 12 - Hood Park, 13 - Greenbelt.

Table 2. Comparison of registration station harvests during the 1991 (May 27-September 30), 1992 (May 18-September 30), 1993 (May 3-September 12), 1994 (May 2-September 25) and 1995 (May 1-September 24) seasons for northern squawfish ≥ 11 inches.

STATION	1991	1992	1993	1994	1995
Hamilton Island	18219	17048	9126	13732	11936
The Fishery	40674	23851	16308	27935	30154
Cascade Locks	9143	6779	1881	--	--
Bingen Marina	12711	12513	6408	5038	11555
Dalles Boat Basin	3828*	6806	4338	7136	22895
LePage Park	32141	16926	10643	--	--
Columbia Point	1104*	11148	5192	6133	12418
Hood Park	3676*	9199	4119	4116	3750
Lyons Ferry	4211*	3131	1466	--	--
Central Ferry Park	7845	--	--	--	--
Chief Timothy Park	1048	--	--	--	--
Greenbelt Boat Ramp	17466	21333	10309	9593	15645
Maryhill Park	1001*	5094	--	--	--
Plymouth Ramp	5556	2414	--	--	--
Windust Park	919"	--	--	--	--
Kalama Marina	--	6799	1605	4664	2724
Gleason Boat Ramp	--	15494	9719	10742	11510
Bayport Marina	--	1606	--	--	--
Willow Grove Park	--	5676	--	--	--
Marine Park (Portco)	--	8637	--	--	--
Ringold	--	5139	--	--	--
Boyer Park	--	5875	1296	--	--
Cathlamet Marina	--	--	3960	4630	7175
Rainier Boat Ramp	--	--	1561	--	--
Washougal Ramp	--	--	5920	9105	8659
Umatilla Ramp	--	--	1000	1000	--
Vernita Rest Area	--	--	9765	11597	15577
Giles French	--	--	--	13430	45790

* Station did not open until July 15, 1991.

-- Not in operation.

Northern squawfish harvest was highest (42,042) in Fishing Location 16 (Table 3), which extends from Miller Island to the John Day Dam tailrace (Appendix Table A-4). Fifty-one percent of the total harvest of northern squawfish ≥ 11 inches came from Fishing Locations 10 (41,353) 14 (19,377) and 16 (42,042) which represent 6% of the fishing locations in the sport-reward fishery area (Table 3). The 10 fishing locations that produced the greatest harvest of northern squawfish ranged from 4,829 to 42,042 fish and accounted for 77% of the total harvest eligible for reward payments (Table 3).

Effort

A total of 12,016 registered anglers participated in the sport-reward fishery. Total effort for the 1995 season was 62,725 angler days, 53.8% greater than the 40,783 angler days in 1994 (Smith et al. 1995), 79.8% greater than the 34,879 angler days in 1993 (Klaybor et al. 1995), 29.1% less than the 88,495 angler days in 1992 (Burley et al. 1994) and 6.9% less than the 67,384 angler days in 1991 (Burley et al. 1992). Returning angler days of effort ranged from 23 in the Ice Harbor Reservoir to 13,439 in the Bonneville tailrace (Figure 2). There were no registration stations in Ice Harbor or Lower Monumental reservoirs in 1995, however the reservoirs were open to participation. Overall, the increase in effort for 1995 compared to 1994 can be attributed to the new tiered reward system.

Angler days of effort are based on total numbers of participating anglers (62,725). Of these participating anglers, 31,999 (51%) returned to registration stations to turn in northern squawfish for rewards and for exit interviews. Mean angler effort by week was 2,987 angler days and ranged from 745 to 5,071 angler days (Figure 3). Mean angler days of effort (participating angler days) by registration station was 4,823 and ranged from 1,851 at Kalama to 10,123 at The Fishery (Figure 5). Effort by fishing location (fishing location could only be recorded for anglers returning to the station) was highest in Locations 9 (3,229) 10 (6,705) and 16 (5,101; Table 3).

Catch per Unit Effort

Overall catch per unit effort (CPUE) for northern squawfish ≥ 11 in 1995 was 3.19 (fish/participating angler day). CPUE for anglers returning to registration stations ranged from 4.57 (fish/returning angler day) in John Day Reservoir to 17.43 (fish/returning angler day) in Lower Monumental Reservoir (Figure 2). Overall CPUE was comparable to 1994 (3.17 fish/angler day) and significantly higher ($P < 0.0001$) than 1993 (2.09 fish/angler day), 1992 (2.11 fish/angler day) or 1991 (2.37 fish/angler day). The slight increase in CPUE for 1995 over 1994 (3.17 fish/angler day) is negligible. The results of this season's incentive program should provide benefits for the next few years if newly recruited anglers continue to participate in coming seasons. Mean CPUE by week was 3.32 (fish/angler day) with a range of 1.58 to 5.87

(fish/angler day; Figure 3). CPUE by registration station ranged from 1.47 (fish/angler day) at Kalama Marina to 6.29 (fish/angler day) at Vernita (Figure 5). CPUE (fish/returning angler day) was highest in Fishing Locations 19 (56.13), 38 (33.33) and 43 (67.67; Table 3).

Fork Length Data

A total of 86,923 northern squawfish (41.4% of all northern squawfish returned to registration stations) were sampled for fork length in 1995 of which 81,752 fish had a fork length greater than or equal to 250 mm. Mean fork length for northern squawfish greater than or equal to 250 mm was 324 mm. The mean fork lengths for each reservoir ranged from 298 mm in the Bonneville Reservoir to 349 mm in Lower Monumental Reservoir (Table 4). Overall mean fork length of northern squawfish greater than 250 mm decreased significantly ($P < 0.0001$) in 1995 (324 mm) from 1991 (350 mm; Table 4). Mean fork length decreased significantly ($P < 0.0001$) in 1995 from 1991 in the Columbia River reservoirs and Bonneville tailrace. However comparison of Snake River mean fork lengths are inconclusive due to relatively small sample sizes for the Ice Harbor, Lower Monumental, and Little Goose reservoirs (Table 4). Comparison of the mean fork length for the Lower Granite Reservoir for 1995 to 1991 does not show a biologically meaningful difference (4 mm).

The mean fork length for all northern squawfish sampled in 1995 was 317.9 mm with the greatest frequency of fork lengths occurring between 250 mm and 274 mm (25.7% of total sample; Figure 6). Mean fork lengths for northern squawfish sampled from the Columbia River ranged from 298 mm in Bonneville Reservoir with the greatest frequency occurring between 250 mm and 274 mm (37.4% of total reservoir sample) and The Dalles Reservoir with the mean of 323 mm with the greatest frequency occurring between 250 mm and 274 mm (23.8% of total reservoir sample) to 334 mm in the McNary Reservoir with the greatest frequency occurring between 250 mm and 274 mm (19.6% of total reservoir sample; Figures 7a and 7b). Snake River fork length means ranged from 311 mm for the Ice Harbor Reservoir to 344 mm for the Lower Granite Reservoir (Figures 7b and 7c), but represent small sample sizes for all but Lower Granite Reservoir.

Table 3. Northern **squawfish** harvest (≥ 1), effort (**returning** angler days) and CPUE (**fish/returning** angler day) by reservoir and fishing location, 1995.

RESERVOIR	FISHING LOCATION	NSF HARVEST	EFFORT	CPUE
Bonneville	Tailrace			
	1	1303	208	6.26
	"	4432	643	6.89
	"	1776	278	6.39
	"	1178	395	2.98
	"	1102	521	2.12
	"	262	113	2.32
	"	689	9 1	7.57
	"	3761	1242	3.03
	"	10295	3229	3.19
	"	10	41353	6.17
Bonneville Res.	11	7400	1552	4.77
"	12	2901	602	4.82
"	13	6615	1183	5.59
"	14	19377	3160	6.13
The Dalles Res.	15	7337	1054	6.96
"	16	42042	5101	8.24
John Day Res.	17	143	7	20.43
"	"	0	0	0
"	19	449	8	56.13
"	20	0	0	0
"	21	9	7	1.29
"	22	352	88	4
"	23	691	250	2.76
McNary Res.	24	80	24	3.33
"	25	5	3	1.67
"	26	141	73	1.93
"	27	339	178	1.9
"	28	2966	499	5.94
"	29	4829	444	10.88
"	30	2716	131	20.73
"	31	7513	413	18.19
"	32	3794	236	16.08
"	33	7229	788	9.17
"	34	0	0	0
"	35	662	301	2.2
Ice Harbor Res.	36	8	14	0.57
"	37	44	3	14.67
"	38	200	6	33.33
Lower Monumental Res.	39	0	1	0
"	40	125	10	12.5
"	41	520	26	20
Little Goose Res.	42	107	2	53.5
"	43	203	3	67.67
"	44	1732	157	11.03
Lower Granite Res.	45	221	16	13.81
"	46	31	3	10.33
"	47	160	36	4.44
"	48	2228	717	3.11
"	49	4499	841	5.35
"	50	3870	484	8
		2099	139	15.1
Totals		199788	31985	

Table 4. Mean fork length comparison by reservoir of NS \geq 11 inches 1991- 1995 (Pr>[t] estimating the probability of the mean FL being significantly different from 1991 t

RESERVOIR	YEAR	n	mean	Pr>[t]
Bonneville Tailrace	1991	9698	341	0.0001
	1992	41842	334	
	1993	28047	321	
	1994	32577	323	
	1995	33039	319	
Bonneville	1991	7550	349	0.0001
	1992	8457	353	
	1993	6481	310	
	1994	4260	338	
	1995	7641	299	
The Dalles	1991	8563	371	0.0001
	1992	17043	364	
	1993	9101	364	
	1994	11564	350	
	1995	3247	320	
John Day	1991	2821	371	0.0001
	1992	2508	364	
	1993	956	365	
	1994	1746	343	
	1995	1060	315	
McNary	1991	4701	356	0.0001
	1992	17024	350	
	1993	13197	339	
	1994	10492	345	
	1995	17787	334	
Ice Harbor	1991	890	360	0.0001
	1992	4565	362	
	1993	45	350	
	1994	19	304	
	1995	53	311	
Lower Monumental	1991	3642	319	0.0001
	1992	2897	309	
	1993	1584	313	
	1994	406	313	
	1995	151	349	
Little Goose	1991	1902	337	0.0001
	1992	4748	330	
	1993	1147	337	
	1994	836	345	
	1995	476	313	
Lower Granite	1991	19122	348	0.0016
	1992	19464	350	
	1993	915	360	
	1994	6893	349	
	1995	536	344	
Combined Total	1991	59650	350	0.0001
	1992	119437	346	
	1993	68797	335	
	1994	68793	335	
	1995	65990	324	

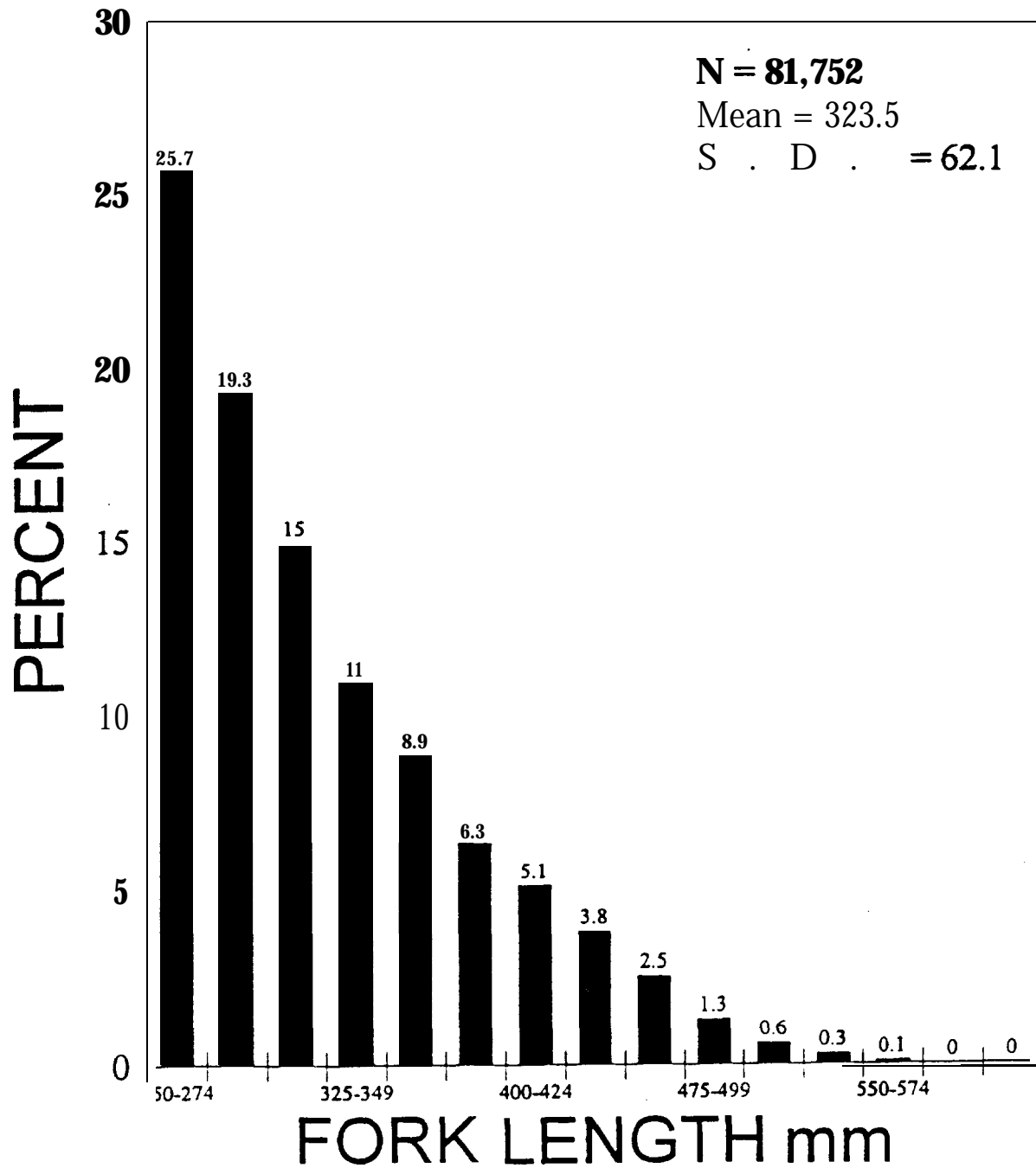


Figure 6. Length frequency distribution of northern squaw-fish ≥ 11 inches total length sampled in 1995.

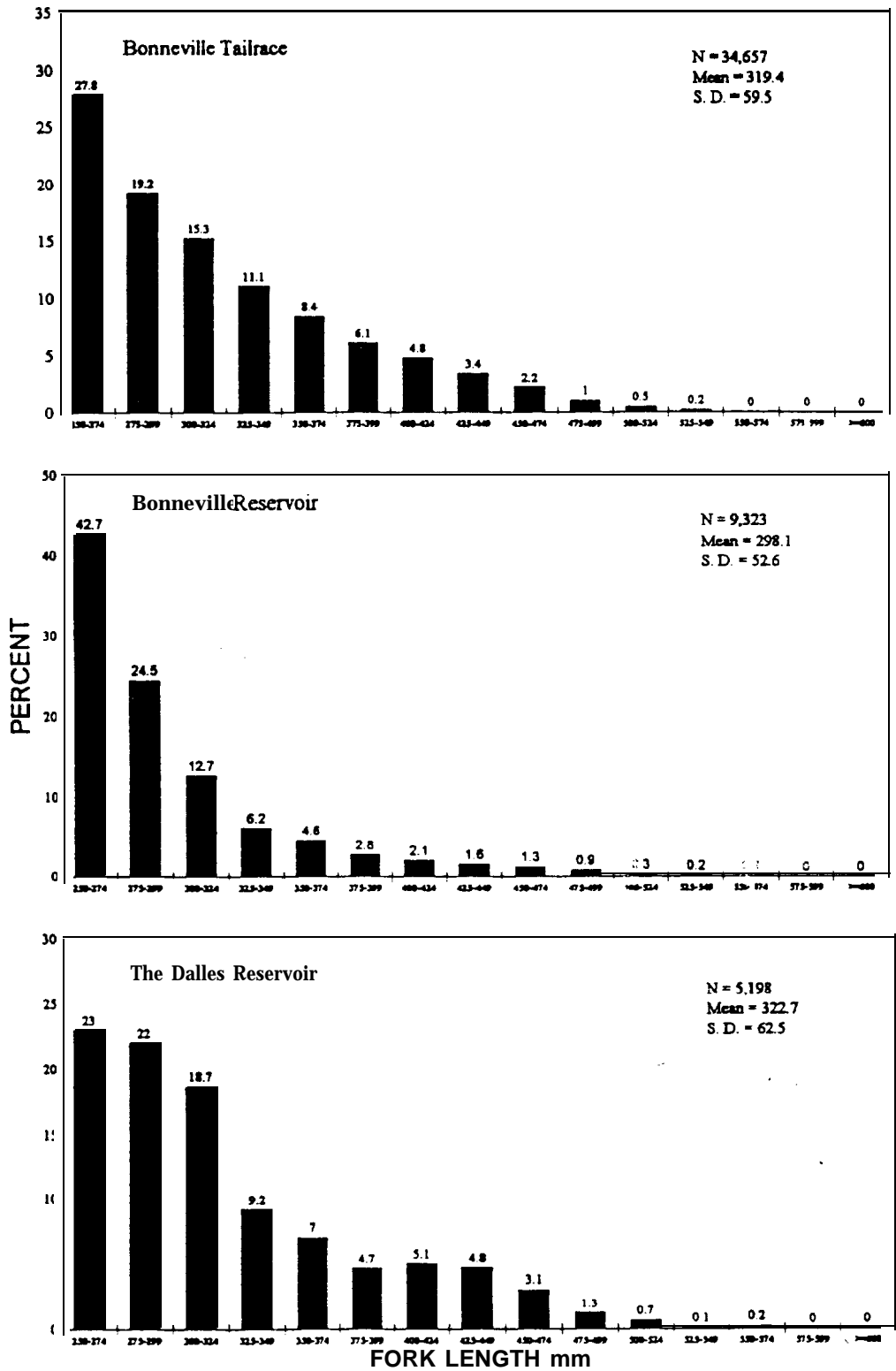


Figure 7a. Length frequency of northern squawfish ≥ 11 inches total length by reservoir in 1995.

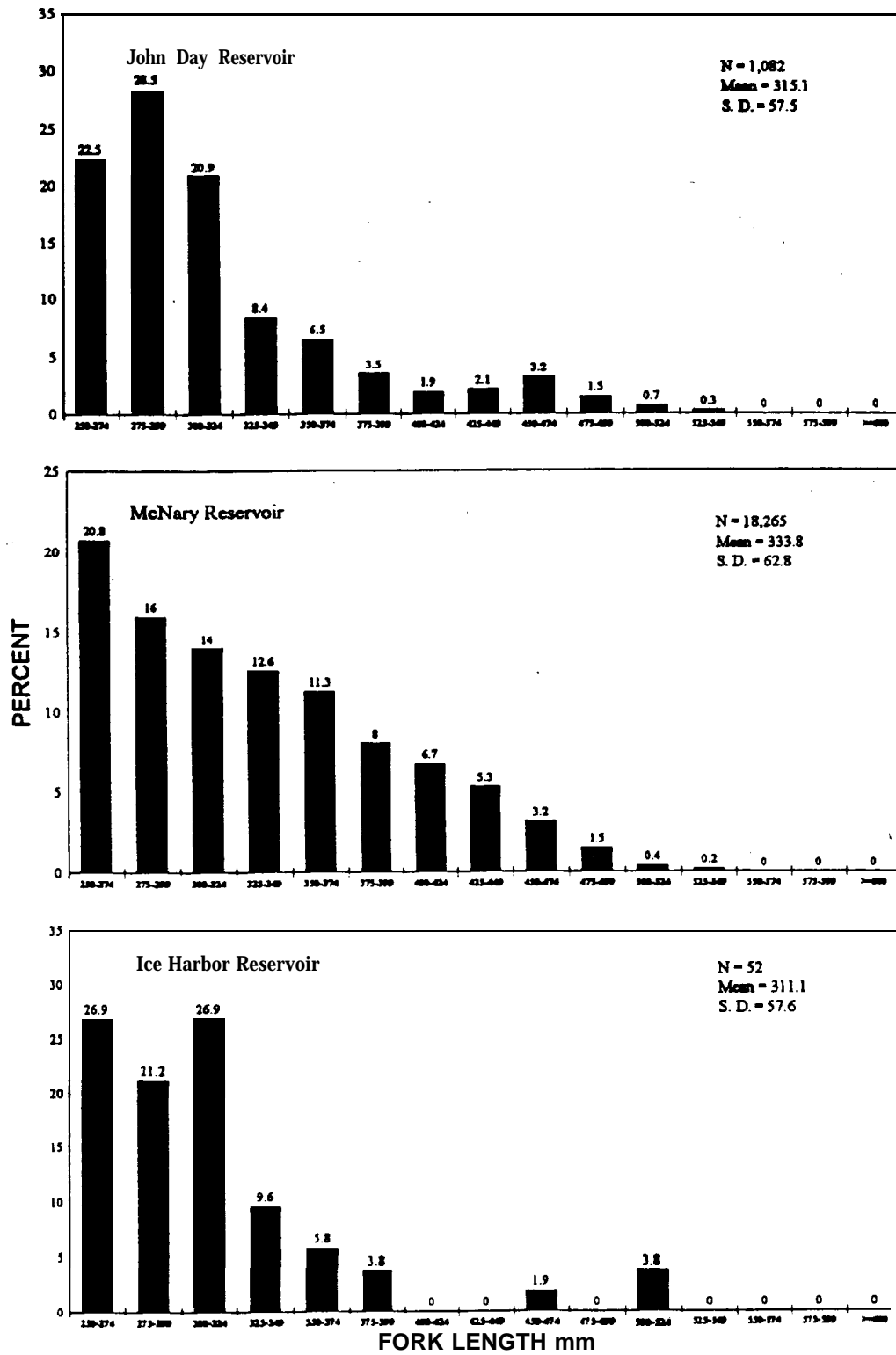


Figure 7b. Length frequency of northern squawfish ≥ 11 inches total length by reservoir in 1995.

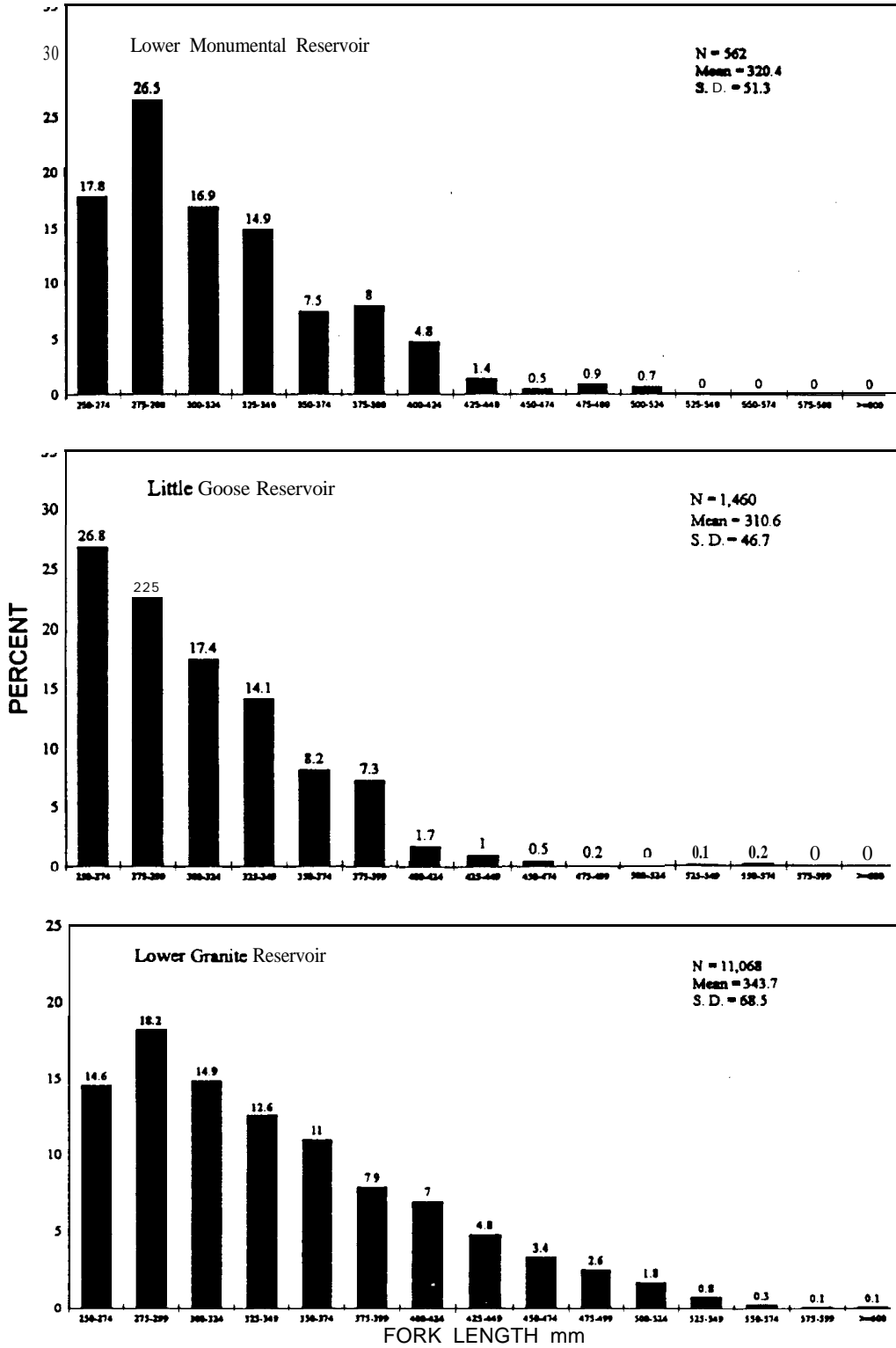


Figure 7c. Length frequency of northern squawfish ≥ 11 inches total length by reservoir in 1995.

Registration and Exit Times

In 1995, anglers registered most frequently between 6 a.m. and 7 a.m. (4,719 anglers) and between 9 p.m. and 10 p.m. (6,718 anglers; Figure 8). Registrations for these two time intervals represent nearly 26% of total registrations during the 24 hours of the day. However, registrations for the morning hours between 6 a.m. and 12 noon (18,868 anglers) represented 42.7% of all registrations while anglers registering in the hours of 12 noon to 6 p.m. (11,949) and 6 p.m. to 12 midnight (9,364) represented 27.1% and 21.2%, respectively, of all registrations. This is a clear indication of preference for the morning hours for registration.

The times for anglers to return to the registration stations with their catch was restricted by the operating hours of the stations to primarily between 1 p.m. and 9 p.m. The most popular time for turning in catches was 8 p.m. to 9 p.m. with 27.5% of all northern squawfish turned in during this time (Figure 8). The second most popular time period was between 1 p.m. and 2 p.m. with 14.2% of all northern squawfish turned in during this time interval. Forty nine percent of all the northern squawfish were turned in between 6 p.m. and 9 p.m. This information suggests that the current operations scheme for the registration stations is probably the best compromise. This scheme appears to meet the needs of sport-reward fishery anglers while containing operating costs to reasonable levels.

Returning and Non-Returning Angler Data

Returning anglers targeted northern squawfish more frequently than did non-returning anglers. Ninety-four percent of returning anglers and 75% of non-returning anglers specifically targeted northern squawfish sometime during their fishing day. While targeting squawfish, 97% of returning anglers and 51% of non-returning anglers caught at least one northern squawfish or other fish species during their fishing day (Table 5).

Catch and harvest estimates for returning anglers were shown to be accurate. Returning angler harvest estimates of northern squawfish ≥ 11 inches (199,556) were within 1% of the actual harvest (199,788), which shows our sampling methodology to be good. Catch and harvest estimates for northern squawfish ≥ 11 inches may be more accurate than other catch and harvest estimates since northern squawfish ≥ 11 inches were returned to the registration stations for a reward. The catch of fishes other than northern squawfish ≥ 11 inches was recorded from angler recollection. The variability in angler recollection of their catch was not considered significant since Klaybor et al. (1995) showed angler recognition does not significantly affect the catch estimate.

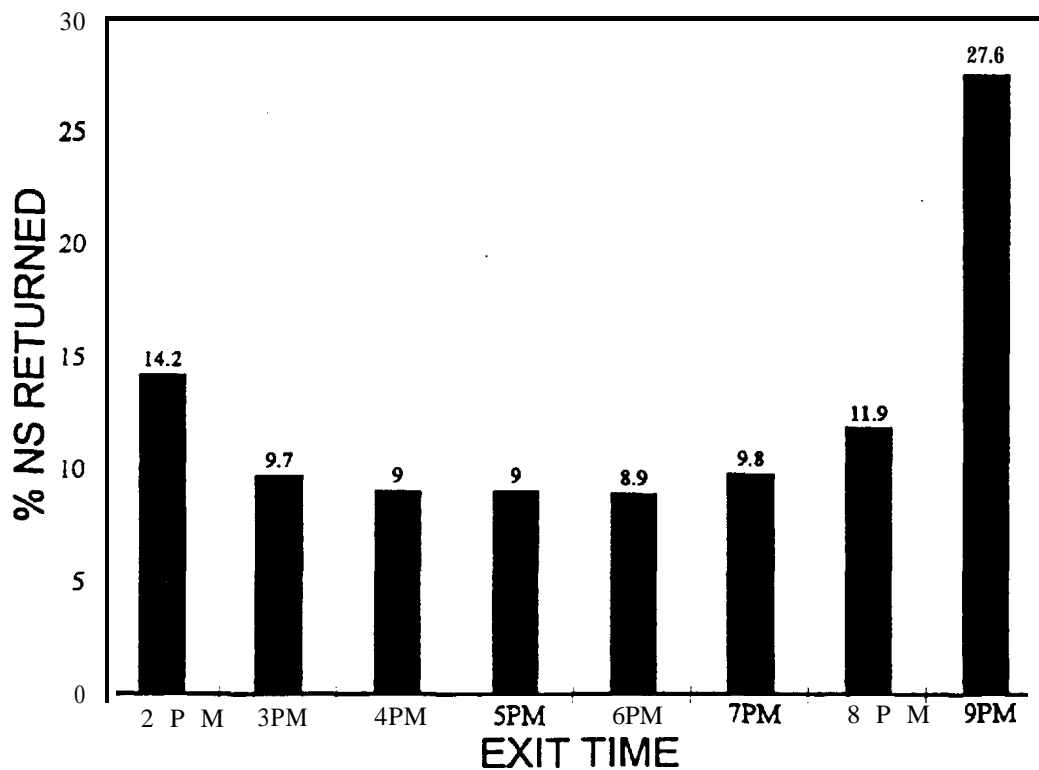
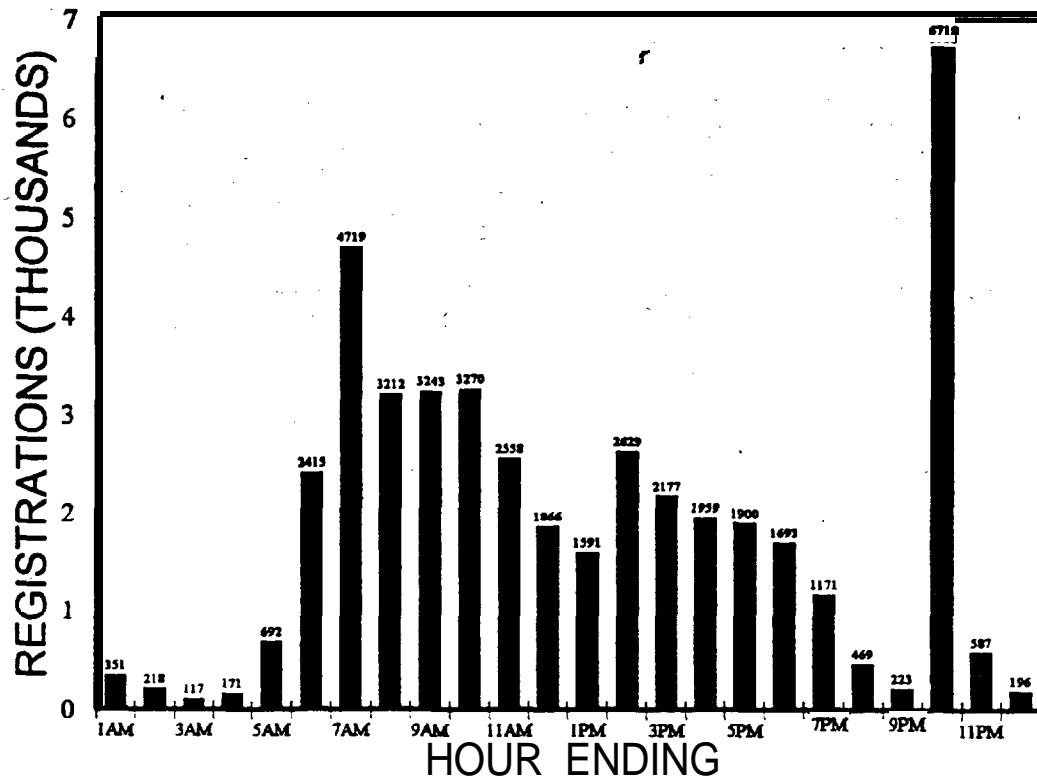


Figure 8. Registration and exit times for northern squawfish sport-reward anglers in 1995.

Table 5. Questionnaire responses from returning and non-returning anglers
(Responses to Q3 are summarized in Table 6.)

		RETURNING ANGLERS	NON-RETURNING ANGLERS
Q1.	NO	6.42%	24.54%
	YES	93.58%	75.46%
Q2.	NO	2.65%	48.67%
	YES	97.35%	51.33%
Q4.	A	17.88%	29.89%
	B	0.93%	2.76%
	C	0.86%	1.12%
	D	55.47%	42.13%
	E	7.06%	8.39%
	F	17.80%	15.11%
Q5.	NO	63.92%	35.80%
	YES	36.08%	64.20%
Q6.	NO	58.02%	63.91%
	YES	41.98%	36.09%
Q7A.	1	23.02%	21.55%
	2	64.04%	29.08%
	3	0.37%	0.23%
	4	12.56%	49.14%
Q7B.	1	77.05%	51.49%
	2	20.04%	39.14%
	3	0.07%	0.06%
	4	2.84%	9.31%
Q7C.	1	75.37%	44.02%
	2	20.95%	37.24%
	3	0.06%	0.06%
	4	3.62%	18.68%
Q7D.	1	74.27%	40.40%
	2	20.81%	31.72%
	3	0.12%	0.00%
	4	4.80%	21.87%
Q7E.	1	68.86%	23.30%
	2	24.04%	27.60%
	3	0.11%	0.07%
	4	7.00%	49.04%
Q7F.	1	71.54%	36.95%
	2	21.79%	29.77%
	3	0.15%	0.00%
	4	6.52%	33.28%
Q8.	NO	2.94%	1.67%
	YES	97.06%	98.33%
Q9.	A	-----	70.00%
	B	-----	21.26%
	C	-----	0.98%
	D	-----	7.76%

Non-returning anglers were not successful at catching northern squawfish ≥ 11 inches. Klaybor et al. (1995) found that most non-returning anglers did not catch enough northern squawfish to make it worthwhile to return to the registration station for a payment voucher. Non-returning anglers caught an estimated 2,411 northern squawfish ≥ 11 inches (Table 6) with harvest estimated at 1,591 fish.

The estimated harvest of northern squawfish < 11 inches by returning anglers was 15,713. Approximately 65% (10,237) of the northern squawfish < 11 inches harvested were returned to the registration stations by returning anglers. Non-returning anglers caught an estimated 21,220 northern squawfish < 11 inches (Table 6) with harvest estimated at 11,282 fish.

Returning anglers caught more fish than did non-returning anglers. Returning anglers caught an estimated 31% more of the five incidental species we evaluated than did non-returning anglers. Returning anglers incidentally caught an estimated 14,217 peamouth, 13,364 smallmouth bass, 4,945 white sturgeon, 1,948 walleye and 1,762 channel catfish. Non-returning anglers incidentally caught an estimated 12,837 peamouth, 9,276 smallmouth bass, 4,002 sturgeon, 1,101 channel cattish and 514 walleye (Table 6). When northern squawfish are included in their catch, returning anglers caught an estimated 11.9 fish/angler day while non-returning anglers caught an estimated 2.4 fish/angler day. The estimated harvest rate of the top five incidentally caught species for returning anglers (24%) was 7% higher than non-returning anglers (17%), but both harvest rates were low. While targeting squawfish, returning and non-returning anglers harvested more walleye (56% and 45% respectively) than any other species except northern squawfish. Harvest data was provided to ODFW for evaluation.

Salmonid catches for returning anglers targeting northern squawfish were low when compared to the number of northern squawfish caught. An estimated .0007 salmonids were caught by returning anglers for every northern squawfish caught and .006 salmonids were caught for every angler day. Returning anglers caught an estimated 64 adult steelhead (*Oncorhynchus mykiss*), 20 adult chinook salmon (*Oncorhynchus tshawytscha*), 11 juvenile steelhead and 13 juvenile chinook salmon from the Columbia River while targeting northern squawfish (Table 7). An estimated 16 adult steelhead were caught in the Snake River by returning anglers targeting northern squawfish (Table 7). Returning anglers released an estimated 69% of all salmonids caught while targeting squawfish.

Table 6. Estimates of selected species caught by returning and non-returning anglers while targeting NS, along with 95% confidence intervals and percent of catch harvested.

RETURNING ANGLERS

SPECIES	SAMPLE CATCH	ESTIMATED CATCH	CONFIDENCE INTERVAL (95%)	PERCENT HARVESTED
NORTHERN SQUAWFISH > 11"	98659	199556	3885	99.80%
NORTHERN SQUAWFISH < 11"	19139	38712	1384	40.59%
PEAMOUTH	7029	14217	846	28.75%
SMALLMOUTH BASS	6607	13364	697	21.67%
WHITE STURGEON	2445	4945	401	1.55%
WALLEYE	963	1948	168	56.39%
CHANNEL CATFISH	871	1762	184	35.02%

Returning anglers = 23091
 Sampled anglers = 11416

NON-RETURNING ANGLERS

SPECIES	SAMPLE CATCH	ESTIMATED CATCH	CONFIDENCE INTERVAL (95%)	PERCENT HARVESTED
NORTHERN SQUAWFISH > 11"	197	2411	338	65.99%
NORTHERN SQUAWFISH < 11"	1734	21220	1732	53.17%
PEAMOUTH	1049	12837	991	19.64%
SMALLMOUTH BASS	758	9276	606	15.70%
WHITE STURGEON	327	4002	324	1.53%
WALLEYE	42	514	87	45.24%
CHANNEL CATFISH	90	1101	137	44.44%

Non-returning anglers = 21293
 Sampled anglers = 1740

Table 7 . Returning and non-returning angler catch and release estimates along with catch and effort ratios for NSF >= 11 inches and selected salmonids in the Columbia and Snake rivers.

Returning Anglers

Species	Columbia River				Snake River				Combined Ratios		
	Salmonids Caught	Salmonids Released	Salmonid/ Nsf Ratio	Salmonid/Effort Ratio	Salmonids Caught	Salmonids Released	Salmonid/ Nsf Ratio	Salmonid/Effort Ratio	Total Salmonid Catch	Salmonid/ Nsf Ratio	Salmonid/Effort Ratio
Adult Steelhead	64	42	0.00042	0.00350	16	15	0.00096	0.00639	80	0.00047	0.00384
Juvenile Steelhead	11	9	0.00007	0.00060	0	0	0.00000	0.00000	11	0.00006	0.00053
Adult Chinook	20	15	0.00013	0.00109	0	0	0.00000	0.00000	20	0.00012	0.00096
Juvenile Chinook	13	4	0.00008	0.00071	0	0	0.00000	0.00000	13	0.00008	0.00062
Adult Sockeye	0	0	0.00000	0.00000	0	0	0.00000	0.00000	0	0.00000	0.00000
Juvenile Sockeye	0	0	0.00000	0.00000	0	0	0.00000	0.00000	0	0.00000	0.00000
"NSF			153693		16709						
**Angler Effort			18306		2504						

Non-Returning Anglers

Species	Columbia River				Snake River				Combined Ratios		
	Salmonids Caught	Salmonids Released	Salmonid/ Nsf Ratio	Salmonid/Effort Ratio	Salmonids Caught	Salmonids Released	Salmonid/ Nsf Ratio	Salmonid/Effort Ratio	Total Salmonid Catch	Salmonid/ Nsf Ratio	Salmonid/Effort Ratio
Adult Steelhead	37	24	0.02100	0.00214	0	0	0.00000	0.00000	37	0.01535	0.00174
Juvenile Steelhead	37	24	0.02100	0.00214	0	0	0.00000	0.00000	37	0.01535	0.00174
Adult Chinook	0	0	0.00000	0.00000	0	0	0.00000	0.00000	0	0.00000	0.00000
Juvenile Chinook	220	208	0.12486	0.01275	73	73	0.11248	0.01808	293	0.12153	0.01376
Adult Sockeye	0	0	0.00000	0.00000	0	0	0.00000	0.00000	0	0.00000	0.00000
Juvenile Sockeye	0	0	0.00000	0.00000	0	0	0.00000	0.00000	0	0.00000	0.00000
"NSF			1762		649						
er Effort			17255		4038						

Incidental catch of juvenile chinook salmon by non-returning anglers in the Columbia and Snake rivers was much higher than any other incidental salmonid catch by either returning or non-returning anglers. Non-returning anglers caught an estimated 37 adult steelhead, 37 juvenile steelhead and 220 juvenile chinook salmon from the Columbia River and 73 juvenile chinook salmon from the Snake River while targeting northern squawfish (Table 7). We estimated .1522 salmonids were caught by non-returning anglers for every northern squawfish caught and .0017 salmonids were caught for every non-returning angler day. Our surveys showed most adult and juvenile salmonids caught by returning and non-returning anglers were caught from the mouth of the Columbia River to Bonneville Dam due to higher angler effort and a greater concentration of adult and juvenile salmonids. Non-returning anglers released an estimated 90% of all salmonids caught while targeting northern squawfish. Incidental salmonid catch estimates in future years should show if more juvenile chinook salmon are consistently caught by non-returning anglers than returning anglers. Non-returning angler catch data was not included in our weekly catch reports in 1995. However, estimates will be included in the 1996 weekly reports by using the 1995 salmonid/effort ratio.

The 1996 northern squawfish sport-reward fishery exceeded the allowable catch of juvenile and adult salmonids in both the Columbia and Snake rivers when returning and non-returning angler catch estimates were combined. Currently, 100% mortality is assumed for all incidentally caught juvenile and adult salmonids in the northern squawfish sport-reward fishery as established in the 1995 biological opinion prepared by the National Marine Fisheries Service (NMFS). We believe 30% mortality will more accurately report the actual mortality of adult and juvenile salmonids associated with the operation of the sport-reward fishery. Using 30% mortality, the 1995 sport-reward fishery would not have exceeded the allowable incidental salmonid catch as established by NMFS.

Word-of-mouth advertising was the most successful form of advertising for returning (55%) and non-returning (42%) anglers (Table 5; see Appendix C for discussion).

Returning anglers were more motivated to fish because of the sport-reward fishery. Non-returning anglers appeared to just want to go fishing and the squawfish sport-reward fishery provided an additional opportunity. Thirty-six percent of returning anglers and 64% of non-returning anglers would have taken a fishing trip if the sport-reward fishery did not exist (Table 5). Our data shows most incidental fishes caught by non-returning anglers would have been caught even if the sport-reward fishery did not exist.

Operation of satellite stations provided anglers with an opportunity to participate in the sport-reward fishery when they normally would not. Fifty-eight percent of returning anglers and 64% of non-returning anglers using satellite stations would not have registered with the sport-reward fishery that day if the satellite station did not

exist (Table 5). Returning anglers (64%) reported that satellite stations did not change their overall participation while non-returning anglers (49%) reported they were not aware of the stations (Table 5; see Appendix C for discussion)

Returning (72-77%) and non-returning anglers (37-51%) reported that higher rewards, \$50 tagged northern squawfish, weekly tournaments, and random drawings increased their participation in the 1995 sport-reward fishery (Table 5). Most returning anglers (69%) reported the BPA tournament increased their participation while 49% of non-returning anglers were not aware of the tournament.

Anglers were pleased with the management of the sport-reward fishery and their interactions with the technicians. Ninety-seven percent of returning anglers and 98% of non-returning anglers reported they were satisfied with the overall management of the 1995 sport-reward fishery. Ninety-one percent of non-returning anglers surveyed said their interaction with sport-reward fishery technicians was either very good or good. Only 1% of non-returning anglers said their interaction with technicians was poor (Table 5).

Recommendations for the 1996 Sport-Reward Fishery

- A. Operate 12 registration stations and nine satellite stations on the Columbia and Snake rivers (Table 8).
- B. Operate Kalama Marina as a satellite of the Cathlamet Registration Station to improve cost effectiveness.
- C. Field operations should remain limited to one shift per day (1 p.m. to 9 p.m.) seven days per week. Self-registration should continue to be available during non-staffed hours.
- D. Registration stations should be located in areas that will achieve and maintain targeted systemwide exploitation rates while maintaining cost effectiveness.
- E. Continue the present streamlined phone survey to monitor the catch and harvest of non-returning anglers, and their level of satisfaction with the sport-reward fishery.

Table 8. Proposed registration stations and satellite sites for the 1996 sport-reward fishery with the approximate time of operation for each satellite and the parent registration station that will operate each satellite site.

Registration station	Satellite site	Time
1. CATHLAMET	Kalama Rainier Marina	9:30 - 11:30 a.m. 7:00 - 9:00 a.m.
2. GLEASON	Chinook Landing	7:00-9:00a.m.
3. WASHOUGAL		
4. THE FISHERY	Cascade Locks	5:30-7:30p.m
5. HAMILTON ISLAND	Beacon Rock	7:30-8:30a.m.
6. BINGEN	Hood River	(registration only).
7. THE DALLES		
8. GILES FRENCH	Maryhill Park	9:30-10:30a.m.
9. COLUMBIA POINT	Ringold	9:00-11:00a.m.
10. VERNITA		
11. HOOD PARK		
12. GREENBELT	Boyer Park	9:00-11:00 a.m

REFERENCES

- Beamesderfer, R.C., and B.E. Rieman. 1991. Abundance and distribution of northern squawfish, and smallmouth bass in John Day reservoir, Columbia River. *Transactions of the American Fisheries Society* 120(4): 439-447.
- Burley, C.C., D.C. Klaybor, G.W. Short, and G.J. Hueckel. 1992. Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake rivers. Report B *in* C.F. Willis and A.A. Nigro, editors. 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. 1991 Annual Report. Contract DE-B 179-90-BP07084, Bonneville Power Administration, Portland, Oregon.
- Burley, C.C., G.J. Hueckel, D.C. Klaybor, P.E. DuCommun, S.S. Smith, W.J. Sooter, E.N. Mattson, and E.C. Winther. 1994. Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake rivers. Report B *in* C.F. Willis, D.L. Ward and A.A. Nigro, editors. Development of a systemwide program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1992 Annual Report, Volume 1. Contract DE-B 179-90BP07084, Bonneville Power Administration, Portland Oregon.
- Hanna, S., B. Anteneh, J. Pampush, M. Morrissey, D. Lin, and G. Foster. 1994. Economic, social, and legal feasibility of commercial, sport and bounty fisheries on northern squawfish. Report H *in* C.F. Willis, D.L. Ward, and A.A. Nigro, editors. Development of a systemwide program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1992 Annual Report, Volume 2. Contract DE-B 179-90BP07084, Bonneville Power Administration, Portland, Oregon.
- Klaybor, D.C., C.C. Burley, S.S. Smith, E.N. Mattson, E.C. Winther, P.E. DuCommun, H.R. Bartlett, and S.L. Kelsey. 1995. Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake rivers. Report B *in* C.F. Willis and D.L. Ward, editors. Development of a systemwide predator control program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1993 Annual Report, Volume 1. Contract DE-B 179-90BP07084, Bonneville Power Administration, Portland, Oregon.

Knutsen, C. J., D. L. Ward, T. A. Friesen, and M. P. Zimmerman. 1995.

Development of a system-wide predator control program: indexing and fisheries evaluation. Report F in C.F. Willis and F. Young. Development of a systemwide predator control program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1994 Annual Report, Section 2. Contract Number 94B 1245 14, Bonneville Power Administration, Portland, Oregon.

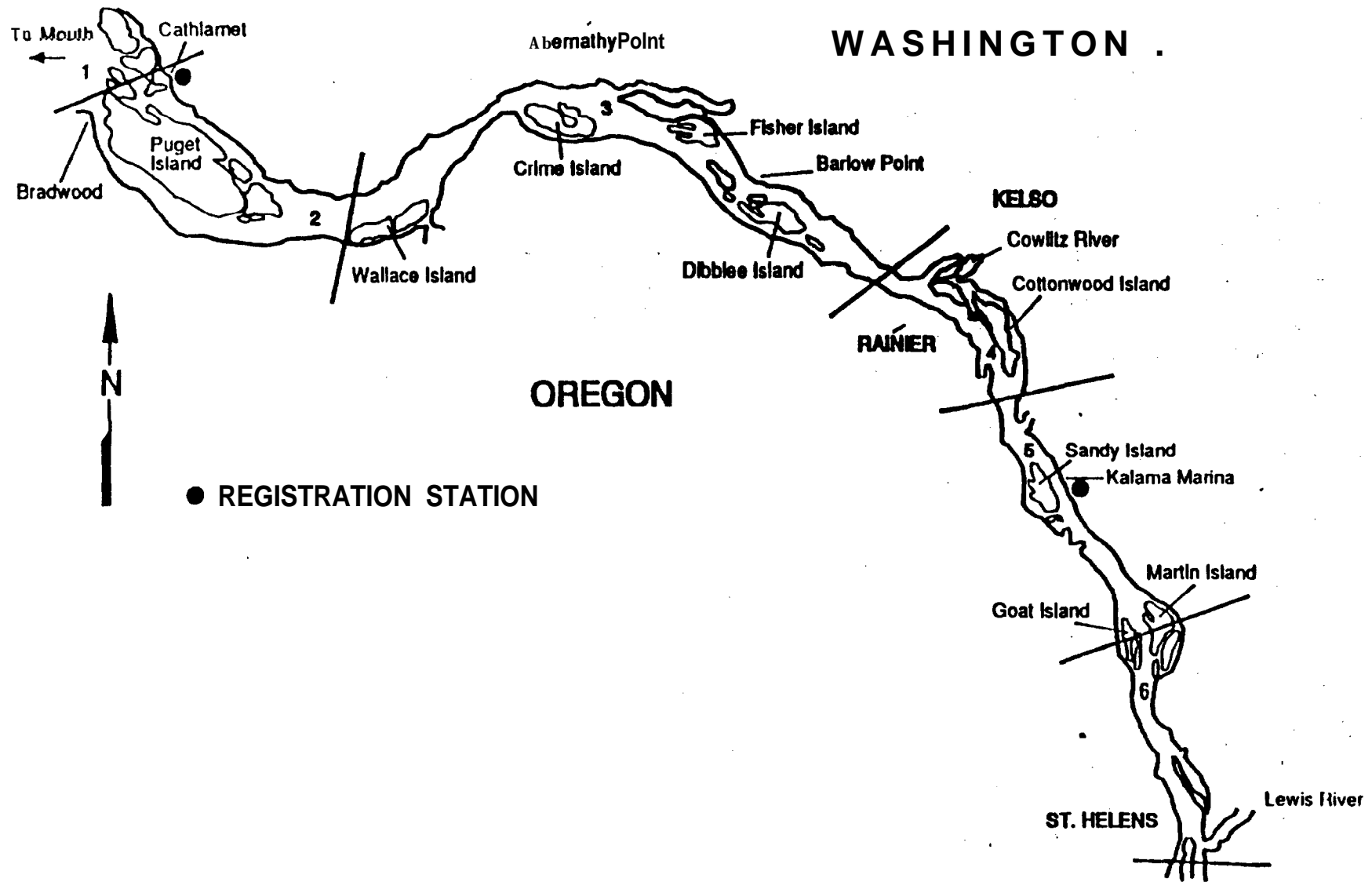
Rieman, B. E., and R. C. Beamesderfer. 1990. Dynamics of a northern squawfish population and the potential to reduce predation in juvenile salmonids in a Columbia River reservoir. *North American Journal of Fisheries Management*. 10:228-241.

Smith, S.S., D.R. Gilliland, E.C. Winther, M.R. Petersen, E.N. Mattson, S.L. Kelsey, J. Suarez-Pena, and J. Hisata. 1995. Development of a systemwide predator control program: Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake Rivers, Washington Department of Fish and Wildlife, Contract Number DE-BI79-90BP07084. 1994 Annual Report to Bonneville Power Administration, Portland, Oregon.

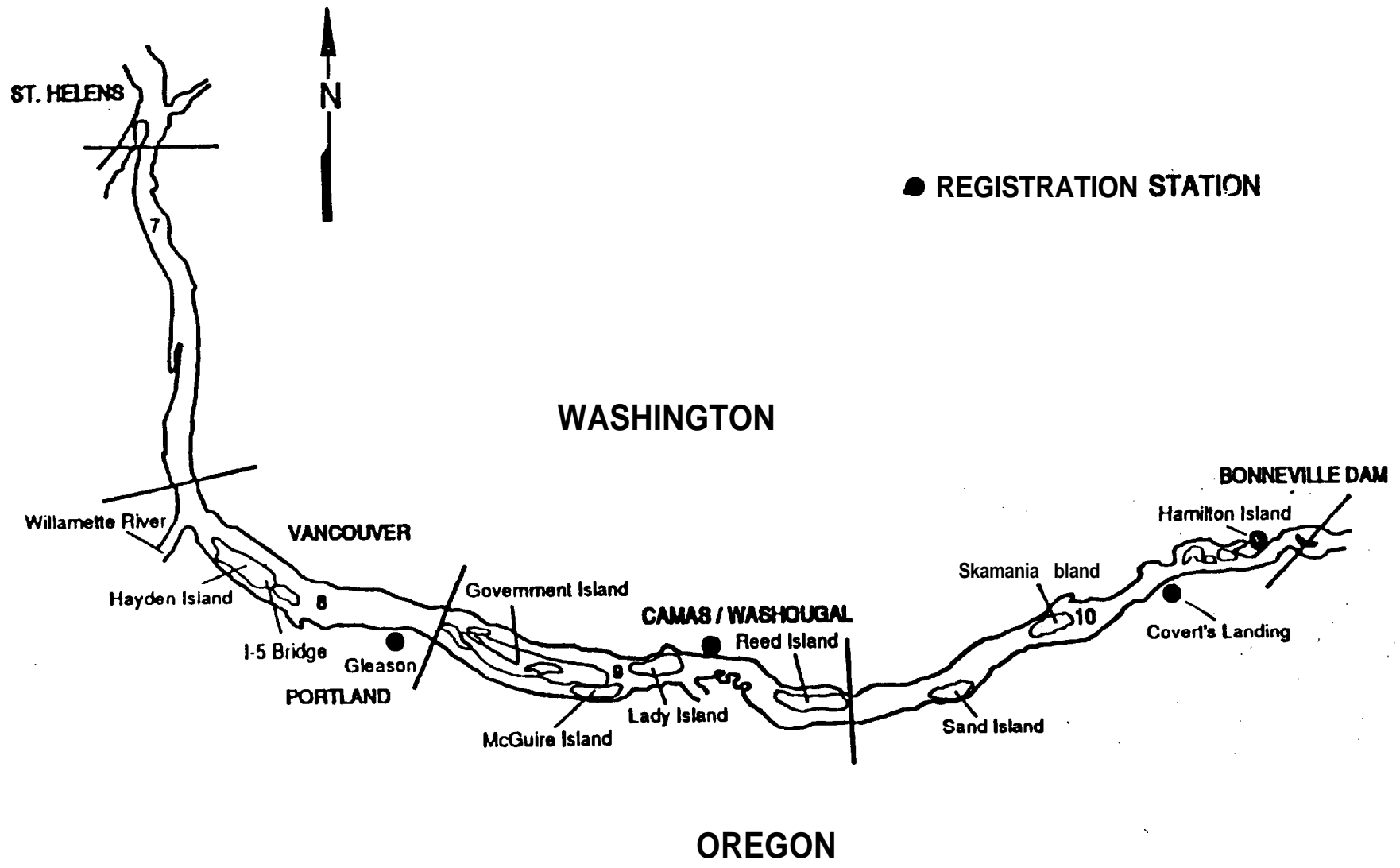
Zimmerman, M.P., C. Knutsen, D.L. Ward, and K. Anderson. 1995. Development of a system-wide predator control program: indexing and fisheries evaluation, Report H in C.F. Willis and D.L. Ward, editors. Development of a systemwide predator control program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1993 Annual Report, Volume 2. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon,

APPENDIX A

Maps with Fishing Location and Codes for the 1995 Sport-Reward Fishery

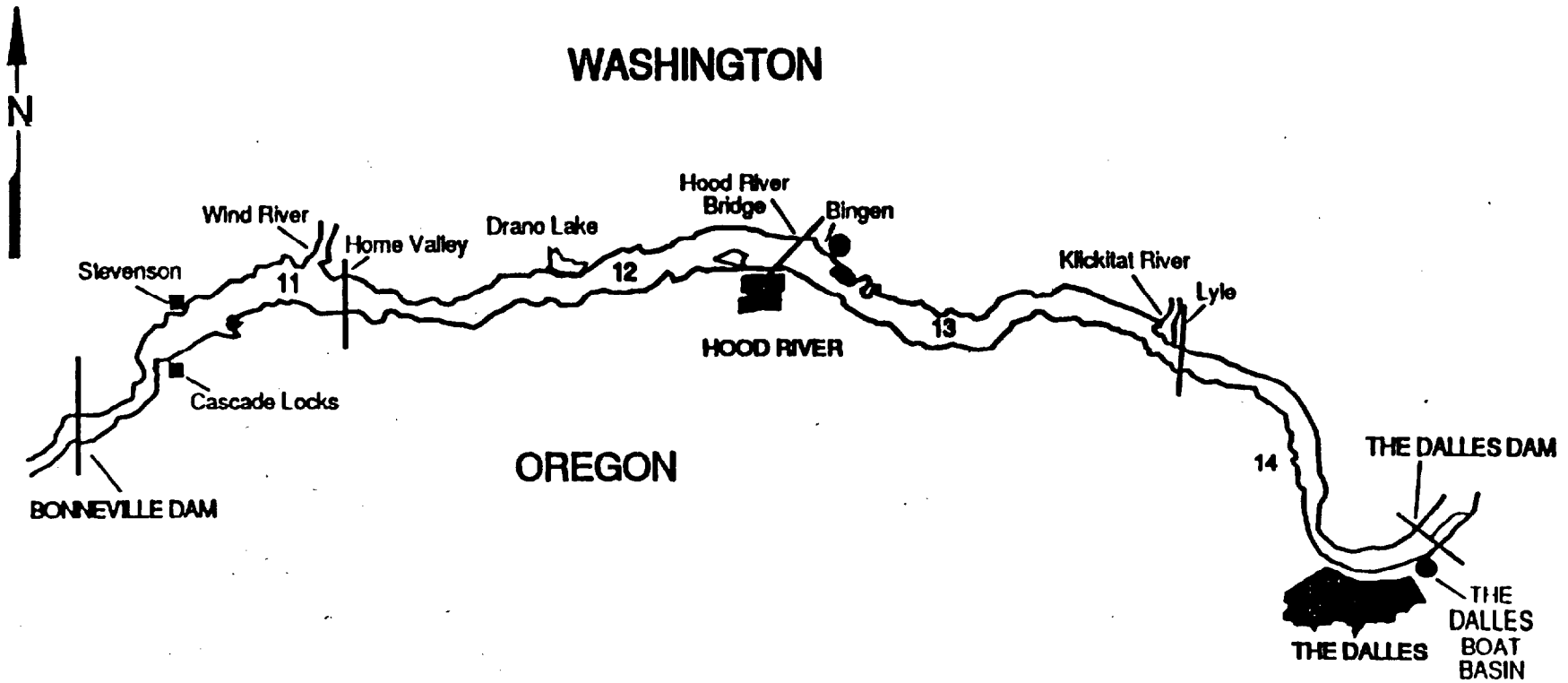


Appendix Figure A- I. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, mouth of the Columbia River to Lewis River.

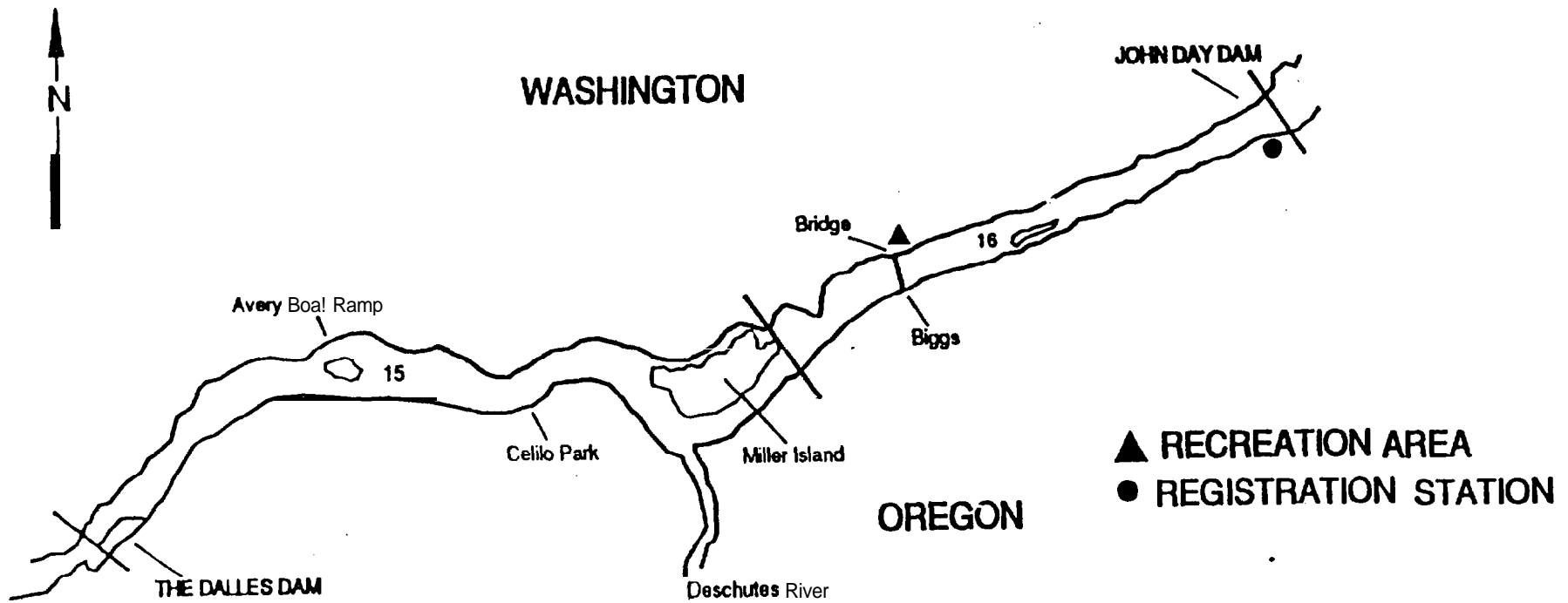


Appendix Figure A-2. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, Lewis River to Bonneville Dam.

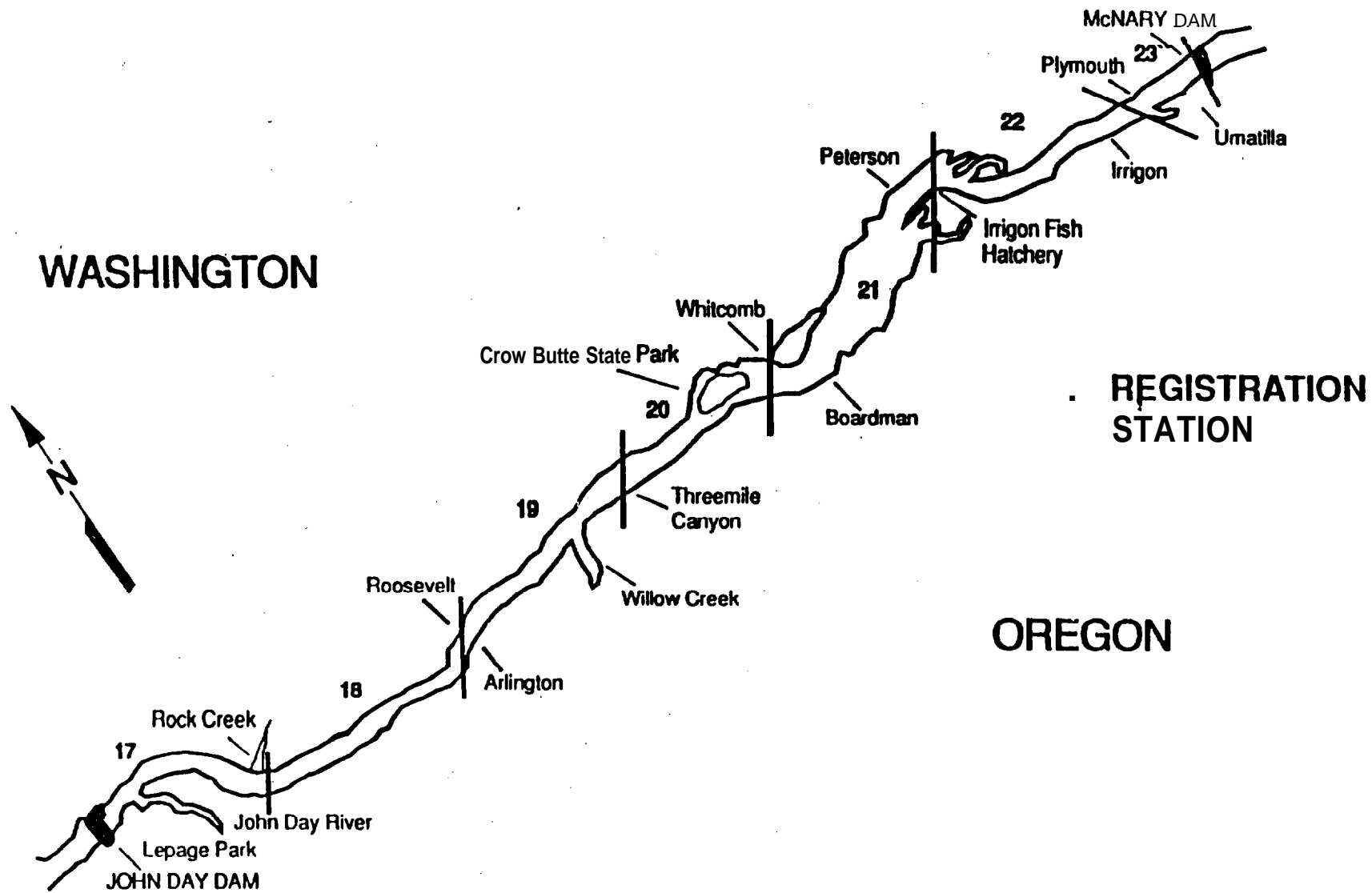
● REGISTRATION STATION



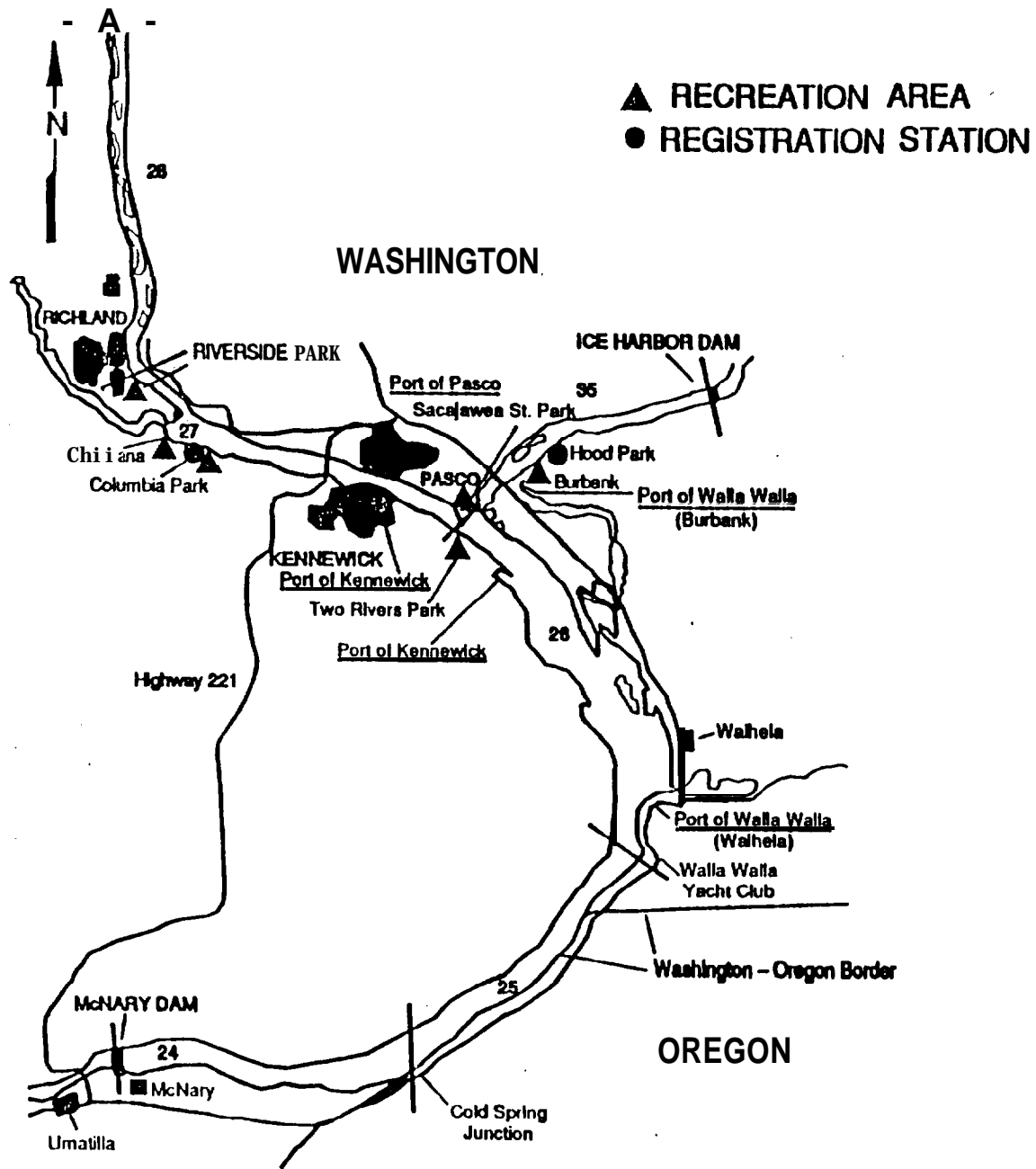
Appendix Figure A-3. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, Bonneville Dam to The Dalles Dam.



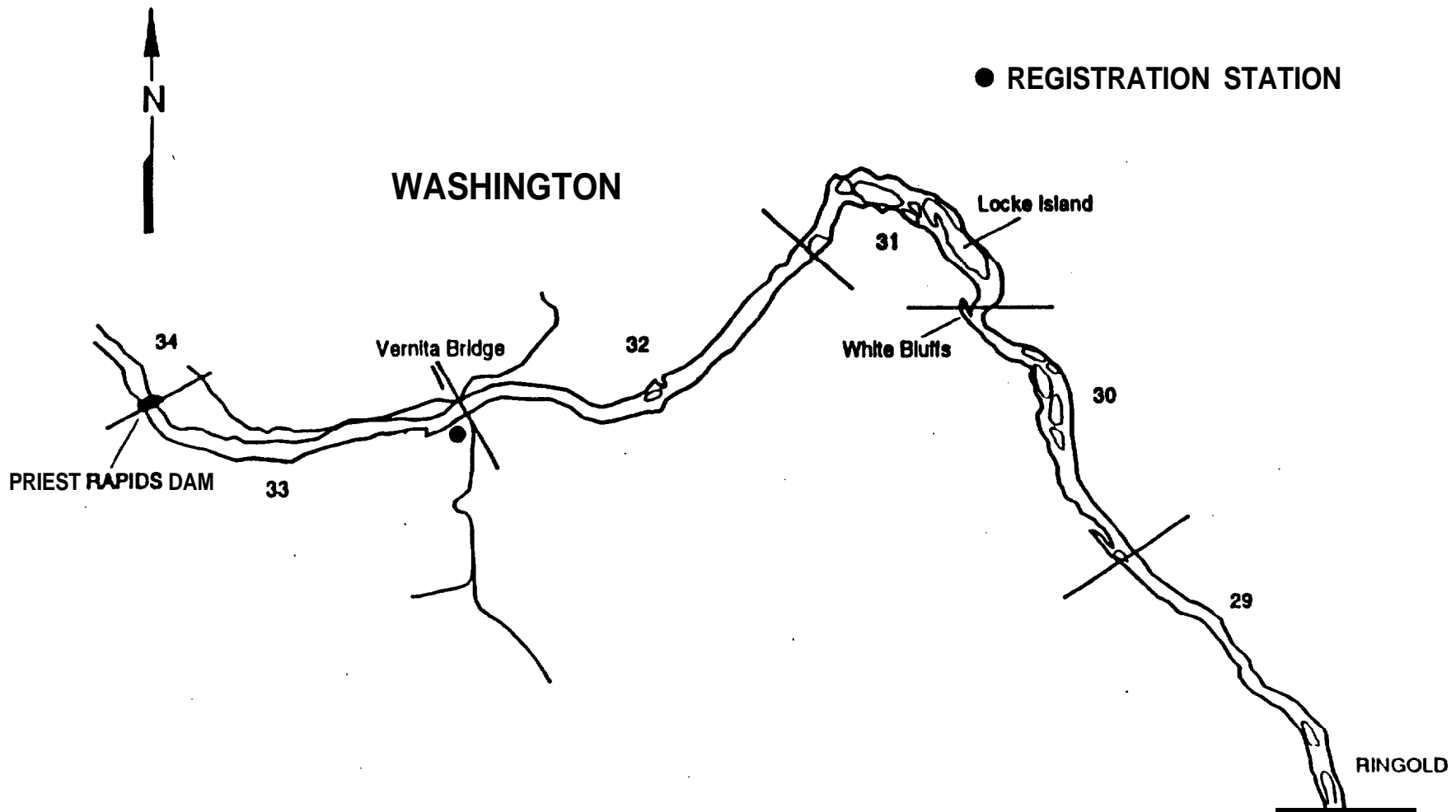
Appendix Figure A-4. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, The Dalles Dam to John Day Dam.



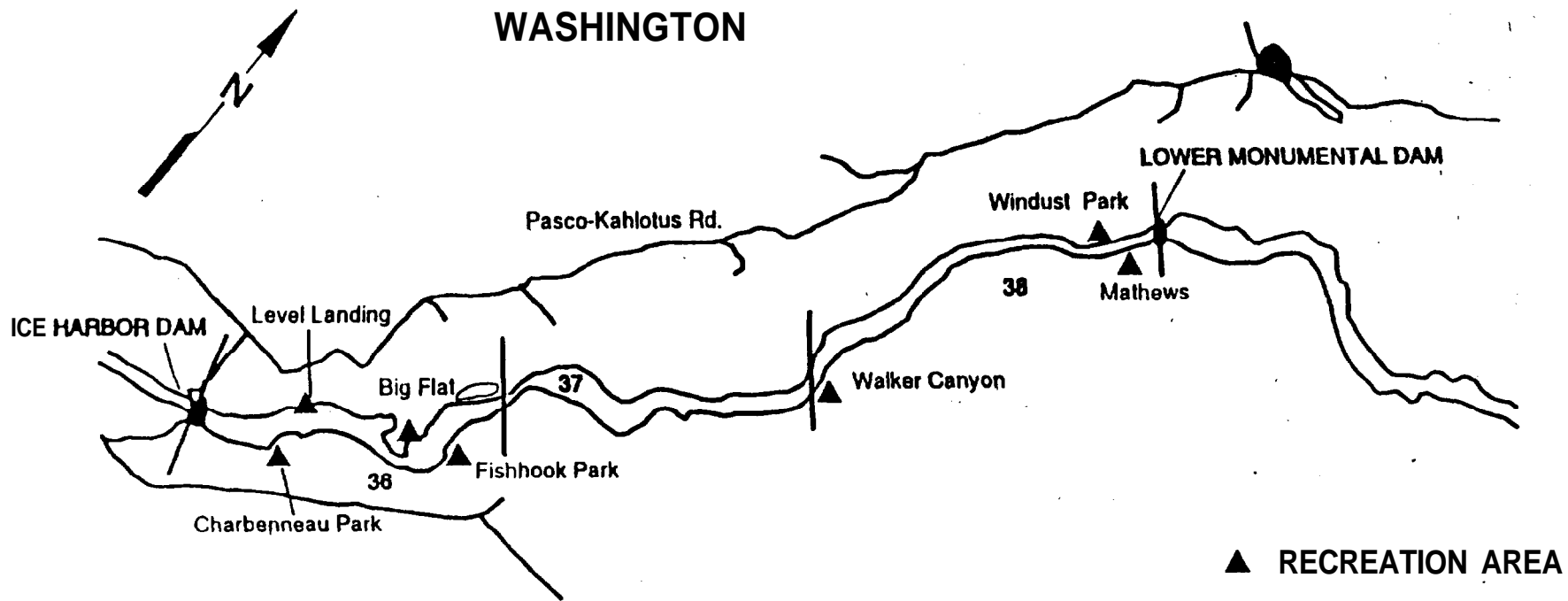
Appendix Figure A-5, 1995, Northern Squawfish Sport-Reward Fishery fishing location codes, John Day Dam to McNary Dam.



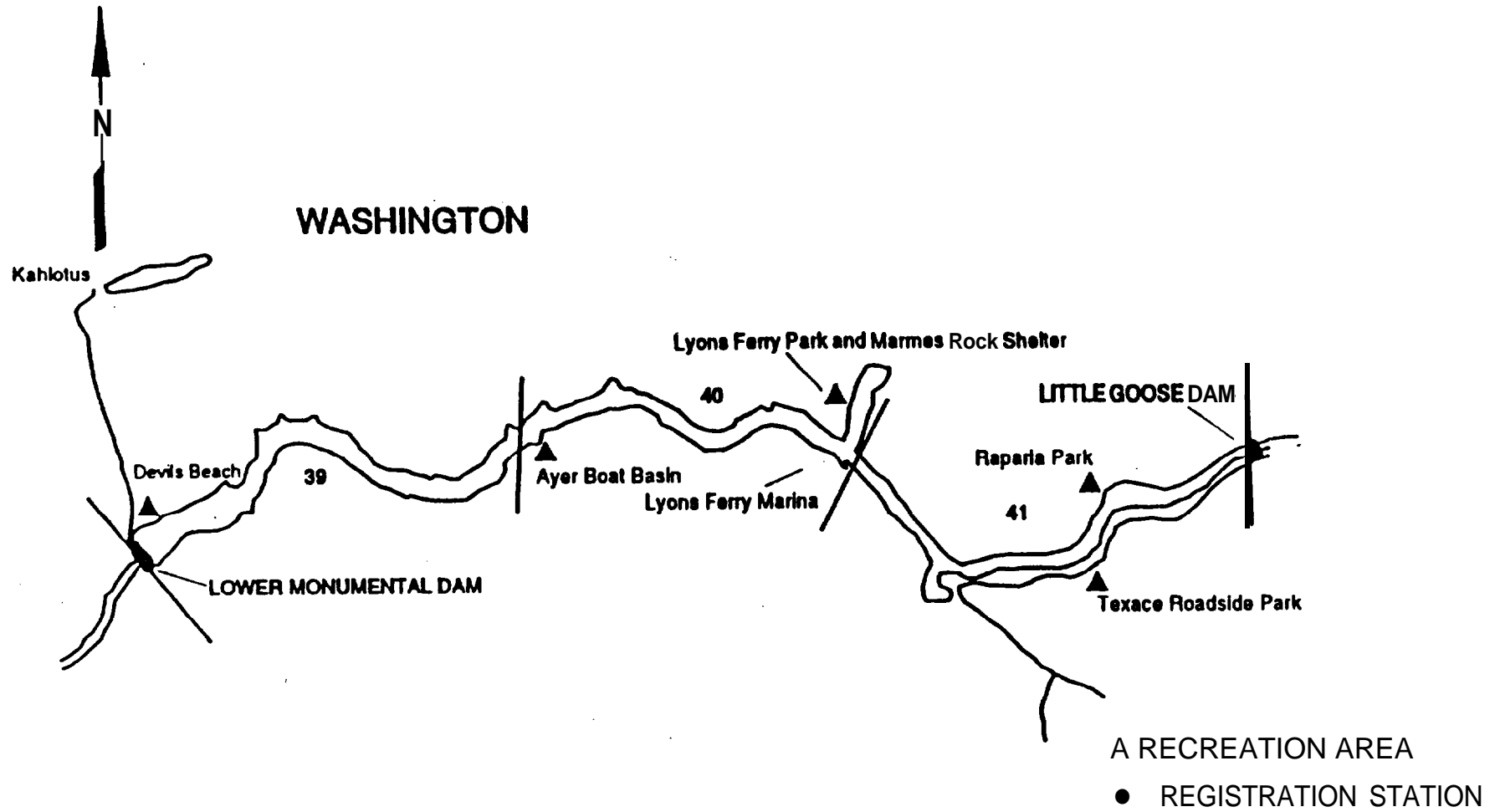
Appendix Figure A-6. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, McNary Dam to Ringold Boat Ram and mouth of Snake River to Ice Harbor Dam.



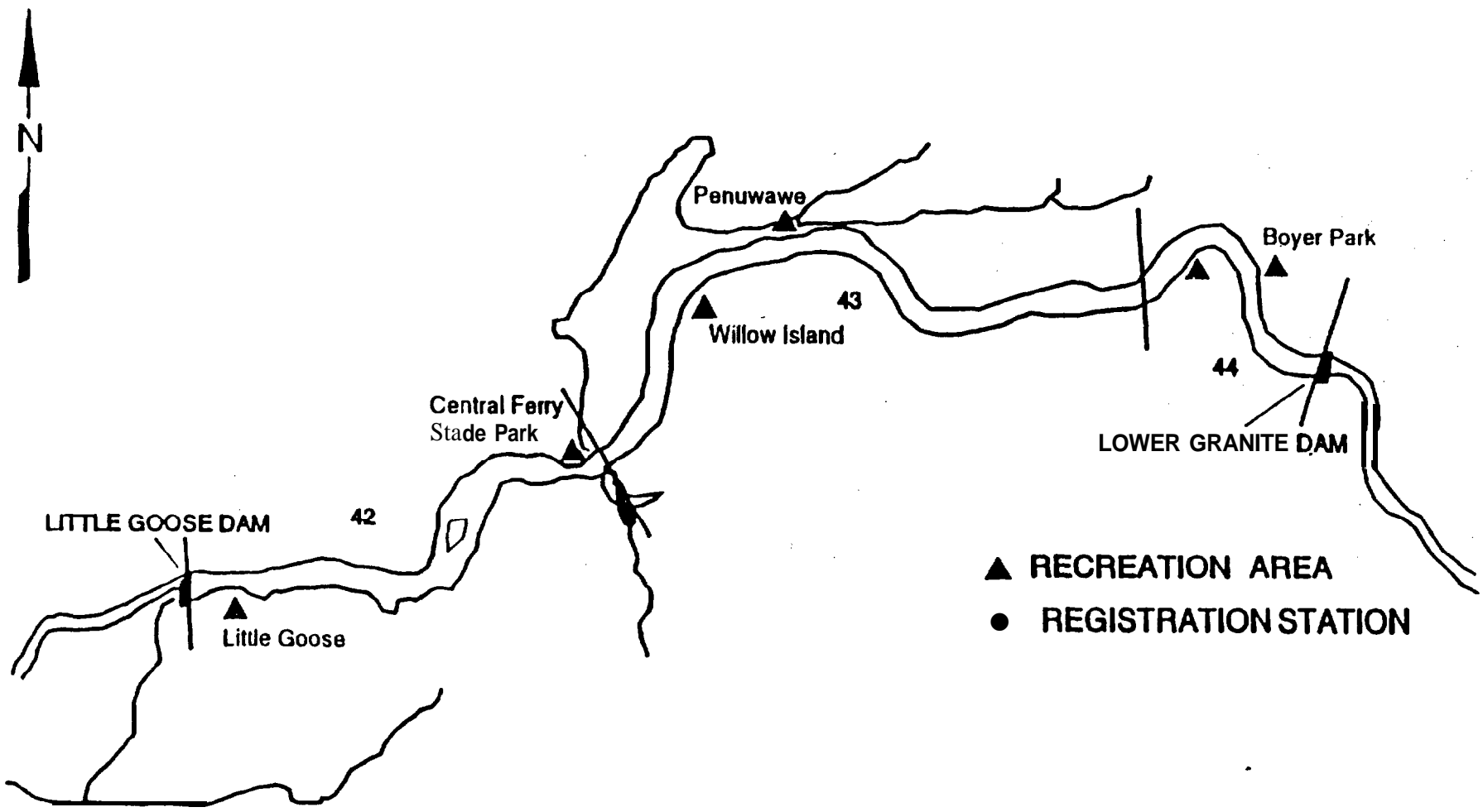
Appendix Figure A-7. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, Ringold Boat Ramp to Priest Rapids Dam.



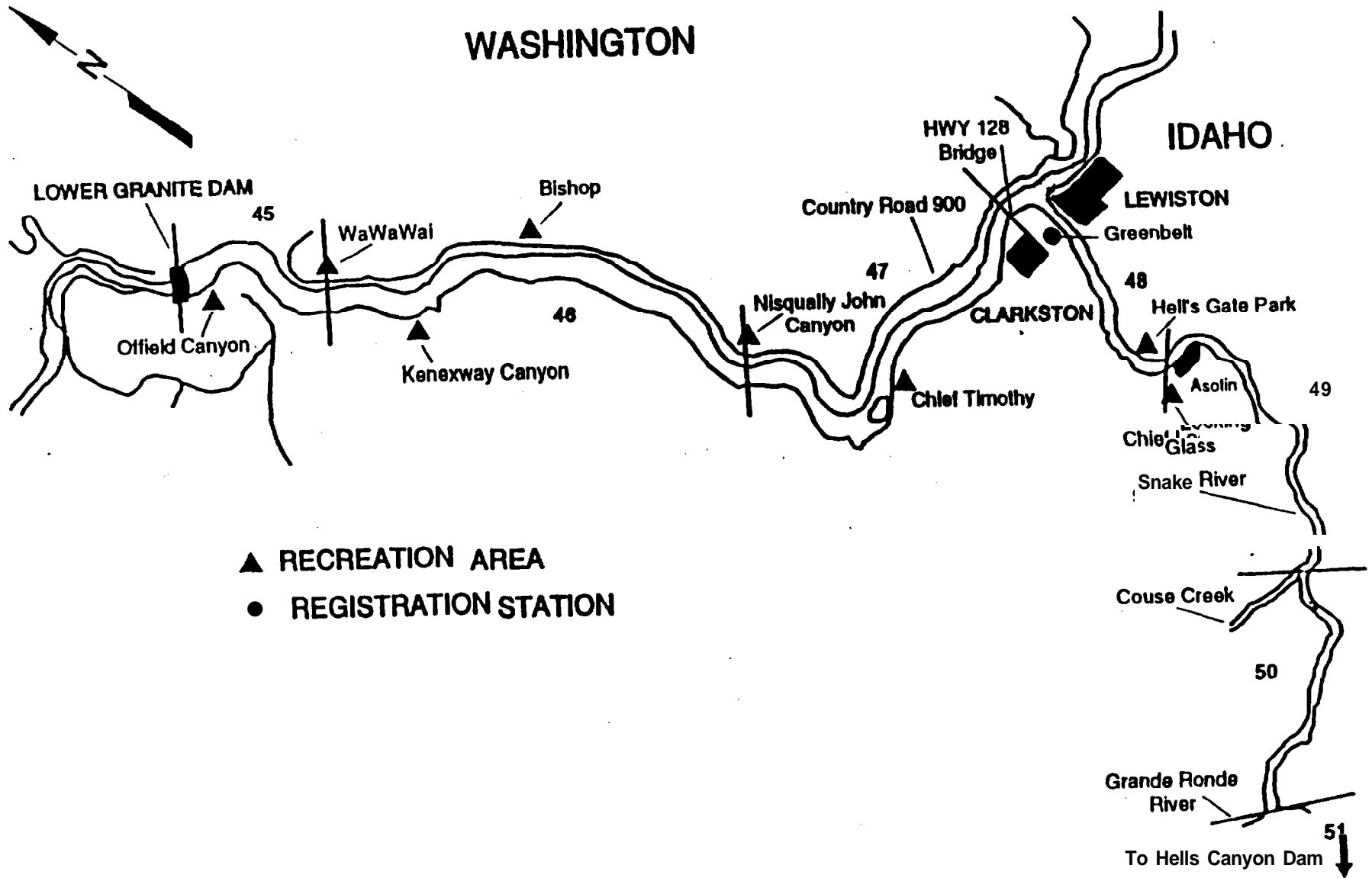
Appendix Figure A-8. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, Ice Harbor Dam to Lower Monumental Dam.



Appendix Figure A-9. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, Lower Monumental Dam to Little Goose Dam.



Appendix Figure A-10. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, Little Goose Dam to Lower Granite Dam.



Appendix Figure A-11. 1995 Northern Squawfish Sport-Reward Fishery fishing location codes, Lower Granite Dam to Hell's Canyon Dam.

APPENDIX B
Fish Species Codes

Table B-1. Sport-Reward Fishery field species codes.

LMB	Bass, Largemouth	JAK	Salmon, Chinook (Jack)
RKB	Bass, Rock	JCK	Salmon, Chinook (Juvenile)
SMB	Bass, Smallmouth	JCH	Salmon, Chum (Juvenile)
SB	Bass, Striped	JCO	Salmon, Coho (Juvenile)
BG	Bluegill	JPK	Salmon, Pink (Juvenile)
BH	Bullhead (Unknown)	JSO	Salmon, Sockeye (Juvenile)
YBH	Bullhead, Yellow	SAN	Sandroller
BBH	Bullhead, Brown	COT	Sculpin, (General)
BLB	Bullhead, Black	AMS	Shad, American
BUR	Burbot	RS	Shiner, Redside
CP	Carp	LFS	Smelt, Longfin
BCF	Catfish, Blue	NSF	Squawfish, Northern
c c	Catfish, Channel	SHP'	Steelhead (Adipose Present)
FCF	Catfish, Flathead	SHA'	Steelhead (Adipose Absent)
AC	Char, Atlantic	JSP	Steelhead, Juvenile (Adipose Present)
CMO	Chiselmouth	JSA	Steelhead, Juvenile (Adipose Absent)
LCH	Chub, Lake	TSS	Stickleback, Three-Spine
TCH	C h u b ; T u i	GRS	Sturgeon, Green
C R C "	Columbia River Chub	w s	Sturgeon, White
C	Crappie (Unknown)	SK	Sucker (Unknown)
BC	Crappie, Black	BRS	Sucker, Bridgelip
WC	Crappie, White	LRS	Sucker, Largescale
LED	Dace , Leopard	LNS.	Sucker, Longnose
LND	Dace , Longnose	MNS	Sucker, Mountain
SD	Dace , Speckled	S	Sunfish, (Unknown)
EUL	Eulachon	GS	Sunfish, Green
'SF	Flounder, Starry	TNC	Tench
GF	Goldfish	BT	Trout, Brown
AG	Grayling, Arctic	CT	Trout, Cutthroat (Unknown)
LM	Lamprey (General)	CCT	Trout, Cutthroat Coastal
PL	Lamprey, Pacific	SCT	Trout, Cutthroat Searun
RL	Lamprey, River	LCT	Trout, Cutthroat Lahontan
WL	Lamprey, Western Brook	DB	Trout, Dolly/Bull (Unknown)
TMT	Madtom, Tadpole	BLC	Trout, Bull (Char)
MQF	Mosquitofish	DVC	Trout, Dolly Varden (Char)
OMM	Mudminnow, Olympic	EB	Trout, Eastern Brook
TMK	Musky, Tiger	GT	Trout, Golden
PMO	Peamouth	LT	Trout, Lake
SP	Perch, Shiner	RB	Trout, Rainbow (Resident)
YP	Perch, Yellow	RU	Trout, Rainbow (Unknown)
P	Pickereel, Grass	TR	Trout, (Unknown)
NP	Pike, Northern	WAL	Walleye
PS	Pumpkinseed	WM	Warmouth
AT	Salmon, Atlantic	LW	Whitefish, Lake
CK	Salmon, Chinook	WF	Whitefish, Mountain
CH	Salmon, Chum	PGW	Whitefish, Pygmy
c o	Salmon, Coho		
K	Salmon, Kokanee		
SA	Salmon, Pacific (Unknown)		
PK	Salmon, Pink		
so	Salmon, Sockeye		
JAT	Salmon, Atlantic (Juvenile)		

* New codes for 1996

. * Conventional naming for NSF Sport-Reward Program

APPENDIX C

Promotional Activities

Introduction

The northern squawfish sport-reward fishery is part of an ongoing predator control program targeting northern squawfish (*Ptychocheilus oregonensis*), which are a major predator of juvenile salmonids (*Oncorhynchus* spp.) in the Columbia River Basin (Rieman et al. 1991). An evaluation of the promotional programs and incentives used during the 1995 sport-reward fishery was conducted to determine whether these activities were able to boost angler effort or increase the harvest of northern squawfish.

The 1995 sport-reward fishery achieved the highest total harvest to date with 199,788 northern squawfish. Catch per unit effort (CPUE) was the highest it had been during the first five years of the program (3.18). There were also 62,725 angler days spent during the 1995 sport-reward fishery, which was a 33% increase from 1994 and the second highest total to date. The average number of trips per angler (returning plus non-returning) increased from 3.33 in 1994 to 3.69 in 1995. An evaluation of promotional activities implemented during 1994 indicated that many activities increased effort, but did not necessarily increase the harvest of northern squawfish or the exploitation rate (Smith et al. 1995).

Promotional activities for the 1995 northern squawfish sport-reward fishery were designed with the primary goal of increasing angler exploitation of northern squawfish. The following objectives were defined to reach the primary goal: (1) develop incentives that encouraged experienced, productive northern squawfish anglers to spend more angler days and/or longer angler days harvesting northern squawfish; (2) recruit anglers to the sport-reward fishery who had never participated, or who participated infrequently; and (3) provide these anglers with enough information and/or instruction on catching northern squawfish so that they would become more effective at harvesting northern squawfish. To address the first objective, the Northern Squawfish Management Program implemented a tiered reward system that paid anglers higher rewards after they reached designated harvest totals. The use of weekly tournaments, which was introduced in August of 1994, was expanded to encompass 17 of the 21 weeks in the 1995 season. The \$50 tagged northern squawfish incentive, the large Bonneville Power Administration (BPA) sponsored tournaments, and the random drawings were also continued in forms similar to 1994. Advertising activities and costs remained at levels similar to 1994.

Methods

Harvest and effort totals for time periods associated with promotional activities were monitored during the season using data collected from angler registration forms and exit interviews. These data were evaluated to determine whether promotional activities produced positive contributions to the 1995 sport-reward fishery in the form of increased effort or harvest.

Sport-reward fishery anglers were also surveyed to obtain data used for evaluation of how various promotional activities affected their participation. Returning anglers were surveyed via the angler questionnaire that was given to every other angler (50%). Ten percent of non-returning anglers were surveyed with the same questionnaire using a telephone survey.

Tiered Reward

The 1995 Northern Squawfish Management Program changed the reward offered for northern squawfish ≥ 11 inches for the first time since 1990. The levels of payment were tiered during the 1995 season to offer anglers the opportunity to earn more money per northern squawfish by reaching designated catch totals over the course of the season. Tier 1 paid anglers the standard \$3 reward for the first 100 northern squawfish turned in. Tier 2 paid anglers \$4 for each northern squawfish from 101 to 400 and Tier 3 paid \$5 for each northern squawfish turned in over 400. Each angler's total cumulative number of northern squawfish paid was tracked by Pacific States Marine Fisheries Commission (PSMFC) and higher rates of pay were automatically made as anglers reached designated catch totals.

The intent of the tiered reward incentive was to encourage the sport-reward fishery's best anglers (those anglers with the highest catch rates) to expend more effort during the season harvesting squawfish. Traditionally, these anglers harvest large numbers of northern squawfish during the first two or three months of the season and then drop out of the fishery as their catch rates fall below levels that they define as "worthwhile." The tiered reward system was intended to encourage anglers to spend more effort early in the season (and to harvest large numbers of squawfish) as they attempted to reach the higher pay levels. It was also hoped that once these anglers reached the higher pay levels, they would find it worthwhile to continue participating for the balance of the season even when catch rates drop.

An additional benefit of the tiered reward system was to attract new anglers to the sport-reward fishery, or to re-enlist the efforts of former program participants with the prospect of earning \$4 or \$5 per squawfish.

The Northern Squawfish Management Program considered the possibility that the tiered reward system would encourage anglers to "pool" their catches to reach higher reward levels. To deter this activity, technicians were instructed to register each

angler separately and to verify that vouchers were only given to registered anglers. Technicians also informed anglers of the tax liability for anglers earning more than \$600 over the course of the season. With these deterrents in place, it was believed that pooling would not be common, or would be restricted to close family members (husband/wife or father/son).

Weekly Tournaments

The format of weekly tournaments conducted during the final five weeks of the 1994 season were broadened in 1995 to include 15 of the 21 available weeks to allow for more winners. It was hoped that by offering anglers additional opportunities to win, the sport-reward fishery would encourage further effort and northern squawfish harvest. Cash prizes were awarded to the three anglers who turned in the three largest northern squawfish (total length) at each registration station for each week from May 1 through June 11 and from July 17 through September 10 (the period from June 12 through July 16 was reserved for the larger Bonneville Power Administration tournaments). Prize amounts were \$125 for first place, \$75 for second and \$50 for third, and were restricted to one prize per angler per week. Qualifying northern squawfish turned in at satellite stations were considered part of the parent registration station. The weekly tournaments were continued an additional two weeks at the six registration stations.

BPA Tournaments

The Bonneville Power Administration sponsored two large tournaments during the 1995 season, which were referred to as the "Westside Tournament" and the "Eastside Tournament." Prizes were awarded for the longest three (total length) northern squawfish turned in at each registration station during the tournament period. The Westside Tournament was co-sponsored by the G.I. Joe's retail chain and included Registration Stations 1-7 during the period of June 17 through June 25. Prizes for the Westside Tournament were gift certificates from G.I. Joe's at \$500 for first place, \$250 for second and \$100 for third and were also restricted to one prize per angler. The Eastside Tournament included Registration Stations 8-13 during the period July 1 through July 9. Prize amounts were the same as for the Westside Tournament, but were awarded as cash instead of gift certificates. The tournament held at the Greenbelt boat ramp used a new and different tournament format for its tournament during this time period. Details of the Greenbelt tournament are covered separately following the general BPA tournament descriptions. Qualifying northern squawfish turned in at satellite stations were considered part of the parent registration station for both the Westside and Eastside tournaments.

The intent of the BPA tournaments was to produce exciting "events" that would attract media attention to the sport-reward fishery and bring new anglers to the program at a time when their chances for success were greatest. It was also hoped

that the prospect of large prizes would inspire regular anglers to expend additional effort and harvest more northern squawfish during the tournament period.

The tournament that was held at the Greenbelt boat ramp as part of the Eastside Tournament was called the “Snake River Northern Squawfish Round-Up” and was a multifaceted community event. It was co-sponsored by KATW Radio, the Costco retail store and Rivet-view Marina. BPA offered the same cash prizes as the other Eastside tournaments, which were used as the grand prize at the end of the tournament week. In addition, there were daily prizes given to anglers turning in the largest northern squawfish by daily sponsors recruited by KATW. There was also a boat, motor and trailer that would be given to a participant if they caught and turned in a special tagged northern squawfish. To be eligible for these additional prizes, anglers were required to obtain a free “tournament license” (in addition to complying with normal sport-reward fishery requirements) from one of the participating retail sponsors. All anglers who registered, but did not obtain the tournament license were only eligible for the grand prize money. An agreement was made between KATW and BPA to provide for additional radio advertising, tournament pamphlets and newspaper advertising.

Tagged Northern Squawfish

The tagged northern squawfish promotion from 1994, which offered \$50 for select tagged northern squawfish, was continued during the 1995 season. Eligible northern squawfish were tagged by Oregon Department of Fish and Wildlife (ODFW) personnel affiliated with the Northern Squawfish Management Program (Zimmerman et al. 1997). To receive the \$50 reward, anglers were required to return tagged northern squawfish to their registration station with the tag still attached and comply with usual sport-reward fishery rules. Tags were submitted to ODFW for verification using a “tag voucher” and verified vouchers were forwarded to PSMFC for payment,

The intent of this incentive was to encourage additional effort by sport-reward fishery anglers who were attempting to catch these higher value northern squawfish with the side benefit of harvesting additional northern squawfish in the process. This incentive also encouraged anglers to fish within the program area since eligible tagged northern squawfish were from areas within the sport-reward fishery’s boundaries and tags that did not qualify were often from radio-tagged northern squawfish or from other studies that were conducted outside the sport-reward fishery’s boundaries,

Random Drawings

Anglers who were paid for tagged northern squawfish were automatically entered into biweekly random drawings for \$250 based on the general geographical area of the registration station where they had turned in their tagged squawfish. Anglers who turned in tagged northern squawfish at Registration Stations 1-7 were entered into one drawing, Stations 8 and 9 a second drawing, Stations 10-12 a third drawing, and

Station 13, a fourth drawing. Anglers were allowed one chance for each tagged northern squawfish that was paid for during the qualifying period. Each drawing contained only the names of anglers from that period; there was no roll-over of angler names from previous periods.

This was a passive incentive that provided a number of different anglers throughout the program area with large rewards during the season. It was hoped that the amount and the frequency of the rewards would attract media attention to the sport-reward fishery and generate increased effort and harvest for the sport-reward fishery. Since the random drawing incentive was only available to anglers who turned in eligible tagged northern squawfish, it also acted as a complement to the tagged northern squawfish incentive by encouraging anglers to fish within program boundaries.

Independent Tournaments

There were four independent tournaments that were held by various groups during the 1995 season. Independent tournaments are characterized as being non-BPA sponsored events that are planned, organized, and promoted entirely by the sponsoring organization with guidance from WDFW.

Independent tournaments were encouraged by WDFW as a way to promote interest in the sport-reward fishery and as a way to increase awareness in the Northern Squawfish Management Program. The intent was to provide sponsoring groups with the appropriate program information (i.e., rules) and with the means for redeeming northern squawfish so that they could contribute to harvest while complying with Northern Squawfish Management Program goals.

The Wahkiakum Conservation District (WCD) held its Third Annual Squawfish Tournament from May 2 through June 12 at the Cathlamet and Kalama registration stations. The tournament was once again open to the public for a \$6 entry fee, which was collected by local retailers that were involved in the tournament. Technicians recorded the lengths of all northern squawfish turned in by tournament participants and this information was forwarded to WCD each week. Weekly prizes were awarded by WCD for first, second and third places to the three anglers with the longest (total length) northern squawfish turned in each week. One grand prize was awarded to the angler turning in the longest northern squawfish over the course of the tournament.

The Lower Columbia Walleye Club (LCWC) held a "Squawfish Round-Up" in conjunction with its Third Annual Walleye Jamboree on July 8 and 9. Entry fees were \$100 per two-person team and tournament organizers arranged with WDFW to ensure that all teams were automatically entered into the sport-reward fishery with the provision that reward money from all northern squawfish caught during the tournament would be donated to a local non-profit group for kids. A temporary

satellite registration station was set up at the tournament location for two hours each day to facilitate collection of squawfish, verification of sizes and issuance of vouchers.

The Ridgefield Marina Tenants Association (RMTA) held a fishing tournament at the Ridgefield Marina on July 4th as part Ridgefield's Fourth of July Celebration. The tournament operated from 12 p.m. until 4 p.m. and was open to the public at no charge. The RMTA tournament was once again organized without any involvement by sport-reward fishery personnel, although tournament organizers did request that WDFW operate a temporary satellite registration station at the marina during the tournament. Prizes were awarded by the RMTA to anglers catching the longest or the most fish of any species. There were special prizes for the longest and the most northern squawfish turned in.

The Big Eddy Marina held a one day northern squawfish tournament on August 26 as a social activity (along with a barbecue) for houseboat tenants of the marina. Prizes were awarded for the most northern squawfish turned in. Tournament organizers made arrangements with WDFW to have a technician available during tournament hours at a temporary satellite registration station to count and collect northern squawfish and to issue vouchers.

1-800 Northern Squawfish Hotline

The sport-reward fishery continued to provide a toll free hotline that was available to anglers for obtaining information about the sport-reward fishery. Information was available on requirements for participation in the sport-reward fishery, weekly and year-to-date harvest and effort totals, voucher information, how to catch northern squawfish (including free seminar dates and times, etc), and incentive program summaries. The hotline was updated weekly with current activities as well as the latest harvest and effort totals.

Advertising

Paid advertisements for the 1995 sport-reward fishery were placed in newspapers, magazines and on radio within the program area. To determine the most effective places for the sport-reward fishery to advertise, returning anglers were surveyed via the angler questionnaire and non-returning anglers by the telephone survey to learn where they had heard about the 1995 sport-reward fishery.

Newspaper and magazine advertisements designed by BPA's advertising agency were used from May through August and were similar in size (1/4 page) and content to advertisements used in 1994. These advertisements provided basic details about the sport-reward fishery and generally targeted people with little or no experience with the program from population centers located near northern squawfish registration stations.

BPA also produced northern squawfish “starter kits” that contained a pamphlet explaining the sport-reward fishery and how to participate, directions to registration stations, an incentive flyer, a Luhr-Jensen technical bulletin on catching northern squawfish and BPA’s *How to Catch* ‘em pamphlet. There was also a free fishing lure (Luhr-Jensen’s **K**rocodile spoon) and a coupon entitling the bearer to “one free northern squawfish” (when redeemed with one real northern squawfish ≥ 11 ”). These free kits were intended to provide information about the sport-reward fishery to the public. The free lure and the northern squawfish coupon were intended to add value to the kit and use of the coupon also served as a way of tracking whether free kits resulted in harvested squawfish. Kits were available by calling BPA or by visiting a G.I. Joe’s retail store.

Results and Discussion

Tiered Reward

Results from returning-angler and non-returning-angler surveys indicated that the tiered reward system was the most popular incentive for anglers participating in the 1995 sport-reward fishery. Seventy-seven percent of returning anglers and 52% of non-returning anglers indicated that the tiered reward system would increase their participation in the sport-reward fishery (Table 5).

There were 4,249 different *successful* anglers (anglers who turned in any number of northern squawfish that were ≥ 11 ” over the course of a season) during the 1995 sport-reward fishery. These anglers were divided into 3,891 at Tier 1 (<101 northern squawfish), 234 at Tier 2 (101 to 400 squawfish), and 124 at Tier 3 (>400 squawfish). These numbers represent 92%, 5% and 3% of the total, respectively. In 1994, out of 3,135 different successful anglers, there were 2,856 (91%) who turned in less than 101 squawfish, 204 (7%) who would have qualified for Tier 2 and 75 (2%) who would have qualified for Tier 3. CPUE remained similar from 1994 to 1995 (3.17 versus 3.18).

The top angler for the 1995 season turned in 3,878 northern squawfish compared to 1994 when the top angler turned in 2,627 squawfish. Anglers who harvested more than 100 northern squawfish over the course of the season accounted for 77% of the total catch in 1994 (99,085 squawfish) and 80% in 1995 (160,318 squawfish). Anglers who turned in 100 to 400 northern squawfish harvested 30% of the total in 1994 (38,509 squawfish), and 23% of the total (46,569 squawfish) in 1995. Anglers who turned in more than 400 northern squawfish harvested 47% (60,576 squawfish) of the total in 1994 and 57% (113,749 squawfish) of the total in 1995. The average number of northern squawfish per trip remained nearly the same for each of the above groups of successful anglers between years.

The overall average number of trips taken per registered angler (returning and non-returning) during the season increased from 3.33 in 1994 to 3.69 in 1995. The average number of trips per season for successful registered anglers increased from 7.07 in 1994 to 7.86 in 1995. The average number of trips per season for registered anglers who turned in 100 to 400 northern squawfish over the course of a season increased from 25 in 1994 to 30 in 1995. The average number of trips per season for registered anglers who turned in more than 400 northern squawfish over the course of a season increased from 51 in 1994 to 60 in 1995. The only group of anglers to show a decrease in the average number of trips per registered angler per season from 1994 to 1995 were those anglers who harvested fewer than 100 northern squawfish over the **course** of the season (7.6 vs. 4.9).

In addition to accounting for more northern squawfish, the 1995 sport-reward fishery surpassed the totals for the previous season in the number of registered angler days spent, and in the number of different anglers who participated. There were increases in the number of registered anglers at all three tier levels, which indicates that whatever attracted new anglers to the program or caused them to expend more effort, affected all anglers equally, regardless of skill level. Since CPUE for all registered anglers (as well as the average number of northern squawfish per trip for successful anglers) remained similar from 1994 to 1995, the increase in effort cannot simply be attributed to better river conditions and/or greater angler success.

Angler surveys of both returning and non-returning anglers indicated that the tiered reward system was the incentive most likely to increase participation. This was especially important for proficient anglers (Tiers 2 and 3) since they had higher average harvests of northern squawfish per trip. Based on trip data for this group of anglers, they were motivated to expend more effort in 1995 than in 1994. The increased effort by these anglers was responsible for bringing the sport-reward fishery an estimated 61,000 additional northern squawfish and enlarged their share of the total harvest from 77% to 80%. While it is true that the tiered reward system was not solely responsible for the improvements in effort and harvest seen during the season, based on the available data, it is likely that the tiered reward system was the single most important incentive offered in 1995.

Weekly Tournaments

There were 370 different anglers who won prizes in the weekly tournaments. Of these anglers, 112 anglers won multiple prizes during the course of the season (including the extension). The most weekly prizes won by a single angler was 15 by an angler at the Cathlamet site.

Since the weekly tournaments were in effect during virtually the entire season, we were unable to attribute any increases in effort to this specific incentive although results of the returning angler and of the non-returning angler surveys indicated that

this incentive “increased the participation” of 74% and 40% of anglers, respectively (Table 5). This was the third most popular incentive offered in 1995.

The weekly tournament incentive was popular with anglers according to technicians although there was some concern that a few anglers were monopolizing the prizes each week. In addition, technicians reported that a few anglers would try to “shop” their large northern squawfish around at several different sites in an attempt to place in the top three. The sport-reward fishery may be able to reduce this by changing the weekly tournaments to biweekly tournaments. This change would allow twice the time for large northern squawfish to be turned in which may reward a more varied group of anglers. The shift to biweekly tournaments in 1996 will also serve as a cost saving measure and should not result in a significant loss of effort for the sport-reward fishery.

BPA Tournaments

During the **Westside** Tournament, 2,502 angler days were spent harvesting 10,377 northern squawfish at Sites 1-7. Both of these totals were higher than the totals for the time period preceding the **Westside** Tournament as well as the time period following the **Westside** Tournament (Appendix Figure C- 1).

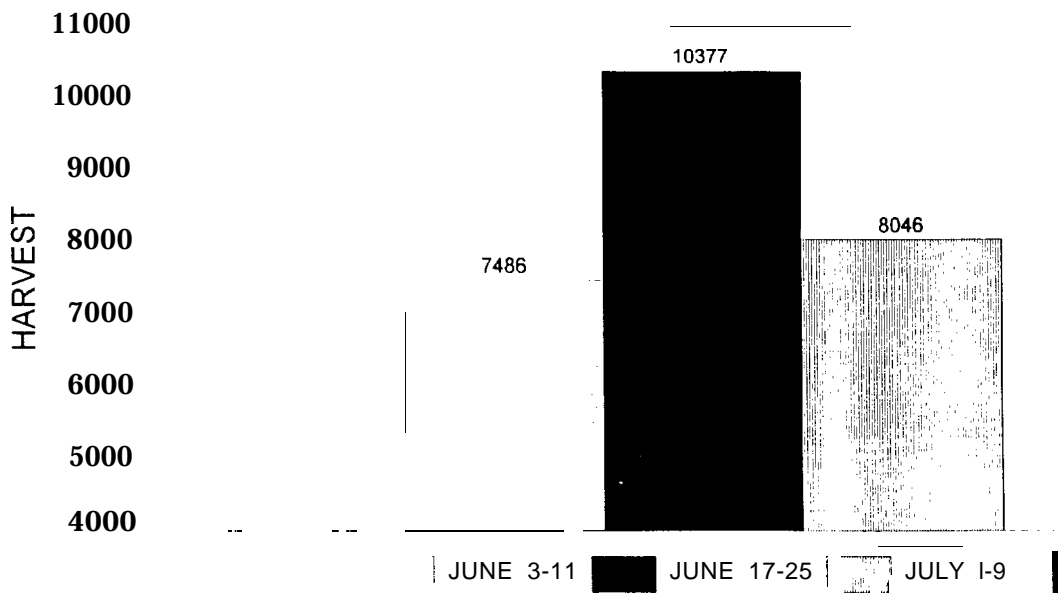
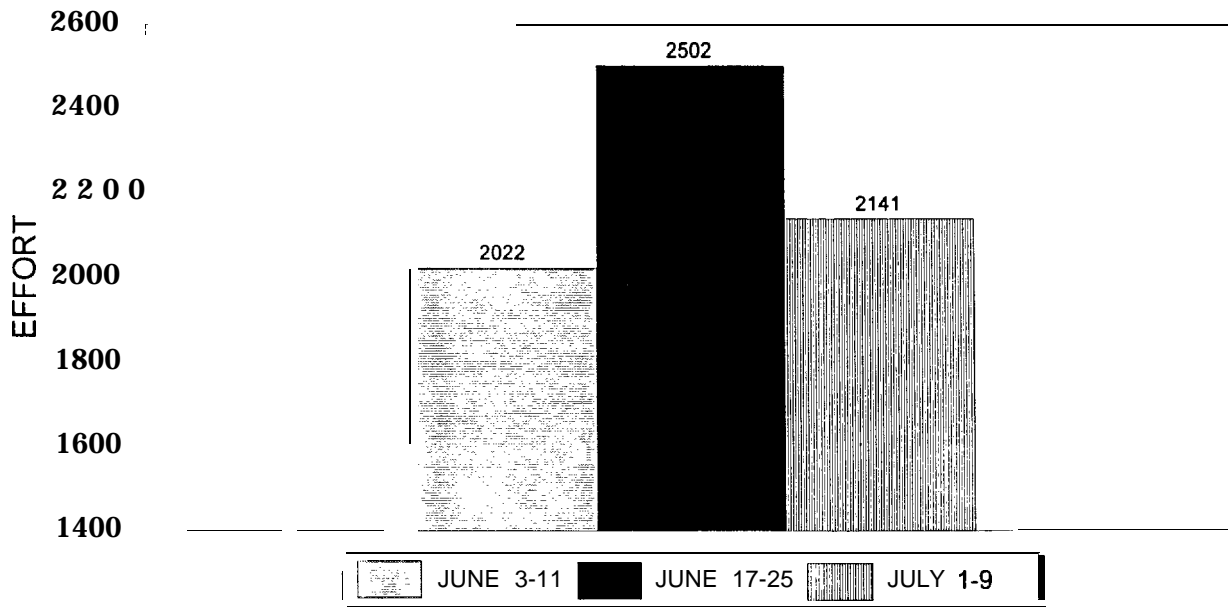
The **Eastside** Tournament results showed that 2,454 angler days were spent harvesting 13,323 northern squawfish at Sites 8-13. Effort during the tournament was about the same as the time period prior to the tournament, but was much higher than the time period following the tournament. Harvest was slightly higher during the tournament than during the preceding period and was much higher than the period following the tournament (Appendix Figure C-2).

While both the **Westside** and the **Eastside** tournaments were able to show increases in both effort and harvest during their respective time periods, it must be noted that these tournaments were scheduled to occur as close to the peak of the season as possible. Some increase in effort and harvest could be expected at this time of year regardless of whether these BPA tournaments were held. According to returning angler responses and to non-returning angler responses, the BPA tournaments “increased their participation” in the sport-reward fishery by 69% and 23%, respectively (Table 5).

Advertising for the **Westside** Tournament and for the Tri-Cities portion of the **Eastside** Tournament was much less than hoped for. The co-sponsor for the **Westside** Tournament did not offer the same advertising support as in the previous year while newspaper advertising was general and did not emphasize the tournaments.

WESTSIDE TOURNAMENT 1995

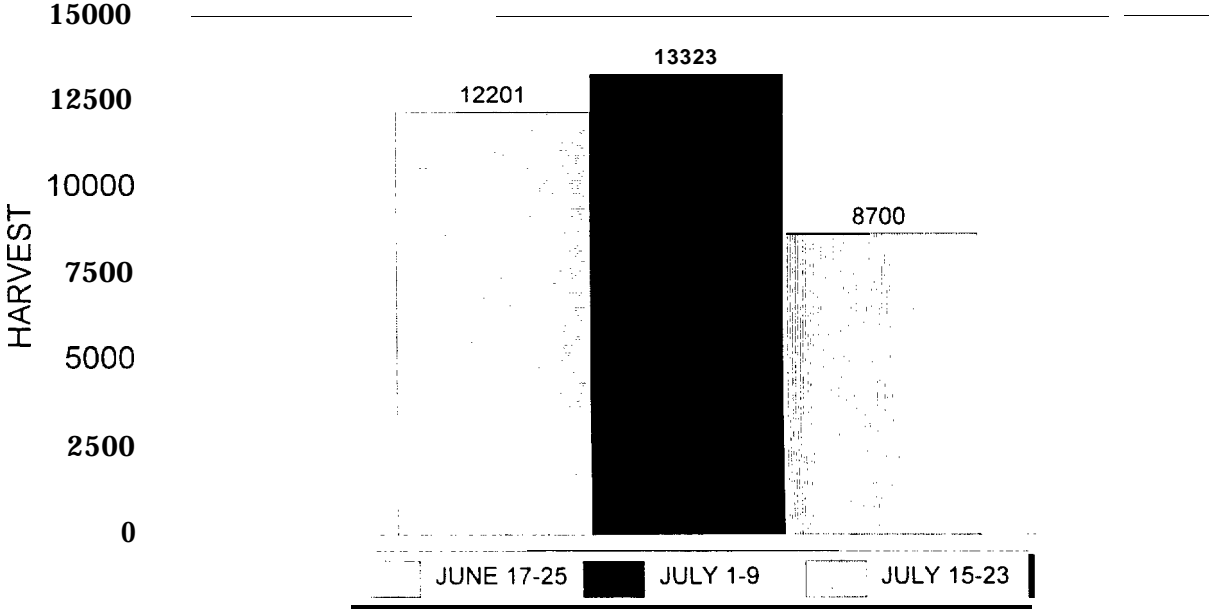
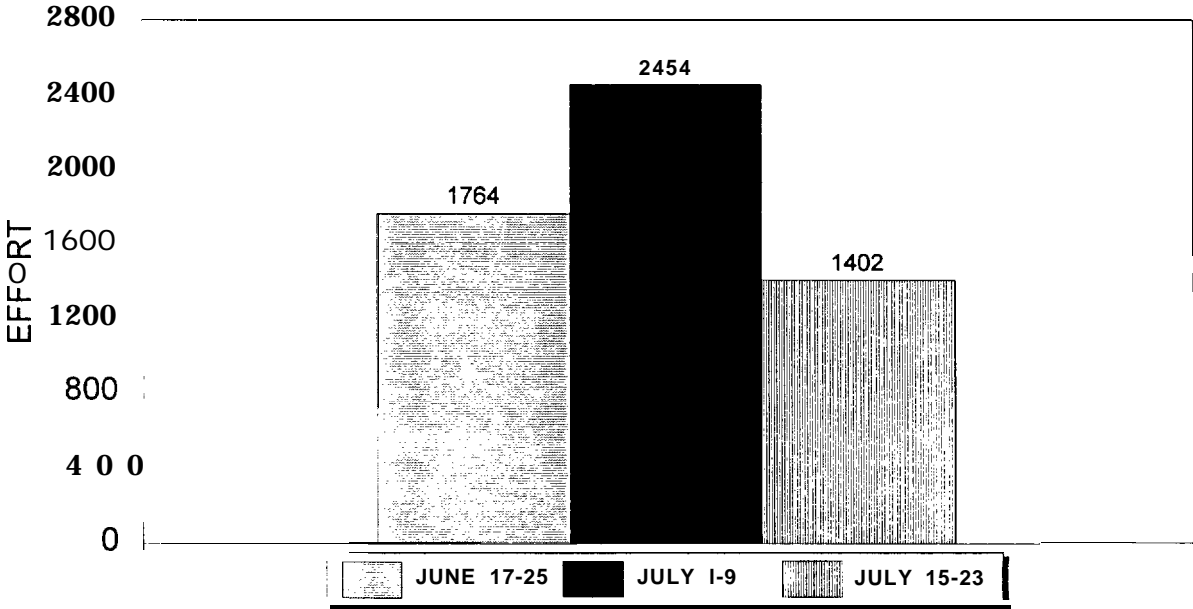
Registration Stations 1 - 7



Appendix Figure C-I. Angler effort and harvest for BPA Westside Tournament.

EASTSIDE TOURNAMENT 1995

Registration Stations 8 - 13



Appendix Figure C-2. Angler effort and harvest for BPA Eastside Tournament.

It is **useful** to look at the results for the Clarkston site (Snake River Northern Squawfish Round-Up) separately during the **Eastside** Tournament since it was promoted differently from the other registration stations involved in this tournament. Effort was substantially higher during the tournament period than the periods preceding or following the tournament. Harvest was also higher during the tournament than before or **after** the tournament although the difference was not as great as seen with effort (Appendix Figure C-3). The improvements seen in effort and harvest would have been much less without the additional media exposure obtained through KATW. Based on the positive results seen in Clarkston, this type of tournament event should be considered in other population centers within the program area. It is unclear whether this type of event is practical in larger population areas due to the likelihood of increased costs and the question of interest among radio stations. A template of the Clarkston tournament will be produced during the off-season so that the Northern Squawfish Management Program may investigate the feasibility of this type of event in 1996.

Tagged Northern Squawfish

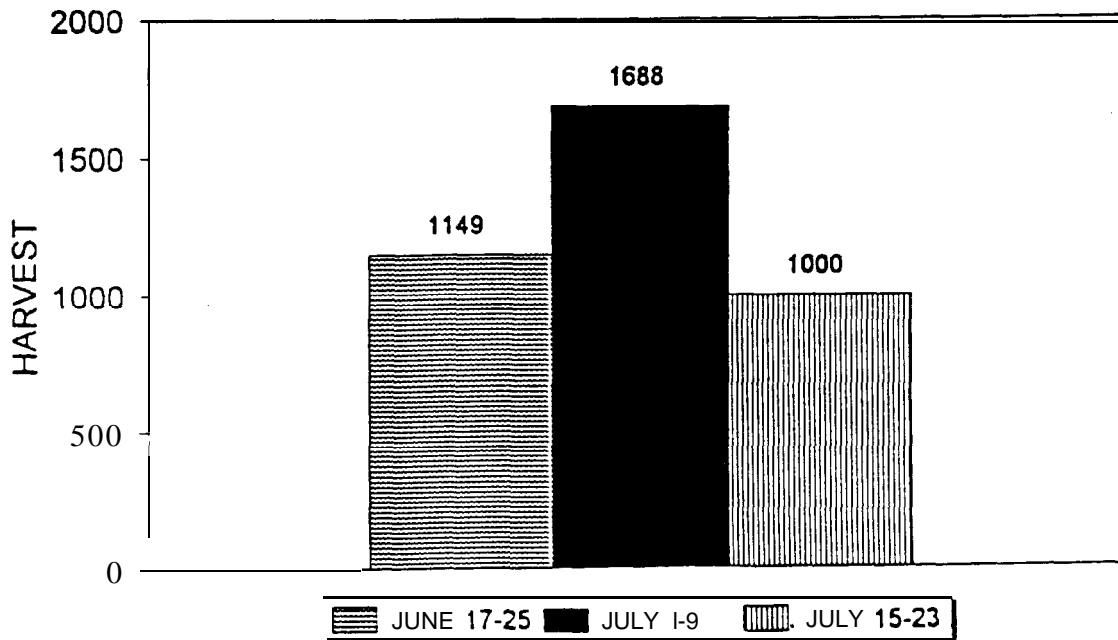
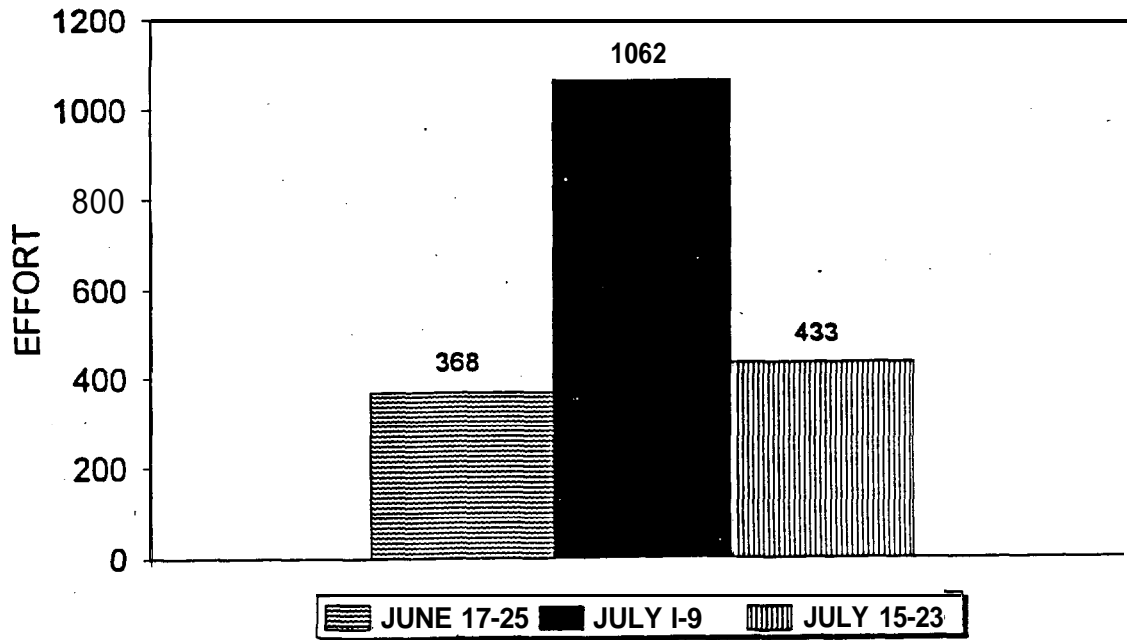
In 1995, 230 tagged northern squawfish turned in by 167 different anglers. Of these, 209 qualified for the \$50 reward. The highest number of eligible tags turned in by one angler was six. The area below Bonneville Dam produced the largest number of eligible tags (of the nine reservoirs) with 130. The registration station at The Fishery processed the largest number of eligible tags with 33, while the site at Greenbelt processed the least with four (Appendix Figure C-4).

Seventy-five percent of returning anglers indicated that the \$50 tag reward “increased their participation” in the sport-reward fishery (Table 5). Forty-four percent of non-returning anglers (the second highest response percentage), indicated that this incentive “increased their participation” in the sport-reward fishery.

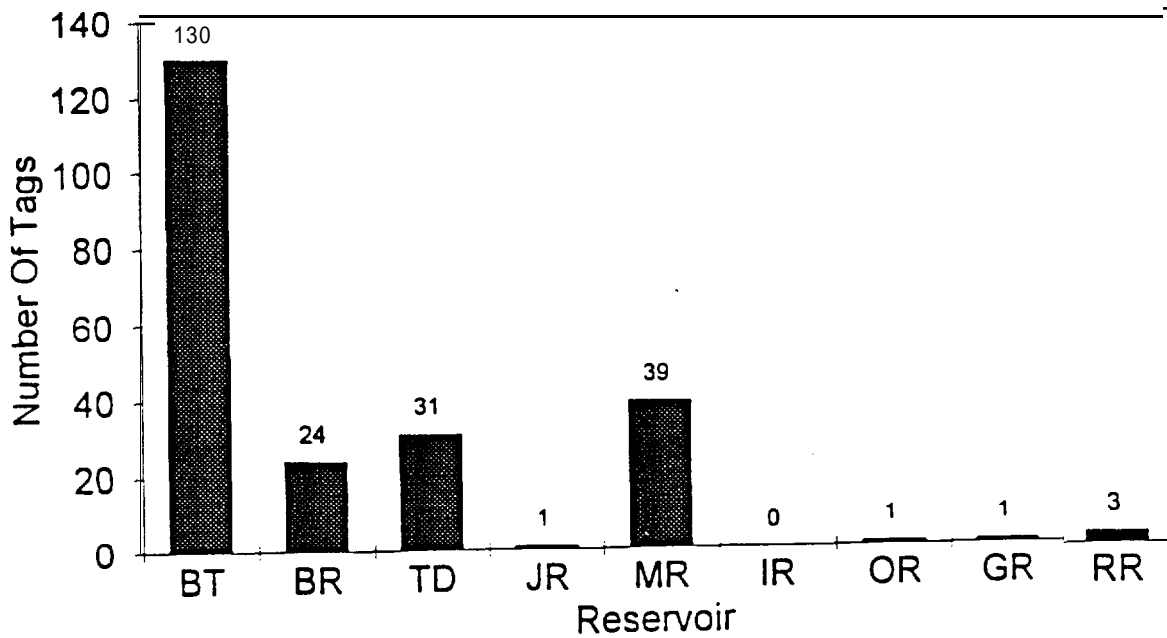
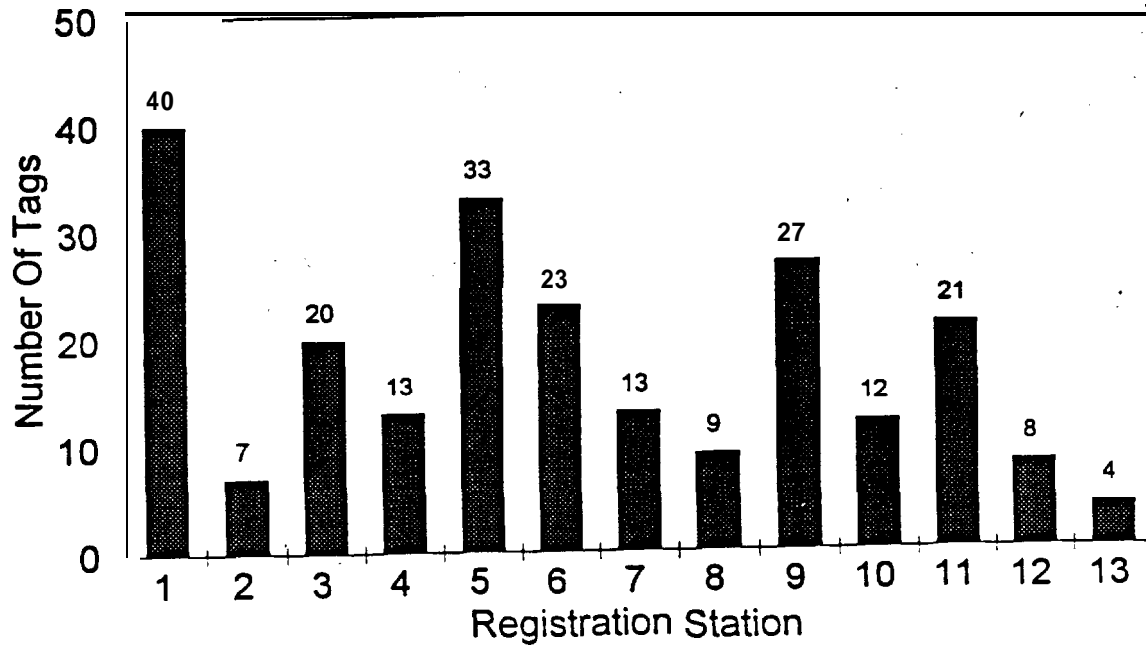
The \$50 tag incentive has continued to be a popular incentive as demonstrated by results from both surveys. The \$50-tag reward incentive is also a valuable tool for encouraging sport-reward fishery anglers to fish within the program area since northern squawfish with eligible tags are primarily found within these boundaries,

Through the use of informational advertising, both with posters at registration stations, and with newspaper advertising, anglers may be made more aware that tagged northern squawfish may be worth \$50. Better advertising may increase the benefit that the \$50 tag incentive will have to the sport-reward fishery by encouraging additional effort and harvest.

EASTSIDE TOURNAMENT 1995
Registration Station 13



Appendix Figure C-3. Angler effort and harvest for Clarkston site only during BPA Eastside Tournament.



Appendix Figure C-3. Tag recoveries by registration station during 1995. Tag recoveries by reservoir during 1995.

Random Drawings

There were 37 winners of the biweekly random drawings out of a possible 44 chances. There were several periods in which no eligible tagged northern squawfish were turned in and paid for, and where no prizes were awarded.

Most returning angler responses (72%) indicated that the random drawings increased their participation in the sport-reward fishery (Table 5). Thirty-seven percent of non-returning angler responses indicated that the random drawing incentive had increased their participation in the sport-reward fishery.

While angler responses to the exit questionnaire and telephone survey indicated that the random drawings increased angler participation in the sport-reward fishery, the passive nature of the incentive made it difficult to define whether increases in effort or harvest during the 1995 season were attributable to this incentive. Anecdotal evidence from WDFW technicians indicated that anglers were happy to win random drawings, but that they did not alter their habits to pursue them.

Independent Tournaments

The Wahkiakum Conservation District tournament results were similar to those from 1994. They reported that their tournament attracted fewer anglers than the previous year (18 versus 30). Harvest totals were not kept, but were estimated to also be similar to 1994's with just over 600 northern squawfish turned in during the six weeks of the tournament.

Eighty anglers participated in the Lower Columbia Walleye Club tournament in 1995, an increase of 23% over 1994. These anglers harvested 43 northern squawfish, which was more than double the tournament's harvest in 1994 of 18 squawfish. These totals represent 48% of the parent site's (Gleason) effort and 22% of the harvest for the two-day period of the tournament. Since this tournament was primarily a walleye tournament and its participants were not actively targeting northern squawfish, these totals show the potential of involving experienced angler clubs in the sport-reward fishery.

The Ridgefield Marina Tenants Association's fishing tournament added one northern squawfish ≥ 11 " and nine angler days to the totals for the 1995 sport-reward fishery. The anglers that participated in this tournament probably would not have taken part in the sport-reward fishery without it. If RMTA tournament organizers are willing to utilize additional guidance from WDFW in the future (i.e., to emphasize northern squawfish harvest), we may wish to continue our involvement in this event as a means of attracting participation to the sport-reward fishery although the benefit to overall northern squawfish harvest is questionable. In reality, the benefit of this type of activity to the sport-reward fishery is minimal although the small cost of sending a technician to their event may make it worthwhile from a public relations standpoint.

The tournament held at the Big Eddy Marina attracted 28 anglers who harvested 30 northern squawfish ≥ 11 " during the one day of the tournament. There were also 146 northern squawfish < 11 " harvested as well. The cost-to-benefit ratios for this event were similar to those for the RMTA tournament

These small independent tournaments were planned and organized entirely by the sponsoring organization with varying levels of guidance from sport-reward fishery personnel. All of these tournaments produced relatively small results (when compared to BPA-sponsored tournaments), however the amount of effort and expense expended by sport-reward fishery staff to get these results was minimal. These tournaments continue to offer an inexpensive way to generate public interest and excitement in the sport-reward fishery, generate some additional effort and harvest, and provide the sport-reward fishery with some positive public relations.

I-800 Northern Squawfish Hotline

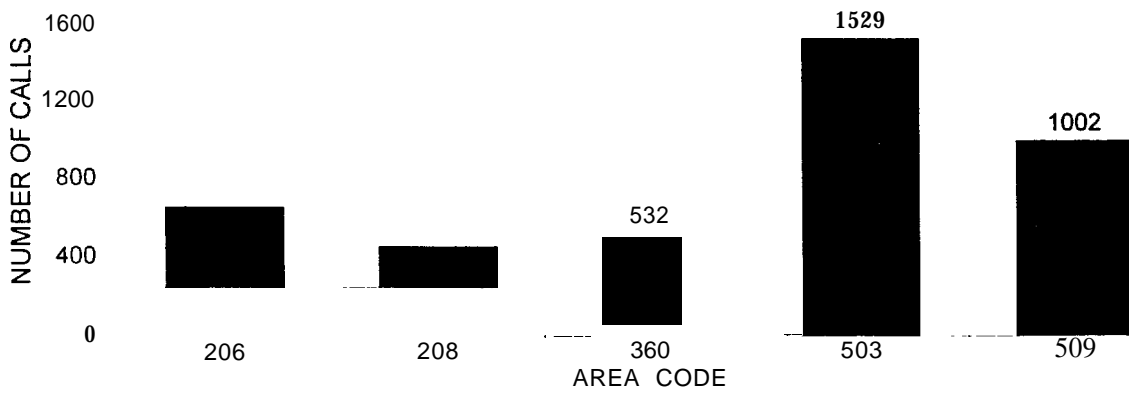
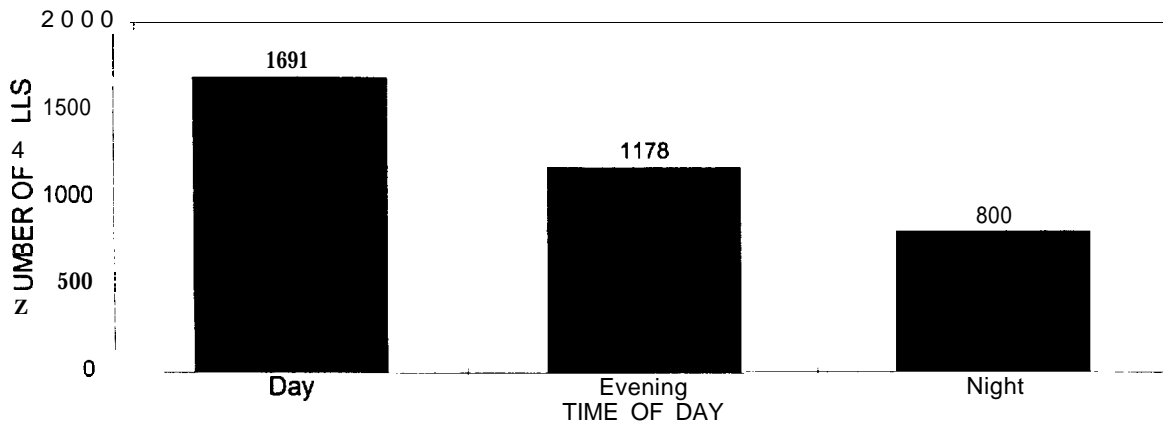
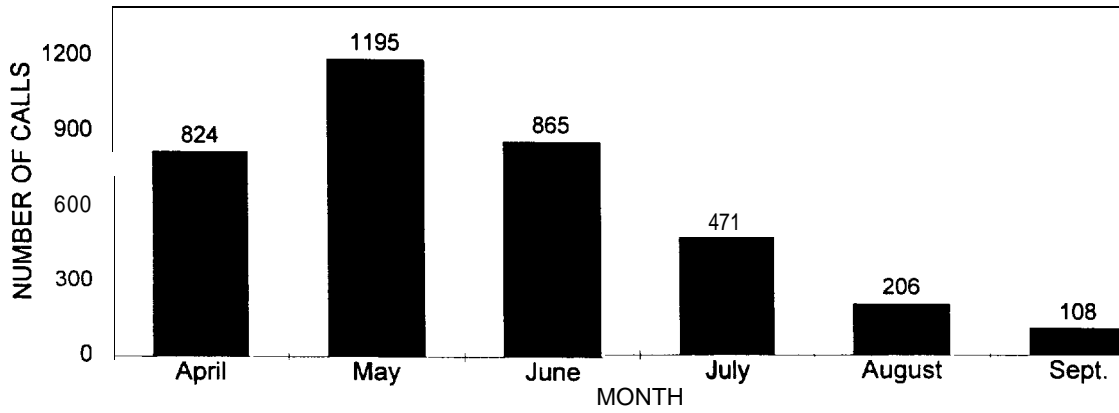
The toll-free Northern Squawfish Hotline was utilized by 3,669 users during the season with an average of 612 users per month and peak usage in May. These 1995 totals are down from 1994, when 5,478 users averaged 1,100 calls per month. Most calls were made during the day and most users called from the "503" area code (Appendix Figure C-5). The northern squawfish hotline cost the sport-reward fishery an average of \$.36 per call in 1995.

The 800 hotline continues to offer an effective method for providing the public with updated information about the sport-reward fishery at a small cost per call. The flexibility allowed with this type of service allows sport-reward fishery staff to modify the hotline as necessary to provide additional information or in response to angler demand for different topics.

Advertising

Returning angler responses indicated that 57% of anglers heard about the sport-reward fishery by word of mouth (Table 5). Non-returning angler responses indicated that 42% heard about the 1995 sport-reward fishery from the same source. Newspaper was the next indicated source of information for both groups with 18% and 30%, respectively. Radio was noted by only 1% of anglers surveyed with the exit questionnaire and by only 3% of anglers contacted during the telephone survey.

There were 64 insertions of the BPA advertisement for the sport-reward fishery that were placed in eight different newspapers within the program area during May through July. There were also a total of nine insertions placed in two regional magazines during the same period.



Appendix Figure C-5. 1 - 800 Hotline usage by month, time of day and area code during 1995.

Radio advertisements were placed on four local radio stations in the Portland/Vancouver area during the two weeks leading up to the start of the **Westside** Tournament. Total cost of radio for the Portland/Vancouver area was \$16,830. Radio was also used in Clarkston during the **Eastside** Tournament as part of the tournament arrangement with KATW radio at a total cost of \$1,000.

Angler responses gathered with the exit questionnaire and/or telephone survey regarding radio indicated that few anglers were informed about the 1995 sport-reward fishery by radio (Table 5). In addition, the relatively high cost of radio used for **Westside** Tournament advertising must be taken into account given its relative lack of results. Based on the positive results seen in Clarkston and on the relatively small cost, the use of radio should be modified to follow the pattern set in Clarkston during the **Eastside** Tournament of 1994. If the sport-reward fishery can gain the interest of radio stations in other population centers within the program area in a manner similar to Clarkston, we may be able to gain more radio coverage for our money than we have in the past.

There were 20,000 northern squawfish starter kits given out to anglers during the 1995 season. There were 1,078 of the coupons (which were included in each kit) redeemed for a “free northern squawfish” during the season. There were 4,249 different anglers who turned in northern squawfish during the 1995 sport-reward fishery, and 25% of them took advantage of this promotion, while 47% of the top 100 anglers used the coupon.

Summary

The objectives of the 1995 incentive programs for the sport-reward fishery were to develop incentives so that experienced, productive northern squawfish anglers would spend more effort harvesting northern squawfish, and to recruit and develop additional productive anglers into the sport-reward fishery by providing them with information and/or instructions for effectively catching squawfish.

The 1995 sport-reward fishery did achieve the highest total harvest to date, the second highest total effort to date, and surpassed the record CPUE rate set in 1994. In addition, through the use of a tiered reward system in 1995, the Northern Squawfish Management Program was able to motivate successful anglers to increase their participation in the program, which significantly improved northern squawfish harvest. The data on incentive activities that was gathered in 1995 should be used to modify the sport-reward fishery’s promotional activities for 1996 (when necessary) to ensure their continued success.

Due to the success of the 1995 sport-reward fishery, objectives for the 1996 season should remain the same. The main components of the 1996 promotional program should continue to be the tiered reward system, the \$50 tag incentive, some

type of frequent, weekly or biweekly tournament, and modified BPA tournaments that are similar to the one held in Clarkston in 1995. Additional effort should **be** spent to strengthen the sport-reward fishery's ability to inform and instruct anglers and the general public about how and where to catch northern squawfish during the season.

Recommendations

The following recommendations are made regarding specific promotional and advertising programs for the 1996 sport-reward fishery.

- A. Maintain the current tiered reward system for northern squawfish ≥ 11 ".
- B. Maintain the current \$50 tagged northern squawfish incentive.
- C. Maintain the use of a weekly or biweekly tournament during the entire season.
- D. Modify the BPA tournaments to follow the Clarkston model.
- E. Eliminate random drawings.
- F. Actively encourage independent tournaments.
- G. Continue use of 800 hotline, modify as necessary.
- H. Emphasize advertising methods that encourage word-of-mouth activity.
- I. Modify radio advertising to follow Clarkston model.
- J. Retain the option to extend the sport-reward fishery if harvest or CPUE warrants.
- K. Investigate further cost efficiencies for northern squawfish starter kits.

Results from the 1995 sport-reward fishery will continue to be evaluated prior to the start of the 1996 season and additional changes may be made as necessary according to the wishes of the Northern Squawfish Management Program.

References

Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleye, and smallmouth bass in John Day Reservoir, Columbia River. *Transactions of the American Fisheries Society* 120:448-458.

Smith, S.E, D.R. Gilliland, E.C. Winther, M.R. Petersen, E.N. Mattson, S.L. Kelsey, J. Suarez-Pena, and J. Hisata. 1995. Development of a systemwide predator control program: Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake Rivers. Washington Department of Fish and Wildlife, Contract DE-BI79-90BP07084. 1994 Annual Report to Bonneville Power Administration, Portland, Oregon.

Zimmerman, M. P., D. L. Ward, T. A. Friesen, and C. J. Knutsen. 1997. Development of a systemwide predator control program: Indexing and fisheries evaluation. Oregon Department of Fish and Wildlife, Contract DE-BI79-90BP07084. 1995 Annual Report to the Bonneville Power Administration, Portland, Oregon.

APPENDIX D

Cost Analysis

Introduction

Evaluation of the northern squawfish sport-reward fishery registration station costs was conducted by Washington Department of Fish and Wildlife (WDFW) for 1994 and 1995. Cost evaluation prior to 1994 was conducted by Dr. Susan Hanna, Oregon State University (Hanna et al. 1992). Total expenditures and expenditures per northern **squawfish** were compared among registration stations. The expenditures per northern squawfish were compared for 1992, 1993, 1994 and 1995. The data were used to determine the effect of cost-saving measures implemented in 1995 and to influence management decisions for 1996.

Cost per registration and satellite station was calculated by (1) determining the portion of the supervising biologist's pay that is associated with each respective registration and satellite station; (2) totaling scientific technician 1's, 2's and intermittent technician pay for each registration and satellite station; and (3) determining breakdown of costs for field offices (i.e., rent, utilities, phone, etc.) and vehicles for each registration and satellite station. Appendix Table D-1 shows a sample breakdown of costs used to calculate the expenditures for each registration and satellite station.

"Relative cost" per northern squawfish by registration and satellite station was determined by dividing the total cost of the registration or satellite station by the total northern squawfish harvested at that registration or satellite station.

1995 Registration Station Cost Analysis

The cost per registration station in 1995 was \$3 1,000 and ranged from \$38,783.70 at Cathlamet to \$27,283.42 at Vernita Bridge (Appendix Table D-2). The costs per registration station were predominately influenced by travel costs and overtime pay associated with the distance technicians must travel from the field office to the registration station and fish processing facilities. Busy registration stations also required more technician hours. The costs associated with those registration stations that had satellite stations showed a slight increase in expenses (Appendix Table D-2).

The overall cost per northern squawfish in 1995 was \$2.03 and ranged from \$.74 per northern squawfish at Giles French to \$10.85 per northern squawfish at Kalama. Giles French achieved the highest harvest (40,766 squawfish) and Kalama the lowest (2,724 squawfish).

Appendix Table D- 1. Sample breakdown of the costs used to calculate the total expenditure for each registration station, 1992- 1995.

ITEM	QUANTITY	UNIT COST	TOTAL COST
PERSONNEL:			
Fisheries Biologist	1.0	\$2,270.00	\$2,270.00
Sci. Tech 2 (5 months)			
REGHOURS	65	\$11.68	\$ 759.20
Sci. Tech 2 (1 position)			
REGHOURS	862.5	\$ 11.68	\$10,074.00
O.T. HOURS	25	\$ 17.52	\$ 438.00
Sci. Tech 1 (1 position)			
REGHOURS	906	\$ 10.17	\$9,214.02
O.T. HOURS	30	\$ 15.17	\$ 455.10
Sci. Tech 1 (Intermittent)			
REGHOURS	324.5	\$ 10.17	\$3,300.17
O.T. HOURS	4	\$ 15.17	\$ 60.68
SHIFT DIFF	588	\$.50	\$ 294.00
SUBTOTAL:			\$26,865.17
FRINGE BENEFITS:			
Full-time Employees		\$ 749.10	
Part-time Employees		\$3,366.40	
SUBTOTAL:		\$4,115.50	
SUPPLIES:		\$ 0.00	
(Purchased from previous years. All items still in use.)			
OPERATION AND MAINTENANCE:			
Field office rental	5	\$200.00	\$1,000.00
*Van Lease			
(PER MONTH)	5	\$286.00	\$1,430.00
SUBTOTAL:			\$2,430.00
INDIRECT COSTS:			
WDFW rate of 20 percent of salaries		\$ 5,373.03	
TOTAL		\$38,783.70	

*Gas included, also varies by registration station.

Appendix Table D-2. Total expenditure per registration station location and expenditure per northern squawfish (NS) removed for 1995.

Registration Station	Total Expenditure	Total Harvest incl. Satellite	Expenditure Per NS incl. Satellite	Expenditure Per NS minus Satellite
Cathlamet	\$38,783.70	7,175	\$ 5.41	\$ 7.03
Kalama	29,555.15	2,724	10.85	10.86
M. J. Gleason	32,344.07	11,510	2.81	3.77
Camas/Washougal	32,586.51	8,659	3.76	No Satellite
Covert's Landing	27,831.97	30,154	.92	1.15
Hamilton Island	30,244.30	11,936	2.53	No Satellite
Bingen	29,573.23	11,555	2.56	2.65
The Dalles	28,573.67	22,895	1.25	No Satellite
Giles French	33,691.86	45,790	.74	.83
Columbia Point Park	28,340.42	12,418	2.28	2.53
Vernita Bridge	27,283.64	15,577	1.75	No Satellite
Hood Park	31,053.29	3,750	8.28	10.34
Greenbelt	<u>35,861.77</u>	<u>15,645</u>	<u>2.32</u>	2.46
TOTAL	\$405,723.58	199,788	\$2.03	\$ 2.24

1992-1995 Registration Station Cost Comparison

The cost per northern squawfish was highest in 1993 (\$10.62; Appendix Table D-3). The total harvest in 1993 was also lower than any other year. A cost comparison of registration stations from 1992-1995 shows the highest cost per northern squawfish came from Kalama (\$10.85) in 1995, Umatilla (\$24.97) in 1994, Umatilla (\$63.19) in 1993 and St. Helens (\$42.66) in 1992 (Appendix Table D-3). Variation in cost per northern squawfish by year was primarily due to (1) changes in northern squawfish harvest totals, (2) equipment purchases, (3) changes in the number of technicians used at the registration stations each year, (4) reduction in program hours of operation, and (5) the addition or subtraction of satellite site totals. The number of registration stations decreased from 20 in 1992, to 18 in 1993, to 14 in 1994, and to 13 in 1995. The major costs for each registration station were similar, therefore, stations with low harvest greatly increased the overall cost per northern squawfish. Registration station hours of operation in 1992 and 1993 were from 9 a.m. to 9 p.m. The hours of operation remained the same in 1995 as they were in 1994, from 1 p.m. to 9 p.m. This reduced technician hours and operation costs, but angler participation increased to an all time high in 1995, as compared to 1993, which was at a level lower than any previous year.

1995 Satellite Registration Stations

The utilization of satellite registration stations generally showed a marked increase in harvest for the parent registration station (Appendix Table D-4). Extra costs to run the satellite sites were limited to mileage cost and *intermittent* technician time. Intermittent technicians worked an average of four to six hours daily, keeping their working time to less than 32 hours a week. An intermittent technician's schedule consisted of driving to the satellite site, set-up of less than 10 minutes, processing of fish (sites were generally open one to two hours), tearing down site, drive time to the next satellite site on route and repeating the process until all satellite sites were worked. These satellite sites proved their worth by the amount of angler participation and harvest. Satellite sites that showed little to no activity were shut-down to maintain efficiency. The cost per northern squawfish at the satellite registration stations in 1995 was \$3.21 — \$1.18 more than parent registration stations (Appendix Table D-3). Total harvest was 18,858 northern squawfish, with the highest at Maryhill State Park (4,923 Squawfish) and the lowest at the John Day Ramp (3 squawfish). The Deep River satellite site was closed down due to no angler participation or northern squawfish harvest. Many satellite sites (i.e., John Day, Deep River) were experimental and subsequently reduced the efficiency of their parent registration stations (Appendix Table D-4).

In summary, the northern squawfish sport-reward fishery has become more cost **efficient** over time and, with the inclusion of satellite registration stations, our cost per northern squawfish decreased at selected registration stations (Appendix Table D-3).

Recommendations for 1996

- A. Increase the efficiency of Kalama registration station by converting it to a satellite registration station or by adding productive satellite sites.
- B. Eliminate Scappoose, Willow Grove, John Day Ramp and Ridgefield satellite registration stations.

Appendix Table D-3. Expenditure per northern squawfish removed by registration station, 1992- 1995.

Registration Station	1992	1993	1994	1995
Cathlamet	-----	\$ 12.22	\$ 9.02	\$ 5.41
Rainier	-----	44.02		-----
Kalama Marina	\$10.25	43.25	13.10	10.85
St. Helens	42.66	-----	-----	-----
Vancouver	8.70	-----		-----
M. J. Gleason	4.61	7.88	4.55	2.81
Camas/Washougal	-----	12.28	5.17	3.76
Hamilton Island	3.67	7.09	2.63	2.53
Covert' Landing	2.66	3.87	1.36	.92
Cascade Locks	9.32	27.87		
Bingen	5.56	9.38	7.10	2.56
The Dalles	8.71	13.67	4.59	1.25
LePage Park	1.68	6.00		-----
Maryhill State Park	11.95	-----	-----	
Giles French	-----	-----	3.35	.74
Plymouth	26.32	-----		
Umatilla	-----	63.19	24.57	
Columbia Point	5.46	12.44	6.24	2.28
Ringold	9.93	-----		-----
Vernita Bridge	-----	6.30	3.45	1.75
Hood Park	6.46	12.07	9.25	8.28
Windust Park	39.23	-----		
Lyons Ferry Park	17.46	39.54	-----	-----
Boyer Park	10.60	46.30		
Greenbelt	3.40	5.33	4.77	2.32
TOTAL	\$ 6.86	\$10.62	\$4.68	\$2.03

Appendix Table D-4. Total expenditure per satellite station location and expenditure per northern squawfish removed for 1995.

Satellite Station	Total Expenditure	Total Harvest	Expenditure Per NS
Scappoose	\$2,884.92	92	\$ 31.35
Rainier	3,745.69	1,411	2.65
Willow Grove	2,632.92	157	16.78
John Day Ramp	1,940.61	3	646.87
Deep River	1,670.61	0	
Chinook Landing	4,326.69	2,656	1.63
Marine Park (Portco)	3,186.84	145	21.98
Ridgefield	2,894.10	53	54.60
Beacon Rock	2,926.39	2,294	1.27
HomeValley	3,678.39	967	3.80
Cascade Locks	7,082.38	2,768	2.56
Hood River	4,880.15	383	12.74
Maryhill State Park	5,259.15	4,923	1.06
Ringold	5,170.07	1,213	4.26
Umatilla Marina	5,424.07	747	7.01
Boyer Park	4,626.07	1,046	4.42
TOTAL	60,714.13	18,858	\$ 3.21

APPENDIX E

Morphological, Electrophoretic, Mitochondrial DNA and Stomach Contents Analysis of a Natural Intergeneric Cyprinid Hybrid Between *Acrocheilus Alutaceus* and *Ptychocheilus Oregonensis*

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Abstract

The northern squawfish sport-reward fishery was implemented in 1991 to reduce predation on downstream migrating salmonids *Uncorhynchus* spp. by lowering the number of predatory northern squawfish *Ptychocheilus oregonensis* in the Columbia and Snake rivers. Anglers participating in the sport-reward fishery began returning fish from the Snake River that appeared to be northern squawfish hybrids. The purpose of this study was to verify the hybrids parentage, compare the hybrids morphometric and morphological structure to that of each parent and determine if the hybrids were piscivorous. Electrophoresis verified the hybrids parents to be northern squawfish and chiselmouth *Acrocheilus alutaceus*. Five diagnostic enzyme loci identified 73 F₁ hybrids and two hybrid backcrosses. Mitochondrial DNA analysis showed 67% of the F₁ hybrids to have northern squawfish maternity and 33% chiselmouth maternity. Abdominal lining color was found to accurately distinguish northern squawfish (white), chiselmouth (black) and F₁ hybrids (grey or grey/white). F₁ hybrids were found to be morphometrically intermediate to their parents. F₁ hybrids were as piscivorous as northern squawfish, but became piscivorous at a longer length

than northern squawfish. Our findings suggest that hybrids should be included in the northern squawfish sport-reward fishery program.

Study Area

All fish examined in this report were caught in the Snake River, Lower Granite Reservoir except for one hybrid from Lower Monumental Reservoir. The majority of hybrids (92%) were sampled from the Snake River above Clarkston, Washington. The Snake River from below Clarkston to Lower Granite Dam accounted for approximately 8% of the hybrids sampled.

Introduction

Taxonomically distinct fishes frequently interbreed and produce viable offspring. A total of 3,759 references concerning natural and artificial hybridization among fishes was compiled by Schwartz (1972, 1981). The natural propensity of fish to hybridize may be accounted for by several characteristics: external fertilization, weak ethological isolating mechanisms, unequal abundance of the two parental species, competition for limited spawning habitat and susceptibility to interaction between recently evolved forms (Campton 1987). Environmental conditions also affect the occurrence of hybridization (Hubbs 1955).

References to hybrid crosses between stream-dwelling cyprinids appear frequently in literature, possibly due to the accidental union of gametes from different species spawning in close proximity (Raney 1940a, Howell and Villa 1976). Chiselmouth *Acrocheilus alutaceus* is a western cyprinid commonly found in the Columbia River system (Wydoski and Whitney 1979). Northern squawfish *Ptychocheilus oregonensis* is also a western cyprinid, but distributed in a wider variety of lakes and streams than chiselmouth (Wydoski and Whitney 1979). Technicians working for the northern squawfish sport-reward fishery (sport-reward fishery) began reporting fishes that appeared to be hybrids between northern squawfish and chiselmouth in 1991 (Burley et al. 1992). The sport-reward fishery offers a reward (\$3-\$5) to anglers who return northern squawfish ≥ 11 " to registration stations. Northern squawfish ≥ 11 " have been shown to be the dominant predator on juvenile salmonids in the Columbia and Snake rivers (Beamesderfer and Rieman 1991). No data could be found on the suspected hybrids to verify their parentage or to show if the hybrids preyed upon juvenile salmonids *Oncorhynchus* spp. In the absence of any data on the putative hybrid, an informed decision could not be made regarding whether or not to include them in the reward program.

Preliminary research uncovered numerous methods to identify and evaluate hybrids. Naturally occurring hybrids have historically been identified by establishing the hybrid to be intermediate between the parent species for certain meristic counts or

morphological measurements. Hubbs and Hubbs (1932) verified that certain sunfish *Lepomis* spp. hybrids display a variety of intermediate characteristics between the parent species by artificial matings. However, not all hybrids exhibit intermediacy. Certain hybrids have been shown to display characteristics more closely associated with one parent (Neff and Smith 1979, Ross and Cavender 1981).

A statistical method called the “hybrid index” was developed by Hubbs and Kuronuma (1942) and Hubbs et al. (1943) to measure the average morphological similarity of an individual fish to each of the suspected parents. The utility of the hybrid index was restricted because it requires the a priori identification of the two parental species and does not account for the variances and covariances of the discriminating traits (Campton 1987).

Multivariate statistical methods (Smith 1973, Neff and Smith 1979) have recently become popular for identifying hybrids, since they circumvent some of the hybrid index shortcomings. Principal components analysis (PCA) is a popular multivariate statistical method that does not require the a priori identification of the hybrid or parent and has the ability to objectively summarize the morphological evidence for natural hybridization. Plotting the first two principal components has the advantage of representing in two dimensions two linear combinations of all the characters used, thus reducing the influence of subjective decisions and individual characters (Smith 1973).

Even with PCA, morphological data can provide only circumstantial evidence for natural hybridization or introgression. Morphological traits generally represent the phenotypic expression of a number of genes and are also influenced by environmental effects (Barlow 1961, Ah and Lindsey 1974, MacGregor and MacCrimmon 1977, Todd et al. 1981). The entire range of the phenotypic variation from morphological traits can therefore not be precisely known. Introgression cannot be determined with morphological data, since F_1 hybrids may not be individually distinguishable from F_2 hybrids ($F_1 \times F_1$) or backcrosses ($F_1 \times$ either parent). Introgressed populations may also appear morphologically identical to one of the parental species (Greenfield and Greenfield 1972).

Electrophoresis is a popular technique for the study of genetic variability within and among populations of plants and animals. Resolution of electromorphs can allow unambiguous identification of hybrids, since proteins (or, more specifically, enzymes) are direct gene products. F_2 hybrids or backcrosses can also sometimes be identified through electrophoresis. The probability of correctly identifying an F_1 , F_2 or backcrossed hybrid increases with the number of independently segregating marker loci (Avice and Avybe 1984).

Determining the nucleotide sequences of mitochondrial DNA (mtDNA) with the use of restriction endonucleases provides one of the newest and most direct methods for investigating genetic variation in natural populations (Campton 1987). MtDNA accumulates substitutions very rapidly, which can be useful in distinguishing genetic

differences in closely related taxa (Wilson et al. 1985). Brown et al. (1979) estimated that in mammals the entire mtDNA molecule evolves ten times faster than a single copy nuclear gene. The strictly maternal inheritance (Gyllensten et al. 1985b and references therein) makes mtDNA a valuable genealogical tool for tracing female lineages (Ferris et al. 1982). On the other hand, the maternal inheritance of mtDNA prevents it from being used as a stand-alone technique for detecting hybridization and introgression because individuals will have only one type of mtDNA, regardless of their parentage (Campton 1987).

Electrophoresis, mtDNA analysis, principal component analysis and stomach contents analysis were chosen to provide a comprehensive understanding of the putative hybrids genetic makeup, morphometric differences and feeding behavior. The first step was to determine if the putative hybrids were true hybrids between chiselmouth and northern squawfish. We then investigated if backcrossed hybrids existed, established the maternity of each hybrid, compared the hybrids piscivorous nature to that of each parent and delineated morphometric and morphological differences.

I. Electrophoretic and Mitochondrial DNA Analysis of Putative Northern Squawfish and Chiselmouth Hybrids

Methods

The fish sampled in this report were supplied by anglers registering at the sport-reward fishery Greenbelt registration station. All fish were caught using hook and line gear. Anglers who regularly participated in the sport-reward fishery were asked to return the putative hybrids and chiselmouth along with their northern squawfish to the registration station. All hybrids were included in the reward program. Technicians collected samples of northern squawfish and chiselmouth from anglers that caught putative hybrids whenever possible. The technicians attempted to visually identify each northern squawfish and chiselmouth based upon their general appearance. Hybrids were identified by the shape of their mouth, which was considered to be intermediate to northern squawfish and chiselmouth, and a grey abdominal lining. No attempt was made to identify hybrid backcrosses. The fish identified by the technicians were compared to the definitive electrophoresis identification.

Electrophoresis Methods

The sampling protocol for the collection of all electrophoretic and mtDNA samples followed the general methods of Phelps et al. (1994). Anglers were asked to return fish alive or as quickly as possible after death, on ice. The length of time each fish was dead, prior to sampling, was obtained from the fishermen and recorded to the nearest hour. The samples were taken as they were returned to the registration station by the anglers from 5/2/95 until 6/30/95. Approximately 1 cm³ each of skeletal muscle, heart,

liver and one entire eyeball were removed from each fish and put in individually labeled plastic culture tubes. The samples were rinsed in clean water to remove superficial contaminants. An additional sample of liver tissue was taken for **mtDNA** analysis. All tissue samples were placed on **dry** ice immediately **after** dissection until they could be transferred to an ultra-freezer for storage at -70° C. Retinal tissue was removed from each fish eye by scraping the posterior of the eyeball.

Horizontal starch-gel electrophoresis was used to assay the genetic variation among the putative hybrids and their parents following the general methods of Aebersold et al. (1987). Locus and allele nomenclature follows Shaklee et al. (1990a). Initial screening for variable loci between species was conducted using tissue samples from the heart, liver, muscle and eye taken from 8 northern squawfish, 9 chiselmouth and 15 suspected hybrids using the systems described in Appendix Table 1. A total of 58 northern squawfish, 57 chiselmouth and 75 putative hybrids were analyzed electrophoretically. We used allelic variation at **PEPA**, **PEPB**, **ADH**, **sAH**, **IDDH**, **MPI**, **LDH-1**, **GPI-1** and **GPI-2** loci to analyze the balance of the liver and muscle samples.

The electrophoretic isozyme phenotypes for each fish at each locus were independently interpreted and scored by two individuals. A supervisor's score was required to resolve any discrepancies. Genotypes were recorded and the allele frequencies for each locus calculated. Alleles were designated by their mobility relative to the most common allele (* 100). Fish with conflicting genotypes among loci were identified as backcrosses. Bayes formula ($1/1+.5^{(n)}$), where n is the number of distinguishing loci, was used to estimate the probability of correctly distinguishing an F₁ hybrid from a backcross.

Mitochondrial DNA Methods

Samples of liver tissue from 64 northern squawfish, 56 chiselmouth and 70 hybrids of the two species were analyzed using restriction fragment length polymorphisms (**RFLPs**) of mitochondrial DNA. Approximately one gram of liver tissue from each sample was pulverized and total genomic DNA was extracted using the method of Robison (1995). The genomic DNA was electrophoresed on a 0.8% agarose gel to examine the quality and quantity of DNA in the extraction. Using specific oligonucleotide primers and the protocol supplied by the manufacturer (#765 and 766, LGL Genetics Inc.), the Cytochrome - b (Cyt-b) region of the **mtDNA** was amplified in each sample using the polymerase chain reaction (PCR) in a 40 ul volume. A four ul aliquot of the amplified product was then electrophoresed on a 2% agarose gel to determine the size and relative quantity of amplified DNA. The remaining aliquot of amplified DNA was evenly divided into separate Eppendorf tubes and digested using one of eight restriction endonucleases **Rsa I**, **Hinf I**, **Mse I**, **Taq I**, **Hha I**, **Pst I**, **Hae III** and **Alu I** along with the restriction buffer supplied by the manufacturer (Promega). **Rsa I**, **Hinf I**, **Mse I** and **Taq I** were chosen for analysis of all samples. Completely digested samples of amplified Cyt-b DNA were electrophoresed on a 3% agarose gel

at 40 volts for 2 hours. The resulting bands in each gel were stained using ethidium bromide (10 mg/ml) and visualized under ultraviolet light. Photographs of each gel were taken and the distance each band migrated on the gel was measured to the nearest mm, including bands from the molecular weight marker (pUC-19). The fragment size in base pairs of each band was calculated using the software package DNA Size.

The northern squawfish, chiselmouth, F₁ hybrids and hybrid backcrosses used in the mtDNA analysis were identified by electrophoresis in the previous section of this report. Known samples of northern squawfish and chiselmouth were assayed to determine the electrophoretic pattern for each species with each restriction endonuclease. The hybrid electrophoretic patterns were compared to the common patterns of northern squawfish and chiselmouth. Matching patterns indicated the maternity of each hybrid.

Results

Technicians from the sport-reward fishery, Greenbelt registration station, identified 59 fish to be chiselmouth and the electrophoretic data showed their identification to be correct for all but one chiselmouth which was shown to be a hybrid backcross. The 76 hybrids identified by technicians were electrophoretically shown to be 73 F₁ hybrids (96%), 2 northern squawfish (2.6%) and 1 hybrid backcross (1.4%). All electrophoretically identified northern squawfish (n=58) were correctly identified by the technicians.

Electrophoretic Results

No allelic variation was found among northern squawfish, chiselmouth and hybrids at 25 loci (Appendix Table 2). Ten loci were shown to be variable within species and five loci were found to be diagnostic (Appendix Table 2). G3PDH-2 showed low activity with heart and muscle tissue in a CAM6.8 buffer, but could possibly be made diagnostic by modifying the buffer system. PEPB with EBT, TRIS-GLY, and LIOH-RW buffers could also become diagnostic with system modifications. PNP was the only loci to show no activity.

Northern squawfish (n=58) and chiselmouth (n=57) showed clearly distinguishable polymorphic allelic variation in 100% of the samples at PEPB, ADH, sAH and IDDH loci (Table 1). PEPA was consistently variable in >99.9% of the fish sampled, with only one rare allele occurring at PEPA*94 (Table 1). Grey/white fish ID 40 was shown to be an F₁ hybrid at PEPA, PEPB and IDDH loci, but possessed a rare allele, not present in either parent at sAH loci. PEPA, PEPB, ADH, sAH and IDDH loci were considered to be diagnostic loci. Chiselmouth were found to always have the MPI* 108 allele, but northern squawfish also showed the MPI* 108 allele in 19% of the samples.

A total of 73 fish were classified as F₁ hybrids since they were found to possess the common alleles of both northern squawfish and chiselmouth from at least one diagnostic loci. All 5 diagnostic loci were used to identify 44 of the F₁ hybrids, 4 diagnostic loci for 20 F₁ hybrids, 3 for 4 F₁ hybrids, 2 for 3 F₁ hybrids and 1 for 2 F₁ hybrids. Bayes formula estimated a 67% probability of correctly distinguishing F₁ hybrids from backcrosses with one diagnostic loci, 80% probability with 2 loci, 89% with 3, 94% with 4 and 97% with 5. Fish ID (identification number) 13 was identified as a hybrid backcross with a chiselmouth, since PEPA, PEPB, and sAH loci showed hybrid alleles, but ADH and IDDH loci show alleles consistent with those of chiselmouth. Fish ID 92 was shown to be a hybrid backcross with a northern squawfish, since PEPB, ADH and sAH loci showed hybrid alleles, but PEPA revealed only northern squawfish alleles.

The observed allele frequency for F₁ hybrids was 50% of each parents common allele frequency for all diagnostic loci (Table 1). Non-diagnostic loci MPI, LDH-1 and GPI-1 showed hybrid allele frequencies to be close to 50% (range 51%-64%) of each parents common allele frequency (Table 1). The greatest variance from the expected 50% hybrid to parent allele frequency was GPI-2*116 (3 1%) and GPI-2*82 (82%) (Table 1).

Mitochondrial DNA Results

The restriction endonuclease fragments from Rsa 1, Hinf 1, Mse 1 and Taq 1 showed band migration patterns from northern squawfish and chiselmouth to be clearly distinguishable (Table 2). The estimated fragment sizes from each band, when added together, closely approximated the actual size of the Cytochrome-b gene for all restriction endonucleases except for Hinf 1 (Appendix Table E-2). Known samples of northern squawfish (n=66) and chiselmouth (n=59) were all shown to have consistent and repeatable banding patterns. All fish analyzed were found to have either northern squawfish or chiselmouth maternity. Complete agreement was found among restriction endonucleases (Rsa 1, Hinf 1, Mse 1 and Taq) regarding the maternity of all fish assayed. The F₁ hybrids (n=73) were shown to have northern squawfish maternity in 67% (n=49) of the samples and chiselmouth maternity in 33% (n=24). Northern squawfish maternity was shown in hybrid backcross ID 13 and chiselmouth maternity in hybrid backcross ID 92.

Table 1. Allele frequencies at 9 polymorphic loci for northern squawfish, chiselmouth, F1 hybrids and hybrid backcrosses. (N)=the number of fish assayed at each loci. Alleles are designated by their mobility relative to the most common allele (*100).

Fish Type	PEPA			PEPB			ADH*			
	(N)	100	94	89	(N)	-143	-100	(N)	139	100
NORTHERN SQUAWFISH	58	1.000	----	----	54	----	1.000	55	----	1.000
CHISELMOUTH	57	----	0.009	0.991	53	1.000	----	53	1.000	----
F1 HYBRID	73	0.500	----	0.500	71	0.500	0.500	64	0.500	0.500
HYBRID BACKCROSS	2	0.750	----	0.250	2	0.500	0.500	2	0.250	0.750

Fish Type	sAH*			IDDH			MPI		
	(N)	160	100	(N)	214	100	(N)	108	100
NORTHERN SQUAWFISH	58	1.000	----	21	----	1.000	58	0.190	0.81
CHISELMOUTH	55	----	1.000	25	1.000	----	57	1.000	----
F1 HYBRID	68	0.500	0.500	44	0.500	0.500	72	0.583	0.417
HYBRID BACKCROSS	2	0.500	0.500	1	1.000	----	2	0.500	0.500

Fish Type	LDH-1			GPI-1*			GPI-2					
	(N)	157	100	37	(N)	-100	-33	45	(N)	116	100	82
NORTHERN SQUAWFISH	58	0.009	0.991	----	58	0.862	0.138	----	58	0.086	0.880	0.034
CHISELMOUTH	57	----	0.939	0.061	57	0.0336	0.847	0.12	57	----	1.000	----
F1 HYBRID	73	----	0.966	0.034	72	0.458	0.465	0.077	73	0.027	0.966	0.007
HYBRID BACKCROSS	2	----	1.000	----	2	0.750	0.250	----	2	----	1.000	----

*To condense this table, fish displaying rare alleles for loci are footnoted: ADH*Northern squawfish #63 -Unclear, but possible rare allele. GPI-1 *F1 hybrid #107 - rare allele with a relative mobility=%67. sAH*F1 hybrid #40 - rare allele

Table 2. The distance in mm that various Cytochrome-b restriction endonuclease fragments migrated (Migrt) on a gel and their estimated fragment size (Frg. Sz.) in base pairs (bp) calculated from a least squares regression using pUC-19 molecular weight marker as a standard.

Rsa I					
Northern Squawfish			Chiselmouth		
Migrt.	Frag. Sz.		Migrt.	Frag. Sz.	
42.5	430		31.5	790	
45	350		42.5	430	
50.5	240				
53	200				
	<u>1220*</u>			<u>1220</u>	

Hinf I					
Northern Squawfish			Chiselmouth		
Migrt.	Frag. Sz.		Migrt.	Frag. Sz.	
45	400		40	520	
48.5	320		51	270	
53	220		53	220	
54.5	200				
57	170				
	<u>1310</u>			<u>1010</u>	

Mse I					
Northern Squawfish			Chiselmouth		
Migrt.	Frag. Sz.		Migrt.	Frag. Sz.	
31.5	830		28.5	1030	
53.5	200		56	170	
56	170				
	<u>1200</u>			<u>1200</u>	

Taq I					
Northern Squawfish			Chiselmouth		
Migrt.	Frag. Sz.		Migrt.	Frag. Sz.	
34	680		24.5	1150	
40	470		57.5	130	
57.5	130				
	<u>1280</u>			<u>1280</u>	

- The estimated size of the amplified Cytochrome-b fragment is equal to 1250 bp

Discussion

The occurrence of hybridization between northern **squawfish** and chiselmouth was confirmed (Appendix Table E-1). Electrophoretic analysis showed northern squawfish, chiselmouth and their hybrids to be remarkably similar in genetic make-up for intergeneric fishes, since no allelic variation (monomorphic) was found to exist among the hybrids or their parents at 25 loci (Appendix Table E-2).

F₁ hybrids were shown to backcross with both northern **squawfish** and chiselmouth, but only one backcross with each parent was identified. The existence of any hybrid backcrosses shows at least a portion of F₁ hybrids are capable of reproduction.

By the end of June, 1995, 4,409 northern squawfish were captured by sport-reward fishery anglers, while only 73 F₁ hybrids and 2 backcrosses were caught. This report was not designed to measure hybrid abundance, but the data indicates that the frequency of F₁ hybridization was low and the occurrence of backcrossing was even lower.

Confidence in our ability to distinguish between F₁ hybrids and hybrid backcrosses increases with the number of distinguishing loci. The possibility exists that some of the fish identified as F₁ hybrids were in fact hybrid backcrosses, since the number of diagnostic loci used to identify F₁ hybrids ranged from 1 to 5.

Excluding hybrid backcrosses, the ability of the sport-reward fishery technicians to visually **identify** northern squawfish (100%), chiselmouth (100%) and their hybrids (96%) was very good. These technicians have identified thousands of northern **squawfish**, chiselmouth and hybrids to develop the ability to distinguish them. Chiselmouth and northern squawfish exist sympatrically throughout the Columbia and Snake rivers. The inability of researchers to accurately identify these hybrids has precluded our ability to find reliable data on the frequency of hybridization in other sections of the Columbia and Snake rivers. A reliable quantitative method of **identifying** these hybrids should be developed and distributed to all researchers sampling fish in the Columbia and Snake rivers.

We were unable to identify F₂ hybrids. The probability of two F₁ hybrids mating to produce an F₂ hybrid was low, since the abundance of F₁ hybrids was probably low. F₂ hybrids may not have existed in our sample or they may have been electrophoretically indistinguishable from F₁ hybrids with our current methodology.

MtDNA analysis was found to be a reliable technique for distinguishing hybrid maternity. The banding patterns found in all four restriction enzymes were distinct enough for northern squawfish and chiselmouth to provide unambiguous results. The estimated size of the restriction fragments totaled to the approximate size of the Cytochrome-b gene for all restriction enzymes, except for **Hinf** 1. The molecular

weight of each fragment was estimated from a linear regression plot of a known standard (pUC-19). The points curve at the low molecular weight end of pUC-19 causing less accuracy in predicting the size of small molecules. Three bands from Hinf 1 were small molecular weight molecules (Table 2) which could cause a lack of precision in the fragment size estimates.

The mtDNA data indicates that F₁ hybridization occurred more frequently (67%) with a female northern squawfish and a male chiselmouth. Similarities in the genetic structure and spawning behavior of northern squawfish and chiselmouth explain the occurrence of hybridization between them, but we cannot explain why hybridization occurred more frequently with female northern squawfish.

Hybridization between the highly piscivorous northern squawfish and the non-piscivorous chiselmouth could be loosely compared to crossing a lion with a cow. The morphometric structure and piscivorous behavior of these unique hybrids should be studied to assist in evaluating how they effect the fish ecology and the dynamics of predation on juvenile salmonids in the Columbia and Snake rivers.

H. Analysis of the Piscivorous Nature and Morphological Characteristics of Northern Squawfish and Chiselmouth Hybrids

Methods

The identification and maternity of the fish analyzed in this report were derived from the previous section of this report.

Digital calipers were used to measure all morphometric measurements except for standard length. Standard length was measured as the straight distance from the tip of the snout to the end of the hypural plate as defined by the flexure line produced by bending the caudal fin (Kilgen and Ragan 1983). Head length was measured from the tip of the snout or upper lip to the most distant point on the opercular bone (not including the fleshy portion). Snout length was measured from the tip of the snout or upper lip to the front of the bony orbital rim. Jaw length was measured from the tip of the lower jaw to the back of the maxillary. The calipers were held parallel to the fishes body when measuring head length, snout length and jaw length. The smallest height of the caudal peduncle was measured. Each fish was also weighed to the nearest gram, sexed and the color of the abdominal lining recorded.

Five morphometric characters (standard length, head length, snout length, jaw length and caudal peduncle height) were used to calculate the principal component scores. The first two principal components were plotted and 95% confidence ellipses drawn around northern squawfish, chiselmouth and the F₁ hybrids. Hybrid backcrosses were not included in this analysis, since only two were found. Abdominal color,

maternity and piscivorous fish were also plotted using the same principal component scores and 95% confidence ellipses.

Discriminant function analysis was used to determine which morphometric ratio (if any) of standard length divided by head length, snout length, jaw length or caudal peduncle height would best discriminate among northern squawfish, chiselmouth and their hybrids.

The entire digestive tract (gut) was removed, placed in a whirl-pak bag and temporarily stored on ice or dry ice until they could be transported to a standard freezer. All digestive tracts were collected prior to 6\15\95 to ensure the availability of juvenile salmonids as possible prey.

The digestive tract contents were analyzed following the general procedures of Petersen et al. (1991). A total of 65 northern squawfish, 60 chiselmouth and 57 hybrid stomach contents were analyzed. The digestive tracts were first thawed and the contents stripped from the gut. Tapeworms were removed and the balance of the solid material digested in a solution of porcine pancreatase (8X), sodium sulfide nonahydrate and tap water. The digested samples were rinsed through a 425 micron mesh sieve with hot water. The remaining solid parts, if any, were analyzed for bones or other body parts that would indicate the presence of juvenile salmonids, sculpin or other fishes. Chi-square was used to determine if the expected frequency of fish present in the guts of northern squawfish, chiselmouth and hybrid samples differed significantly from the observed.

Results

Electrophoretically identified F₁ hybrids were found to be morphometrically intermediate to their chiselmouth and northern squawfish parents for all anatomical measurements (Table 3). Mean and standard deviation values were lowest for chiselmouth and highest for northern squawfish (Table 3). Chiselmouth possess the smallest mean mouth size (jaw length mean=10.96 mm) followed by F₁ hybrids (jaw length mean=20.44 mm) and northern squawfish (jaw length mean=30.87 mm). Female chiselmouth, F₁ hybrids and northern squawfish showed smaller mean values than males for all morphometric measures (Table 4).

The first and second principal component scores from northern squawfish, chiselmouth and F₁ hybrids were plotted in Figure 1 and show no overlap of the 95% confidence ellipses. Component I (X axis) represents the overall size differences among the specimens, ranging from small on the left to large on the right (Figure 1). Component II (Y axis) represents among species discriminations derived from the combined effect of all variables (Figure 1). The total variance explained by the two components represents 98% of the total 5 character data matrix variance. The 95% confidence ellipses for northern squawfish, chiselmouth and F₁ hybrids contained only fish from their respective groups (Figure 1).

Discriminant function analysis showed the ratio of standard length divided by jaw length to be a very good discriminator of northern squawfish, chiselmouth and F_1 hybrids. Fish with a standard length >200 mm were found to work best in this analysis. Chiselmouth were all correctly identified ($n=56$). F_1 hybrids were correctly identified in 97.2% ($n=69$) of the observations and northern squawfish 98.5% ($n=64$). Three fish were misclassified. One northern squawfish was classified as a F_1 hybrid, One F_1 hybrid was classified a chiselmouth and another F_1 hybrid a northern squawfish. The mean standard length -jaw length ratio for chiselmouth (25.26) was the highest followed by F_1 hybrids (13.84) and northern squawfish (9.96). A standard length -jaw length ratio between 12.5 and 20 has a high probability () of being a hybrid. Greater than 21.5 indicates a chiselmouth and <11.5 a northern squawfish. Chiselmouth and F_1 hybrids with ratios between 20 and 21.5 cannot be confidently differentiated. F_1 hybrids and northern squawfish with ratios between 11.5 and 12.5 also not capable of being confidently differentiated. Northern squawfish backcross ID 92 possessed a ratio of 11.7 and chiselmouth backcross ID 13 had a ratio of 13.07.

Table 3. Descriptive statistics calculated from chiselmouth, F I hybrid and northern squawfish morphometric data.

CHISELMOUTH

Variable	N	Mean	Std Dev	Minimum	Maximum
Standard	59	272.88	34.28	116	329
Head Length	59	58.61	7.01	28.5	70.8
Jaw Length	59	10.96	1.91	5.20	13.90
Snout length	59	21.69	3.10	9.00	31.50
Caudal Peduncle	59	20.43	2.84	a.70	25.40

F1 HYBRID

Variable	N	Mean	Std Dev	Minimum	Maximum
Standard Length	73	278.78	46.98	188.00	384.00
Head Length	73	66.32	11.82	43.60	100.00
Jaw Length	73	20.44	4.16	11.10	29.90
Snout Length	73	24.36	4.88	15.00	35.10
Caudal Peduncle	73	23.15	3.63	15.50	30.50

NORTHERN SQUAWFISH

Variable	N	Mean	Std Dev	Minimum	Maximum
Standard Length	68	302.04	70.38	159.00	479.00
Head Length	68	79.94	19.73	48.50	128.80
Jaw Length	68	30.87	9.23	13.50	54.10
Snout Length	68	29.40	8.17	1a.20	49.30
Caudal Peduncle	68	28.11	6.63	11.60	45.10

Table 4. Descriptive statistics calculated from chiselmouth, F 1 hybrid and northern squawfish morphometric data by sex.

CHISELMOUTH						
Variable	SEX	N	Mean	Std Dev	Minimum	Maximum
Standard	Female	44	280.48	27.49	161.00	329.00
Head Length		44	59.92	6.05	34.10	70.80
Jaw Length		44	11.23	1.50	7.40	13.90
Snout Length		44	22.23	2.74	11.80	31.50
Caudal Peduncle		44	20.91	2.51	11.40	25.40
Standard	Male	15	250.6	42.83	116.00	297.00
Head Length		15	54.79	6.39	28.50	63.40
Jaw Length		15	10.18	2.71	5.20	13.90
Snout Length		15	20.11	3.64	9.00	23.70
Caudal Peduncle		15	19.03	3.34	8.70	22.30
F1 HYBRID						
Variable	SEX	N	Mean	Std Dev	Minimum	Maximum
Standard	Female	37	291.70	48.81	211.00	384.00
Head Length		37	68.93	12.85	50.20	100.00
Jaw Length		37	21.58	4.31	14.10	29.90
Snout Length		37	25.34	5.02	18.10	35.10
Caudal Peduncle		37	23.59	3.76	16.80	30.50
Standard	Male	36	265.50	41.62	188.00	326.00
Head Length		36	63.50	10.40	43.60	80.90
Jaw Length		36	19.28	3.70	11.10	24.90
Snout Length		36	23.35	4.57	15.00	31.90
Caudal Peduncle		36	22.69	3.48	15.50	28.80
NORTHERN SQUAWFISH						
Variable	SEX	N	Mean	Std Dev	Minimum	Maximum
Standard	Female	38	312.82	88.56	159.00	479.00
Head Length		38	83.56	24.44	48.50	128.80
Jaw Length		38	32.71	11.47	13.50	54.10
Snout Length		38	31.12	10.05	19.70	49.30
Caudal Peduncle		38	29.06	6.32	11.60	45.10
Standard	Male	30	288.40	33.09	194.00	347.00
Head Length		30	75.35	9.93	51.30	91.10
Jaw Length		30	28.53	4.35	18.30	35.70
Snout Length		30	27.23	4.08	18.20	33.80
Caudal Peduncle		30	26.62	3.28	16.90	31.90

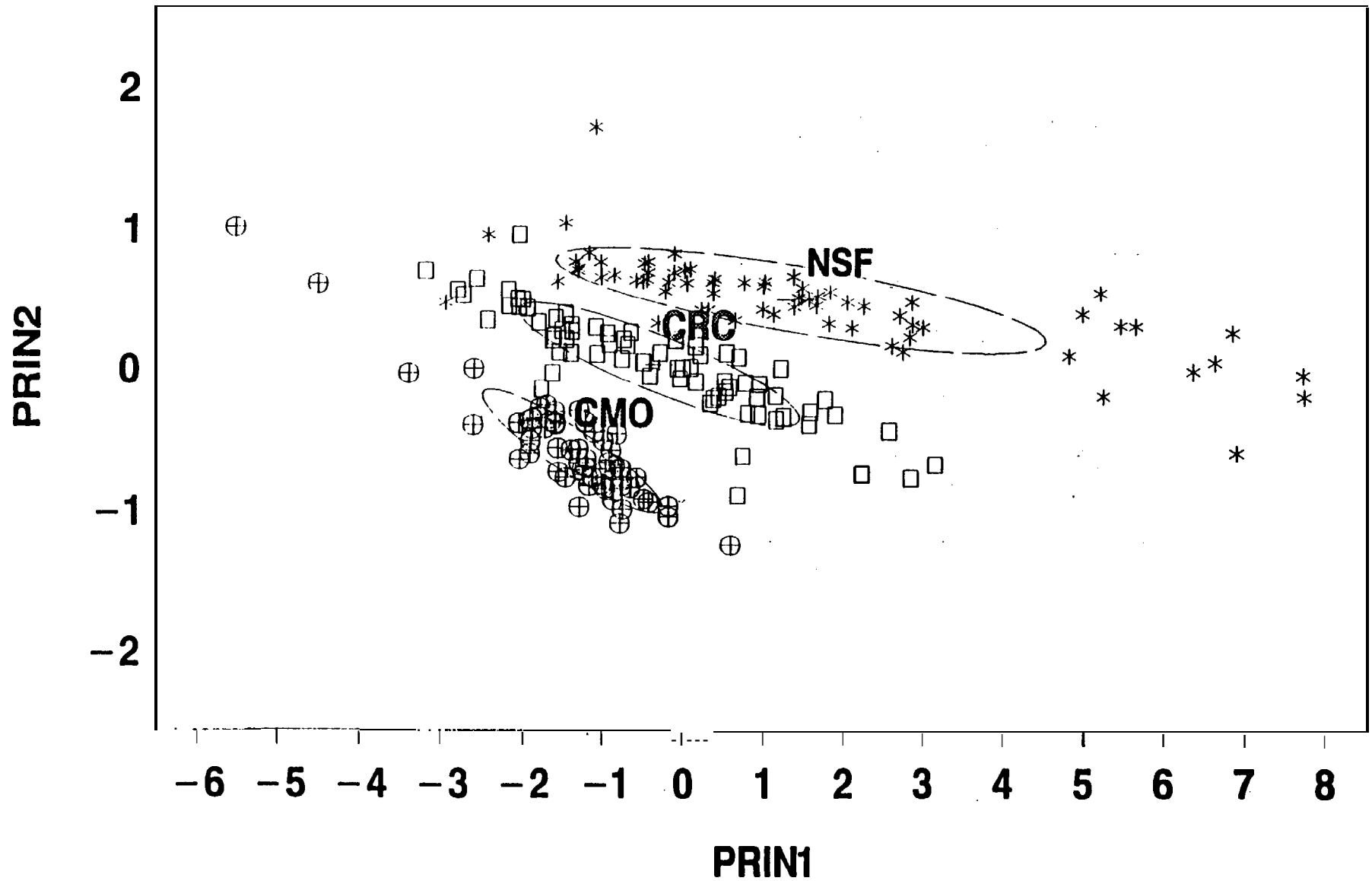


Figure 1. The first two principal components plotted by species: **CMO** = chlselmouth, **CRC**= FI hybrld and **NSF**= northern squawfish with 95% confidence ellipses. Prln1 accounts for 92% of the total varlation and prln2 6%.

Fish possessing black abdominal lining (n=56) were all found to be chiselmouth. **White abdominal lining** was always found in northern squawfish, except for two **grey/white** northern squawfish. Fish with a grey abdominal lining were found to be 97% **F₁ hybrids (n=65)** and 3% chiselmouth (n=2). **Grey/white abdominal lining** was comprised of 66.6% **F₁ hybrids (n=8)**, 16.67% northern squawfish (n=2) and 16.67% hybrid backcrosses (n=2). **F₁ hybrids (n=73)** predominantly had grey abdominal lining (89.04%, n=65), but 10.96% (n=8) of the **F₁** sample were shown to have **grey/white** coloration.

The principal component plot by abdominal lining color revealed similarities between hybrid backcrosses and hybrids with **grey/white** lining (Figure 2). The two hybrid backcrosses were both **grey/white**. Hybrid northern squawfish backcross ID 92 was found to be morphometrically intermediate to northern squawfish and **F₁** hybrids (Figure 2). Hybrid chiselmouth backcross ID 13 was found to be morphologically similar to a large **F₁** hybrid and seven other **grey/white F₁** hybrids were found clustered near ID 13. The probability of the seven **F₁** hybrids actually being backcrosses was found to be low (6% for the 2 fish identified with 4 loci and a 3% probability for the 5 fish identified with 5 loci).

The principal component plot by abdominal lining (Figure 2) showed no overlap of the 95% confidence ellipses for black, white or grey, but the **grey/white** ellipse overlapped with the grey ellipse and individual **grey/white** members fell within the white ellipse. The 2 **grey/white** northern squawfish fell within the northern squawfish ellipses (Figure 2).

The gut contents from 182 fish were analyzed for the presence of diagnostic fish bones. Electrophoretic analysis showed the sample to consist of 67 northern squawfish, 59 chiselmouth, 54 **F₁** hybrids and 2 hybrid backcrosses. Diagnostic fish bones were found in 10 northern squawfish and 8 **F₁** hybrids. The observed frequencies of northern squawfish (14.93%) and **F₁** hybrids (14.81%) with fish bones present in their guts did not differ significantly from the expected frequencies ($X^2 = 0$, $df=1$, $P < .986$). Chiselmouth showed no evidence of a piscivorous diet. The sample size of confirmed hybrid backcrosses (2) was too small to confidently evaluate their diet, but no diagnostic fish bones were found in their stomachs. Diagnostic **salmonid** fish bones were found in two **F₁** hybrids and one northern squawfish.

No fish bones were found in the stomachs of fish exhibiting a black abdominal lining (n=57). The observed frequencies of fish bones present in fish with grey (8.33%) **grey/white** (33.33%) or white (15.38%) abdominal linings were not significantly different from the expected frequencies ($X^2 = 4.97$, $df=2$, $P < .083$). Diagnostic **salmonid** fish bones were found in the stomachs of two fish with **grey/white** abdominal linings and one fish with a white abdominal lining.

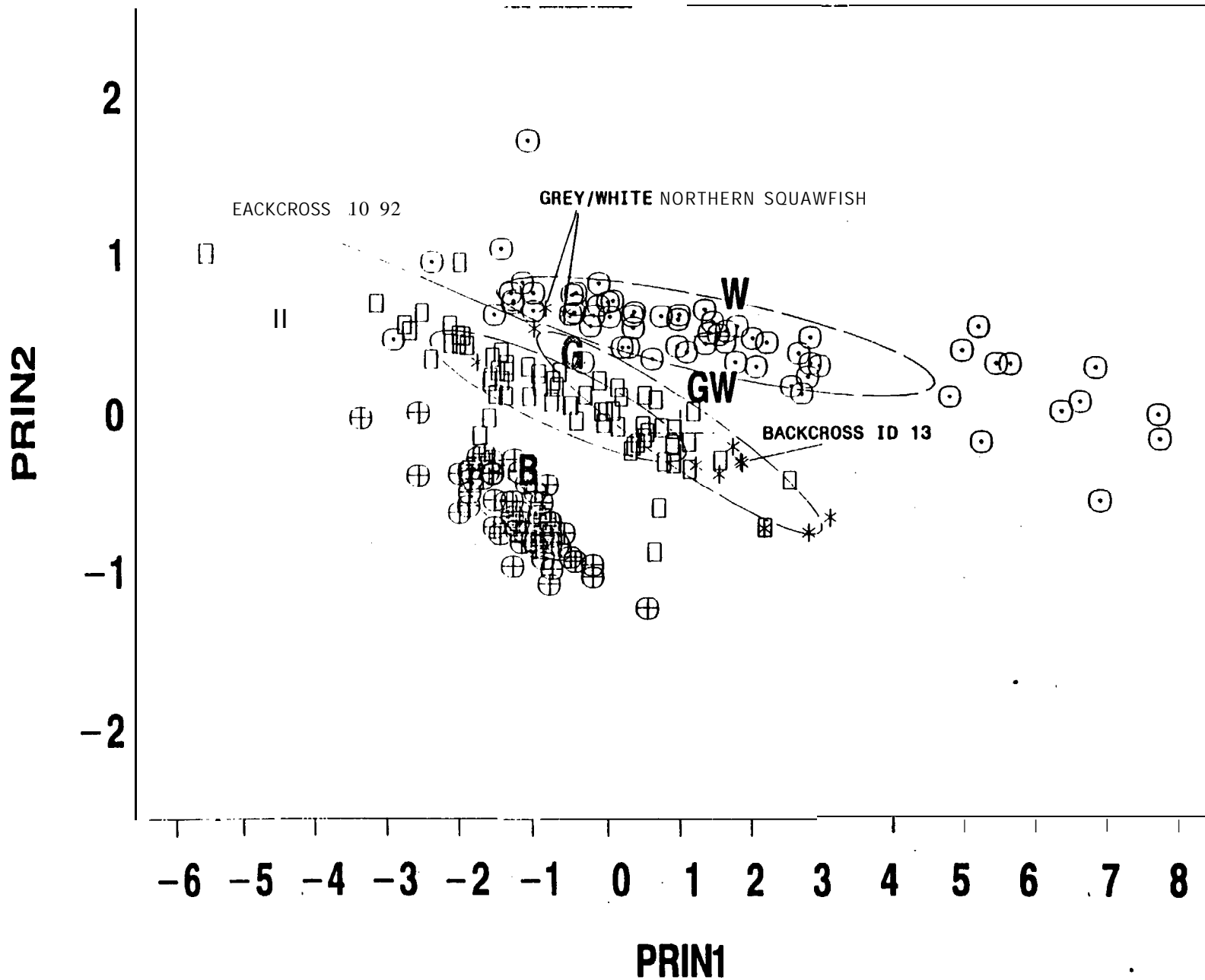


Figure 2. The first two principal components plotted by gut color: W = white, B = black, G = grey and GW = grey/white with 95% confidence ellipses. Prin1 accounts for 92% of the total variation and prin2 6%.

The 95% confidence ellipse drawn around the 18 piscivorous fish (10 northern squawfish and 8 F₁ hybrids) (Figure 3) covered a large portion of the northern squawfish ellipse, but only a small portion of the F₁ hybrids ellipse. The smallest piscivorous F₁ hybrids were longer than the smallest piscivorous northern squawfish (Figure 3). Four of the 8 grey/white hybrids found outside of the F₁ hybrid ellipses were found to be piscivorous.

The maternity of each fish was plotted in Figure 4 and no discernable morphometric differences were shown to result from the hybrids maternity.

Discussion

Although genetically similar, northern squawfish, chiselmouth and their hybrids were morphometrically distinct with the hybrids intermediate between the parents (Figure 1). The hybridization between northern squawfish and chiselmouth mixes the genes of the highly piscivorous northern squawfish and the completely non-piscivorous chiselmouth. The piscivorous nature of the northern squawfish prevails in the hybrid over the non-piscivorous nature of chiselmouth. Although the frequency of piscivorous F₁ hybrids was not significantly different ($P > .986$) from the frequency of piscivorous northern squawfish, we have not compared potential differences in their consumption rates. One form of piscivorous intermediacy in the F₁ hybrids was expressed by the hybrids tendency to become piscivorous at a greater standard length than northern squawfish (Figure 3).

Abdominal lining color was found to be a reliable discriminator of northern squawfish, chiselmouth and hybrids, since 97% of northern squawfish were found to have white lining, 97% of chiselmouth had black lining and all hybrids (F₁ and backcrossed) had either grey or grey/white lining. Both hybrid backcrosses had grey/white abdominal lining, but so did eight F₁ hybrids and two northern squawfish. Distinguishing F₁ hybrids from hybrid backcrosses using abdominal lining color was not found to be feasible at this time due to the small sample size of hybrid backcrosses and the genetic variability found in fish possessing grey/white lining. Morphometrically the grey/white northern squawfish fell within the 95% confidence ellipses for northern squawfish (Figure 2), which further validates the electrophoretic results. The classifying of abdominal lining color as black, grey, grey/white or white was somewhat subjective and may be a minor source of error in visually classifying hybrids and their parents. Distinctions between black and white were easy, but the difference in grey and grey/white or black and grey require further clarification.

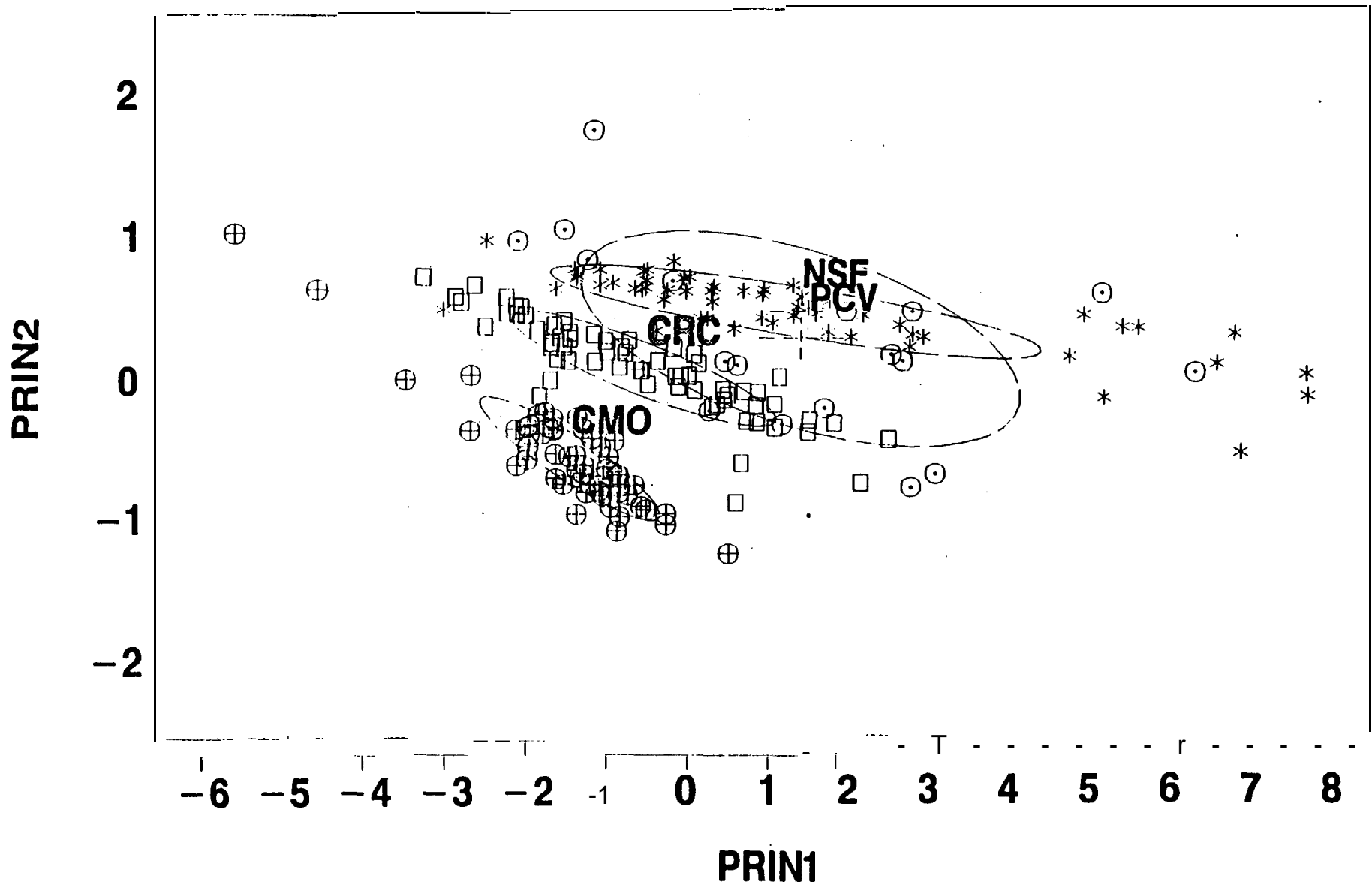


Figure 3. The first two principal components showing piscivorous fish (**PCV**): **CMO** =chiselmouth, **CRC** = FI hybrid and **NSF**= northern squawfish with 95% confidence ellipses. Prin1 accounts for 92% of the total variation and prin2 6%.

The ratio of standard length to jaw length could be used to identify F_1 hybrids. Researchers working in the Snake river can confidently identify these hybrids by taking two simple measurements (standard length and jaw length) and dividing them. Ratios between 12.5 and 20 can be considered hybrids. The sample size of hybrid backcrosses was too small to evaluate their ratios. The ratio of the northern squawfish backcross (11.7) fell, as expected, within the gray zone between northern squawfish and F_1 hybrids (11.5-12.5). The chiselmouth backcross ratio (13.07) was not close to the chiselmouth range (>2 1.5) and fell closer to the northern squawfish end of the F_1 hybrid range (12.5-20).

Morphometrically ID 92 (hybrid backcross with northern squawfish) falls at the edge of both the gray (hybrid) and white (northern squawfish) confidence ellipses (Figure 2), which verifies this fish to be, as expected, morphometrically intermediate to northern squawfish and F_1 hybrids. Hybrid backcross ID 13 was electrophoretically shown to be a chiselmouth backcross and morphometrically falls outside of the F_1 hybrid confidence ellipses towards the area of larger fish (Figure 2). ID 13 was not found to be morphometrically close to chiselmouth, like ID 92 was to northern squawfish. The maximum standard length (329 mm) and jaw length (13.9 mm) found in chiselmouth (Table 3) was less than the standard length (332 mm) and jaw length (25.4 mm) found in ID 13. Could hybrid backcrosses maintain the larger features of northern squawfish even when the F_1 hybrid backcrosses with a chiselmouth? The sample size of hybrid backcrosses was too small to make confident statements regarding the effect of backcrossing on their morphometrics. A larger sample of hybrid backcrosses should be collected, perhaps over time, to better understand the morphological affects of hybridization,

The stomach contents analysis found no significant difference ($P>.986$) in the piscivorous nature of northern squawfish and F_1 hybrids, which shows at least some similarity in their feeding habits. If we can assume that hybrids were similar in their feeding habits and therefore as catchable as northern squawfish, then the relative abundance of F_1 hybrids to northern squawfish in Lower Granite Reservoir was low. Additional research would be necessary to confidently evaluate hybrid abundance.

Northern squawfish maternity occurred more frequently (67%) than chiselmouth maternity (33%) in F_1 hybrids, but no discernable morphometric differences could be seen among F_1 hybrids based on maternity in the plot of principal components (Figure 4). Piscivorous behavior was also not found to significantly ($P>.454$) change based on the hybrids maternity. F_1 hybrid maternity was not considered to be an important variable in evaluating the F_1 hybrids.

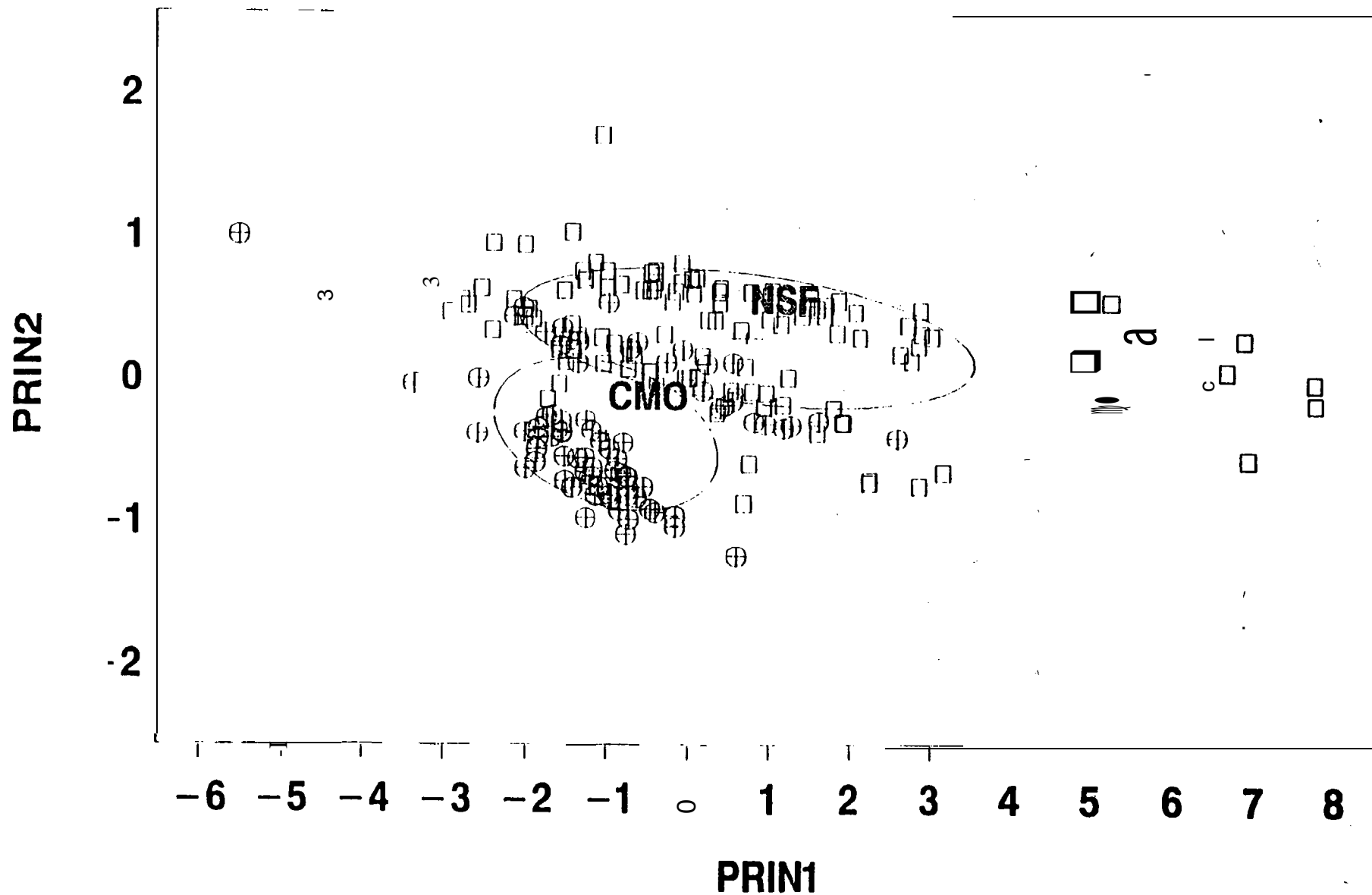


Figure 4. The first two principal components plotted by maternity: CMO=chiselmouth and NSF=northern squawfish with 95% confidence ellipses. Prin1 accounts for 92% of the total variation and prin2 6%.

The F_1 hybrids smaller mean jaw length (20.44 mm) than northern squawfish (30.87) and the principal component plot of piscivorous fish (Figure 3) indicate that F_1 hybrids need to obtain a longer length than northern squawfish to be capable of predation. The increased length F_1 hybrids must obtain to become predators could be offset by a faster growth rate. Further research should be conducted to estimate the hybrids grow rate relative to northern squawfish. Although the number of hybrids (F_1 and backcrossed) present in Lower Granite Reservoir is suspected to be low, we have shown these hybrids to be piscivorous and capable of reproduction, which is reason enough to recommend their inclusion in the sport-reward fishery reward program.

By lowering the numbers of northern squawfish, the sport-reward fishery could increase the frequency of hybridization. The abundance of F_1 hybrids and backcrosses should be monitored, since an increase in the frequency of hybridization could have dramatic effects on the genetic integrity of northern squawfish and chiselmouth, as well as, the dynamics of juvenile salmonid predation in the Snake River. Random Amplified Polymorphic DNA (RAPD) analysis should be investigated as a possible method of more confidently distinguishing between F_1 hybrids and hybrid backcrosses.

Management Recommendations

- A. Northern squawfish and chiselmouth hybrids should be included in the reward program for the sport-reward fishery.
- B. The relative abundance of these hybrids should be monitored at greenbelt registration station by comparing the hybrid to northern squawfish catch ratios among years. Increases in hybrid catch rates could indicate an increase in hybrid abundance. The hybrids can be identified using morphometric data and abdominal lining color.
- C. Provide Oregon Department of Fish and Wildlife with hybrid scale samples for age and growth analysis.
- D. Provide hybrid tissue samples to the University of Idaho Genetics Lab for RAPD analysis to develop reliable methods for distinguishing F_1 hybrids and backcrosses.

References

- Abersold, P. B., G. A. Winans, D. J. Teel, G.B. Milner, and F. M. Utter. 1987. Manual for starch gel electrophoresis: a method for the detection of genetic variation. NOAA Technical Report NMFS 61. U. S. Department of Commerce.

- Ali, M.Y., and C.C. Lindsey. 1974. Heritable and temperature induced meristic variation in the mendaka, *Oryzias latipes*. Canadian Journal of Zoology 52: 959-976.
- Avise, J. C., and M. J. Avyle. 1984. Genetic analysis of reproduction of hybrid white bass X striped bass in the Savannah Rivers. Transactions of the American Fisheries Society 113: 563-570.
- Barlow, G. W. 1961. Causes and significance of morphological variation in fishes. Systematic Zoology 10: 105-117.
- Beamesderfer, R.C., and B.E. Rieman. 1991. Abundance and distribution of northern squawfish, and smallmouth bass in John Day reservoir, Columbia river. Transactions of the American Fisheries Society Vol. 120 4: 439-447.
- Brown, W. M., M. George, and A. C. Wilson. 1979. Rapid evolution of animal mitochondrial DNA. Proc. Nat'l Acad. Sci. 76(4):1967-1971.
- Burley, C.C., D.C. Klaybor, G.W. Short, and G.J. Hueckel. 1993. Evaluation of the northern squawfish sport-reward fishery in the Columbia and Snake rivers, report B in C.F. Willis and A.A. Nigro, editors. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1991 Annual Report. Contract DE-BI1 79-90BP07084, Bonneville Power Administration, Portland, Oregon.
- Campton, D. E. 1987. Natural hybridization and introgression in fishes. In Population Genetics and Fishery Management, ed. N. Ryman and F. Utter (University of Washington Press, Seattle), 161 - 192.
- Ferris, S. D., R. D. Sage, and A. C. Wilson. 1982. Evidence of mtDNA sequences that common laboratory strains of inbred mice are descended from a single female. Nature 295: 163-165.
- Greenfield, D. W. and T. Greenfield. 1972. Introgressive hybridization between *Gila orcutti* and *Hesperoleucus symmetricus* (Pisces: Cyprinidae) in the Cuyama River Basin, California. I. Meristics, morphometrics and breeding. Copeia 1972: 849-859.
- Gyllensten, U., D. Wharton, and A. C. Wilson. 1985b. Maternal inheritance of mitochondrial DNA during backcrossing of two species of mice. Journal of Heredity. 76: 321-324.
- Howell, W. M. and J. Villa. 1976. Chromosomal homogeneity in two sympatric cyprinid fishes of the genus *Rhinichthys*. Copeia 1976: 112-116.

- Hubbs, C. L. 1955. Hybridization between fish species in nature. *Systematic Zoology* 4: 1-20.
- Hubbs, C. L., and L. C. Hubbs 1932. Experimental verification of natural hybridization between distinct genera of sunfishes. *Papers of the Michigan Academy of Science, Arts and Letters* 15: 427-437.
- Hubbs, C. L., and K. Kuronuma 1942. Hybridization in nature between two genera of flounder in Japan. *Papers of the Michigan Academy of Science, Arts and Letters* 27: 267-306.
- Hubbs, C. L., L. C. Hubbs, and R.E. Johnson. 1943. Hybridization in nature between species of catostomid fishes. *Contributions of the Laboratory of Vertebrate Biology, University of Michigan* 22: 1-77.
- Kilgen, R. H., and J. G. Ragan 1983. *Laboratory manual for ichthyology*. Morton Publishing Co., 295 West Hampden, Suite 104, Englewood, Colorado 80110.
- MacGregor, R. B., and H. R. MacCrimmon. 1977. Evidence of genetic and environmental influences on meristic variation in the rainbow trout, *salmo gairdneri* Richardson. *Environmental Biology of Fishes* 2:25-33.
- Neff, N. A., and G. R. Smith. 1979. Multivariate analysis of hybrid fishes. *Systematic Zoology* 28: 176-196.
- Petersen, J. H., D. B. Jepsen, R. D. Nelle, R.S. Shiverly, R.A. Tabor, and T.P. Poe. 199 1. System-wide significance of predation on juvenile salmonids in Columbia and Snake rivers. U. S. Fish and Wildlife Service, Contract number DE-AI79-90BP07096. 1990 Annual Report to Bonneville Power Administration, Portland, Oregon.
- Phelps, S.R., L.L. LeClair, S. Young, and H. L. Blankenship. 1994. Genetic diversity patterns of chum salmon in the Pacific Northwest. *Canadian Journal of Fisheries and Aquatic Sciences*. 5 1 (Suppl. 1): 65-83.
- Raney, E. 1940a. Nests under the water. *Bull. New York Zoological Society* 43: 127-135.
- Robison, B. 1995. Genetic relationship between maternal lineages of sympatric anadromous and resident forms of *Oncorhynchus nerka* determined through PCR-RFLP analysis. Master's Thesis, University of Idaho, Moscow, ID 83844.
- Ross, M. R., and T. M. Cavender. 1981. Morphological analyses of four experimental intergeneric cyprinid hybrid crosses. *Copeia* 1981 377-387.

- Schwartz, F. J. 1972. World literature to fish hybrids, with an analysis by family, species, and hybrid. Publications of the Gulf Coast Research Laboratory Museum, No. 3, 328 pp.
- Schwartz, F. J. 1981. World literature to fish hybrids, with an analysis by family, species, and hybrid: Supplement I. NOAA technical Report NMFS SSRF-750, U.S. Dept. of Commerce, 550 pp.
- Shaklee, J. B., F. W. Allendorf, D. C. Morizot, and G. S. Whitt. 1990. Gene nomenclature for protein-coding loci in fish. Transactions of the American Fisheries Society 119:2- 15.
- Smith, G.R. 1973. Analysis of several hybrid cyprinid fishes from western North America. Copeia 1973: 395-410.
- Todd, T.N., G. R. Smith, and L. E. Cable. 1981. Environmental and genetic contributions to morphological differentiation in ciscoes (Coregoninae) of the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences. 38: 59-67.
- Wilson, A. C., R. L. Cann, S. M. Carr, M. George, Jr., U. B. Gyllensten, K. M. Helm-Bychowski, R. G. Higuchi, S. R. Palumbi, E. M. Prager, R. D. Sage, and M. Stoneking. 1985. Mitochondrial DNA and two perspectives on evolutionary genetics. Biological Journal of the Linnaean Society 26: 375-400.
- Wydoski, R. S. and R.R. Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle.

Appendix Tables

Appendix Table 1. Baseline screening protocol. All gels 13cm wide.

Muscle

CAME6.8 [THICK GEL 35mm origin, 5 1/2 hrs @ 250V (max 90 mA)]

FH

IDHP & PGDH

ADA

PGK a+c scrape and stain AK

MEP & PGM a+c (3X G1P, 20mg oxaloacetate)

PEP-LT h PEPD

AAT c only

G3PDH a+c (c only if no anodal slices)

RW (nonzap) [THICK GEL 35mm origin, 5 hrs @ 80mA (max 400V)] LKB

EST-D scrape & stain LDH

AAT

GPI (2X F6P)

G3PDH

PEPB & PEPA

NTP (stain in fume hood) (500 mg Ascorbic Acid)

CK (on top slice if no bottom slice is available)

Tris-Gly [THICK GEL 35mm origin, 5 1/2 hrs @ 600V (max 90 mA)] LKB

FDHG

ADA

GPI (2X F6P)

ALAT (3X ADP & NAD)

MPI & PEPB (cut at the middle dye mark - top for MPI, bottom for PEPB)

PGM (3X G1P)

CK

CAM 6.0 [THIN GEL 40mm origin, 5 1/2 hrs @ 250V (max 75 mA)]

(blank)

FH

MEP & PGM a+c 20mg oxaloacetate

PEPB cathode only

MDH a+c (2X all ingredients)

Heart

EBT (nonzap) [THICK GEL 35mm origin, 5 hrs @ 80mA (max 400 V)]

Appendix Table 1. Baseline screening protocol cont.

AAT
PEPB & PEPA
PEPD
SOD
TPI
GR

CAME6.8N [Add 8ml of NAD buffer solution (1 5mg/ml) to the gel immediately

before degassing -- and add 2ml to cathodal electrode tray]
[THICK GEL 35mm origin, 5 1/2 hrs @ 250V (max 90 mA)]

AH
GAPDH
MEP (40 mg oxaloacetate)
G3PDH (2X all ingredients)
SOD
MDH (2X all ingredients) IDHP

Liver

CAME6.8 [THICK GEL 35mm origin, 5 1/2 hrs @ 250V (max 90 mA)]

MDH (2X all ingredients)

AH
PGK
IDHP
ADH (cathode only)
MEP
PGM (a+c)

RW (nonzap) [THIN GEL 35mm origin, 5 hrs @ 80mA (max 400V)] LKB

LDH
IDDH
bGLUA (bGA)
AAT
ADH (cathode only)

CAMS.8 [THIN GEL 35mm origin, 5 1/4 hrs @ 250V (max 75 mA)]

(blank)
bGLUA (bGA) a+ c
PEPB (cathode only)
MEP
AH

Appendix Table 1. Baseline screening protocol cont.

Tris-Gly [THIN GELS 35mm origin, 5 hrs @ 550V (max 75 mA)] LKB

IDDH
bGLUA
bGALA
AAT
AH

Eye

Tris-Gly [THIN GEL 35mm origin, 5 hrs @ 550V (max 75 mA)] LKB

AAT
CK (2X all ingredients)
TPI
MPI
LDH

CAM6.8 [THIN GEL 35mm origin, 4 hrs @ 250V (max 75 mA)]

GR
IDHP & PGDH
LDH
CK
PNP

Appendix Table 2. Loci, tissues and buffer system combinations screened in northern squawfish and chiselmouth chub to identify diagnostic loci and alleles.

<u>Locus</u>	<u>Buffer</u>	<u>Tissues</u>	<u>Use in this study</u>
AAT-1	CAME6.8	M, H	Species difference, mobilities of alleles too similar to be useful.
AAT-2	TRIS-GLY	M, H	Variable in NSF < 5%, Monomorphic in CMO
	LIOH-RW	M	Variable in NSF < 5%, Monomorphic in CMO
	EBT	H	Variable in NSF < 5%, Monomorphic in CMO
AAT-3	TRIS-GLY	E	Monomorphic
	LIOH-RW	L	Insufficient enzyme activity
ADA-1	TRIS-GLY	M	Variable in NSF > 5%, null allele in some NSF and all CMO. Not used due to a null allele.
to a null	CAME6.8	M	Variable in NSF > 5%, null allele in some NSF and all CMO. Not used due to a null allele.
ADH	CAME6.8	L	Diagnostic: NSF = 100, CMO = 139
mAH-1	CAME6.8	H	Monomorphic
mAH-2	CAME6.8	H	Monomorphic
sAH	CAME6.8	L	Diagnostic: NSF = 100, CMO = 160
	TRIS-GLY	L	Monomorphic
AK	CAME6.8	M	Monomorphic
ALAT	TRIS-GLY	M	Monomorphic
CK-1	LIOH-RW	M	Monomorphic
	TRIS-GLY	M	Monomorphic
CK-2	CAME6.8	E	Monomorphic
	TRIS-GLY	E	Monomorphic
CK-3	CAME6.8	E	Monomorphic
	TRIS-GLY	E	Monomorphic
ESTD	LIOH-RW	M	Species difference, mobilities of alleles too similar to be useful.
FBALD	TRIS-GLY	E	Monomorphic
FH	CAME6.8	M	Variable in CMO < 5%, Monomorphic in NSF
	CAM6.1	M	Species difference, mobilities of alleles too similar to be useful.
GAPDH-1	CAME6.8	H	Monomorphic
GAPDH-2	CAME6.8	H	Monomorphic
GR	CAME6.8	E	Monomorphic
	EBT	E	Monomorphic
bGLUA	TRIS-GLY	L	Not used: poor resolution
	LIOH-RW	L	Monomorphic
GPI-A	TRIS-GLY	M	Variable in NSF < 5%. Monomorphic in CMO
	LIOH-RW	M	Variable in NSF < 5%, Monomorphic in CMO
GPI-B	LIOH-RW	M	Variable in NSF and CMO > 5%
	TRIS-GLY	M	Variable in NSF and CMO > 5%
G3PDH-1	CAME6.8	M, H	Monomorphic
	TRIS-GLY	M	Monomorphic
G3PDH-2	CAME6.8	M, H	Possibly diagnostic, low activity

Appendix Table 2. Continued.

<u>Locus</u>	<u>Buffer</u>	<u>Tissues</u>	<u>Use in this study</u>
FDHG	TRIS-GLY	M	Monomorphic
IDDH-1	TRIS-GLY	L	Diagnostic: NSF = 100, CMO = 2 14
IDHP-1	CAME6.8	M, H, E	Monomorphic
IDHP-2	CAME6.8	L, H	Monomorphic
LDH- 1	LIOH-RW	M	Variable in NSF at < 5% and in CMO at > 5%
	TRIS-GLY	M	Variable in NSF at < 5% and in CMO at > 5%
LDH-2	CAME6.8	E	Variable in NSF at < 5% and monomorphic in CMO
	TRIS-GLY	E, M	Variable in NSF at < 5% and monomorphic in CMO
MDH-A	CAME6.8	H, L	Monomorphic
MDH-B	CAME6.8	M, H	Monomorphic
MEP-1	CAME6.8	M, H	Monomorphic - poor resolution
	CAM6.1	M	Monomorphic - poor resolution
MEP-2	CAME6.8	M, H	Monomorphic - poor resolution
	CAM6.1	M	Monomorphic - poor resolution
MPI	TRIS-GLY	M, E	Variable in NSF at > 5% and monomorphic in CMO
NTP	LIOH-RW	M	Variable in NSF at < 5% and monomorphic in CMO
PEPLT	CAME6.8	M	Monomorphic
PEPA	TRIS-GLY	M	Diagnostic: NSF = 100, CMO = 89
	LIOH-RW	M	Diagnostic: NSF = 100, CMO = 89
	EBT	H	Diagnostic: NSF = 100, CMO = 89
PEPD	CAME6.8	M	Variable in NSF and CMO at > 5%
	EBT	H	Variable in NSF and CMO at > 5%
	CAM5.8	M	Variable in NSF and CMO at > 5%
PEPB	CAMS.8	L, H	Diagnostic: NSF = -100, CMO = -143
	EBT	H	Possibly diagnostic
	TRIS-GLY	M	Possibly diagnostic
	LIOH-RW	M	Possibly diagnostic
PGDH	CAME6.8	M, E	Monomorphic
PGK	CAME6.8	M	Monomorphic
PGM	CAME6.8	M, L	Monomorphic
	CAM6.1	M	Monomorphic
	TRIS-GLY	M	Monomorphic
PNP	CAM6.8	E	No activity
SOD-1	CAME6.8	H	Species difference, mobilities of alleles too similar to be useful.
	LIOH-RW	M	Species difference, mobilities of alleles too similar to be useful.
	EBT	H	Monomorphic
SOD-2	EBT	H	Monomorphic
TPI- 1	TRIS-GLY	E	Monomorphic
TPI-2	TRIS-GLY	E	Monomorphic

Report B

Northern Squawfish Sport-Reward Payments

Prepared by

Russell G. Porter

**Pacific States Marine Fisheries Commission
45 S.E. 82nd Drive, Suite 100, Gladstone, OR 97202**

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INTRODUCTION

The Pacific States Marine Fisheries Commission (PSMFC) provided fiscal services for payment of the squawfish sport-fishery 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. Standard vouchers were issued for all fish over 11 inches that were not tagged. The number of fish turned in were recorded on vouchers and verified by the creel clerk. Tagged fish received a special tagged voucher. Tagged vouchers were issued for each individual tagged fish turned in. The vouchers were then sent by the angler to our “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 16, 1995, 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. Tagged vouchers were sent to the Oregon Department of Fish and Wildlife post office box by the angler for verification. The angler attached the tag to the voucher in a small envelope provided at the check station. Once verified or rejected by the Oregon Department of Fish and Wildlife, all tag vouchers were delivered to PSMFC for payment. Verified tag vouchers were paid at \$50 per tag and rejected tag vouchers were paid at the standard reward of \$3-\$5 per fish based on a tiered reward structure that was implemented for the first time this year. The following sections summarize the vouchers paid in 1995.

New in 1995 was the issuance of plastic “Pred-a-Cards” to participating anglers. These cards had the angler’s name, address and social security number embossed on the card. The angler used the card to register and to receive a voucher when fish were turned in at the check station, The card was designed to eliminate errors on vouchers because of the new tiered reward structure, and to speed up check out at the check station. A total of 1,799 anglers requested and were issued these cards. This represented a large majority of the successful anglers. A total of 3,078 separate anglers were successful in catching squawfish during the season and turned in at least one qualifying fish per voucher. Of this total, 2,719 were paid at the Tier 1 reward of \$3 (100 fish or less). A total of 235 anglers reached Tier 2 (\$4 per fish) where the total fish landed was 101-400 fish. A total of 124 anglers reached the Tier 3 level (\$5 per fish) and had over 400 fish caught,

VOUCHER PAYMENTS

A total of 21,253 vouchers were processed and paid during the 1995 fishing season. They represented 196,878 fish for a total possible reward payment of \$792,005. Of this total, 19,965 were standard vouchers representing 196,668 fish (\$781,505). Tagged fish were turned in on special tag vouchers that were designed for one fish per voucher. A total of 210 tagged vouchers were received for the 210 tagged fish caught. The payments for these fish totaled \$10,500. The breakdown of the 21,253 vouchers processed is summarized in Table 1.

Table 1. Summary of vouchers for the 1995 sport-reward fishery.

Voucher Type	# Vouchers	# Fish	\$ Value	Mean fish/voucher
Standard (\$3.00 - \$5.00)	19,965	196,656	\$781,456	9.85
Coupon (\$3.00)	(Received) 1,078	1,078	\$ 3,234	N/A
Tagged (\$50.00)	210	210	\$ 10,500	N/A

Voucher processing proceeded smoothly. Depending on volume received, checks were cut and mailed to the angler within 1-5 days after receipt of the voucher. Those vouchers that had missing or incomplete information were returned to the angler for completion, or to WDFW as appropriate.

UNPAID VOUCHERS/MISCELLANEOUS PAYMENTS

A total of 26 vouchers for 58 fish (\$174 - \$290) remained unpaid. These represent vouchers that had missing data and were returned to the angler, but the angler chose not to complete them and send them back for payment. Therefore, these vouchers were not paid and not counted in the totals under the **Voucher Payment** section.

In addition to the voucher payments, a number of tournaments, drawings and prizes were awarded during the season. The monetary amounts paid out for all parts of the program during 1995 are summarized in Table 2.

Table 2. Itemized pay-out schedule for the 1995 sport-reward fishery.

Program	\$ Paid
Standard Vouchers (@ Tiered Reward)	\$781,505
Tagged Fish Vouchers	\$ 10,500
Standard Voucher Coupons (1078)	\$ 3,234
Weekly Tournaments (195 Prizes)	\$ 48,750
Two Week Extension Tournaments (six remaining stations): (12 Prizes)	\$ 3,000
Special Tag Drawings (37 Prizes)	\$ 9,250
G.I. Joes Tournaments (21 Gift Certificate Prizes) (Not included in total)	\$ 5,950
Upper River Tournaments (18 Prizes paid in cash)	\$ 5,100
Total:	\$861,339

MISCELLANEOUS WORK

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 1996.

1995 SPORT-REWARD PAYMENTS SUMMARY

Table 3 is a summary of the vouchers received and paid as of the end of January 1996.

Table 3. Summary of vouchers received and paid as of the end of January 1996.

	Number	\$ Amount
TOTAL DOLLARS PAID OUT:		\$861,339
Total Fish Paid (including tags)	196,878	\$792,005
<i>[Excess Rewards Paid over "all" fish @ \$3]</i>		\$191,501
Fish Paid at Tier 1:	70,732	\$212,196
Fish Paid at Tier 2:	60,371	\$241,484
Fish Paid at Tier 3:	65,565	\$327,825
Tags Returned:	210	\$10,500
Tag Drawing Prizes (bi-weekly)	37 total*	\$9,250
<i>*Note: No winner @ Stations 8-9 for weeks 17-18, 19-20.</i>		
<i>No winner @ Stations 10-12 for weeks 21-22.</i>		
<i>Also: No winner @ Station 13 for weeks 3-4, 5-6, 11-12, & 21-22.</i>		
Coupons Returned:	1,078	\$3,234
Weekly Tournaments (all stations)	15total	\$48,750
Two Week Extension Tournaments (six remaining stations):		\$3,000
Total Tournaments:		\$51,750
June 17-25 Downriver: 21 prizes in G.I. Joe's gift certificates		\$5,950
July 1-9 Upriver: 18 prizes in cash		\$5,100
Number of Pred-a-cards ordered and/or issued		1,799
Number of Separate Anglers:		3,078
Anglers at Tier 3		124
Anglers at Tier 2		235
Anglers at Tier 1		2,719
Anglers with 10 fish or less		1,867
Anglers with 1-2 fish		816
Top Anglers:		
* 1. Ulyess Woody	(3,878 + 1 Tag)	\$18,940
* 2. Judith Strader	(3,119 + 1 Coupon)	\$15,098
* 3. Marjorie Tibbs	(2,789 + 3 Tags)	\$13,595
* 4. Terry Garrick	(2,749 + 1 Coupon)	\$13,248
<i>* (Note: Does not include drawings or tournament winnings)</i>		

Report C

**Controlled Angling and Longlining for Northern Squawfish
at Selected Dams on the Columbia and Snake Rivers**

Prepared by

**Ken Collis
Kathy McRae
Jack McCormack
Roy Beaty**

**Columbia River Inter-Tribal Fish Commission
729 NE Oregon, Suite 200, Portland, OR 97232**

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Personnel from the U.S. Army Corps of Engineers provided invaluable assistance in the completion of our work: Jim Kuskie and Dennis Schwartz (Bonneville Dam); Jim Williams and Bob Cordie (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 also wish to thank the Oregon Department of Fish and Wildlife (ODFW) for the use of its boat.

We thank Colleen Fagan, Keith Hatch, George Lee, Blaine Parker, Manuel Villalobos, and Jed Volkman for their comments on an earlier draft of this report

ABSTRACT

Field crews used hook-and-line and longlining techniques to catch northern squawfish (*Ptychocheilus oregonensis*) at eight mainstem dams on the lower Columbia and Snake rivers from May through August 1995. A total of 5,488 predator-sized (≥ 250 mm fork length) northern squawfish were caught using both gears (hook and line: 5,299; longline: 189) which was 33% of the 1994 catch. The catch per angler hour (CPAH) for hook-and-line angling was 0.7 in 1995, compared to 1.6 the previous year. Catch rates for longlines were 0.009 catch per hook hour (CPUE) or 28.4 hooks set per northern squawfish caught (hooks/northern squawfish), which was similar to previous longlining efforts. Overall hook-and-line angling effort was reduced (1995: 7,289 angler hours; 1994: 10,002 angler hours) in response to the almost universal decline in catch rates at Columbia and Snake River dams. These declines were likely caused by previous removals and increased spill at mainstem dams that resulted in a change in the distribution of northern squawfish and juvenile salmonids near dams. Boat angling effort was increased (1995: 943 angler hours; 1994: 771 angler hours) to target protected shoreline areas outside the reach of dam-based anglers where northern squawfish were presumed to reside during high spill periods. Overall catch rates for

boat angling were higher than for dam-based angling, particularly at John Day and McNary dams where boat angling was tested extensively. As in past years, effort in 1995 was augmented using volunteer anglers (northern squawfish catch: 391; effort: 694.7 angler hours; CPAH: 0.6), with a total of 12 sport-angling groups participating in the program in 1995, compared to four groups in 1994.

Incidental catch was 8.3% of the total hook-and-line catch and 12.9% of the longlining catch. Incidental catch increased for hook-and-line angling and decreased for longlining from previous years. White sturgeon (*Acipenser transmontanus*) constituted the largest percentage of the incidental catch for both hook-and-line (55%) and longlining (71%) fisheries. Five salmonids were caught by hook-and-line in 1995, compared to 12 in 1994, and all were either cut loose or unhooked and released in good condition. No salmonids were caught on longlines.

Catch rates of northern squawfish were compared to dam outflow; to smolt passage indices; and among anglers, time periods, baits, and sites at each dam. These results are briefly discussed and used in developing recommendations for future angling activities.

INTRODUCTION

The eight hydroelectric dams on the lower Columbia and Snake rivers have converted a once free-flowing river into a series of reservoirs that prolong the seaward migration of juvenile salmonids (*Oncorhynchus* spp). Reservoirs provide predatory fish with conditions more suitable for feeding, especially near dams (Raymond 1979; Rieman et al. 1991). A principal predator, northern squawfish (*Ptychocheilus oregonensis*), has been targeted for control in the lower Columbia and Snake rivers by the Columbia River Northern Squawfish Management Program to reduce juvenile salmonid mortality due to predation.

Northern squawfish can be effectively removed from areas near dams using hook-and-line angling (Vigg et al. 1990; Beaty et al. 1993; Parker et al. 1993; CRITFC 1994, 1995) and longlining techniques (Mathews et al. 1990, 1991, 1992). Over the past five years, hook-and-line angling crews have caught over 110,000 predator-sized (≥ 250 mm fork length) northern squawfish at eight dams on the lower Columbia and Snake rivers. From 1989 to 1992, longlines caught roughly 10,000 predator-sized northern squawfish, with seasonal catch rates as much as three times higher in areas near dams as compared to midreservoir locations (Mathews et al. 1992; Mallette et al. 1993).

In 1995, the Columbia River Inter-Tribal Fish Commission (CRITFC) and its member tribes endeavored to (1) remove northern squawfish from areas near dams

using hook-and-line angling and longling techniques; (2) minimize the incidental catch of salmonids, white sturgeon (*Acipenser transmontanus*), and other game fish; and (3) improve our effectiveness in carrying out these fisheries.

METHODS

Study Area

In 1995, effort was distributed among eight U.S. Army Corps of Engineer dams on the lower Columbia and Snake rivers (Table C-1, Figure C-1). Removal activities were confined to the boat-restricted zones (BRZs) at these dams, with most of our effort focused in the tailraces.

Additionally, northern squawfish incidentally captured in an upstream migration trap at Threemile Dam on the Umatilla River were enumerated and sacrificed. The methods used were the same as those described in Ashe et al. (1994). Results are in Appendix Table A- 1.

Crew Scheduling

Most of the hook-and-line angling effort and all the longlining effort was focused at Columbia River dams, where catch rates in previous years have been consistently higher (Tables C-1 and C-2). Snake River dams were fished by a single roving crew that spent a majority of its time at Lower Granite and Little Goose dams (Table C-2). Crews working on the Columbia River rotated between dams more than in previous years due to greater variation in productivity among dams (Table C-2).

Volunteer anglers augmented the effort of our technicians at selected dams on the Columbia River (Table C-2). In 1995, participation by volunteer sport-angling groups increased threefold from the previous year, with a total of 12 groups volunteering to work at least one four-hour shift during June and July (Table C-2). As many as eight individuals per group signed up to work shifts scheduled from Thursday through Sunday.

Table C-1. Distribution of predator removal effort at Columbia and Snake River dams in 1995. Crew-days worked includes days on which volunteer crews worked under the supervision of technicians.

River and dam	River km	Season	Number of crew-days worked
Columbia River			
Bonneville	233	May 8 - Aug 23	145
The Dalles	310	May 8 - Aug 23	62
John Day	348	June 26 Aug 29	49
McNary	470	May 25 - Aug 29	65
Snake River			
Ice Harbor	16	July 17 - July 20	3
Lower Monumental	68	July 25 - July 26	2
Little Goose	113	June 6 Sept 1	9
Lower Granite	172	May 15 - Aug 30	36

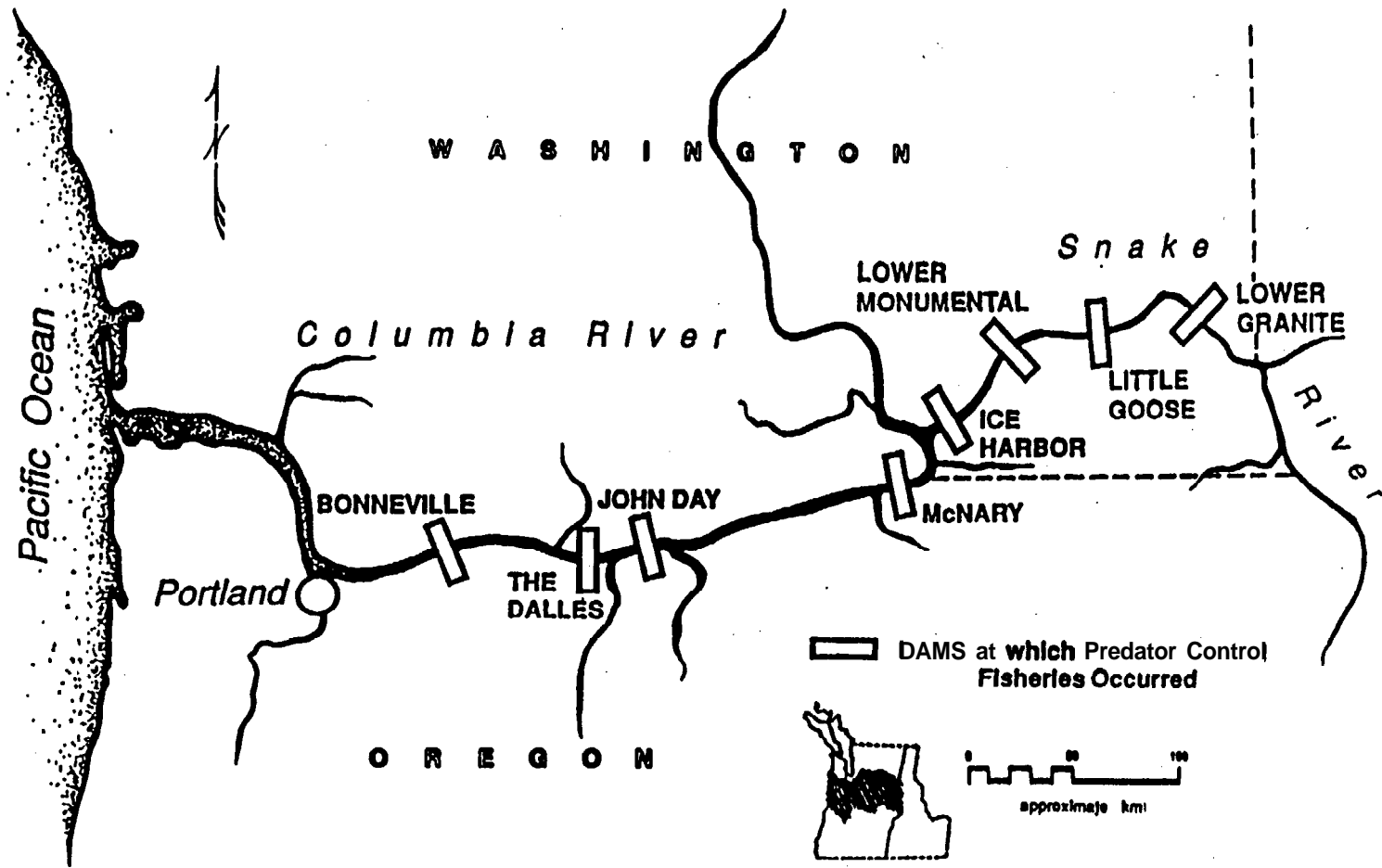


Figure C-1. Dams where controlled angling operations for northern squawfish were conducted in 1995.

Table C-2. Methods applied by crew type and organization for removal of northern squawfish at Columbia and Snake river dams in 1995.

Crew type and organization	Dam(s)	Dates (crew-days)
Dam Angling		
Technicians ¹ CRITFC	Bonneville, The Dalles, John Day, McNary	May 31 - Aug 23 (45)
CTUIR	John Day, McNary	May 25 - Aug 29 (53)
CTWS	Bonneville, The Dalles, John Day, McNary	May 8 - Aug 23 (82)
NPT	Little Goose, Lower Granite, Ice Harbor, John Day, Lower Monumental	May 15 - Sept 1 (51)
YIN	John Day	June 26 - Aug 29 (16)
Volunteer Crews		
Beaverton Steelheaders	Bonneville	June 25 - July 23 (3)
Chehalem Valley Steelheaders	Bonneville	June 24 (1)
McLoughlin Steelheaders	Bonneville	July 30 (1)
Mid-Columbia Bass Anglers	McNary	June 16 - July 14 (2)
Portland Steelheaders	Bonneville	June 3 - July 15 (4)
Salmon Corps	McNary	Aug 4 (1)
Sandy Steelheaders	Bonneville	June 9 - July 21 (4)
The Dalles Rod & Gun Club	The Dalles	June 15 - June 29 (3)
Tom McCall Steelheaders	Bonneville	June 17 - July 29 (4)
Tualatin Valley Steelheaders	Bonneville	June 3 - July 22 (4)
Warm Springs Ladies	Bonneville	July 9 - July 16 (2)
Yamhill River Steelheaders	Bonneville	June 10 (1)
Boat Angling		
Technicians ¹ CRITFC	Bonneville, The Dalles, John Day, McNary	June 30 - Aug 15 (20)
CTWS	The Dalles, McNary	Aug 14 - Aug 15 (2)
CTUIR	McNary	June 26 - Aug 29 (25)
YIN	The Dalles, John Day	June 27 - Aug 29 (30)
Longlining		
Technicians* CRITFC	Bonneville, The Dalles, John Day, McNary	July 11 - Aug 15 (23)

¹ CRITFC = Columbia River Inter-Tribal Fish Commission; CTUIR = Confederated Tribes of the Umatilla Indian Reservation; CTWS = Confederated Tribes of Warm Springs Reservation of Oregon; NPT = Nez Perce Tribe; YIN = Yakama Indian Nation

Field Procedures

In an attempt to increase 1995 production, crews tested hook-and-line angling and longlining gears. Hook-and-line angling equipment and techniques, including measures to minimize incidental catch, were essentially the same as those used the previous four years (Parker et al. 1993). Boats were again used to access areas within the BRZ outside the reach of dam-based hook-and-line anglers.

In 1995, longlining was tested within the BRZs to supplement hook-and-line angling. One mobile crew used both hook-and-line and longlining techniques and adjusted its effort in favor of whichever gear or combination of gears was most productive. The longline gear used was developed by the University of Washington to capture northern squawfish and is described in detail in Mathews et al. (1990). To minimize the impacts of longlines on white sturgeon, most lines were set near the surface and none were set on the river bottom. Also, lines were checked at least once every four hours and light-weight gangion leaders were used so that larger fish could break free from the longline. All incidentally caught fish were recorded and immediately released back into the river.

Northern squawfish were either kept in on-site freezers or coolers for rendering, or sacrificed and returned to the river. All tagged fish recovered were recorded and reported to the appropriate agencies.

Data Collection and Analysis

In 1995, data were collected as in previous years (Parker et al. 1993) using hand-held computers and transmitted daily via modem to CRITFC's Portland office. Anomalous data were identified using custom computer programs, then investigated and corrected if necessary. Weekly summary reports of catch and effort at each dam were provided to the Columbia Basin Fish and Wildlife Authority via an electronic bulletin board system.

Each crew was provided biweekly reports showing the relative productivity of different baits, sites, and time-periods at each dam. Crews used this information to set their daily work schedules and to select the most effective baits and sites at each dam.

Dam outflow and juvenile fish passage data were provided by the Fish Passage Center. Because daily values varied greatly, catch per angler hour (CPAH) was plotted against dam outflow and smolt passage indices using progressive averages, calculated from the most current seven days' values, for all variables.

Unless otherwise noted, all data summaries are for hook-and-line angling only. In general, longlining data are dealt with separately.

RESULTS AND DISCUSSION

Northern Squawfish Catch

In 1995, hook-and-line anglers caught 5,299 predator-sized northern squawfish in 7,289 hours of fishing, for a seasonal CPAH of 0.7 (Table C-3). Longlines caught 189 predator-sized northern squawfish in 21,072 hook hours, for a catch per hook hour (CPUE) of 0.009 or 28.4 hooks set per northern squawfish caught (hooks/northern squawfish; Table C-3; *see Angling Gear and Techniques* for further discussion of the relative effectiveness of different angling gears and techniques). Among-year comparisons of catch and effort for hook-and-line angling are provided in Appendix B and discussed below (*see Temporal Effects*).

Spatial Effects

In 1995, angling effort was concentrated at Columbia River dams, where catch rates were consistently higher than at Snake River dams (Appendix Table B-1). Crews at Columbia River dams caught 4,783 northern squawfish in 6,189 hours of effort for an overall CPAH of 0.8 (Table C-3). Anglers at Snake River dams captured 516 northern squawfish in 1,099 hours of effort, resulting in a CPAH of 0.5 (Table C-3).

Among Columbia River dams, the largest catch (2,422) and highest CPAH (1.2) were at Bonneville and John Day dams, respectively (Table C-3). The greatest angling effort (2,823 hours) was expended at Bonneville Dam, where catch rates had been high in previous years (Appendix Table B-1). On the Snake River, Little Goose Dam had the highest CPAH (1.0) and Lower Granite Dam had the largest catch (320) and greatest angler effort (798 hours; Table C-3). Relative catch rates indicate that more effort should have been expended at John Day and Little Goose dams to maximize our productivity in 1995 (Figure C-2).

Angling effort was focused in tailrace sites which were more productive than forebay sites (Table C-4). These results were consistent with results from previous years (Vigg et al. 1990; Beaty et al. 1993; Parker et al. 1993; CRITFC 1994, 1995). However, differences in productivity between the tailrace and forebay were less pronounced in 1995, perhaps due to increased spill (*see Dam Operations and Smolt Passage*).

Table C-3. Northern **squawfish** (NSF) catch and effort for dam and boat angling and longlining at Columbia and Snake river dams in 1995.

River and dam	Dam and boat angling			Longlining								Total NSF
	NSF	Effort (anlgar hrs)	CPAH ^a	NSF	# of hooks set	Hooks /NSF	# hooks/line	# of lines set	Effort (line hrs)	Effort (hook hrs)	CPUE ^b	
Columbia River												
Bonneville	2,422	2,823.1	0.9	16	900	56.2	69.2	13	47.9	3,314.7	0.005	2,438
The Dalles	409	919.7	0.4	5	450	90.0	90.0	5	17.3	1557.0	0.003	414
John Day	950	776.7	1.2	144	2,724	18.9	77.8	35	161.4	12,556.9	0.011	1,094
McNary	1,002	1,669.8	0.6	24	1,289	53.7	71.6	18	52.5	3,759.0	0.006	1,026
Total	4,783	6,189.3	0.8	189	5,363	28.4	75.5	71	279.1	21,072.0	0.009	4,972
Snake River												
Ice Harbor	9	80.3	0.1	—	—	—	—	—	—	—	—	9
Lower Monumental	1	38.1	0.0	—	—	—	—	—	—	—	—	1
Little Goose	186	182.9	1.0	—	—	—	—	—	—	—	—	186
Lower Granite	320	798.2	0.4	—	—	—	—	—	—	—	—	320
Total	516	1,099s	0.5	—	—	—	—	—	—	—	—	516
Grand Total	5,299	7,288.8	0.7	189	5,363	28.4	75.5	71	279.1	21,072.0	0.7	5,488

^a CPAH = catch-per-angler-hour

^b CPUE = catch-per-longline-hour

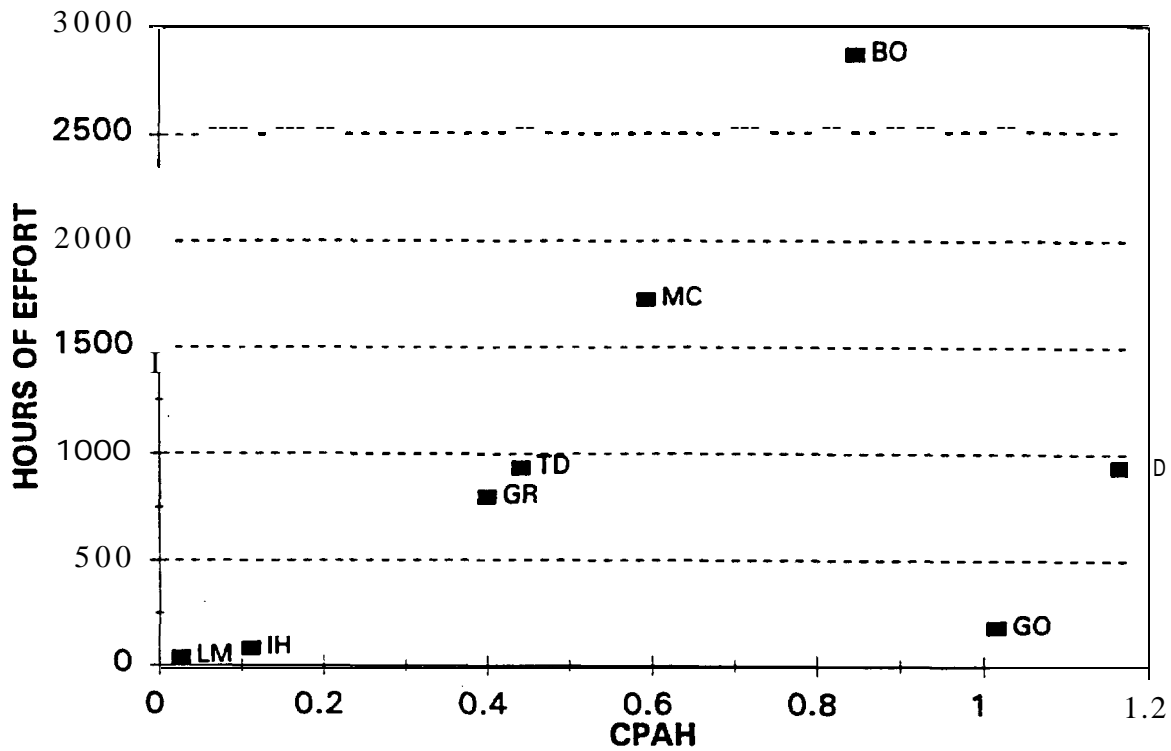


Figure C-2. Seasonal catch per angler hour (**CPAH**) and total hours fished at Columbia and Snake river dams in 1995. BO = Bonneville; TD = The Dalles; JD = **John** Day; MC = **McNary**; IH = Ice Harbor; LM = Lower **Monumental**; GO = Little Goose; GR = Lower Granite.

Table C-4. Northern **squawfish** (NSF) catch, angler hours (effort), and catch per angler hour (CPAH) in **tailrace** and **forebay** fishing sites at Columbia and Snake River dams in 1995. Includes only those dams where both **forebay** and **tailrace** sites were fished.

River and dam	Forebay			Tailrace		
	NSF	Effort	CPAH	NSF	Effort	CPAH
Columbia River						
Bonneville	503	757.2	0.7	1,935	2,113.9	0.9
The Dalles	5	19.6	0.3	409	917.4	0.4
John Day	0	1.3	0.0	1,094	936.8	1.2
McNary	7	20.6	0.3	1,019	1,701.6	0.6
Total	515	798.7	0.6	4,457	\$669.7	0.8
Snake River						
Little Goose	23	29.0	0.8	163	153.8	1.1
Lower Granite	12	39.4	0.3	308	758.8	0.4
Total	35	68.4	0.5	471	912.6	0.5
Grand Total	550	867.1	0.6	4,928	6,582.3	0.7

Temporal Effects

Hook-and-line angling catch (5,299 fish) for the 1995 season was 33% of the 1994 catch (Appendix Table B-1). The overall CPAH for hook-and-line angling also declined from 1.6 in 1994 to 0.7 in 1995 (Appendix Table B-1). In 1995, hook-and-line angling effort was reduced 27% from 1994 levels (Appendix Table B-1) in response to the decline in catch rates at all Columbia and Snake river dams except Little Goose. These declines were likely caused by previous removals and increased spill at **mainstem** dams that changed the distribution of northern squawfish and juvenile salmonids near dams (*see Dam Operations and Smolt Passage*; Faler et al. 1988; Hansel et al. 1994; Isaak and Bjornn 1994). Among-year comparisons of catch and effort of northern squawfish for 1991 through 1995 are in Appendix Table B-1.

Declines in catch and catch rate in 1995 from the previous year were more pronounced at Columbia River dams than at Snake River dams (Appendix Table B-1). Northern squawfish catch on the Columbia River (4,783) was 31% of the 1994 catch, whereas catch on the Snake River (516) in 1995 was 68% of the catch the previous year. CPAH declined 0.9 and 0.2 fish per angler hour from 1994 to 1995 at Columbia and Snake River dams, respectively. The biggest declines in catch rate were at The Dalles and Bonneville dams. There are many possible explanations for these declines. First, large numbers of northern squawfish were removed from locations in the vicinity of Bonneville and The Dalles dams (S. Smith, WDFW, personal communication), perhaps depleting the local populations of northern squawfish that may immigrate into these areas to feed. Additionally, the tailraces at these dams are far larger in area than at the other dams, making it more difficult to locate concentrations of northern squawfish that might be smaller and more dispersed as a result of increased spill (*see Dam Operations and Smolt Passage*),

Little Goose Dam was the only dam where catch rate increased from 1994 (0.5) to 1995 (1.0; Appendix Table B-1). This increase was largely due to a more focused effort at Little Goose Dam late in the season, when catch rates were high, presumably because spill had been terminated (Appendix Table A-2; *see Dam Operations and Smolt Passage*; Isaak and Bjornn 1994).

In 1995, monthly northern squawfish catch, effort, and CPAH were highest in July and August at Columbia and Snake River dams, respectively (Figure C-3). Weekly catch rates at Columbia River dams indicate that an earlier start at John Day Dam may have been productive (Figure C-4). Weekly totals of catch, effort, and CPAH at Snake and Columbia River dams in 1995 are listed in Appendix Tables A-2 and A-3. Comparisons of weekly CPAH among years at Columbia and Snake River dams are provided in Appendix Figures B-1 through B-4.

Although there are differences among individual dams, the highest CPAH at Columbia River dams was from 6:01 p.m. to 12 a.m. and from 6:01 a.m. to 12 p.m. at Snake River dams (Table C-5).

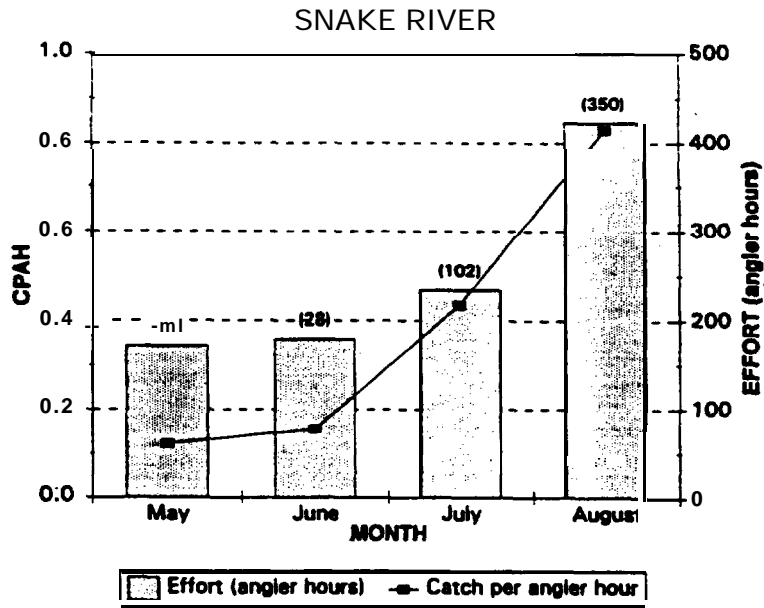
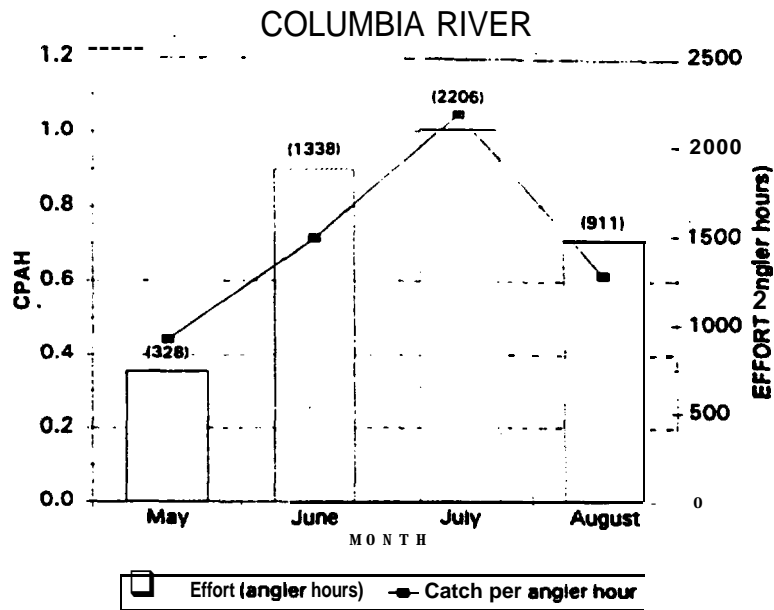


Figure C-3. Monthly northern squawfish catch (in parentheses), catch per angler hour (CPAH), and effort at Columbia and Snake river dams in 1995.

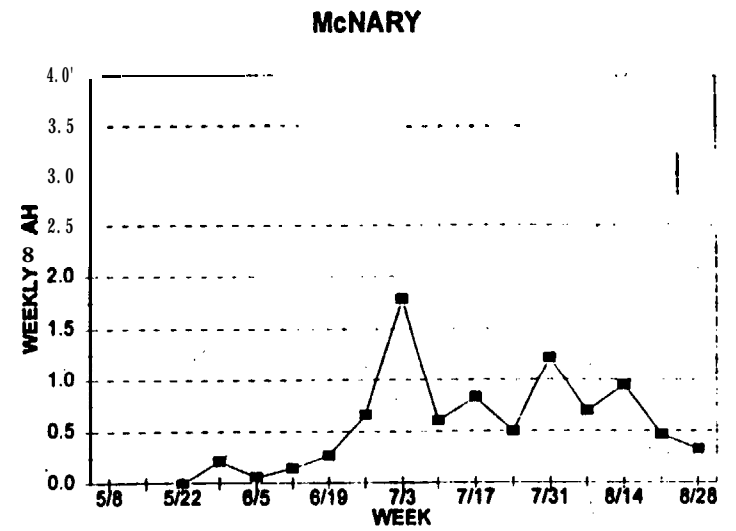
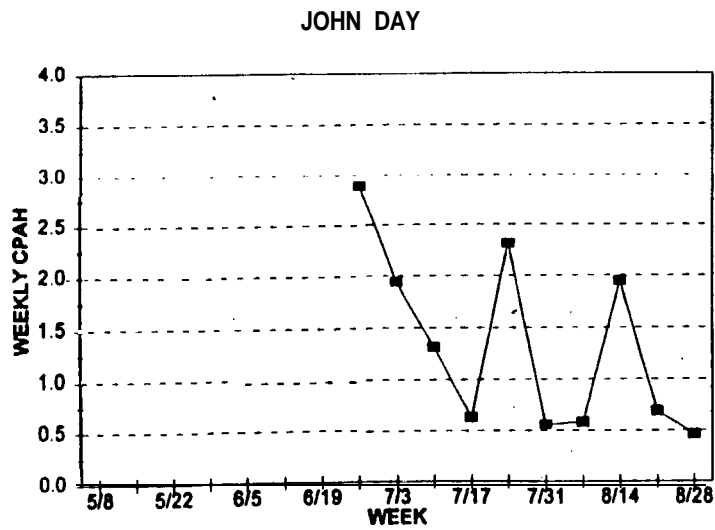
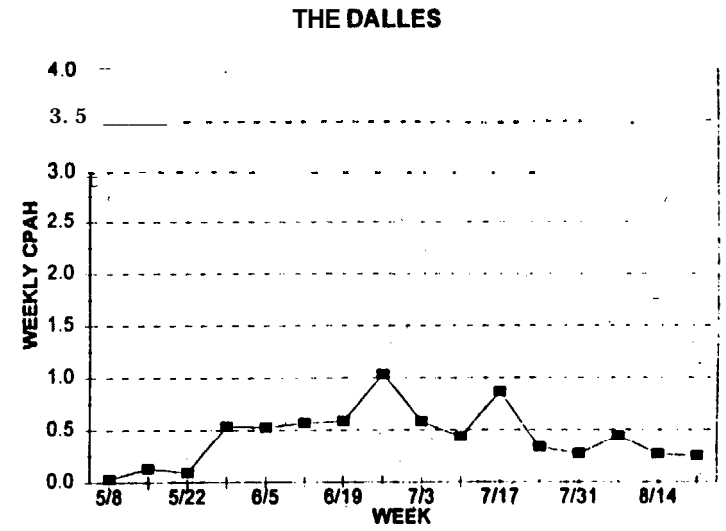
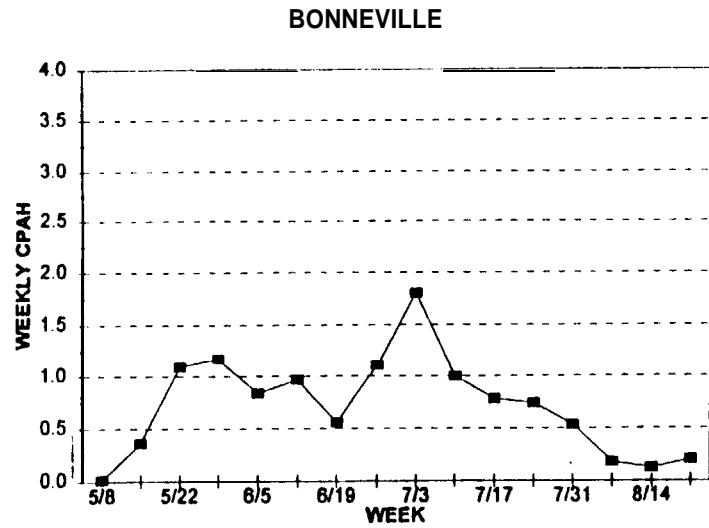


Figure C-4. Weekly average catch per angler hour (CPAH) of northern squawfish at Columbia River dams in 1995.

Table C-5. Northern **squawfish** (NSF) catch, angler hours (effort), and catch per angler hour (CPAH) for dam- and boat-angling (combined) during four different **diel** periods at Columbia and Snake river dams in 1995.

River and dam	0001-0600			0601-1200			1201-1800			1801-2400		
	NSF	Effort	CPAH	NSF	Effort	CPAH	NSF	Effort	CPAH	NSF	Effort	CPAH
Columbia River												
Bonneville	129	237.7	0.5	160	245.9	0.7	533	700.0	0.8	1600	1,639.5	1.0
The Dalles	39	167.1	0.2	44	102.1	0.4	70	230.4	0.3	256	420.2	0.6
John Day	37	65.1	0.6	30	52.9	0.6	267	239.3	1.1	616	419.5	1.5
McNary	109	295.5	0.4	175	265.7	0.7	371	539.6	0.7	347	568.9	0.6
Total	314	765.4	0.4	409	666.6	0.6	1,241	1,709.3	0.7	2819	3,048.0	0.9
Snake River												
Ice Harbor	—	—	—	3	35.4	0.1	5	35.6	0.1	1	9.4	0.1
Lower Monumental	0	6.0	0.0	1	32.1	0.0	—	—	—	—	—	—
Little Goose	2	14.2	0.1	168	134.0	1.3	16	34.7	0.5	—	—	—
Lower Granite	53	152.6	0.3	212	440.4	0.5	54	190.4	0.3	1	14.8	0.1
Total	55	172.9	0.3	384	641.9	0.6	75	260.6	0.3	2	24.1	0.1
Grand Total	369	938.2	0.4	793	1,308.4	0.6	1,316	1,970.3	0.7	2,821	3,072.2	0.9

Angling Gear and Techniques

A variety of gear and techniques were used in 1995 to increase productivity. These different methods allow greater flexibility in adapting to changes in the distribution, feeding habits, and other behaviors that affect catchability of northern squawfish. Increased spill, for example, causes northern squawfish to seek out more protected shoreline areas away from the dam (Faler et al. 1988; Hansel et al. 1994; Isaak and Bjornn 1994), rendering dam-based angling less effective (*see Dam Operations and Smolt Passage*). In 1995, boat angling effort was increased (1994: 771 hours; 1995: 943 hours) to target concentrations of northern squawfish outside the reach of dam-based anglers. Overall catch rates for boat angling were higher than for dam-based angling, particularly at John Day and McNary dams, where boat angling was tested extensively (Table C-6). Despite higher catch rates using boats, CPAH's declined from previous years, suggesting that some northern squawfish may move out of the boat restricted zone (BRZ) as a result of spill and/or they are less concentrated within the BRZ and, therefore, more difficult to locate.

When first tested as part of the Northern Squawfish Management Program, longlining had great promise as a removal method, especially when deployed near dams (Mathews et al. 1990, 1991, 1992). Later efforts that deployed longlines exclusively in non-BRZ locations, with many lines set on or near the river bottom, were not productive and had an unacceptably high bycatch of white sturgeon (Malette et al. 1993).

In 1995, we deployed longlines in the BRZs at Columbia River dams, with most lines set on the surface of the water. Limited effort (279.1 longline hours or 21,072.0 hook hours) produced a catch of 189 predator-sized northern squawfish and a catch per hook hour (CPUE) of 0.009, or 28.4 hooks/northern squawfish (Table C-3), comparable to results from early longlining efforts (1989- 1991: 24.7 hooks/northern squawfish; Mathews et al. 1992). Catch rates of northern squawfish varied by depth and longline set type (Table C-7). In general, midwater (CPUE = 0.012; hooks/northern squawfish = 23.7) sets were more productive than surface (CPUE = 0.008; hooks/northern squawfish = 29.9) sets, with a vertical midwater longline set producing the highest catch rate (CPUE = 0.016; hooks/northern squawfish = 18.5; Table C-7). Incidental catch results for longlining are discussed below (*see Incidental Catch*).

Table C-6. Northern squawfish (NSF) catch, angler hours (effort), and catch per angler hour (CPAH) for dam- and boat-angling (combined) at Columbia and Snake river dams in 1995.

River and dam	Dam angling									Boat angling		
	Technicians			Volunteer crews			Total			NSF	Effort	CPAH
	NSF	Effort	CPAH	NSF	Effort	CPAH	NSF	Effort	CPAH			
Columbia River												
Bonneville	2,038	2,201.5	0.9	364	587.7	0.6	2,402	2,789.2	0.9	20	33.9	0.6
The Dalles	377	828.5	0.5	17	48.1	0.4	394	876.6	0.4	15	43.2	0.3
John Day	163	184.0	0.9	—	—	—	163	184.0	0.9	787	592.7	1.3
McNary	730	1,337.5	0.5	10	58.9	0.2	740	1,396.4	0.5	262	273.3	1.0
Total	330	4,551.5	0.7	391	694.7	0.6	3,699	\$246.2	0.7	1,084	943.1	1.1
Snake River												
Ice Harbor	9	80.3	0.1	—	—	—	9	80.3	0.1	—	—	—
Lower Monumental	1	38.1	0.0	—	—	—	1	38.1	0.0	—	—	—
Little Goose	186	182.9	1.0	—	—	—	186	182.9	1.0	—	—	—
Lower Granite	320	798.2	0.4	—	—	—	320	798.2	0.4	—	—	—
Total	516	1,099.5	0.5	—	—	—	516	1,099.5	0.5	—	—	—
Grand Total	3,824	\$651.0	0.7	391	694.7	0.6	4,215	6,345.7	0.7	1,084	943.1	1.1

Table C-7. Northern squawfish (NSF) catch and effort for different longline set types at Columbia and Snake river dams in 1995.

Depth and set type	NSF	# of hooks set	Hooks/ NSF	# of lines set	# hooks/ line	Effort (line hrs)	Effort (hook hrs)	CPUE ^a
Mid-water								
Horizontal set	3	90	30.0	1	90.0	5.1	459.0	0.006
Vertical set	34	630	18.5	9	70.0	30.5	2,135.0	0.016
"W" set ^b	1	64	64.0	1	64.0	1.8	115.2	0.009
"V" set ^c	8	308	38.5	4	77.0	15.5	1,193.5	0.007
Total	46	1,092	23.7	15	72.8	52.9	3,851.1	0.012
Surface								
Horizontal set	143	4,271	29.9	56	76.3	226.2	17,259.1	0.008
Total	143	4,271	29.9	56	76.3	226.2	17,259.1	0.008
Grand Total	189	5,363	28.4	71	75.5	279.1	21,072.0	0.009

^a CPUE = catch-per-longline-hour

^b "W" set was a line with the **ends** and middle on the surface and the line between hanging below the surface to form a "W".

^c "V" set was a line with the **ends** on the surface and the line between hanging below **the** surface to form a "V".

As in past years, hook-and-line angling in 1995 was augmented by using volunteer anglers (northern squawfish catch: 391; effort: 694.7; CPAH: 0.6; Table C-6). A total of 12 sport-angling groups participated in the program in 1995 (Table C-2), compared to four groups in 1994 (CRITFC 1995). There were 143 individual volunteers in 1995, compared to 61 from the previous year. In 1995, 84% of the volunteer effort was at Bonneville Dam because the majority of the volunteer groups were from the Portland area and found work at Bonneville Dam to be most convenient. Volunteer angling continues to be an important part of our dam-angling program. Not only does it provide a cost-effective way to catch northern squawfish, but it also provides an opportunity to educate the public about the Northern Squawfish Management Program.

Catch rates varied by angler at each dam (Figure C-5), probably due to differences in angler ability or technique, bait selection (Table C-S), and choice of fishing site (see *Spatial Effects*). Overall, catch rates were highest using hard plastic lures (CPAH = 1.1), followed by soft plastic lures (CPAH = 0.7), which were used most often by anglers (Table C-8; see for relative effectiveness of different baits by dam). We will continue to try to recruit and hire experienced hook-and-line anglers and provide them with inseason information (e.g., reports showing the relative productivity of different baits, sites, and time periods at each dam) to improve their effectiveness.

Dam Operations and Smolt Passage

When discharge rates at hydroelectric dams are high, as was the case in 1995, predator-prey interactions within the tailrace BRZ are probably affected. Increased flow affects both the ability of northern squawfish to hold in areas preferred for feeding and the distribution and residence time of juvenile salmonids near dams (Faler et al. 1988; Mesa and Olson 1993; Hansel et al. 1994; Isaak and Bjornn 1994). During periods of high discharge at McNary Dam, radio-tagged northern squawfish residing near the dam moved more than 2.5 km downstream, only to move back again when discharge decreased (Faler et al. 1988). Those fish that remained within the tailrace during high flow periods were found outside the main river channel (Faler et al. 1988) — in backwaters and protected shoreline areas — through which juvenile salmonids migrate.

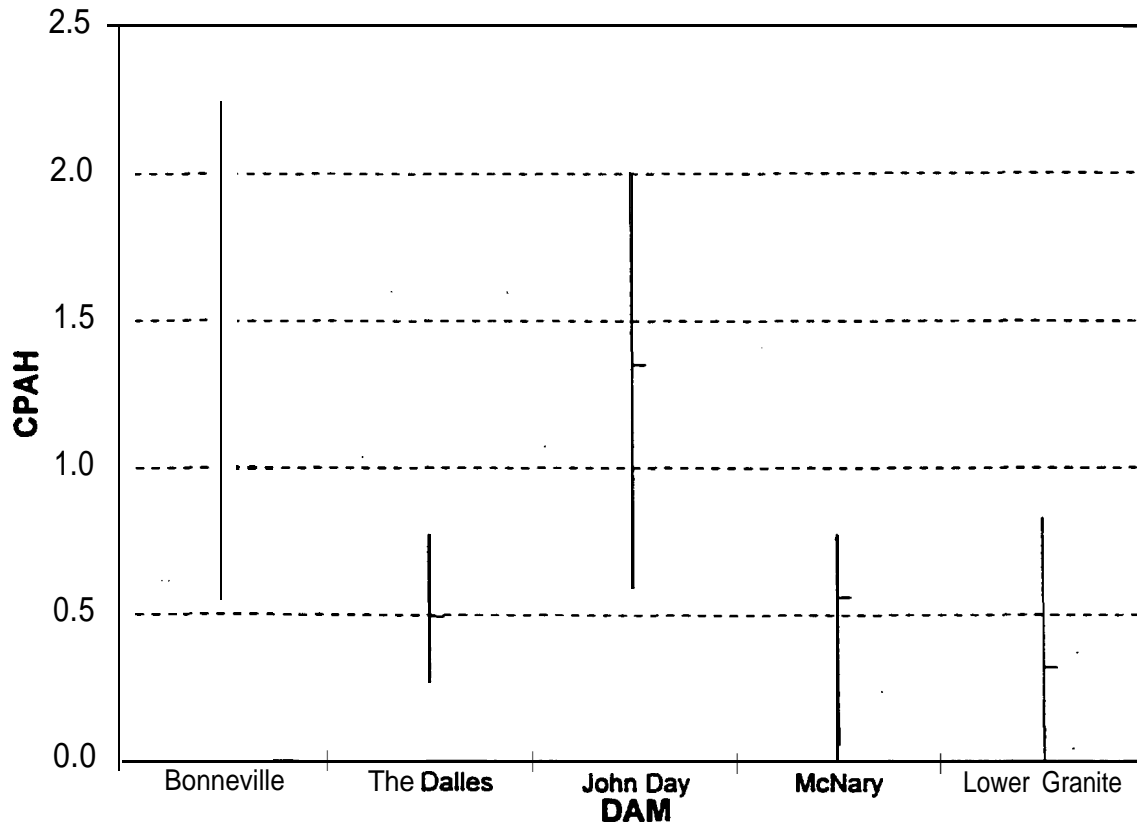


Figure C-5. Range in catch per angler hour (CPAH) for individual anglers at each dam. Volunteer angling crews and anglers who worked fewer than 50 hours are not included. Average catch per angler hour at each dam is indicated by a horizontal mark.

Table C-8. Northern squawfish (NSF) catch, angler hours (effort), and catch per angler hour (CPAH) for baits used at Columbia and Snake River dams in 1995.

Dam	Season totals by dam				Season totals by river system			
	Bait ^a	NSF	Effort	CPAH	Bait ^a	NSF	Effort	CPAH
Bonneville	HPO	857	738.4	1.2	Columbia River			
	SPO	1,468	1,808.5	0.8	HPO	1,374	1,241.8	1.1
	MIS	3	3.8	0.8	MIS	3	3.8	0.8
	NBO	91	250.7	0.4	SPO	3,064	4,313.8	0.7
	CL0	3	20.8	0.1	NBO	326	568.4	0.6
	HML	0	1.1	0.0	CL0	16	50.6	0.3
The Dalles	SPO	339	695.6	0.5	HML	0	11.0	0.0
	HPO	58	126.0	0.5	Snake River			
	CL0	1	3.5	0.3	HML	4	6.8	0.6
	NBO	11	94.0	0.1	CL0	237	451.4	0.5
	HML	0	0.7	0.0	SPO	125	249.1	0.5
John Day	NBO	101	48.3	2.1	HPO	19	48.1	0.4
	HPO	379	255.1	1.5	NBO	131	334.1	0.4
	SPO	462	463.7	1.0	MIS	0	10.1	0.0
	CL0	8	9.1	0.9	Grand Total			
	HML	0	0.5	0.0	HPO	1,393	1,289.9	1.1
McNary	NBO	123	175.4	0.7	SPO	3,189	4,562.8	0.7
	HPO	80	122.3	0.7	NBO	457	902.4	0.5
	SPO	795	1,346.0	0.6	CL0	253	501.9	0.5
	CL0	4	17.2	0.2	HML	4	17.8	0.2
	HML	0	8.8	0.0	MIS	3	13.9	0.2
Ice Harbor	CL0	6	30.4	0.2				
	NBO	3	20.9	0.1				
	HML	0	0.8	0.0				
	HPO	0	3.1	0.0				
	MIS	0	5.6	0.0				
	SPO	0	19.5	0.0				
	CL0	1	31.1	0.0				
Lower Monumental	HPO	0	2.6	0.0				
	NBO	0	3.4	0.0				
	SPO	0	1.0	0.0				
	CL0	54	51.5	1.0				
Little Goose	SPO	76	73.3	1.0				
	NBO	56	55.6	1.0				
	HPO	0	2.2	0.0				
	MIS	0	0.3	0.0				
	HML	4	5.9	0.7				
Lower Granite	CL0	176	338.4	0.5				
	HPO	19	40.2	0.5				
	SPO	49	155.2	0.3				
	NBO	72	254.1	0.3				
	MIS	0	4.3	0.0				

^a Bait descriptions:

HPO = Hard Plastic (such as Rat-L-Traps, Rapalas, and other plugs)

SPO = Soft Plastic (such as grubs, tubes, fish-like grubs)

MIS = Miscellaneous (items not in any of the above categories)

NBO = Natural Bait (such as salmon smolts, lamprey, worms)

CL0 = Combination Lures (any combination of the classes listed above)

HML = Hard Metal Lures (such as spoons, spinners, Zonars)

We expect that a major cause for the significant decline in catch rates of northern squawfish at most dams in 1995 was due to increased spill. Our data, although cursory, seems to provide some support for this hypothesis. There appears to be an inverse relationship between outflow and CPAH in the short term at many dams; that is, local peaks in CPAH often coincide with declines in discharge (Figures C-4 and C-7; CRITFC 1995). Also, peaks in catch rate of northern squawfish often coincide with periods of increased juvenile salmonid passage at some dams, particularly when passage periods occur when outflow rates are low (Figures C-6 and C-7; CRITFC 1995). Boat angling within the BRZ was more effective in catching northern squawfish than dam-based angling (Table C-6; *see Angling Gear and Techniques*), presumably because boats allowed anglers access to areas away from the dam where some northern squawfish reside during high spill periods. Furthermore, increases in the 1995 catch of northern squawfish in the sport-reward fishery conducted outside the BRZs might be partially explained by greater availability of northern squawfish to sport anglers due to spill-induced movements of northern squawfish from areas near dams (i.e., BRZs) to midreservoir locations (WDFW unpublished data). Assuming predation rates are higher near dams than at midreservoir locations (Raymond 1979, Rieman et al. 1991), these results support a management approach that uses high spill in dam tailraces to disperse both northern squawfish and juvenile salmonids, and, in turn, to reduce predation rates on outmigrating juvenile salmonids (Faler et al. 1988; Mesa and Olson 1993; Shively et al., in press).

Incidental Catch

Incidental catch was 8.3% of the total hook-and-line catch (Appendix Tables A-4 and A-5; Appendix Figure B-5), compared to 12.9% for longlining (Figure C-8). These percentages represent an increase in incidental catch for hook-and-line angling from previous years (1991: 7.9%; 1992: 5.8%; 1993: 5.5%; 1994: 2.3%; Appendix Figure B-5) and a decrease for longlining (1989: 31%; 1990: 27%; 1991: 34%; 1992: 64%; Mathews et al. 1992). White sturgeon constituted the largest percentage of the incidental catch for both hook-and-line (55%; Appendix Tables A-4 and A-5) and longlining (71%) fisheries. The catch rate of white sturgeon did not differ for surface (CPUE = .07) and midwater (CPUE = .07) longline sets.

Five salmonids were caught by hook and line in 1995, compared to 12 in 1994. All were either cut loose or unhooked and released in good condition (Appendix Table A-6). No salmonids were caught on longlines (Figure C-8). See Appendix Tables A-6 through A-9 for incidental catch summaries for individual dams.

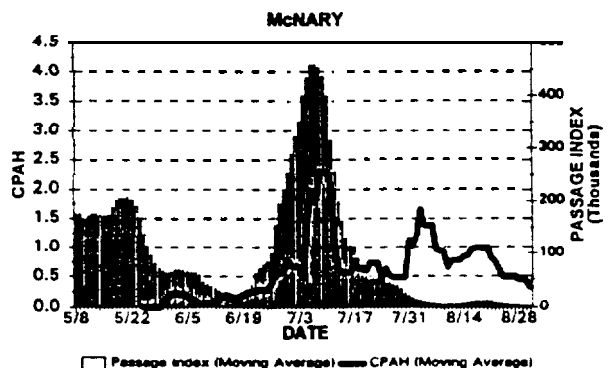
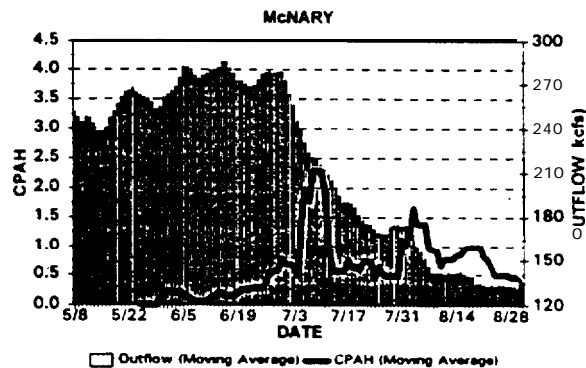
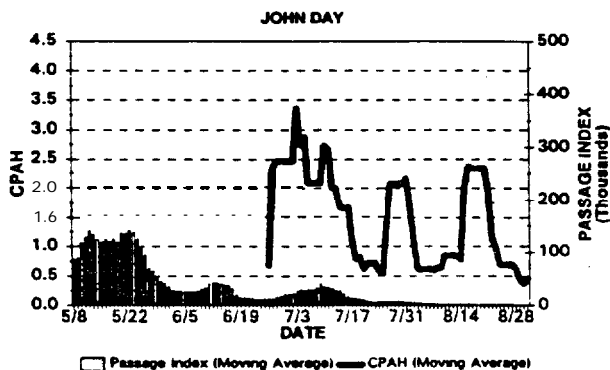
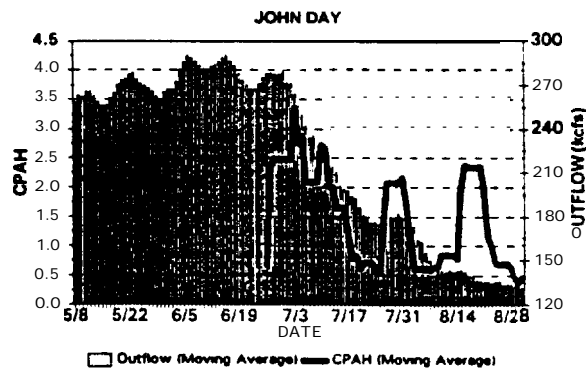
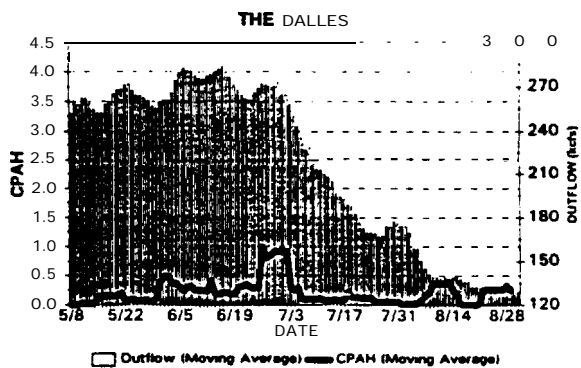
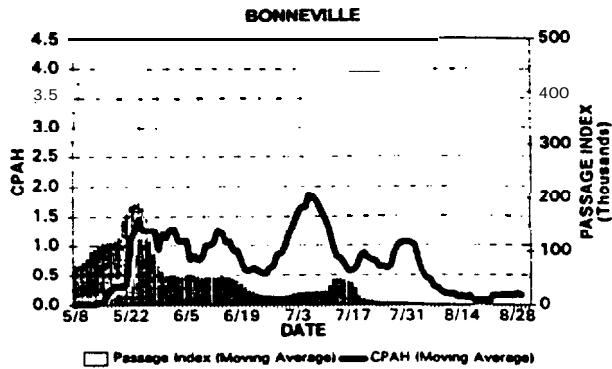
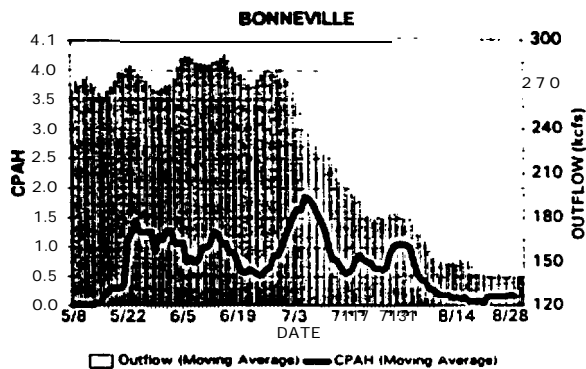


Figure C-6. Northern squawfish catch_per angler hour (CPAH), project outflow, and smolt passage indices at Columbia River dams in 1995. Passage data were not available for The Dalles Dam.

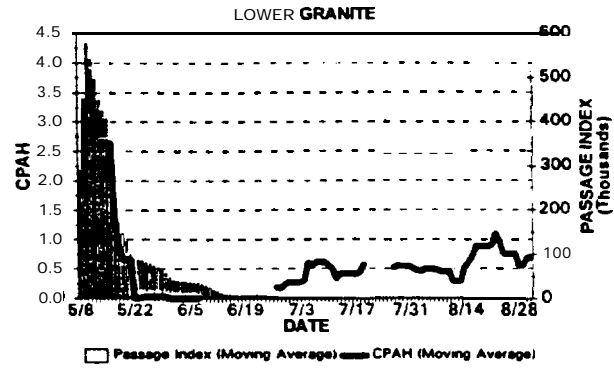
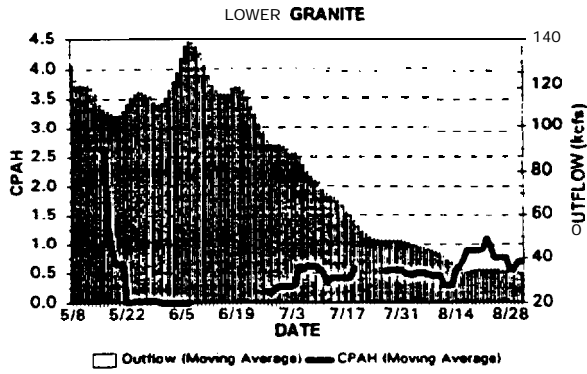
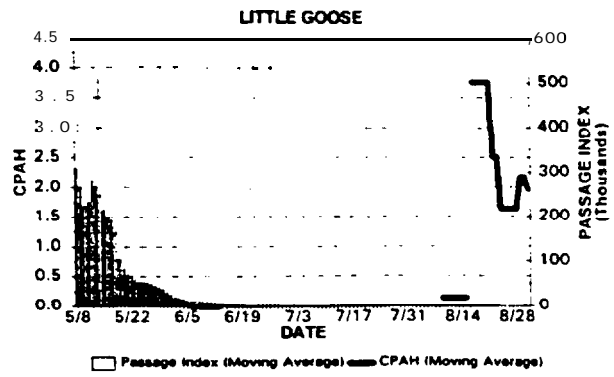
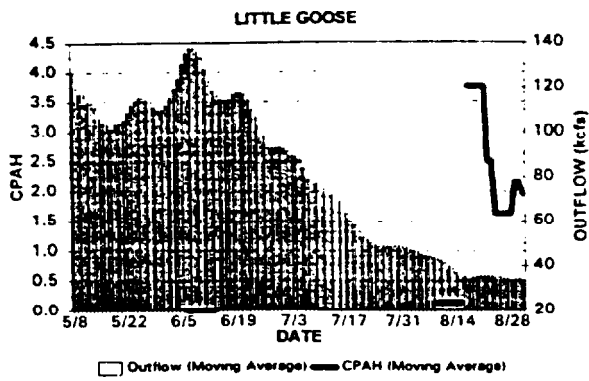
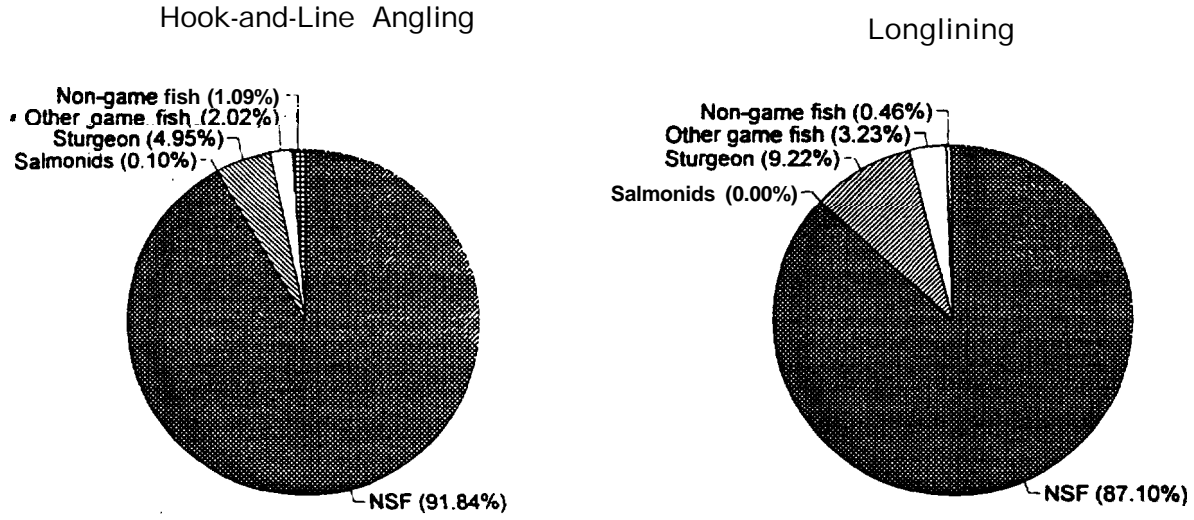


Figure C-7. Northern squawfish catch per angler hour (CPAH), project outflow, and smolt passage indices at Snake River dams in 1995.

COLUMBIA RIVER



SNAKE RIVER

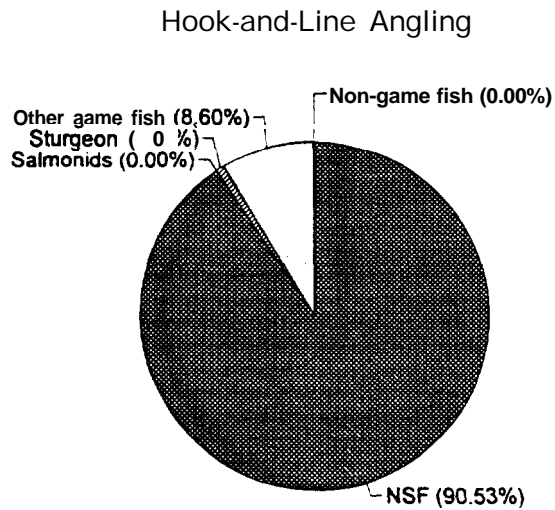


Figure C-8. Percentage of total catch of northern squawfish (NSF), salmonids, sturgeon, other game fish (catfish, walleye, and bass), and non-game fish (shad and other) for hook-and-line angling and longlining at Columbia and Snake river dams in 1995 .

CONCLUSIONS AND RECOMMENDATIONS

1. **Conclusion** — Declines in catch rates were observed at most dams in 1995. These declines were likely caused, primarily, by increased spill at **mainstem** dams that changed the distribution of northern squawfish and juvenile salmonids near dams.

Recommendation — Assuming that the 1996 spill schedule is similar to 1995, reduce dam-angling efforts and focus them more in time and space. Using mostly mobile crews, monitor catch rates at or near Columbia and Snake River dams and shift angler effort to the most productive locations.

2. **Conclusion** — Using different angling methods allows greater flexibility in adapting to changes in the distribution, feeding habits, and other behaviors that affect catchability of northern squawfish. For example, boat angling within the BRZ was more effective in catching northern squawfish than dam-based angling, presumably because boats allowed anglers access to areas away from the dam, where northern squawfish reside during periods of high spill.

Recommendation — Increase boat-angling effort near dams to target concentrations of northern squawfish beyond the reach of dam-based anglers, particularly during periods of high spill. Continue testing longlining and other hook-and-line angling techniques. Additionally, test the use of gill nets near dams as an alternative sampling technique. Hook-and-line angling should be used to locate concentrations of northern squawfish and, when warranted, longlines and gill nets can be deployed. Sampling effort should be continually adjusted in favor of whichever gear or combination of gears that prove most productive.

3. **Conclusion** — Volunteer angling efforts continue to be productive in catching northern squawfish at a low cost. Furthermore, the volunteer program provides participants with an opportunity to learn about the Columbia River Northern Squawfish Management Program in general, and to work cooperatively with tribal people.

Recommendation — Maintain the same level of volunteer effort (10-12 groups) in 1996 as in 1995. Two technicians will be dedicated to coordinating and overseeing these operations.

4

4. **Conclusion** — Catch rates varied by angler at each dam. These differences are due to variation in angler ability or technique, as well as angler choice of baits and fishing sites.

Recommendation — Continue to recruit and hire experienced hook-and-line anglers and provide them with **inseason** information (e.g., reports showing the -relative productivity of different baits, sites, and time periods at each dam) to help improve their effectiveness. Also, encourage information exchange among crews by scheduling different crews to work together and by organizing **inseason** meetings.

REFERENCES

- Ashe, B., R. E. Beaty, and M. P. Villalobos. 1994. Investigation of northern squawfish concentrations in tributaries to the **mainstem** Columbia, Snake, and Clearwater rivers. Pages 263-301 *in* C. F. Willis and D. L. Ward, editors. Development of a systemwide predator control program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1993 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.
- Beaty, R. E., B. L. Parker, K. Collis, and K. McRae. 1993. The use of controlled angling to manage northern squawfish populations at selected dams on the Columbia and Snake rivers. Pages 111-185 *in* C. F. Willis and A. A. Nigro, editors. Development of a systemwide predator control program: **stepwise** implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1993 Annual report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.
- CRITFC (Columbia River Inter-Tribal Fish Commission). 1995. Controlled angling for northern squawfish at selected dams on the Columbia and Snake rivers in 1994. Pages 103-152 *in* C. F. Willis and F. R. Young, editors. Development of a systemwide predator control program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1994 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.
- CRITFC (Columbia River Inter-Tribal Fish Commission). 1994. Controlled angling for northern squawfish at selected dams on the Columbia and Snake rivers in 1993. Pages 163-220 *in* C. F. Willis and D. L. Ward, editors. Development of a systemwide predator control program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1993 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

- Faler, M. P., L. M. Miller, and K. I. Welke. 1988. Effects of variation in flow on distributions of northern squawfish in the Columbia River below McNary Dam. *North American Journal of Fisheries Management* 8:30-35.
- Hansel, H. C., R. S. Shively, G. S. Holmberg, T. P. King, T. L. Martinelli, and M. B. Sheer. 1994. Movements and distribution of radio-tagged northern squawfish near The Dalles and John Day dams. Pages 17-73 *in* T. P. Poe, editor. Significance of selective predation and development of prey protection measures for juvenile salmonids in the Columbia and Snake river reservoirs. 1993 Annual Report. Contract DE-AI79-88BP9 1964, Bonneville Power Administration, Portland, Oregon.
- Isaak, D. J., and T. C. Bjornn. 1994. Movements of northern squawfish in the lower Snake River during 1993. Pages 1-27 *in* T. P. Poe, editor. Significance of selective predation and development of prey protection measures for juvenile salmonids in the Columbia and Snake river reservoirs. 1993 Annual Report. Contract DE-AI79-88BP91964, Bonneville Power Administration, Portland, Oregon.
- Malette, C., S. J. Banks, T. C. Neil!, and P. M. Pierce. 1993. Feasibility investigation of a commercial longline fishery for northern squawfish in the Columbia River downstream from Bonneville Dam. Pages 9-54 *in* C. F. Willis and A. A. Nigro, editors. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1992 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.
- Mesa, M. G., and T. M. Olson. 1993. Prolonged swimming performance of northern squawfish. *Transactions of the American Fisheries Society* 122: 1104- 1110.
- Mathews, S., T. Iverson, J. Lynch, and B. Mahoney. 1992. Northern squawfish harvest technology: Implementation feasibility in the Columbia River. University of Washington. Special Issue Paper (prepared for the Bonneville Power Administration). Seattle, Washington. 74 pp.
- Mathews, S. B., and T. K. Iverson. 1991. Evaluation of harvest technology for potential northern squawfish commercial fisheries in Columbia River reservoirs. Pages 261-326 *in* A. A. Nigro, editor. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1990 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

- Mathews, S. B., T. K. Iverson, R. W. Tyler, and G. Ruggerone. 1990. Evaluation of harvest technology for potential northern squawfish commercial fisheries in Columbia River reservoirs. Pages 278-354 in A. A. Nigro, editor. Developing a predation index and evaluating ways to reduce salmonid losses to predation in the Columbia River Basin. 1989 Annual Report. Contract DE-AI79-88BP92122, Bonneville Power Administration, Portland, Oregon.
- Parker, B. L., K. Collis, B. Ashe, R. E. Beaty, and K. McRae. 1993. Controlled angling for northern squawfish at selected dams on the Columbia and Snake rivers in 1992. Pages 129-182 in C. F. Willis and A. A. Nigro, editors. Development of a systemwide predator control program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1992 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.
- Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108:505-529.
- Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleye, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:448-458.
- Shively, R. S., T. P. Poe, M. B. Sheer, and R. Peters. In Press. Criteria for reducing predation by northern squawfish near juvenile salmonid bypass outfalls at Columbia River dams. Regulated Rivers: Research and Management.
- Vigg, S., C. C. Burley, D. L. Ward, C. Mallette, S. Smith, and M. Zimmerman. 1990. Development of a systemwide predator control program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. Pages 261-326 in A. A. Nigro, editor. Development of a systemwide predator control program: **stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1990 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

APPENDIX A
1995 Tabular Data

Appendix Table A-1. Northern squawfish (NSF) captured in an upstream migration trap at Threemile Dam in 1995.

Date	NSF	Date	NSF
04-Apr-95	1	25-May-95	112
07-Apr-95	1	26-May-95	103
10-Apr-95	1	28-May-95	134
12-Apr-95	1	30-May-95	91
20-Apr-95	1	31-May-95	26
22-Apr-95	5	01-Jun-95	27
23-Apr-95	20	02-Jun-95	8
24-Apr-95	30	05-Jun-95	47
25-Apr-95	49	06-Jun-95	27
26-Apr-95	90	07-Jun-95	6
27-Apr-95	12	09-Jun-95	12
28-Apr-95	16	11-Jun-95	10
16-May-95	2	13-Jun-95	2
18-May-95	17	19-Jun-95	3
19-May-95	8	22-Jun-95	18
20-May-95	115	23-Jun-95	46
22-May-95	141	26-Jun-95	69
23-May-95	147	27-Jun-95	34
24-May-95	137	30-Jun-95	28
Total		1,594	

Appendix Table A-2. Northern squawfish (NSF) catch, angler hours (effort), and catch per angler hour (CPAH) for dam- and boat-angling (combined), by statistical week, at Snake River dams in 1995.

Statistical week: dates	Ice Harbor			Lower Monumental			Little Goose			Lower Granite		
	NSF	Effort	CPAH	NSF	Effort	CPAH	NSF	Effort	CPAH	NSF	Effort	CPAH
20: 05/08 - 05/14	—	—	—	—	—	—	—	—	—	—	—	—
21: 05/15 - 05/21	—	—	—	—	—	—	—	—	—	17	18.4	0.9
22: 05/22 - 05/28	—	—	—	—	—	—	—	—	—	4	105.0	0.0
23: 05/29 - 06/04	—	—	—	—	—	—	—	—	—	0	69.0	0.0
24: 06/05 - 06/11	—	—	—	—	—	—	0	64.0	0.0	—	—	—
25: 06/12 - 06/18	—	—	—	—	—	—	—	—	—	—	—	—
26: 06/19 - 06/25	—	—	—	—	—	—	—	—	—	—	—	—
27: 06/26 - 07/02	—	—	—	—	—	—	—	—	—	28	93.9	0.3
28: 07/03 - 07/09	—	—	—	—	—	—	—	—	—	21	37.6	0.6
29: 07/10 - 07/16	—	—	—	—	—	—	—	—	—	49	118.5	0.4
30: 07/17 - 07/23	9	80.3	0.1	—	—	—	—	—	—	—	—	—
31: 07/24 - 07/30	—	—	—	1	38.1	0.0	—	—	—	22	39.6	0.6
32: 07/31 - 08/06	—	—	—	—	—	—	—	—	—	52	107.6	0.5
33: 08/07 - 08/13	—	—	—	—	—	—	3	20.6	0.1	20	67.3	0.3
34: 08/14 - 08/20	—	—	—	—	—	—	34	9.0	3.8	54	70.7	0.8
35: 08/21 - 08/27	—	—	—	—	—	—	79	48.4	1.6	42	54.6	0.8
36: 08/28 - 09/03	—	—	—	—	—	—	70	40.8	1.7	11	15.9	0.7
Total	9	80.3	0.1	1	38.1	0.0	186	182.9	1.0	320	798.2	0.4

Appendix Table A-3. Northern squawtish (NSF) catch, angler hours (effort), and catch per angler hour (CPAH) for dam- and boat-angling (combined), by statistical week, at Columbia River dams in 1995.

Statistical week: dates	Bonneville			The Dalles			John Day			McNary		
	NSF	Effort	CPAH	NSF	Effort	CPAH	NSF	Effort	CPAH	NSF	Effort	CPAH
20: 05/08 - 05/14	1	65.1	0.0	1	30.3	0.0	—	—	—	—	—	—
21: 05/15 - 05/21	57	156.8	0.4	13	98.3	0.1	—	—	—	—	—	—
22: 05/22 - 05/28	115	105.5	1.1	8	85.1	0.1	—	—	—	0	17.5	0.0
23: 05/29 - 06/04	123	105.0	1.2	35	65.4	0.5	—	—	—	16	73.3	0.2
24: 06/05 - 06/11	181	216.8	0.8	18	34.2	0.5	—	—	—	8	126.8	0.1
25: 06/12 - 06/18	241	250.3	1.0	20	35.2	0.6	—	—	—	26	170.8	0.2
26: 06/19 - 06/25	165	297.1	0.6	41	70.1	0.6	—	—	—	36	133.1	0.3
27: 06/26 - 07/02	223	201.5	1.1	130	126.2	1.0	162	56.0	2.9	81	122.8	0.7
28: 07/03 - 07/09	547	304.1	1.8	15	25.8	0.6	98	50.5	1.9	111	62.2	1.8
29: 07/10 - 07/16	241	241.8	1.0	15	34.3	0.4	162	123.4	1.3	53	88.1	0.6
30: 07/17 - 07/23	169	217.8	0.8	14	16.2	0.9	94	148.6	0.6	63	75.8	0.8
31: 07/24 - 07/30	210	284.0	0.7	23	69.6	0.3	145	62.7	2.3	61	122.2	0.5
32: 07/31 - 08/06	122	228.7	0.5	9	33.8	0.3	63	112.7	0.6	145	119.3	1.2
33: 08/07 - 08/13	15	83.7	0.2	41	92.4	0.4	53	91.1	0.6	88	126.3	0.7
34: 08/14 - 08/20	2	15.9	0.1	11	42.1	0.3	130	66.8	1.9	236	250.6	0.9
35: 08/21 - 08/27	10	49.1	0.2	15	60.9	0.2	39	56.5	0.7	64	137.6	0.5
36: 08/28 - 09/03	—	—	—	—	—	—	4	8.7	0.5	14	43.4	0.3
Total	2,422	2,823.1	0.9	409	919.7	0.4	950	776.7	1.2	1,002	1,669.8	0.6

Appendix Table A-4. Monthly species composition of the combined dam- and boat-angling catch at Columbia and Snake River dams in 1995.

River and month	Percent NSF ^a in total catch	Percent by-catch in total catch	Percent of total catch							
			Salmonids	Sturgeon	Bass	Cattish	Walleye	Shad	Other	
Columbia River										
May	92.13	7.87	0.28	5.06	1.97	0.00	0.00	0.00	0.00	0.56
June	92.47	7.53	0.21	4.49	1.31	0.35	0.14	0.69	0.35	
July	95.13	4.87	0.04	3.58	0.78	0.00	0.30	0.13	0.04	
August	83.89	16.11	0.00	8.47	1.20	1.93	1.20	0.09	3.22	
Total	91.84	8.16	0.10	4.95	1.09	0.50	0.42	0.27	0.83	
Snake River										
May	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June	73.68	26.32	0.00	0.00	0.00	26.32	0.00	0.00	0.00	0.00
July	83.61	16.39	0.00	3.28	1.64	11.48	0.00	0.00	0.00	0.00
August	94.59	5.41	0.00	0.27	1.62	3.51	0.00	0.00	0.00	0.00
September	78.95	21.05	0.00	0.00	10.53	10.53	0.00	0.00	0.00	0.00
Total	90.53	9.47	0.00	0.88	1.75	6.84	0.00	0.00	0.00	0.00
Grand Total										
May	92.57	7.43	0.27	4.77	1.86	0.00	0.00	0.00	0.00	0.53
June	91.99	8.01	0.20	4.38	1.28	1.01	0.13	0.67	0.34	
July	94.55	5.45	0.04	3.56	0.82	0.57	0.29	0.12	0.04	
August	86.61	13.39	0.00	6.39	1.30	2.34	0.89	0.07	2.40	
September	78.95	21.05	0.00	0.00	10.53	10.53	0.00	0.00	0.00	
Total	91.71	8.29	0.09	4.55	1.16	1.12	0.38	0.24	0.74	

^a Northern squawfish

Appendix Table A-5. Monthly by-catch for the combined dam- and boat-angling by condition at release at Columbia and Snake River dams in 1995. 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.

River and month	Total catch (all species)	Total by-catch	Salmonids				Sturgeon				Bass			Cattish			Walleye			Shad	Other	
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3			
Columbia River																						
May	356	28	1	0	0	0	5	0	0	13	7	0	0	0	0	0	0	0	0	0	2	
June	1,447	109	1	0	0	2	16	0	0	49	19	0	0	4	1	0	2	0	0	10	5	
July	2,319	113	0	0	0	1	16	0	0	67	18	0	0	0	0	0	7	0	0	3	1	
August	1,086	175	0	0	0	0	20	1	0	71	13	0	0	20	0	1	13	0	0	1	35	
Total	5,208	425	2	0	0	3	57	1	0	200	57	0	0	24	1	1	22	0	0	14	43	
Snake River																						
May	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	38	10	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
July	122	20	0	0	0	0	4	0	0	0	2	0	0	14	0	0	0	0	0	0	0	0
August	370	20	0	0	0	0	1	0	0	0	6	0	0	13	0	0	0	0	0	0	0	0
September	19	4	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
Total	570	54	0	0	0	0	5	0	0	0	10	0	0	39	0	0	0	0	0	0	0	0
Grand Total																						
May	377	28	1	0	0	0	5	0	0	13	7	0	0	0	0	0	0	0	0	0	2	
June	1,485	119	1	0	0	2	16	0	0	49	19	0	0	14	1	0	2	0	0	10	5	
July	2,441	133	0	0	0	1	20	0	0	67	20	0	0	14	0	0	7	0	0	3	1	
August	1,456	195	0	0	0	0	21	1	0	71	19	0	0	33	0	1	13	0	0	1	35	
September	19	4	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	
Total	5,778	479	2	0	0	3	62	1	0	200	67	0	0	63	1	1	22	0	0	14	43	

Appendix Table A-6. Monthly species composition of the combined dam- and boat-angling catch at Columbia River dams in 1995.

Dam and month	Percent NSF ^a in total catch	Percent by-catch in total catch	Percent of total catch						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
Bonneville									
May	93.64	6.36	0.35	5.65	0.00	0.00	0.00	0.00	0.35
June	91.93	8.07	0.11	6.59	0.11	0.00	0.00	1.14	0.11
July	95.80	4.20	0.00	3.97	0.00	0.00	0.00	0.22	0.00
August	63.06	36.94	0.00	29.73	0.00	0.00	0.90	0.00	6.31
Total	92.87	7.13	0.08	6.13	0.04	0.00	0.04	0.50	0.35
The Dalles									
May	88.33	11.67	0.00	1.67	10.00	0.00	0.00	0.00	0.00
June	90.64	9.36	0.43	2.55	5.53	0.00	0.85	0.00	0.00
July	64.42	35.58	0.00	25.96	8.65	0.00	0.96	0.00	0.00
August	67.86	32.14	0.00	18.75	7.14	1.79	4.46	0.00	0.00
Total	80.04	19.96	0.20	10.76	7.05	0.39	1.57	0.00	0.00
John Day									
June	99.39	0.61	0.00	0.00	0.61	0.00	0.00	0.00	0.00
July	97.42	2.58	0.18	0.00	1.29	0.00	1.11	0.00	0.00
August	90.28	9.72	0.00	0.69	0.35	0.69	2.43	0.00	5.56
Total	95.67	4.33	0.10	0.20	0.91	0.20	1.31	0.00	1.61
McNary									
May	76.92	23.08	0.00	7.69	7.69	0.00	0.00	0.00	7.69
June	91.12	8.88	0.59	0.59	2.37	2.96	0.00	0.00	2.37
July	98.23	1.77	0.00	0.88	0.59	0.00	0.00	0.00	0.29
August	87.83	12.17	0.00	6.26	0.70	2.96	0.00	0.17	2.09
Total	91.42	8.58	0.09	3.74	1.00	2.01	0.00	0.09	1.64

^a Northern squawfish

Appendix Table A-7. Monthly by-catch for the combined dam- and boat-angling by condition at release for Columbia River dams in 1995. 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.

Dam and month	Total catch (all species)	Total by-catch	Salmonids				Sturgeon				Bass			Cattish			Walleye			Shad	Other
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3		
Bonneville																					
May	283	18	1	00	0	4	0	0	12	00	0	00	0	0	0	0	0	0	0	0	1
June	880	71	0	00	1	9	0	0	49	10	0	00	0	0	0	0	0	0	10	1	
July	1,334	56	0	00	0	11	0	0	42	00	0	00	0	0	0	0	0	0	3	0	
August	111	41	0	00	0	3	0	0	30	00	0	00	0	1	0	0	0	0	0	7	
Total	2,608	186	1	00	1	27	0	0	133	10	0	00	0	1	0	0	0	13	9		
The Dalles																					
May	60	7	0	00	0	1	00	0	60	0	00	0	0	0	0	0	0	0	0	0	
June	235	22	1	00	0	6	00	0	13	0	0	00	0	2	0	0	0	0	0	0	
July	104	37	0	00	0	2	0	0	25	90	0	00	0	1	0	0	0	0	0	0	
August	112	36	0	00	0	6	0	0	15	80	0	20	0	5	0	0	0	0	0	0	
Total	511	102	1	00	0	15	0	0	40	36	0	20	0	8	0	0	0	0	0	0	
John Day																					
June	163	1	0	00	0	0	00	0	10	0	00	0	0	0	0	0	0	0	0	0	
July	542	14	0	00	1	0	00	0	70	0	00	0	6	0	0	0	0	0	0	0	
August	288	28	0	00	0	1	00	1	10	0	20	0	7	0	0	0	0	0	0	16	
Total	993	43	0	00	1	1	00	1	90	0	20	0	13	0	0	0	0	0	0	16	
McNary																					
May	13	3	0	00	0	0	00	1	10	0	0	0	0	0	0	0	0	0	0	1	
June	169	15	0	00	1	1	00	0	40	0	41	0	0	0	0	0	0	0	0	4	
July	339	6	0	00	0	3	00	0	20	0	00	0	0	0	0	0	0	0	0	1	
August	575	70	0	00	0	10	1	0	25	40	0	16	0	1	0	0	0	0	1	12	
Total	1,096	94	0	00	1	14	1	0	26	11	0	20	1	1	0	0	0	1	18		

Appendix Table A-8. Monthly species composition of the combined dam- and boat-angling catch at Snake River dams in 1995.

Dam and month	Percent NSF in total catch	Percent by-catch in total catch	Percent of total catch						
			Salmonids	Sturgeon	Bass	Cattish	Walleye	Shad	Other
Ice Harbor									
July	75.00	25.00	0.00	16.67	0.00	8.33	0.00	0.00	0.00
Total	75.00	25.00	0.00	16.67	0.00	8.33	0.00	0.00	0.00
Lower Monumental									
July	25.00	75.00	0.00	0.00	0.00	75.00	0.00	0.00	0.00
Total	25.00	75.00	0.00	0.00	0.00	75.00	0.00	0.00	0.00
Little Goose									
June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	97.16	2.84	0.00	0.57	1.70	0.57	0.00	0.00	0.00
September	78.95	21.05	0.00	0.00	10.53	10.53	0.00	0.00	0.00
Total	95.38	4.62	0.00	0.51	2.56	1.54	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	73.68	26.32	0.00	0.00	0.00	26.32	0.00	0.00	0.00
July	86.79	13.21	0.00	1.89	1.89	9.43	0.00	0.00	0.00
August	92.27	7.73	0.00	0.00	1.55	6.19	0.00	0.00	0.00
Total	89.14	10.86	0.00	0.56	1.39	8.91	0.00	0.00	0.00

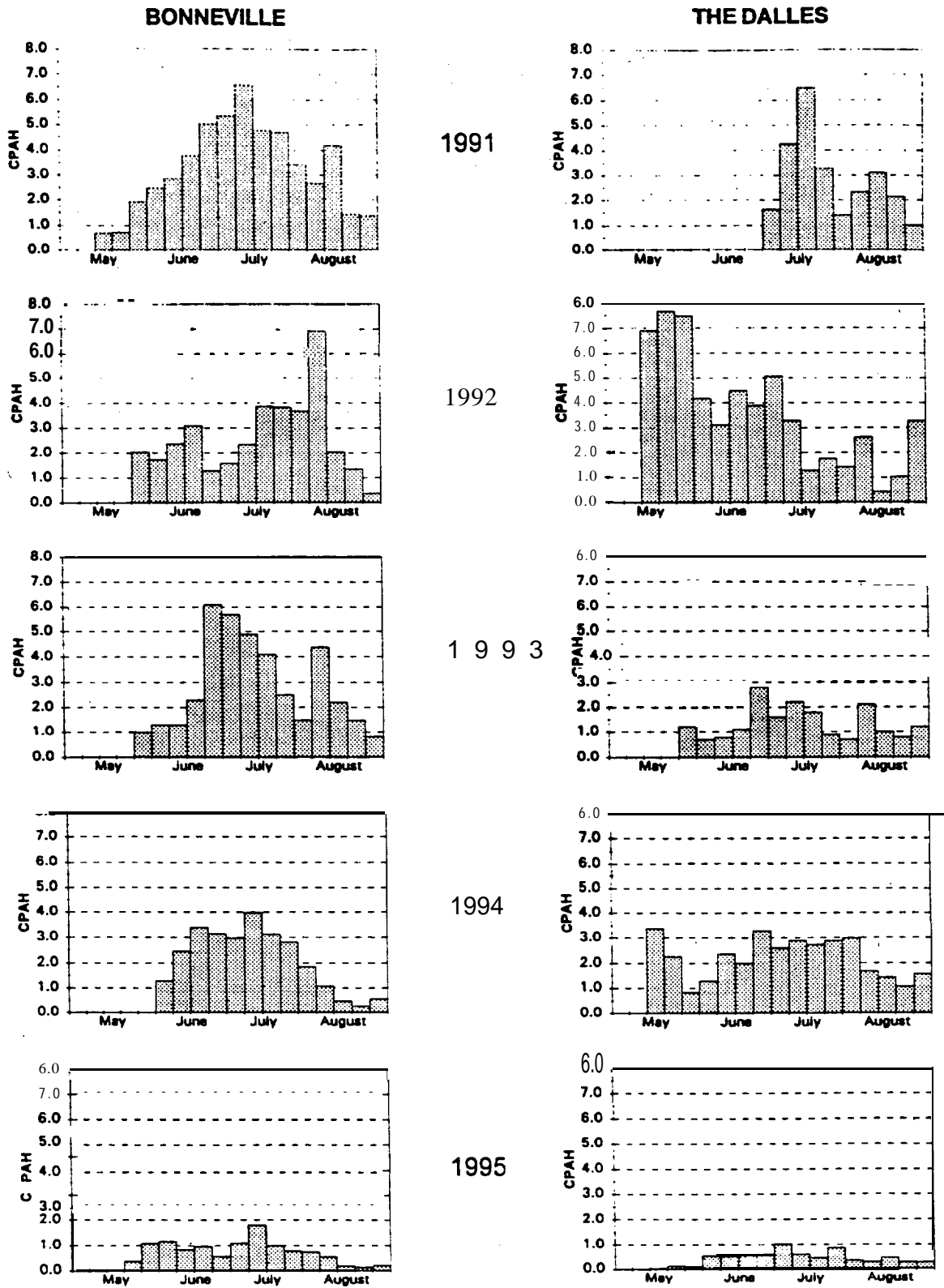
^a Northern squawfish

APPENDIX B

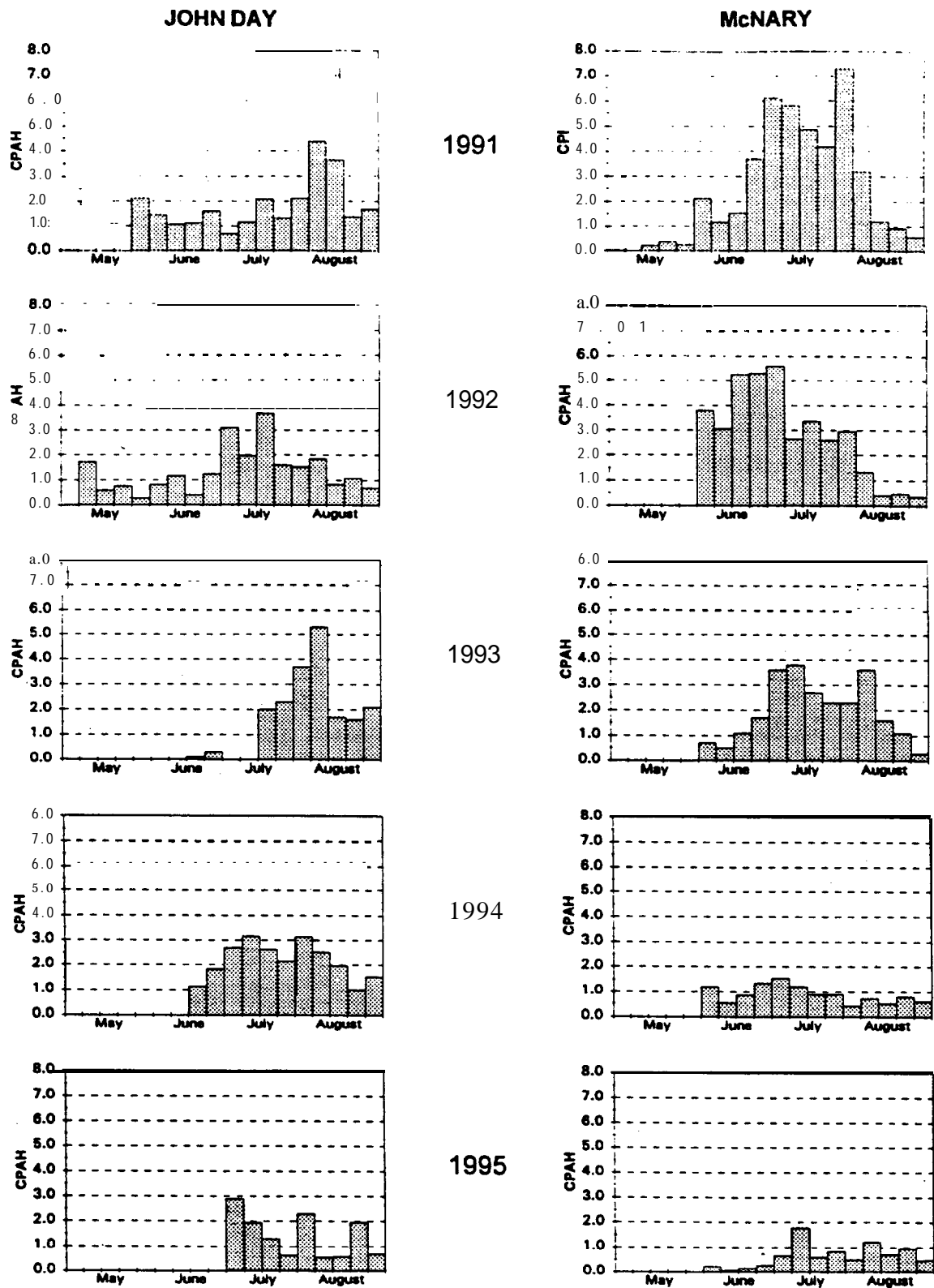
Among-Year Comparisons

Appendix Table B-1. Northern squawtish (NSF) catch, angler hours (effort), and catch-per-angler-hour (CPAH) for dam- and boat-angling (combined) at Columbia and Snake River dams, 1991-1995.

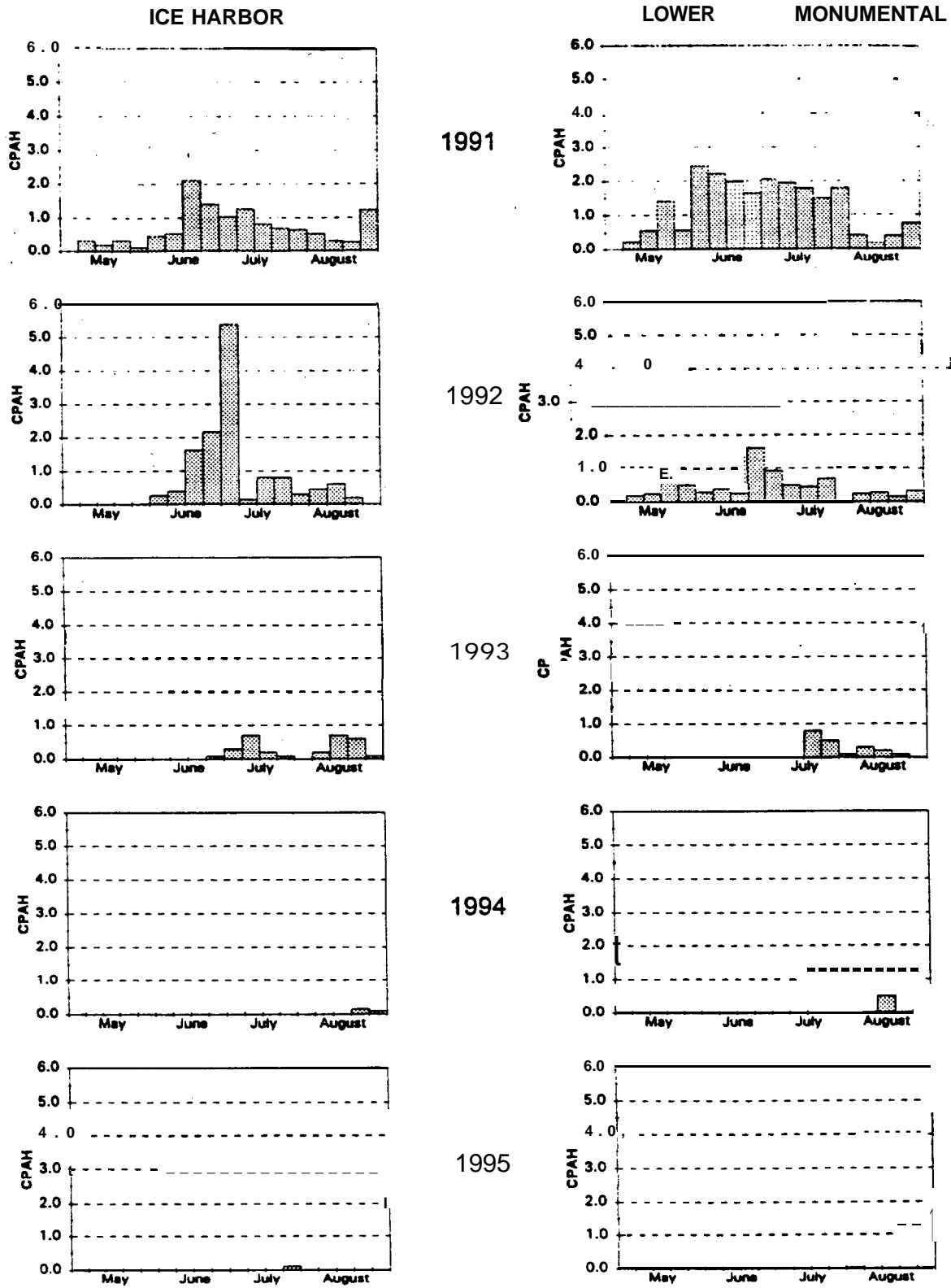
Year		Columbia River dams					Snake River dams					Grand total
		Bonneville	The Dalles	John Day	McNary	Total	Ice Harbor	Lower Monumental	Little Goose	Lower Granite	Total	
1991	NSF	8,131	3,674	5,004	8,348	25,157	1,486	3,313	4,915	4,480	14,194	39,351
	Effort	2,621	1,333	2,816	3,416	10,186	2,052	2,471	2,140	2,448	9,112	19,298
	CPAH	3.1	2.8	1.8		2.4 2.5	0.7	1.3	2.3	1.8	1.6	2.0
1992	NSF	4,814	7,561	3,427	7,297	23,099	278	475	1,664	2,352	4,769	27,868
	Effort	1,781	2,496	2,775	2,523	9,575	298	943	3,062	2,880	7,183	16,758
	CPAH	2.7	3.0	1.2	2.9	2.4	0.9	0.5	0.5	0.8	0.7	1.7
1993	NSF	5,836	2,712	2,509	5,148	16,205	122	105	100	678	1,005	17,210
	Effort	1,991	1,992	1,561	2,780	8,324	404	396	378	734	1,911	10,235
	CPAH	2.9	1.4	1.6	1.9	1.9	0.3	0.3	0.3	0.9	0.5	1.7
1994	NSF	5,238	4,393	3,083	2,556	15,270	23	27	92	685	827	16,097
	Effort	2,232	2,064	1,649	2,966	8,910	141	55	203	692	1,092	10,002
	CPAH	2.3	2.1	1.9	0.9	1.7	0.2	0.5	0.5	1.0	0.8	1.6
1995	NSF	2,422	409	950	1,002	4,783	9	1	186	320	516	5,299
	Effort	2,823	920	777	1,670	6,190	80	38	183	798	1,099	7,289
	CPAH	0.9	0.4	1.2	0.6	0.8	0.1	0.0	1.0	0.4	0.5	0.7
Total	NSF	26,441	18,749	14,973	24,351	84,514	1,918	3,921	6,957	8,515	21,311	105,825
	Effort	11,448	8,805	9,578	13,355	43,186	2,975	3,903	5,966	7,552	20,397	63,582
	CPAH	2.3	2.1	1.6	1.8	2.0	0.6	1.0	1.2	1.1	1.0	1.7



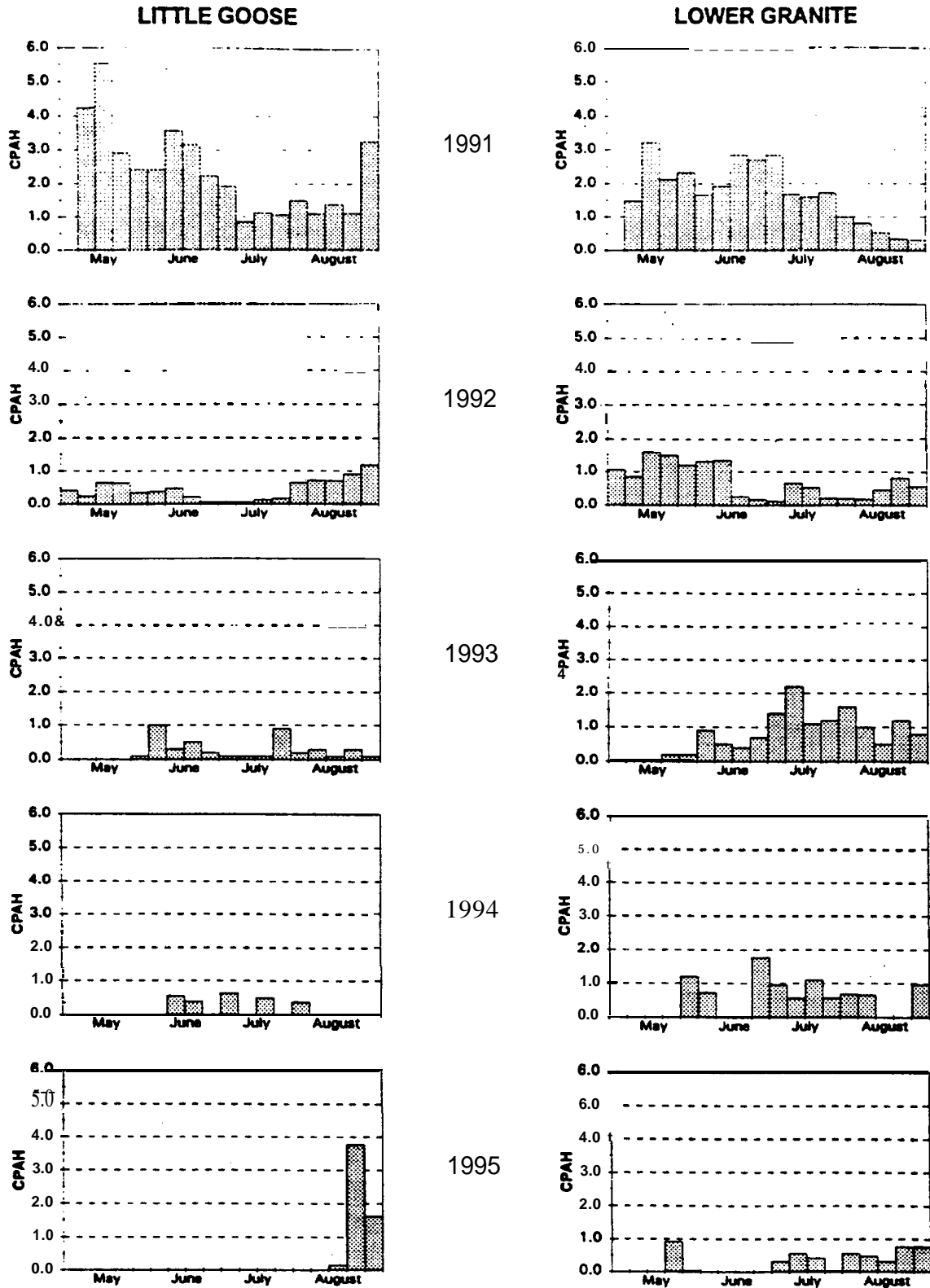
Appendix Figure B-1. Monthly northern squawfish catch per angler hour (CPAH) at Bonneville and The Dalles dams for 1991 through 1995.



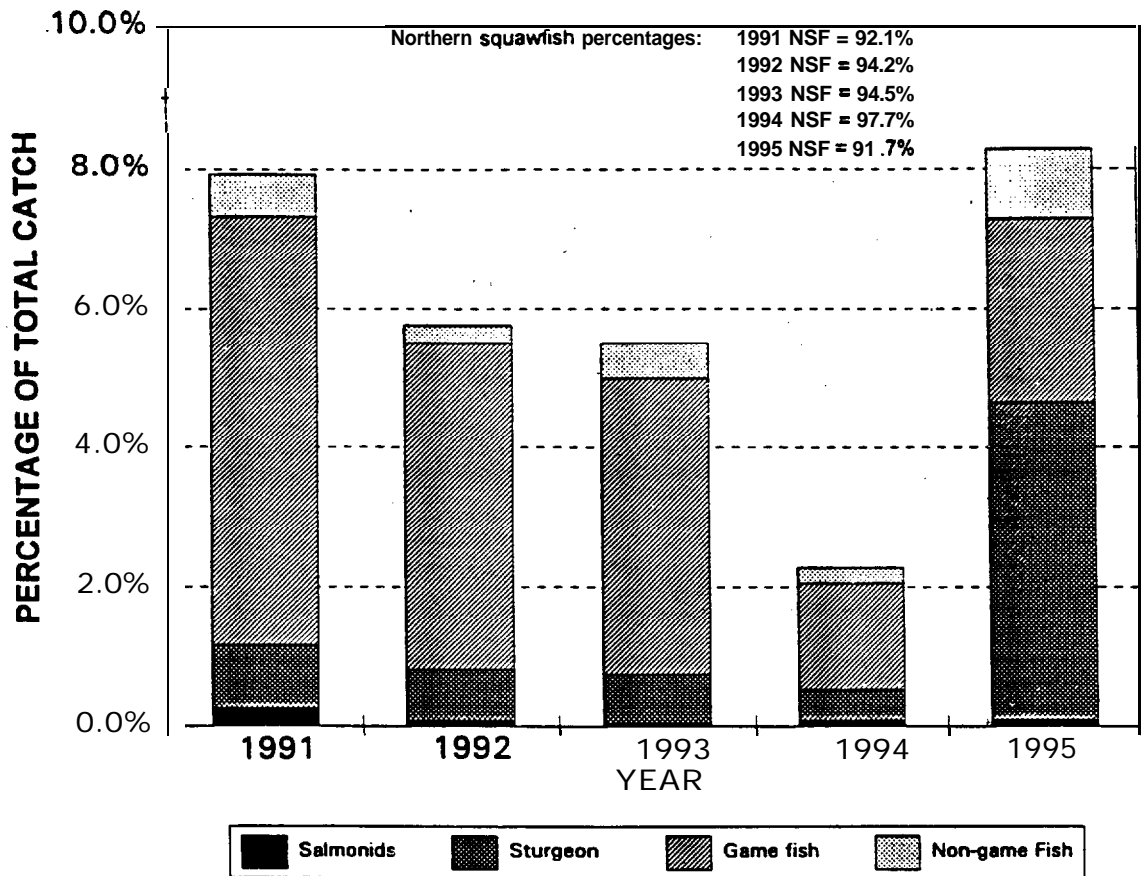
Appendix Figure B-2. Monthly northern squawfish catch per angler hour (CPAH) at John Day and McNary dams for 1991 through 1995.



Appendix Figure B-3. Monthly northern squawfish catch per angler hour (CPAH) at Ice Harbor and Lower Monumental dams for 1991 through 1995.



Appendix Figure B-4. Monthly northern **squawfish** catch per angler hour (CPAH) at Little Goose and Lower Granite dams for 1991 through 1995.



Appendix Figure B-5. Catch composition for combined dam- and boat-angling at Columbia and Snake river dams, 1991 through 1995.

Report D

**Site-specific Removal of Northern Squawfish Aggregated
to Feed on Juvenile Salmonids during the Spring
in the Lower Columbia and Snake Rivers**

Prepared by

**Ken Collis
Jack McCormack
Kathy McRae
Roy Beaty**

**Columbia River Inter-Tribal Fish Commission
729 NE Oregon, Suite 200, Portland, OR 97232**

1995 Annual Report

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ABSTRACT

As part of a site-specific fishery, small-mesh gill nets caught 9,484 predator-sized (2250 mm fork length) northern squawfish (*Ptychocheilus oregonensis*) from areas where they concentrate to feed on hatchery-released juvenile salmonids (*Oncorhynchus* spp.) in the lower Columbia and Snake rivers. Most of these fish were caught in the Columbia River (96%), primarily at locations in Bonneville Pool (91%). The mouth of the Klickitat River was the most productive location fished in terms of both total gill-net catch (7,556) and catch per net hour (CPUE; 5.7), followed by two other locations in Bonneville Pool. Outside Bonneville Pool, the highest catch and CPUE were at Levey Landing in Ice Harbor Pool, with a gill-net catch of 23 1 predator-sized northern squawfish and a CPUE of 2.1. Gill nets caught large predators (average fork length = 410.5 ± 0.8 mm), with significantly larger fish caught on the Columbia River (412 ± 0.9 mm) than on the Snake River (379.2 ± 2.6 mm). The total incidental catch was 10,248 fish, with suckers (*Catostomus* spp.) being the most common of the incidentally caught species in both the Columbia and Snake rivers. Salmonid bycatch (196) was reduced 33% from the previous year, largely due to the elimination of Merwin trapping in 1995. Further developments and changes to the site-specific fishery are recommended to improve efficiency and productivity.

INTRODUCTION

In 1990, the Columbia River Northern Squawfish Management Program was implemented to reduce predation by northern squawfish (*Ptychocheilus oregonensis*) on outmigrating juvenile salmonids (*Oncorhynchus* spp.) in the lower Columbia and Snake rivers. The program goal is to sustain a 10-20% annual exploitation rate on predator-sized northern squawfish, which over several years may result in a 50% or greater reduction in predation on juvenile salmonids (Rieman and Beamesderfer 1990). Various predator-control fisheries were implemented as part of the Northern Squawfish Management Program, among which was a site-specific gill-net fishery.

Site-specific gillnetting was first implemented as a test fishery in 1993. Small-mesh gill nets were used to remove northern squawfish from areas where they concentrate and feed on hatchery-released juvenile salmonids (Collis et al. 1995a). We hypothesized that by sampling in areas where northern squawfish are expected to concentrate, we could maximize catch rates of opportunistic predators that feed on both wild and hatchery-reared juvenile salmonids. We found that catch rates of predator-sized (≥ 250 mm fork length) northern squawfish more than doubled from before to after release at three locations where hatchery salmon were released in Bonneville Pool (Collis et al. 1995a). Northern squawfish caught after the release of juvenile salmonids had a significantly higher frequency of occurrence and mean number of juvenile salmonids in their guts compared to fish caught before release (Collis et al. 1995a). The average length of fish captured in the site-specific fishery was greater than in all other predator-control fisheries in 1993, with the exception of dam angling (Willis and Ward 1994).

Based on these data, we expanded this fishery in 1994 to include additional locations where hatchery fish were released on the lower Columbia and Snake rivers. In 1994, we used gill nets to remove over 9,000 predator-sized northern squawfish, for a seasonal CPUE of 6.6. The incidental impacts of this fishery on salmonids were low, despite high concentrations of both juvenile and adults at the sampling locations. Merwin traps were also tested as part of this fishery in 1994 and were ineffective (Collis et al. 1995b).

We continue to investigate the step-wise implementation of a site-specific fishery using small-mesh gill nets to locate and target feeding concentrations of northern squawfish. Our objectives in the current study were to (1) investigate additional locations where northern squawfish might concentrate to feed on hatchery-released juvenile salmonids, specifically below Bonneville Dam, and (2) continue to develop a methodology that maximizes our catch of predator-sized northern squawfish, while further reducing impacts to salmonids.

METHODS

Study Area

In 1995, the site-specific gill-net fishery was conducted at locations' between the mouth of the Elokommin River and the head of Lake Wallula (McNary Pool) on the Columbia River, and the mouth of the Grande Ronde River on the Snake River (Figures D-1 and D-2; Tables D-1 and D-2). Sampling was conducted where northern squawfish were expected to concentrate to feed on juvenile salmonids, specifically below hatchery release points, near dams, and near the mouths of tributaries.

Crew Scheduling

The Fish Passage Center and hatchery managers provided hatchery-release information used in determining crew schedules. Criteria utilized in crew scheduling were (1) date and location of hatchery release (Tables D- 1 and D-2); (2) estimated time of arrival of the released fish at the sampling location; (3) size and number of the fish released; (4) previous success in catching northern squawfish and the incidental catch rate of salmonids at a sampling location; (5) site-specific hydrologic conditions; and (6) logistics. Schedules were set on a weekly basis, but often changed daily depending on catch success and last-minute changes in release schedules. Because of the large number of potential sampling locations and the limited number of crews, previous catch success at a location was, in most cases, given the highest priority in crew scheduling decisions.

In 1995, four boat crews sampled from March 24 through June 29. Crews generally worked at a location from an hour after sunset to an hour after sunrise. If fishing success for northern squawfish during a given night was low relative to a nearby location, or operational criteria (Collis et al. 1995b; see below) established to limit salmonid catch were reached, crews would often relocate to another location that same night.

Technicians were assisted in the field by student volunteers enrolled in a cooperative education program at Mount Hood Community College. In 1995, four volunteers worked one night a week for the duration of the season for college credit and work experience in fisheries science.

¹A location is defined as a moderate-size reach of one shoreline and adjacent mainstream waters that extend approximately 3 km upstream and downstream from a landmark.

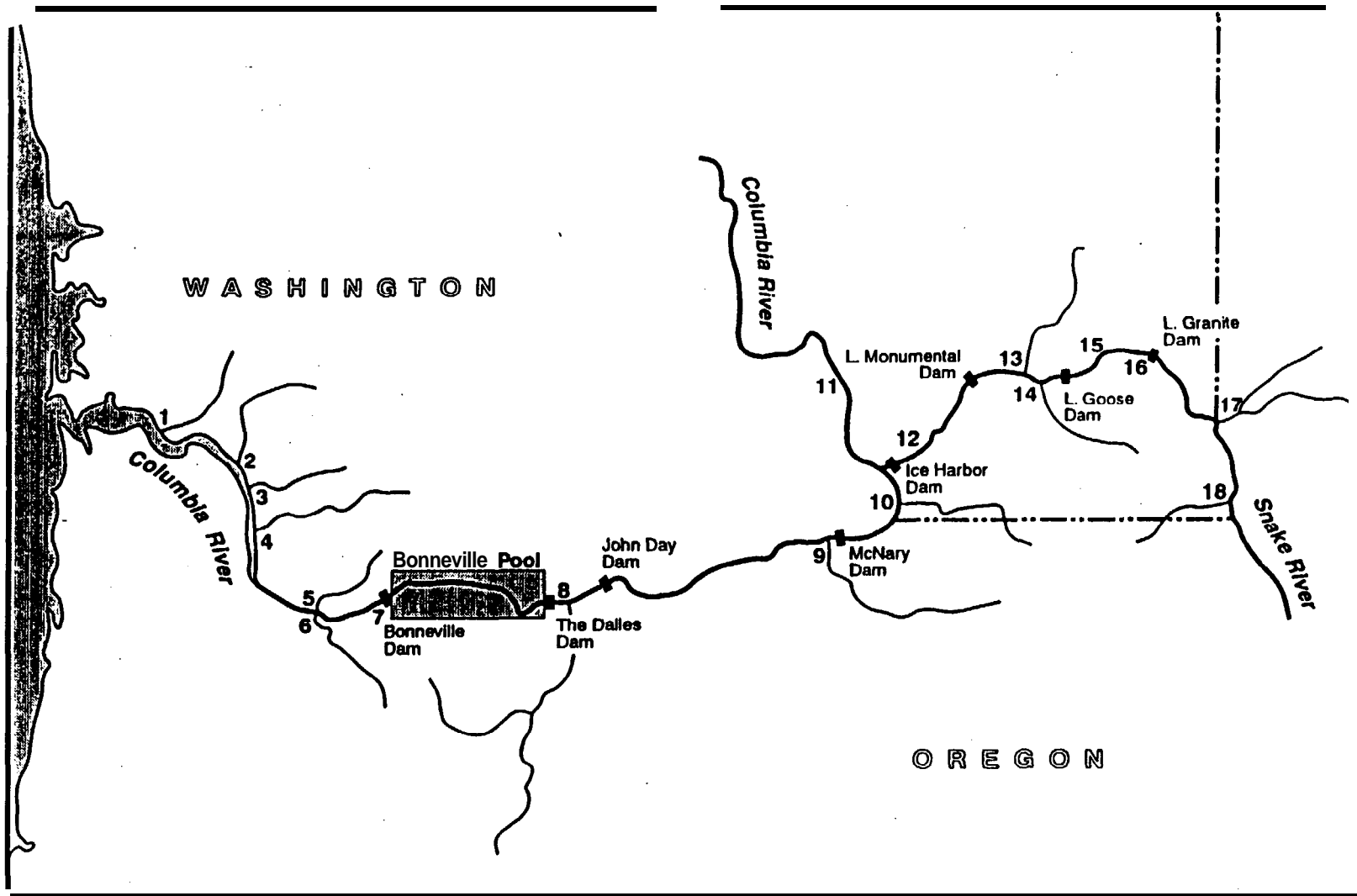


Figure D-i. Sampling locations above and below Bonneville Pool (see Figure 2-2 for sampling locations in Bonneville Pool), 1995. Locations are: 1 = Elokomin River; 2 = Cowlitz River; 3 = Kalama River; 4 = Lewis River; 5 = Washougal River; 6 = Sandy River; 7 = Tanner Creek; 8 = Miller Island and Celilo Marina; 9 = Umatilla River; 10 = Walla Walla River; 11 = Hanford Ferry; 12 = Levey Landing; 13 = Lyons Ferry; 14 = Tucannon River; 15 = Central Ferry; 16 = Lower Granite Dam; 17 = Clearwater River and Potlach River; and 18 = Grande Ronde River.

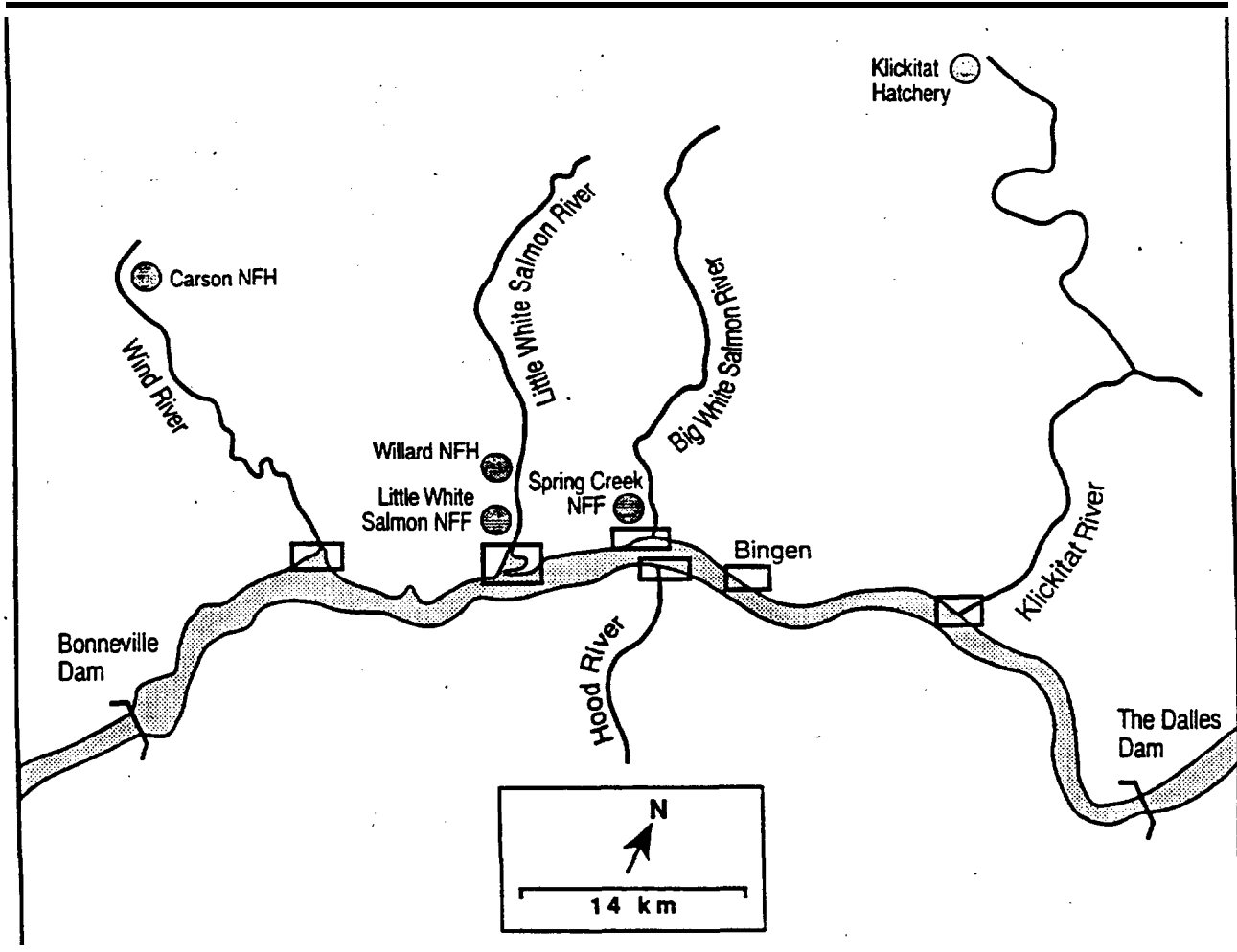


Figure D-2. Sampling locations (shown in boxes) in Bonneville Pool, 1995. Locations are (left to right): Wind River; Drano Lake; Spring Creek; Hood River; Bingen Marina; and Klickitat River.

Table D-1 Distribution of site-specific fishery effort at locations on the Columbia River in 1995.

Reach/pool and location (RKm)	Crew-nights fished ^a and number of smolts ^b released during week beginning:														
	3/20	3/27	4/03	4/10	4/17	4/24	5/01	5/08	5/15	5/22	5/29	6/05	6/12	6/19	6/26
Below Bonneville															
Elokomin River (68)			☒	■						1	■				
Cowlitz River (109)			■		□		1 ■				■	1 ☒		■	
Kalama River (119)			□		■	□	1	□		■		1		1	
Lewis River (140)	■		□	□		1									
Sandy River (195)		□	□			1	□								
Washougal River (195)		□				2 8				1	■			■	
Tanner Creek (232)				■		□		5 ■	■	1	■	■			
Bonneville Pool															
Wind River (248)		1		1 ■	1 □										
Drano Lake (261)		4		2 ■	2	4	3	1	3	2	1		2	4	■
Spring Creek (269)				■			1	1	1 ■	1					
Hood River (270)		□	□	□			1	1							
Bingen Marina (277)							2	3	1	1	1		1		
Klickitat River (290)	1	2	4 ■	3	9 ■	9 □	8 □	6	6 ■	6	7 □	11	7	8	4
The Dalles Pool															
Celilo Marina (325)											1				
Miller Island (330)											1				
John Day Pool															
Umatilla River (465)			2	□				□	1		■		5	3	
McNary Pool															
Walla Walla River (505)			□		□				1				1		
Hanford Ferry (557)															2 ☒

^a Locations having no number associated with a given week were not sampled.

^b □ = ≤ 500,000 smolts; □ = 500,000-1,000,000 smolts; ■ = ≥ 1,000,000 smolts

Table D-2. Distribution of site-specific fishery effort at locations on the Snake River in 1995.

Reach/pool location (RKm)	Crew-nights fished ^a and number of smolts ^b released during week beginning:														
	3120	3/27	4/03	4110	4/17	4/24	5101	5108	5/15	5/22	5129	6/05	6/12	6/19	6/26
Ice Harbor Pool															
Levey Landing (21)										4	1	3			
Lower Monumental Pool															
Lyons Ferry (95)					□		1		1						
Tucannon River (100)				□			1		1						
Little Goose Pool															
Central Ferry (132)							1								
Lower Granite Pool															
Lower Granite Dam (172)			□				1								
Cleat-water River (224)			1 □	■	■	■	1		1						3 ^c
Grande Ronde River (272)			1 ⊠	□											

^a Locations having no number associated with a given week were not sampled.

^b □ = < 500,000 smolts; ◻ = 500,000–1,000,000 smolts; ■ = ≥ 1,000,000 smolts

^c Sampling during this week was at the Potlatch River (RM 12), 6/27-6/29.

Field Procedures

Three or four small-mesh gill nets (2.4 m deep x 45.6 m long constructed from 7.6-m panels with the repeating mesh size sequence of 4.4 cm and 5.1 cm bar measures) were fished concurrently by each crew. Most nets were placed perpendicular to shore on the river bottom for approximately 45 minutes. Initially, nets were placed in sites where northern squawfish were likely to concentrate based on river conditions, such as back eddies or protected coves. Once we sampled a number of different sites, nets were placed in the most productive sites and moved whenever catch rates fell below one to two northern squawfish per net hour or when two or more adult salmonids were caught at that site during the night (Collis et al. 1995b). All incidentally caught fish were identified and immediately released.

In 1995, operational criteria established to minimize potential impacts to salmonids were revised somewhat from the previous year (Collis et al. 1995b). Specifically, the season length was extended to the end of June, the daily fishing period was extended to an hour past sunrise, and the sockeye salmon (*Oncorhynchus nerka*) passage criterion that determined cessation of fishing within a reach or reservoir on the Columbia River (Collis et al. 1995b) was amended so that fishing could continue once that criterion was reached, but only inside tributary mouths. We believed that these changes would increase our ability to catch northern squawfish without risking greater impacts to salmonids.

Data Collection and Analysis

We identified and enumerated the catch and measured fork length (mm) from a random sample of up to three northern squawfish per net. Unless otherwise noted, subsequent data summaries and analyses include only predator-sized (≥ 250 mm fork length) northern squawfish. We compared catch and CPUE for different areas and time periods.

Incidentally caught salmonids 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 juvenile or adult and examined for external marks or fin clips. Specific information on condition was collected for each salmonid caught, including the presence of blood, whether the fish freed itself from the net, and where on the body the fish was caught in the net.

Statistical comparisons are by Student t-test (*t*). Probability (*P*) values are two-tailed. Means are expressed as $\bar{X} \pm SE$.

RESULTS AND DISCUSSION

Northern Squawfish Catch

In 1995, we caught a total of 9,634 northern squawfish (Table D-3), the majority (98.4%) were predator-sized. Overall, gill nets were fished for 2,427 net-hours and caught 9,484 predator-sized northern squawfish for a CPUE of 3.9. The seasonal catch rate declined from 1994 (CPUE = 6.6; Collis et al. 1995b) due to more time spent investigating new locations that turned out to be less productive compared to established sampling locations. Furthermore, changes in water conditions either precluded, or made more difficult, sampling at sites that were previously productive, such as at some sites at mouth of the Klickitat River and all sites at Tanner Creek (see below).

As in 1994, Bonneville Pool was the most productive of the seven pools and one reach (below Bonneville Dam) in both total catch (8,668) and CPUE (4.7) of northern squawfish (Figure D-3). Of the remaining pools, Ice Harbor was the most productive (Figures D-3), with a catch of 231 northern squawfish and CPUE of 2.1. Generally, gillnetting effort was distributed in pools or reaches (Figure D-3) and at locations (Table D-3) according to that area's relative CPUE. The productivity of Bonneville and Ice Harbor pools relative to other areas was largely due to the productivity of the Klickitat River and Levey Landing, respectively.

As in the previous year, the mouth of the Klickitat River was the most productive location fished in 1995 (CPUE = 5.7; Table D-3), although the catch rate declined from 1994 (CPUE = 10.1; Collis et al. 1995b). This decline was partially due to the low pool height in Bonneville in 1995, which prevented us from fishing the most productive sites the previous year. Levey Landing (CPUE = 2.1) was the most productive location outside of Bonneville Pool, followed by Tanner Creek (Table D-3). Based on past research (Ledger-wood et al. 1994, 1995) we expected catch rates at Tanner Creek to be higher, but high flows limited our ability to fish gill nets effectively. Although no hatchery-reared salmonids were released at Levey Landing or Bingen Marina, juvenile salmonids released from upriver locations were observed to concentrate and hold at these locations. We suspect this is because both locations are backwater habitats with artificial lighting. Hatchery-reared salmonids, which exhibit positive phototactic behavior (Fields et al. 1958) concentrate in these and other areas having similar characteristics that provide northern squawfish with excellent feeding opportunities (Nh4FS, unpublished data).

Table D-3. Northern squawfish (NSF) catch, effort, and CPUE (catch per net hour) for gill nets in 1995

River and location	Effort (net hours)	Small NSF (< 250 mm)	Large NSF (≥ 250 mm)	CPUE ^a
Columbia River				
Klickitat River	1,324.8	94	7,556	5.7
Wind River	38.8	0	97	2.5
Drano Lake	317.0	11	723	2.3
Lewis River	12.9	2	27	2.1
Tanner Creek	68.5	5	134	2.0
Bingen Marina	118.8	4	228	1.9
Kalama River	31.9	14	58	1.8
Walla Walla River	20.9	3	37	1.8
Spring Creek	31.8	5	56	1.8
Celilo Marina	10.8	0	18	1.7
Sandy River	3.1	0	4	1.3
Washougal River	26.2	0	26	1.0
Umatilla River	139.1	1	136	1.0
Hood River	8.8	0	8	0.9
Hanford Ferry	23.8	0	20	0.8
Miller Island	8.5	0	7	0.8
Cowlitz River	19.5	1	12	0.6
Elokomin River	4.3	0	2	0.5
Total	2,209.6	140	9,149	4.1
Snake River				
Levey Landing	112.1	4	231	2.1
Tucannon River	4.9	0	9	1.8
Central Ferry	13.2	2	22	1.7
Grande Ronde River	3.7	0	5	1.3
Clearwater River	36.2	1	36	1.0
Potlach River	16.1	1	12	0.7
Lower Granite Dam	9.6	1	7	0.7
Lyons Ferry	21.1	1	13	0.6
Total	217.0	10	335	1.5
Grand Total	2,426.6	150	9,484	3.9

^aCPUE for NSF ≥ 250 mm (fork length)

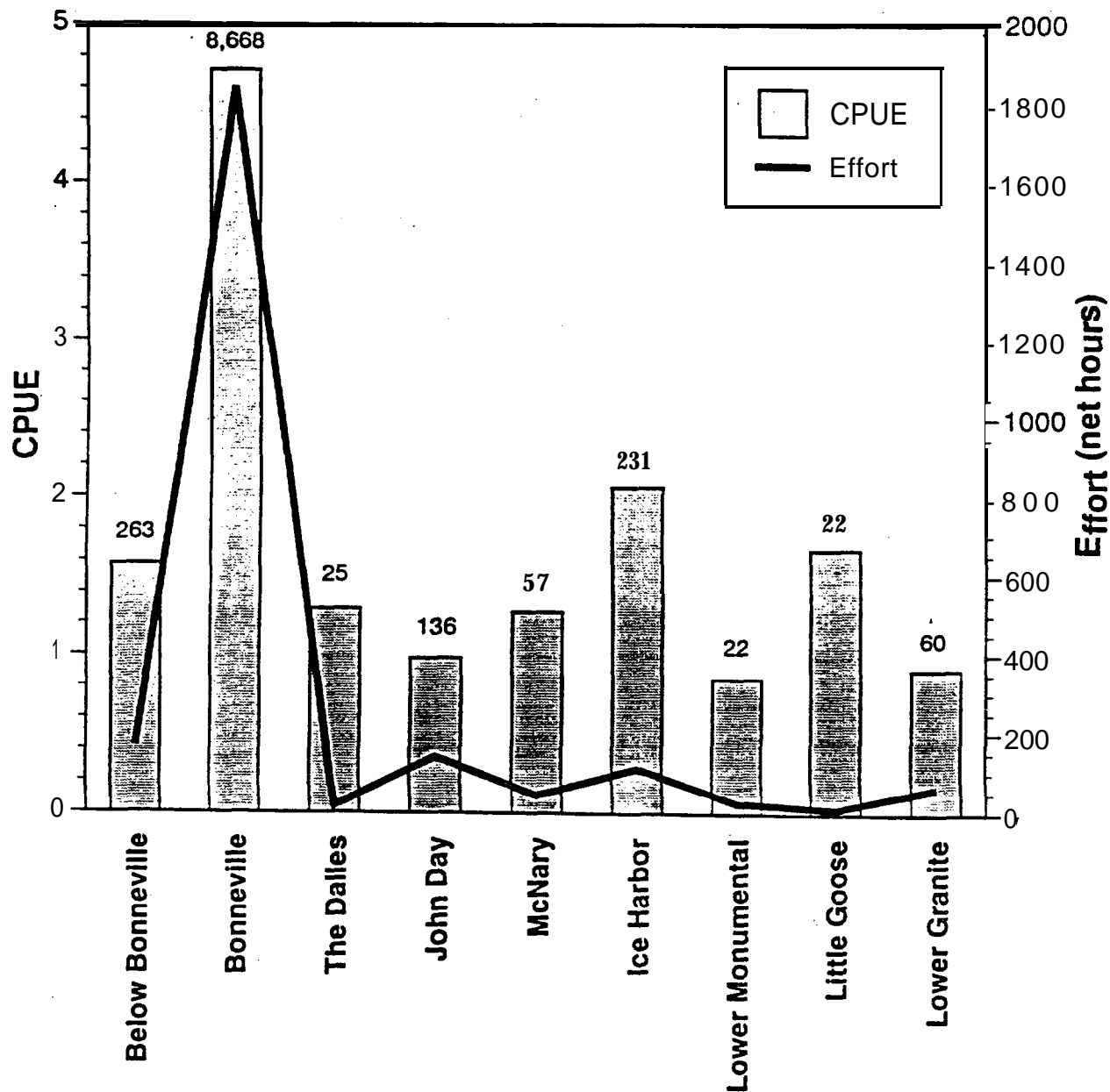


Figure D-3. Northern squawfish catch (values above bars), effort, and catch per net hour (CPUE) on the Columbia River below Bonneville Dam and in lower Columbia and Snake River reservoirs in 1995.

The highest monthly catch and effort in 1995 was in May on both the Columbia and Snake rivers (Figure D-4). The highest catch rates of northern squawfish were in April and May on the Columbia and Snake rivers, respectively (Figure D-4). Colder water temperatures in 1995, as compared to 1994, likely reduced catch rates in March and April and perhaps overall (Collis et al. 1995b). Feeding activity and metabolic rate of northern squawfish are reduced with lower water temperatures (Vigg et al. 1991).

The timing and duration of elevated catch rates of northern squawfish appear to be closely related to the release and subsequent residence time of the hatchery-reared fish at a sampling location (Thompson 1959; Thompson and Tufts 1967; Ledgerwood et al. 1994, 1995; Collis et al. 1995a). In 1995, we found further evidence in support of this relationship at the Klickitat River (Figure D-5) — the only location sampled continuously throughout the season, both before and after hatchery releases. Of 28 dates when catch rates were above the seasonal mean for that location, 26 (92.8%) of those dates fell within a hatchery release period (Figure D-5). Furthermore, on 15 dates sampled following the end of the last release period, catch rates never exceeded the seasonal mean (Figure D-5).

Catch rates of northern squawfish increased gradually from 8 p.m. to 4 a.m., and reached a peak between 4 a.m. and 5 a.m. before declining steadily through dawn (Figure D-6). This pattern was similar to that observed the previous year (Collis et al. 1995b) and appears to correspond with diel fluctuations in downstream migration of juvenile salmonids noted elsewhere (Mains and Smith 1964).

Site-specific gillnetting caught larger northern squawfish ($X = 410.5 \pm 0.8$ mm) as compared to all other predator-control fisheries in 1995 (D. Ward, ODFW, personal communication) as was the case the previous year (Knutsen et al. 1995). Significantly ($t = 9.1$ $p < .0001$) larger fish were caught on the Columbia River ($X = 412.4 \pm 0.9$ mm, $N = 5,268$) as compared to the Snake River ($X = 379.2 \pm 2.6$ mm, $N = 314$; Figure D-7), which was not consistent with results from other predator-control fisheries in 1995 (D. Ward, ODFW, personal communication). The size difference between fish caught on the Columbia and Snake rivers is likely an artifact of the sampling locations fished. The majority of the sampling on the Columbia River was conducted in areas where northern squawfish were feeding; hence, mostly predator-sized fish were captured. On the Snake River, we had difficulty finding feeding concentrations and, therefore, were sampling from the population at large.

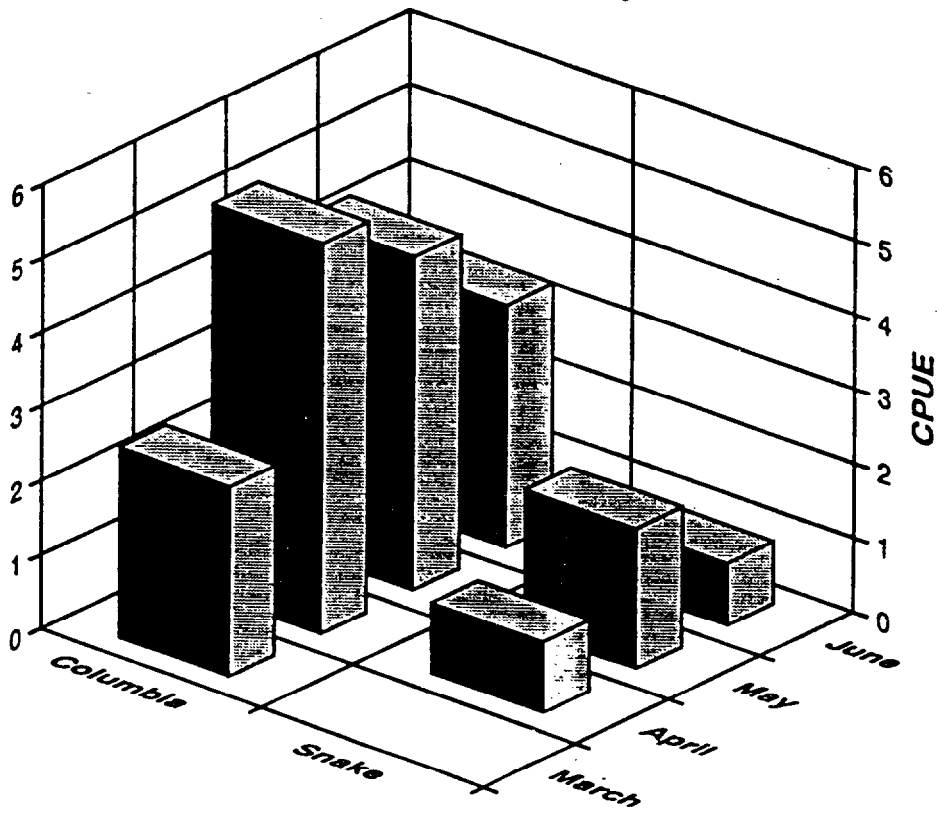
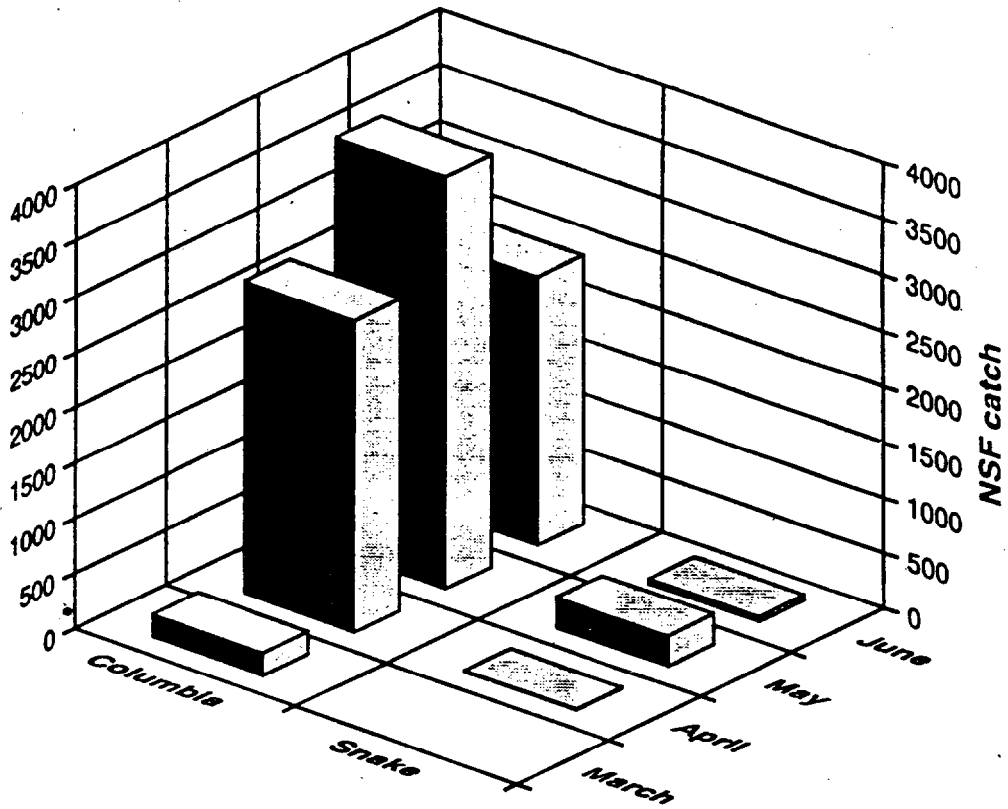


Figure D-4. Monthly gill net catch and catch per net hour (CPUE) of northern squawfish (NSF) in the Columbia and Snake rivers in 1995.

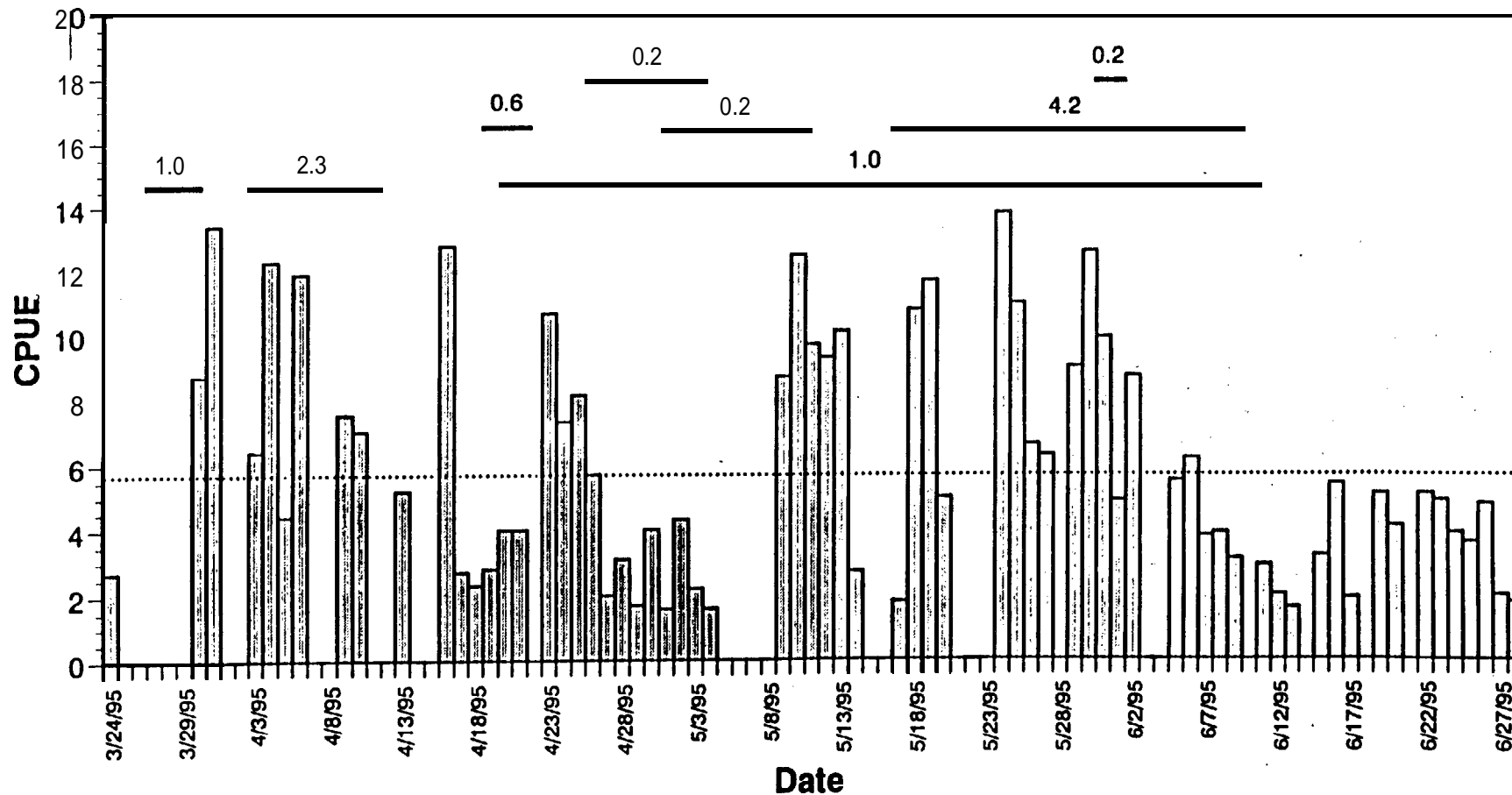


Figure D-5. Daily northern squawfish catch per net hour (CPUE) as it relates to the dates and number of hatchery-reared salmonids released in the Klickitat River in 1995. Solid lines over bars represent voluntary releases periods and the number above each line is the total number (in millions) of salmonids released. Dashed line is the mean CPUE (5.7) for northern squawfish at the Klickitat River in 1995. Sampling did not take place on dates without bars.

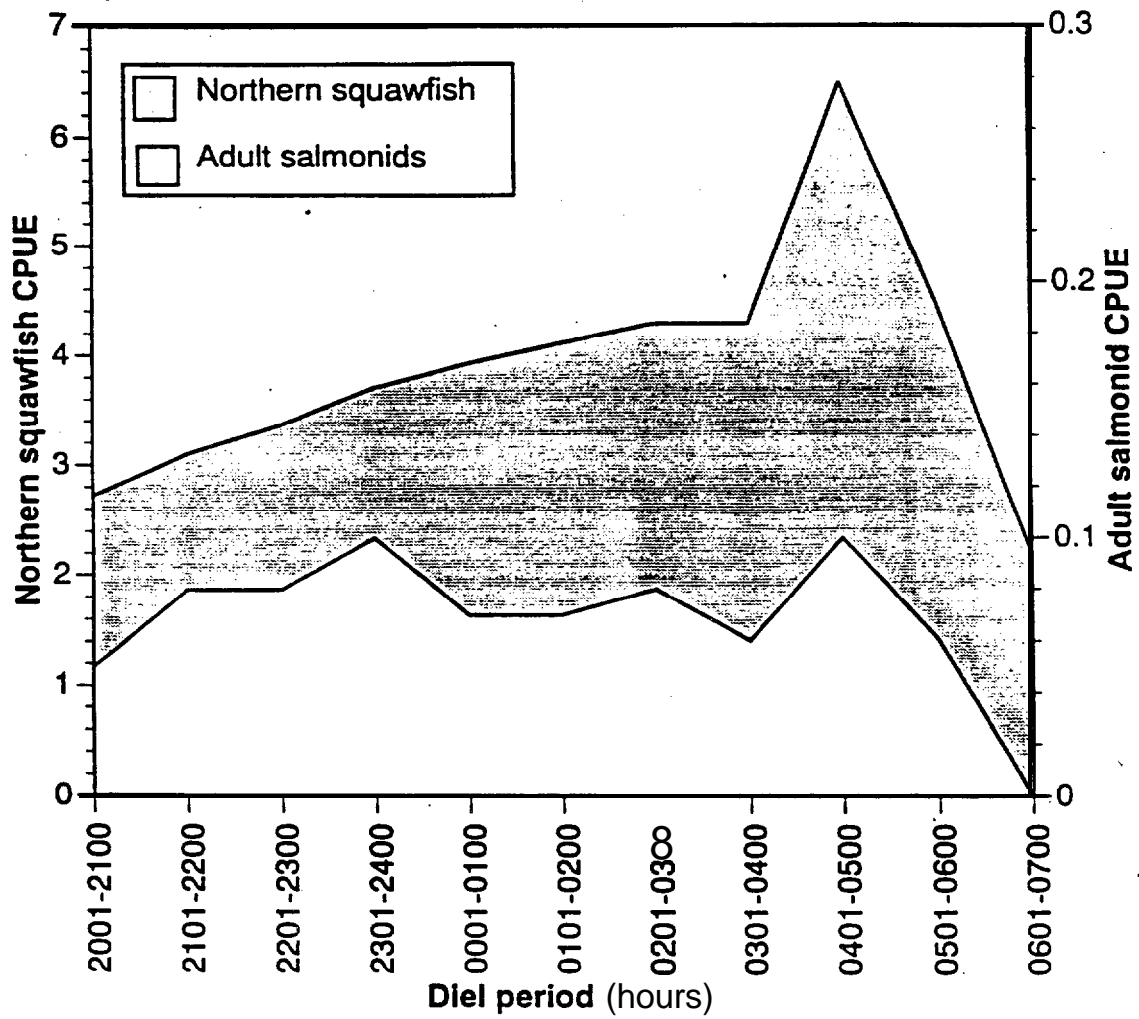


Figure D-6. Catch per net hour (CPUE) of northern squawfish and adult salmonids in gill nets during different diel periods in 1995.

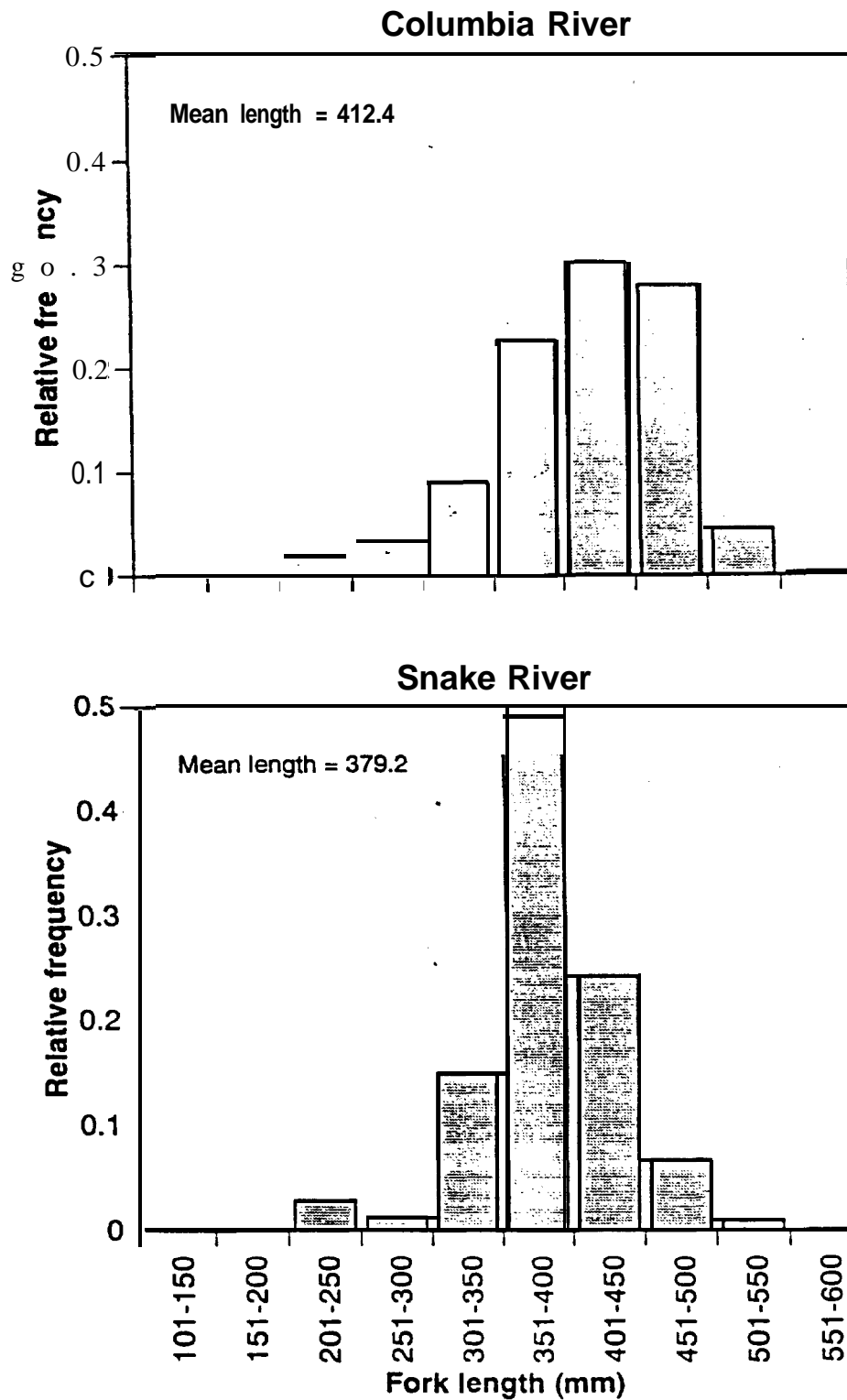


Figure D-7. Size distribution of northern squawfish caught in gill nets in the Columbia and Snake rivers in 1995.

Incidental Catch

In 1995, 10,248 fish (5.1% of the total catch) were incidentally caught in gill nets (Table D-4). Incidentally caught species composed 49% and 8.1% of the total catch on the Columbia and Snake rivers, respectively (Figure D-5). Suckers (*Catostomus* spp.) were the most common incidentally caught species on both the Columbia and Snake rivers (3.1% and 52% of the total catch, respectively; Table D-4), followed by white sturgeon on the Columbia River (7% of total catch; Figure D-8) and channel catfish on the Snake River (14% of total catch; Table D-4).

We caught 196 salmonids (1% of total catch) in 1995 (Table D-5). The salmonid catch declined 33% from the 294 caught in 1994 (Collis et al. 1995b), largely due to the elimination of Merwin trapping in 1995. The majority of the salmonid gill-net catch was adults (91%) and most (81%) were likely to survive at release (Table D-5). Of the total adult salmonid catch, 40% were steelhead (*Oncorhynchus mykiss*; Table D-5). Salmonids comprised 1% and 0.1% of the total catch on the Columbia and Snake rivers, respectively (Table D-5).

Catch rates of adult salmonids remained relatively constant for different diel periods. However, they declined rapidly from 5:01 a.m. to 7 a.m. (Figure D-6), which was consistent with data from last year (Collis et al. 1995b).

RECOMMENDATIONS

1. Focus effort at the most productive times and locations as determined inseason and in previous years.

Based on two years of data, the Columbia River, particularly Bonneville Pool, is the most productive area to conduct site-specific gillnetting for northern squawfish. We propose to focus the majority of our effort at locations in Bonneville Pool in 1996. We will continue to monitor inseason catch rates to schedule crews at the most productive times and locations:

2. Investigate new locations where we have evidence to suggest catch rates of northern squawfish would be high.

Although most of our effort will be focused at locations previously sampled, we plan to investigate some new locations in 1996. Specifically, backwater areas that have artificial lighting such as the forebay of Bonneville Dam. The mouth of the Deschutes River is also proposed, but will require approval of the Warm Springs Fish and Wildlife Committee and the Oregon Department of Fish and Wildlife.

Table D-4. Species composition of gill-net catch in the site-specific fishery in 1995.

Species	Columbia River	Snake River	Total
Northern squawfish <i>Ptychocheilus oregonensis</i>	9,289	345	9,634
Sucker <i>Catostomus</i> spp	5,649	955	6,604
White sturgeon <i>Acipenser transmontanus</i>	1,263	25	1,288
Channel cattish <i>Ictalurus punctatus</i>	220	261	481
Common carp <i>Cyprinus carpio</i>	357	91	448
American shad <i>Alosa sapidissima</i>	277	18	295
Peamouth <i>Mylocheilus caurinus</i>	242	32	274
Bass <i>Micropterus</i> spp.	188	40	228
Salmonids <i>Oncorhynchus</i> spp	194	2	196
Walleye <i>Stizostedion vitreum</i>	184	0	184
Chiselmouth <i>Acrocheilus alutaceus</i>	64	18	82
Crappie <i>Pomoxis</i> spp.	32	6	38
Mountain whitefish <i>Prosopium williamsoni</i>	34	0	34
Bluegill <i>Lepomis macrochirus</i>	20	3	23
Yellow perch <i>Perca flavescens</i>	3	12	15
Brown bullhead <i>Ictalurus nebulosus</i>	5	0	5
Char <i>Salvelinus</i> spp.	3	0	3
Brown trout <i>Salmo trutta</i>	3	0	3
Starry flounder <i>Platichthys stellatus</i>	2	0	2
Pacific lamprey <i>Lampetra tridentata</i>	2	0	2
Unidentified ^a	28	15	43
Total	18,059	1,823	19,882

^a Species information not available for these fish; however, none were salmonids.

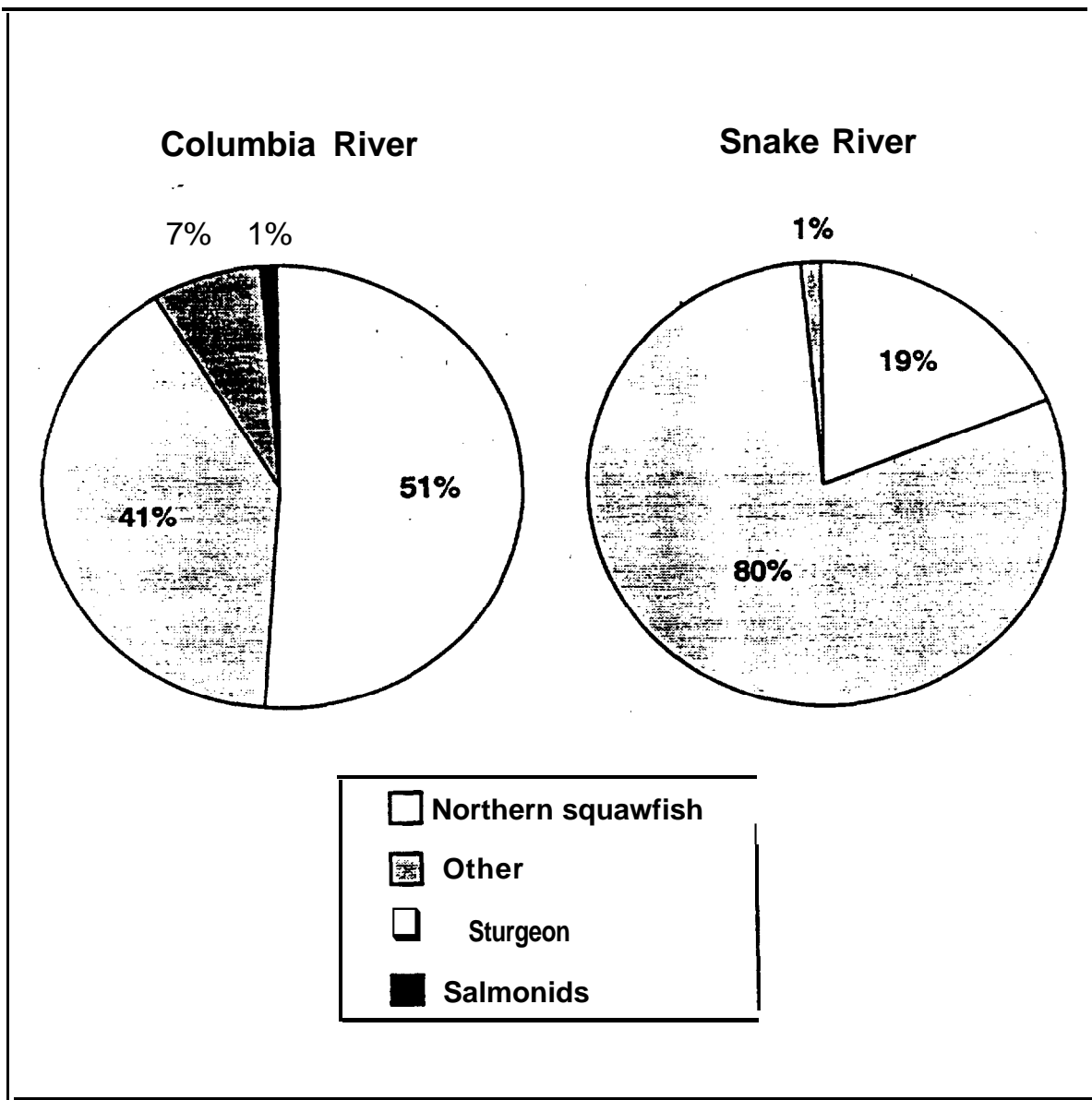


Figure D-8. Percent of total catch of northern squawfish and incidentally caught species for gill nets in 1995.

Table D-5. Salmonid bycatch by species and condition at release from gill nets in 1995. Condition codes: (1) minimal injury, certain to survive; (2) moderate injury, may or may not survive; (3) dead, nearly dead, or certain to die. Only locations where salmonids were captured are shown.

River and location	Adult salmonids												Juv. salmonids ^b		
	Chinook			Steelhead			Sockeye			Other ^a			1	2	3
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Columbia River															
Klickitat River	49	2	6	29	8	4	0	0	0	0	0	0	4	0	4
Drano Lake	26	0	2	6	1	1	0	0	0	0	0	0	6	0	0
Washougal River	7	0	0	2	0	0	0	0	0	0	1	0	1	0	0
Bingen Marina	1	0	0	2	2	0	0	0	0	0	0	0	0	0	0
Cowlitz River	0	1	0	3	0	0	0	0	0	0	0	0	0	1	0
Kalama River	1	0	0	2	1	0	1	0	0	0	0	0	0	0	0
Lewis River	1	1	0	0	1	1	0	0	0	1	0	0	0	0	0
Tanner Creek	1	0	1	2	0	0	0	0	0	0	0	0	1	0	0
Hood River	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spring Creek	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Umatilla River	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Wind River	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Hanford Ferry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Walla Walla	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Total	90	4	9	51	13	6	1	0	0	1	1	0	12	1	5
Snake River															
Levey Landing	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Total	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Grand Total	91	4	9	52	13	6	1	0	0	1	1	0	12	1	5

^a Cutthroat trout

^b Not identified to species

Our results at Levey Landing and Bingen Marina, coupled with observations at the forebay of Bonneville Dam, suggest that these and other areas with backwater habitats having artificial lighting might be productive locations for site-specific gillnetting.

In the past, the Deschutes River has been an area of concern due to potential impacts to salmonids and for that reason we have yet to sample that location. We have demonstrated over the past three years of site-specific gillnetting that salmonids can be sufficiently protected from undue harm. This, coupled with considerable anecdotal evidence that suggests predation rates are high at this location, may warrant further consideration.

3. Test the use of alternative methods, including hook-and-line angling and different gillnetting techniques.

Northern squawfish have been successfully targeted for removal using hook-and-line, yet this gear has not been tested as part of our site-specific fishery. We plan to investigate the use of hook-and-line and other gillnetting techniques such as driftnetting so that we might develop more productive and efficient removal methods,

4. Continue to identify ways to reduce bycatch of salmonids and protect salmonids and other sensitive species from harm.

“Incidental catch of salmonids will be closely monitored so that decisions can be made to reduce bycatch of salmonids, particularly listed stocks.

REFERENCES

Collis, K., R. E. Beaty, and B. R. Crain. 1995a. Changes in catch rate and diet of northern squawfish associated with the release of hatchery-reared juvenile salmonids in a Columbia River reservoir. *North American Journal of Fisheries Management* 15:346-357.

Collis, K., R. E. Beaty, J. McCormack, and K. McRae. 1995b. Site-specific removal of northern squawfish aggregated to feed on juvenile salmonids in the spring in the lower Columbia and Snake rivers. Pages 153-186 *in* C. F. Willis and F. R. Young, editors. Development of a systemwide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1994 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.

- Fields, P. E., A. K. Murray, D. E. Johnson, and G. L. Finger. 1958. Guiding migrant salmon by light repulsion and attraction in fast and turbid water. Technical Reports 36 and 41. University of Washington, College of Fisheries, Seattle, Washington.
- Knutsen, C. J., D. L. Ward, T. A. Friesen, and M. P. Zimmerman. 1995. Development of a systemwide predator control program: indexing and fisheries evaluation. Pages 203-263 *in* C. F. Willis and F. R. Young, editors. Development of a systemwide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1994 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.
- Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, M. A. Toner, T. P. Poe, and H. L. Hansen. 1995. Effectiveness of predator removal for protecting juvenile fall chinook salmon released from Bonneville Hatchery. Pages 303-352 *in* C. F. Willis and D. L. Ward, editors. Development of a systemwide predator control program: stepwise implementation of a predator index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1993 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.
- Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, L. T. Parker, T. P. Poe, and H. L. Hansen. 1994. Effectiveness of predator removal for protecting juvenile fall chinook salmon released from Bonneville Hatchery, 1992. Pages 295-360 *in* C. F. Willis and A. A. Nigro, editors. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1992 Annual Report. Contract DE-BI79-90BP07084, Bonneville Power Administration, Portland, Oregon.
- Mains, E. M., and J. M. Smith. 1964. The distribution, size, and current preferences of seaward migrant chinook salmon in the Columbia and Snake rivers. Washington Department of Fisheries, Fisheries Research Papers 2(3), Olympia, Washington.
- Rieman, B. E., and R. C. Beamesderfer. 1990. Dynamics of a northern squawfish population and the potential to reduce predation on juvenile salmonids in a Columbia River reservoir. *North American Journal of Fisheries Management* 10:228-241.
- Thompson, R. B. 1959. Food of the squawfish *Ptychocheilus oregonensis* (Richardson) of the lower Columbia River. U.S. Department of the Interior, Fish and Wildlife Service, Fishery Bulletin 158:43-58.

- Thompson, R. B., and D. F. Tufts. 1967. Predation by Dolly Varden and northern squawfish on hatchery-reared sockeye salmon in Lake Wenatchee, Washington. *Transactions of the American Fisheries Society* 96: 424-427.
- Vigg, S., T. P. Poe, L. A. Prendergast, and H. C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleye, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. *Transactions of the American Fisheries Society* 120:42 1-43 8.
- Willis, C. F., and D. L. Ward, editors. 1994. Development of a systemwide predator control program: **Stepwise** implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. 1993 Annual Report. Contract DE-B 179-90BP07084, Bonneville Power Administration, Portland, Oregon.

Report E

**Handling and Transportation of Northern Squawfish
Harvested under the Columbia River
Northern Squawfish Management Program**

Prepared by

**Jon Pampush
Charles F. Willis**

**S.P. Cramer and Associates, Inc.
Portland, Oregon**

1995 Annual Report

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We also thank Frank Young (Columbia Basin Fish and Wildlife Authority), Russell Porter (Pacific States Marine Fisheries Commission), and Bill Maslen and John Skidmore (Bonneville Power Administration) for their support for this work and for their comments on an earlier draft of this report.

This work was funded as a subcontract by the Pacific States Marine Fisheries Commission (Contract 94-107) under a base contract with the Bonneville Power Administration (BPA Project 90-077).

ABSTRACT

Three fisheries for harvesting northern squawfish (*Ptychocheilus oregonensis*) were implemented under the Columbia River Northern Squawfish Management Program during the spring and summer of 1995. In all, 214,572 northern squawfish were harvested. Harvested fish must be handled and transported from points of harvest to points of appropriate end-use or disposal to comply with state laws and social ethics prohibiting wanton waste of this resource.

We describe the fish handling and transportation system that we implemented in 1995. This system required cooperation and coordination of activities among private-sector end users of harvested northern squawfish and managers who were responsible for fishery implementation. The 1995 system included a food-grade fish collection network, established in a section of the lower Columbia River, that packaged and sold frozen northern squawfish to Stoller Fisheries, Inc. in Spirit Lake, Iowa. Fish harvested in other program areas were rendered or killed and returned to the Columbia River.

The total spent for implementing the entire fish handling system in 1995 was \$142,164 as of January 1, 1996. With cost recovery from sale of northern squawfish to Stoller Fisheries, Inc., the net cost for the fish handling system was \$133,480.

INTRODUCTION

This report provides a description and cost summary of the 1995 northern squawfish (*Ptychocheilus oregonensis*) handling system. This system included a combination of food-grade collection and rendering. Food-grade northern squawfish were frozen, packaged and sold to Stoller Fisheries in Spirit Lake, Iowa. Non-food-grade northern squawfish were picked up by rendering companies for a charge and converted to animal feed. Field logistics, food-grade processing information, other end-uses and future recommendations are also discussed.

PROJECT DESCRIPTION

Fish Handling Options Available to the Program

In 1994, we examined the cost-effectiveness of two alternative options for handling northern squawfish harvested under the Columbia River Northern Squawfish Management Program. These options included rendering all the northern squawfish harvested by the program or selling some of the carcasses to Stoller Fisheries and rendering the remaining volume. Rendering is the lowest value end-use available to the program. The products of rendering are animal feed supplements and oil. Renderers do not pay for the carcasses. Rather, they charge a pick-up and disposal fee that is assumed by the handling project. Stoller Fisheries purchases food-grade freshwater fish, minces the flesh, and sells the product to processors of frozen fish products.

In September 1994, we provided to the program a cost comparison between these handling options and we demonstrated that a combination of food-grade handling and rendering was the least-cost handling option available to the program that satisfied our handling requirements. Food-grade northern squawfish provides a cash return to the program, but more handling is required to maintain quality. Rendering requires less fish handling, but the project must pay for pick-up and disposal of the carcasses. Our assessment of handling options focused on whether the revenue generated from the sale of food-grade fish offsets the added cost for the additional fish handling required to maintain food-grade quality.

Fish Handling Requirements

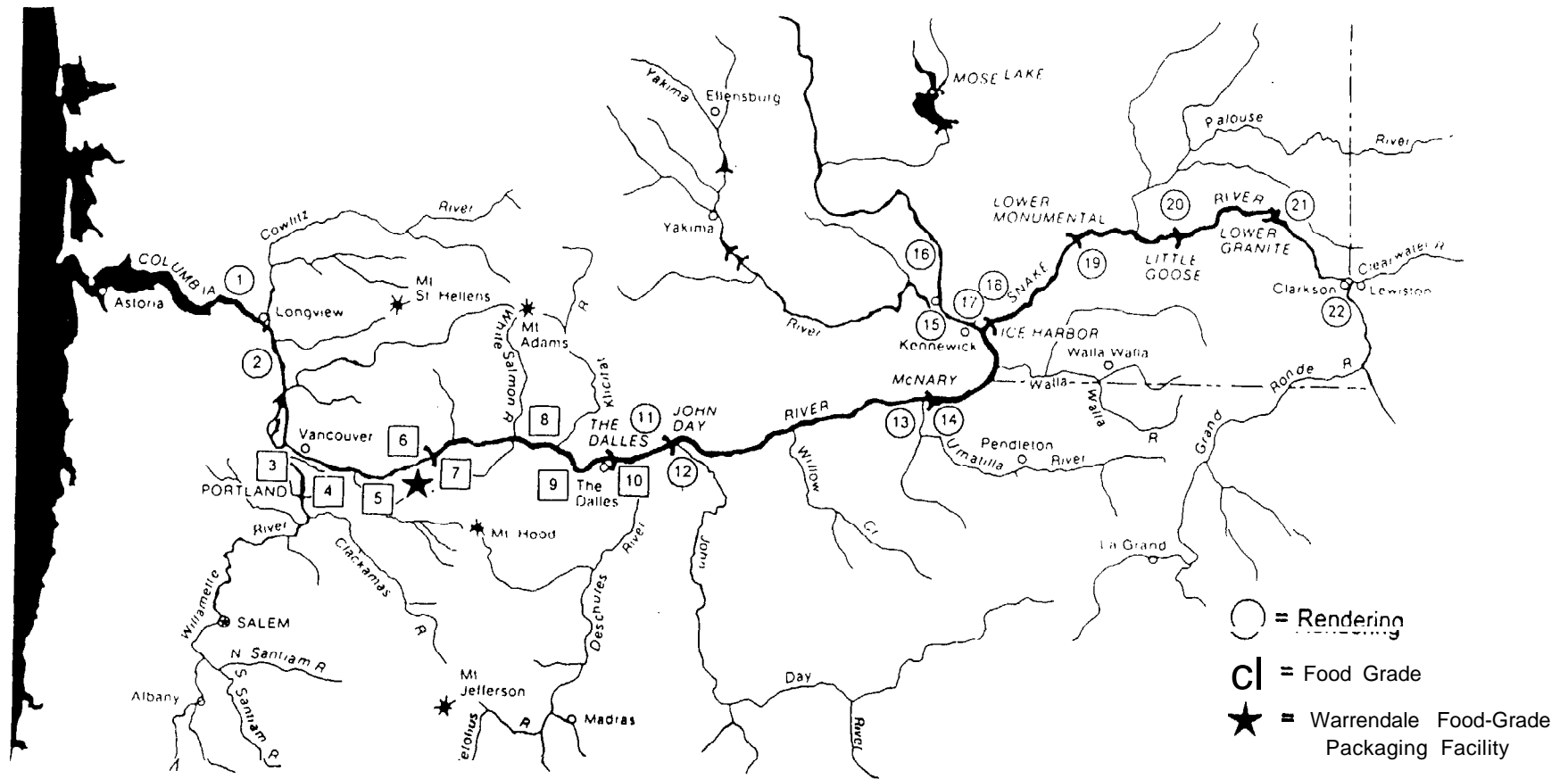
The northern squawfish handling network requires some basic services, facilities and equipment. Following is a review of the minimum handling requirements.

1. The carcasses must be removed from the field daily and stored in a secure cooler. Leaving barrels of carcasses outside overnight is unacceptable for sanitary and security reasons. Only very small quantities can be frozen in chest freezers and removed later. Large quantities must be collected and transported to storage centers on a daily basis.
2. The renderer in Portland requires carcasses in at least fair condition because the facility is located within the city limits and odor complaints are frequent.
3. Labor is required to transport carcasses to central receiving locations and to assist with disposal or shipping to other destinations. This labor can be provided by the handling network or by Washington Department of Fish and Wildlife (WDFW) technicians. Because of declining harvest rates, food-grade collection from the dams is no longer economically feasible and these northern squawfish carcasses can be returned to the Columbia River.
4. Central storage locations must have at least a walk-in cooler and cleaning facilities. Otherwise the carcasses must be picked-up daily by a renderer at a prohibitive cost. **Unrefrigerated** northern squawfish carcasses deteriorate rapidly and emit a powerful odor.

METHODS

Description of the 1995 Food-Grade Fish Handling Network

In 1995, we implemented a limited food-grade collection network centered near Warrendale, Oregon. Larry Stoller of Stoller Fisheries, Inc. in Spirit Lake, Iowa, bought whole, frozen northern squawfish for \$0.11 per pound and paid \$0.04 per pound for transportation from the collection center in Oregon to his plant in Iowa. Food-grade fish were collected from Gleason, Washougal, The Fishery, Hamilton Island, Bingen, The Dalles and Giles French sport-reward fishery registration sites and from Bonneville Dam (Figure 1).



Spa-t-Reward Sites

1	Cathlamet	cl 5	The Fishery	11	Giles French	17	Hood Park
2	Kalama	6	Hamilton Island	13	Umatilla	22	Greenbelt
3	Gleason	8	Bingen	15	Columbia Point		
4	Washougal	9	The Dalles	16	Vernita		

Dams

cl 7	Bonneville Dam	18	Ice Harbor Dam
10	The Dalles Dam	19	Lower Monumental Dam
12	John Day Dam	20	Little Goose Dam
14	McNary Dam	21	Lower Granite Dam

Figure 1. Map of northern squawfish collection and processing network

The food-grade collection area was again quite productive in terms of northern squawfish harvested. Although it represented only about 20% of the total program area, it produced 67% of the programwide harvest. The food-grade handling area was logistically favorable because most travel was along relatively short distances by way of Interstate 84. These two features combined to minimize fish handling and transportation costs.

The fish handling network employed a driver who collected the iced northern squawfish from drop-off locations (Portland, Oregon; Bonneville Dam; and The Dalles, Oregon) and delivered them to the Warrendale, Oregon, facility where they were packaged and frozen (Figure 1). Coolers were cleaned by the fish handler at the Dalles and Warrendale facilities.

Dam-angling and sport-reward technicians provided very high yields of food-grade squawfish, about 90%, but a significant number of northern squawfish that appeared in the sport-reward fishery early in the season were rendered because they were too small for food-grade processing. Fifty-nine percent (84,950 pounds) of the northern squawfish harvested from the food-grade area (145,000 pounds) were shipped to Stoller for processing. Toward the end of the season, when it became apparent that a third full truck-load was not attainable and to reduce handling costs, all northern squawfish from the food-grade area were rendered (about 26,000 pounds). Pick-ups at Bonneville Dam were discontinued midseason when harvest rates began to decline.

Description of Rendering-Only Fish Handling Areas

The rendering-only locations included Kelso, Pasco, and Clarkston, Washington (Figure 1). The rendering only locations were facilities that provided walk-in coolers, disposal barrels and cleaning equipment. Sport-reward fishery technicians delivered northern squawfish carcasses to these locations, deposited them into barrels, and cleaned their coolers. The facility manager would provide assistance as needed to drivers who came to pick up fish to be rendered. Rendering-only northern squawfish harvest locations handled about 63,000 pounds of northern squawfish during the 1995 season.

Efforts were made in previous years to collect food-grade northern squawfish from the areas that are now rendering-only areas. However, relatively small numbers of fish harvested, difficult handling logistics, and the high cost of ice needed to preserve food-grade fish quality precluded cost-effective food-grade handling in these areas.

Due to cost restraints and transportation difficulties, no effort was made in 1995 to collect northern squawfish harvested at any dams except Bonneville or from the site-specific gill-net fishery. Uncollected northern squawfish were returned to the Columbia River.

RESULTS AND DISCUSSION

Cost Recovery Through Sale of Food-Grade Fish

Sale of food-grade northern squawfish to Stoller Fisheries, Inc. generated \$8,684 in direct revenues (from 78,950 pounds of minceable northern squawfish). Stoller also paid \$3,398 in transportation charges that otherwise would have been borne by the program as rendering pick-up charges. Table 1 summarizes Stoller's processing figures and payment totals for the 1995 season. Stoller received two shipments of northern squawfish from the program during 1995. Table 2 provides information concerning processing dates, food-grade yields and revenues generated from each shipment.

1995 Overall Fish Handling System Cost Summary

The cost associated with the 1995 northern squawfish handling system is summarized in Table 3. The cost to operate the 1995 food-grade network (not including cost recovery from fish sales to Stoller Fisheries, Inc.) was \$55,570. Total cost for the rendering-only areas (Kelso, Pasco, and Clarkston) during the 1995 season was \$11,761. The projectwide direct handling cost for both the food-grade collection area and rendering-only locations was, therefore, \$67,331. The cost of the materials to package the frozen northern squawfish in 1995 was \$1,966. These materials included waxed fish boxes (50-pound capacity) and plastic box liners. The fixed cost for managing the project and for coordinating among participants was \$72,867 as of January 1, 1995. Therefore, the total spent for the project was \$142,164. With cost recovery (i.e., fish sales to Stoller Fisheries, Inc.), the net project cost was \$133,480.

Other End Uses for Northern Squawfish Harvested in 1995

Scott Lewis from Oregon State University was given 1,000 pounds of low quality northern squawfish from the food-grade fish handling area for use as bait to facilitate his crayfish research.

Table 1. Summary of Stoller Fisheries, Inc. processing and payment information during 1995.

Total Fish Shipped:	86,278 pounds
Total Fish Processed:	78,950 pounds
% Processed 91.5%”	
Total Reimbursement (78,881 pounds @ \$0.1 l/pound)	\$8,684 ^b
Shipping paid by Stoller (91,050 pounds @ \$0.04/pound)	\$3,398”
Total sales value including shipping costs	\$12,082 ^d

^a Seven percent of the northern squawfish received by Stoller were not food-grade quality due to small size, shipping damage or poor quality.

^b Stoller paid cash for usable northern squawfish only (78,881 pounds).

^c Stoller paid for shipping from Oregon to Iowa. This amount was a savings to the program not a cash payment.

^d This total represents the total value of Stoller’s contribution to the program (cash payment and shipping costs).

Table 2. Summary of processing and payments by shipment of northern squawfish to Stoller Fisheries, Inc. during 1995

Shipment #1 Processed July 11, 1995:

Total Fish received:	41,278 pounds
Fish too small or of low quality:	6,228 pounds
Net processed fish:	35,050 pounds
% processed (food-grade);	84.9%
Amount received (@ \$0.1 l/pound):	\$3,855.50

Shipment #2. Processed November 8, 1995

Total Fish received:	45,000 pounds
Fish too small or of low quality:	1,100 pounds
Net processed fish:	43,900 pounds
% processed (food-grade);	97.6%
Amount received (@ \$0.1 l/pound):	\$4,829.00

Total Amount Received	\$8,684.50
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Table 3. Summary of the total cost for the 1995 northern squawfish handling network through January 1, 1995.

Program component	Total cost
Food-Grade Collection	\$55,570
Rendering only Collection	\$11,761
Equipment Handling and Storage	\$1,966
Fixed Costs (Administration, contracts, negotiations, coordination and field supervision)	\$72,867
Total	\$142,164
Cost Recovery (Stoller sales)	\$8,684
Total, after Cost Recovery	\$133,480

CONCLUSIONS AND RECOMMENDATIONS

The 1995 northern squawfish handling network was successful overall, but some obvious improvements can be made for the future. The program realized an \$8,684 cash return from the sale of food-grade northern squawfish to Stoller Fisheries. However, it became apparent in 1995 that significant logistical changes must be made to **further** reduce handling costs. These changes would benefit either handling option and would further improve the feasibility of a food-grade network.

In 1996, the northern squawfish handling network will be administered by the Washington Department Fish and Wildlife (WDFW) rather than S.P. Cramer and Associates. This transfer of responsibility will save the overall program money because there is no longer a need for an interagency handling coordinator. Only sport-reward northern squawfish will need to be handled in the future and WDFW already has the staff and experience to assume this responsibility. We make the following recommendations to reduce costs and improve the handling network overall.

1. WDFW should assume as much transportation responsibility as possible. The WDFW technicians who operate the satellite check stations could possibly transport carcasses to a central location for packaging or rendering. Such a system would greatly reduce costs by eliminating the need to subcontract transportation services.
2. WDFW satellite offices relocated in Oregon along Interstate 84 would save considerable time by decreasing distances between drop-off locations. A satellite office at or near The Fishery and in The Dalles would allow for fast and efficient transport of all the carcasses harvested between Portland and Giles French Park.
3. If WDFW assumed increased transportation responsibilities and relocated satellite offices, a truly efficient food-grade network could be operated. Much of the costs associated with previous food-grade efforts were for transportation and drop-off location rental. A reconfigured network could cut the handling costs by at least a third compared to previous years and still realize an equal or larger return from sales to Stoller or other interested processors.
4. The above mentioned recommendations would also greatly benefit a rendering only program as well.
5. Unless substantial savings could be found elsewhere, the rendering only subcontractors of 1995 should again be used in 1996. They have all provided several seasons of inexpensive, relatively trouble-free service. Finding quality, reliable service has proven to be a challenge and these subcontractors have been outstanding.

6. Northern squawfish harvested from the dam-angling and site-specific fisheries should be returned to the river. This is the least expensive method of disposal for these carcasses.

DEVELOPMENT OF A SYSTEMWIDE PREDATOR
CONTROL PROGRAM: STEPWISE IMPLEMENTATION OF A
PREDATION INDEX, PREDATOR CONTROL FISHERIES, AND
EVALUATION PLAN IN THE COLUMBIA RIVER BASIN
(NORTHERN SQUAW-FISH MANAGEMENT PROGRAM)

SECTION II: EVALUATION

1995 ANNUAL REPORT

Prepared by:

Franklin R. Young

**Columbia Basin Fish and Wildlife Authority
Portland, OR 97201**

In Cooperation With

**Columbia Basin Fish and Wildlife Authority
Columbia River Inter-Tribal Fish Commksion
Confederated Tribes of the Umatilla Indian Reservation
Confederated Tribes of the Warm Springs Reservation
National Marine Fisheries Service
Nez Perce Tribe
Oregon Department of Fish ad Wildlife
Pacific States Marine Fisheries Commission
S.P. Cramer and Associates, Inc.
Washington Department of Fish and Wiie
Yakama Indian Nation**

Prepared for:

**u. s. Department of Energy
Bonneville Power Administation
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621**

**Project Number 90-O77-00
Contract Number 94BI24514**

APRIL1997

SECTION II. EVALUATION

Cooperators

**Columbia Basin Fish and Wildlife Authority
Oregon Department of Fish and Wildlife
Pacific States Marine Fisheries Commission**

Report F

**Development of a Systemwide Predator Control Program:
Indexing and Fisheries Evaluation**

Prepared by

**Mark P. Zimmerman
David L. Ward
Thomas A. Friesen
Chris J. Knutsen**

**Oregon Department of Fish and Wildlife
Columbia River Coordination Program
17330 S.E. Evelyn Street, Clackamas, OR 97015**

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ABSTRACT

We are reporting progress on evaluation of the Columbia River Northern Squawfish Management Program in 1995. Our objectives in 1995 were to (1) evaluate exploitation rate and size composition of northern squawfish (*Ptychocheilus oregonensis*) captured in various fisheries, compare incidental catch of non-target species among fisheries, and estimate reductions in predation on juvenile salmonids since implementation of the Northern Squawfish Management Program; and (2) evaluate changes through 1995 in relative abundance, consumption, size and age structure, growth, and fecundity of northern squawfish in lower Columbia and Snake River reservoirs and in the Columbia River downstream from Bonneville Dam.

Systemwide exploitation of northern squawfish in 1995 was 13.5% for sport-reward, 0.3% for dam-angling, and 1.9% for site-specific fisheries. Mean fork length of harvested northern squawfish was 327 mm in the sport-reward, 367 mm in the dam-angling and 411 mm in the site-specific gill-net fisheries. The dam-angling fishery had the lowest percentage (4.5%) of incidental catch relative to the total number of fish caught. Incidental catch was 29.8% in the sport-reward fishery and 57.3% in the site-specific fishery.

We estimate that potential predation by northern squawfish on juvenile salmonids in 1996 will be reduced 36% from pre-program levels. Eventual reductions in predation were dependent upon various levels of sustained exploitation. However, it appeared feasible to reduce overall northern squawfish predation by at least 40%.

Compared to previous years, relative abundance of northern squawfish in 1995 decreased downstream from Bonneville Dam, in John Day Reservoir, and in the Snake River. Relative abundance in Bonneville and The Dalles reservoirs was similar to previous years. Consumption indices of northern squawfish declined downstream from Bonneville Dam and increased in Lower Granite Reservoir relative to previous years. Consumption indices in the remain@ areas were generally similar to previous years. Predation indices in 1995 were lower than previous years in nearly all areas.

Proportional stock density (PSD) of northern squawfish was generally lower in 1995 than previous years. Estimates of PSD from 1991-1995 were generally below levels that would have been expected without northern squawfish fisheries. Variations in recruitment from 1989-91 and in exploitation in 1995 should result in decreased PSD estimates in 1996 for Bonneville Reservoir and the Columbia River downstream from Bonneville Dam, whereas PSD in John Day Reservoir should remain similar to 1995.

There is no evidence to date that northern squawfish have compensated in growth or fecundity in response to sustained harvest.

INTRODUCTION

The goal of the Columbia River Northern Squawfish Management Program is to reduce mainstem predation mortality on juvenile salmonids. From 1990 through 1992, we estimated the relative magnitude of northern squawfish (*Ptychocheilus* **crew**) abundance, consumption, and predation in the Columbia River impoundments (MM), 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. In 1993, we again sampled Columbia River impoundments to evaluate changes from 1990. In 1994 and 1995, we sampled in areas where we felt we could obtain precise estimates of northern squawfish predation that would facilitate comparisons among years. In this report we describe our activities and findings in 1995, and wherever possible, evaluate any changes from previous years.

Our objectives in 1995 were to (1) compare exploitation rate, size composition, and incidental catch among northern squawfish fisheries, and estimate reductions in

predation on juvenile salmonids since implementation of the management program; and (2) evaluate changes through 1995 in dative abundance, consumption, size and age structure, growth, and fecundity of northern squawfish in lower Columbia and Snake River reservoirs and in the Columbia River downstream from Bonneville Dam.

METHODS

Fishery Evaluation

Field Procedures

Three northern squawfish fisheries were conducted in 1995. **The sport-reward fishery** was implemented by the Washington Department of Fish and Wildlife (WDPW) from May 1 through September 24 throughout the lower Columbia and Snake rivers. **The dam-angling fishery** was implemented by the Columbia River Inter-Tribal Fish Commission (CRITIC), the Confederated Tribes of the Warm Springs Reservation of Oregon, the **Confederated Tribes of the Umatilla Indian Reservation**, the Confederated Tribes and Bands of the Yakama Indian Nation (YIN), and the Nez Perce Tribe (NPT) **from May 8 through September 1 at Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose and Lower Granite dams.** A site-specific gill-net fishery was implemented by CRITFC, YIN, and NPT from March 24 through June 29 downstream from Bonneville Dam and in Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs.

We estimated exploitation rates of northern squawfish for each fishery based on recovery of fish tagged primarily before implementation of 1995 fisheries. We used electrofishing boats and bottom gill nets to collect northern squawfish from March 1 to May 31. Sampling effort was randomly allocated in all river kilometers (RKm) from RKm 71 through Priest Rapids Dam tailrace (RKm 639) on the lower Columbia River, and on the Snake River from RKm 0 through RKm 229, excluding Ice Harbor Reservoir. Fish greater than 240 mm fork length were tagged with a serially numbered spaghetti tag and given a secondary mark (lower caudal tin hole punch). Tags were recovered from each fishery from April 8 through September 25.

Data Analysis

We used mark-and-recapture data to compare exploitation rates of northern squawfish among fisheries and memoirs. Exploitation rates were calculated for one-week periods and summed to yield total exploitation rates for each fishery (Beamesderfer et al. 1987). We adjusted exploitation rates for tag loss (4.8%) during the season.

We compared mean fork lengths and length frequencies of northern squawfish among fisheries, and incidental catches among fisheries. We compared mean fork lengths of fish harvested by sport-reward and dam-angling fisheries among years (1990-95). Information on size of northern squawfish harvested in the site-specific gill-net fishery was supplied to us by CRITFC.

We used the "Loss Estimate Spreadsheet Model" (Zimmerman et al. 1995) to estimate reductions in predation relative to predation prior to implementation of the management program. The model incorporates age-specific exploitation rates on northern squawfish and resulting changes in age structure to estimate changes in predation. We used a 10-year "average" age structure (based on catch curves) for a pre-exploitation base, and assumed constant recruitment. Age-specific consumption was incorporated, however, potential changes in consumption, growth, and fecundity due to removals were not considered likely. The model therefore estimates changes in potential predation related directly to removals. This in effect allows us to estimate what the effects of removals would be if we were able to hold all variables except exploitation constant.

We estimated both the potential predation reduction in 1996 based on observed exploitation rates, and the eventual maximum potential predation reduction assuming (1) continuing exploitation at 1995 levels, and (2) continuing exploitation at mean 1991-95 levels. In addition to reductions in overall predation, we estimated reductions in predation on juvenile salmonids originating in the Snake River upstream from Lower Granite Dam. We calculated 95% confidence intervals for all predation reduction estimates.

Biological Evaluation

Field Procedures

To evaluate changes in relative abundance and consumption for northern squawfish, we used boat electrofishing to collect northern squawfish in the following areas: upper Lower Granite Reservoir (RKm 221-229), Little Goose Reservoir tailrace, Lower Monumental Reservoir tailrace, John Day Reservoir, The Dalles Reservoir forebay and tailrace, Bonneville Reservoir, Bonneville Dam tailrace, and three sections in the Columbia River downstream from Bonneville Dam tailrace (RKm 117-121, RKm 171-177, and RKm 190-196). Sampling schedules, methods, and gear specifications were as described in previous reports (Vigg et al. 1990, Ward et al. 1991, Parker et al. 1994, Zimmerman et al. 1995, Knutsen et al. 1995). We collected digestive tracts of all northern squawfish ≥ 250 mm fork length and preserved them using methods described by 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

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), determined sex (male, female, undetermined) and maturity (undeveloped or immature developing, ripe, or spent), and collected gonad (ripe females only) and scale samples.

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 used scale samples from northern squawfish collected primarily by electrofishing for age determinations. We used gravimetric quantification (Bagenal 1968) to estimate fecundity of northern squawfish. Details of aging and fecundity procedures are given in Parker et al. (1995).

Data Analysis

We used catch per unit effort of standard electrofishing runs as an index of northern squawfish density and calculated indices of northern squawfish abundance as the product of the northern squawfish density index and reservoir or area-specific surface area (Ward et al. 1995). We compared density and abundance indices from 1990 through 1995 for all sampling areas.

The following formula was developed as a consumption index (CI) by 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). Spring (May-June) and summer (July-September) consumption indices were compared from 1990 to 1995 for all sampling areas. We plotted the daily juvenile salmonid passage index at lower Columbia and Snake River dams to compare timing of consumption index sampling with concentrations of juvenile salmonids present in each area. We used the product of abundance and consumption indices to calculate predation indices for spring and summer periods. We compared predation indices among years for reservoirs and areas where data had been collected each year.

Because fishery exploitation rates increase with increasing size of northern squawfish (Zimmerman et al. 1995), sustained fisheries should decrease the abundance of large fish relative to the abundance of smaller fish. We used proportional stock density [PSD = $100 \cdot (\text{number of fish at least quality length}) / (\text{number of fish at least stock length})$; Anderson 1980] to compare size structure of northern squawfish populations among years (1990-95) in the Columbia River downstream from Bonneville Dam, Bonneville Reservoir, and John Day Reservoir. Stock and quality sizes for northern squawfish have been defined as 250 mm and 380 mm fork length (Beamesderfer and Rieman 1988, Parker et al. 1995).

Comparisons of PSDs among years may be biased by (1) fluctuating year-class strengths that influence the number of stock-size fish (Mesa et al. 1990), and (2) size-selectivity of sampling gear (Beamesderfer and Rieman 1988). To reduce bias, we used information on relative year-class strengths and natural mortality rates of northern squawfish to estimate PSDs that would be expected with and without program implementation and used size-selectivity of our sampling gear to adjust observed PSD estimates (Knutsen et al. 1995). We then compared observed and expected PSDs.

To evaluate changes in growth rate after implementation of the management program, we used observed length-at-age data for female northern squawfish from the Columbia River downstream from Bonneville Dam, and from Bonneville and John Day reservoirs. We determined regression parameters (slope and y-intercept) for fork length on age using only those ages where growth rate was linear (ages 5 through 14 downstream from Bonneville Dam and Bonneville Reservoir, ages 5 through 13 in John Day Reservoir). We compared relationships among years (1990-95) using joint 95% family confidence regions for estimates of parameter pairs (Neter et al. 1985). Parameter pairs were considered significantly different if point estimates (center-point of ellipse) were outside the confidence region for another year.

We compared mean fecundity (number of developed eggs per female) and mean relative fecundity (number of developed eggs per gram of body weight) for the area downstream from Bonneville Dam and John Day Reservoir. We determined regression parameters for the regression of fecundity on fork length and compared relationships among years (1991-95) for each area using joint 95% family confidence regions for estimates of parameter pairs (Neter et al. 1985). Sample size for the fecundity-length relationship in Bonneville Reservoir (N=6) was inadequate in 1995 to make meaningful comparisons with previous years.

RESULTS

Fishery Evaluation

We tagged and released 1,427 northern squawfish throughout the lower Columbia and Snake rivers. A total of 188 tagged northern squawfish were recaptured in the three fisheries: 164 in the sport-reward fishery, three in the dam-angling fishery, and 21 in the site-specific gill-net fishery.

Exploitation rates among reservoirs in which tagged fish were recaptured ranged from 4.6% in Lower Monumental Reservoir to 22.5% in McNary Reservoir (Table 1 and Figure 1; Appendix A). John Day Reservoir was the only area in which no tagged fish were recovered. The systemwide exploitation rate in 1995 was 13.5% in the sport-reward fishery, 0.3% in the dam-angling fishery, and 1.9% in the site-specific fishery. Total exploitation rate (all fisheries combined) in 1995 was 15.6%, the highest annual rate observed to date (Table 2). Sport-reward exploitation rates have increased from 1991-95 downstream from Bonneville Dam, and in The Dalles and McNary reservoirs, and have declined in Snake River reservoirs (Appendix Table A-1). Dam-angling exploitation rates have declined from 1991-95 in nearly every area (Appendix Table A-2). Exploitation in the site-specific fishery in 1995 was similar to 1994 when the fishery was implemented.

The mean size of northern squawfish harvested systemwide in 1995 was 327 mm in the sport-reward fishery, 367 mm in the dam-angling fishery, and 411 mm in the site-specific gill-net fishery (Figure 2). Mean size in 1995 was lower than 1994 for the sport-reward and dam-angling fisheries, and similar to 1994 for the site-specific fishery (Knutsen et al. 1995).

Mean size of northern squawfish harvested by dam angling in Bonneville Dam tailrace and Bonneville, The Dalles, and John Day reservoirs was lower in 1995 than any previous year (Table 3). Sample sizes for dam angling in McNary Reservoir and the Snake River reservoirs were too small (<5) to estimate mean fork length in 1995. The mean size of fish harvested in 1995 by sport-reward anglers was lower than 1994 in all locations except The Dalles Reservoir (Table 3). Sample sizes for sport reward in John Day, Ice Harbor, Lower Monumental, and Little Goose reservoirs were too small (≤ 5) to estimate mean size in 1995. The mean size of northern squawfish harvested in the site-specific fishery was similar between 1994 and 1995 in reservoirs where the fishery was conducted both years.

Table 1. Exploitation rates (%) of northern squawfish ≥ 250 mm among fisheries in 1995.

Area or reservoir	Sport reward	Dam angling	Site-specific	Total
Downstream from				
Bonneville Dam	16.2	0.2	0.2	16.6
Bonneville	3.5	0.0	5.9	9.4
The Dalles	15.0	0.0	1.1	16.1
John Day	0.0	0.0	0.0	0.0
McNary	22.5	0.0	0.0	22.5
Lower Monumental	0.0	4.6	0.0	4.6
Little Goose	2.9	2.8	0.0	5.7
Lower Granite	6.4	0.0	0.0	6.4
Systemwide	13.5	6.3	1.9	15.6

Table 2. Total exploitation rates of northern squawfish ≥ 250 mm from 1991-95.

Area or reservoir	1991	1992	1993	1994	1995
Downstream from					
Bonneville Dam	8.1	11.8	7.1	13.0	16.6
Bonneville	15.2	6.8	4.6	11.2	9.4
The Dalles	10.5	7.2	7.0	10.7	16.1
John Day	13.3	14.3	10.5	5.8	0.0
McNary	5.2	5.6	16.5	14.0	22.5
Ice Harbor	17.5				
Lower Monumental	27.0	7.7	3.1	0.8	4.6
Little Goose	18.4	18.1	6.6	9.2	5.7
Lower Granite	16.8	14.6	12.6	8.1	6.4
Systemwide	11.3	12.2	8.5	13.1	15.1

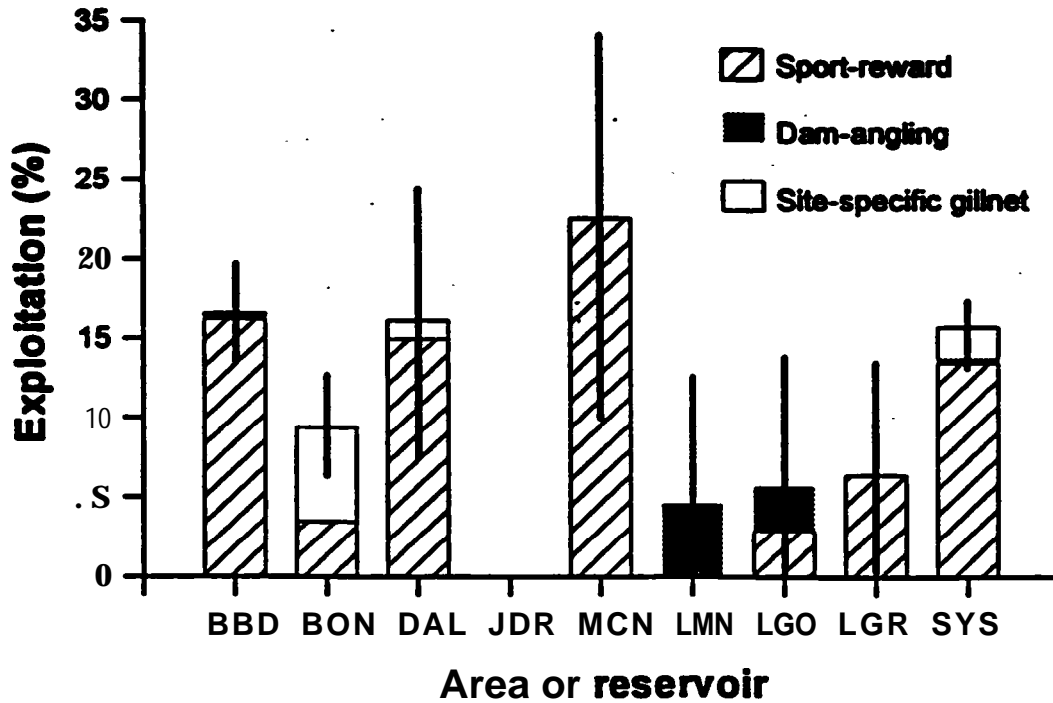


Figure 1. Exploitation rates of northern squawfish ≥ 250 mm by fishery during 1995. Vertical lines are 95% confidence intervals for total exploitation rates (all fisheries combined). Areas are downstream from Bonneville Dam (BBD), systemwide (SYS), and reservoirs are Bonneville (BON), The Dalles (DAL), John Day (JDR), McNary (MCN), Lower Monumental (LMN), Little Goose (LGO), and Lower Granite (LGR) reservoirs.

In 1995 the various fisheries reported 93,177 incidentally caught fish including northern squawfish <250 mm (Table 4). The incidental catch rate was 4.5% in the dam-angling fishery, 29.8% in the sport-reward fishery, and 57.3% in the site-specific fishery. Northern squawfish <250 mm, other cyprinids, smallmouth bass (*Micropterus dolomieu*), catostomids, and white sturgeon (*Acipenser transmontanus*) were the most common incidentally caught fish. Salmonids made up only 0.2% of the total catch and 0.7% of the incidental catch for all fisheries combined. The proportion of predator-sized (≥ 250 mm) northern squawfish relative to the total number of northern squawfish harvested was highest in the dam-angling fishery (100.0%) and lowest in the sport-reward fishery (83.8%).

Results from the Loss Estimate Spreadsheet Model indicate that potential predation by northern squawfish on juvenile salmonids in 1996 may be reduced 36% from pre-program levels (Table 5). Predation on Snake River stocks will be similar to predation on other stocks. Eventual reductions in potential predation vary depending on estimates of sustained exploitation. However, it appears feasible to reduce potential northern squawfish predation by at least 40%.

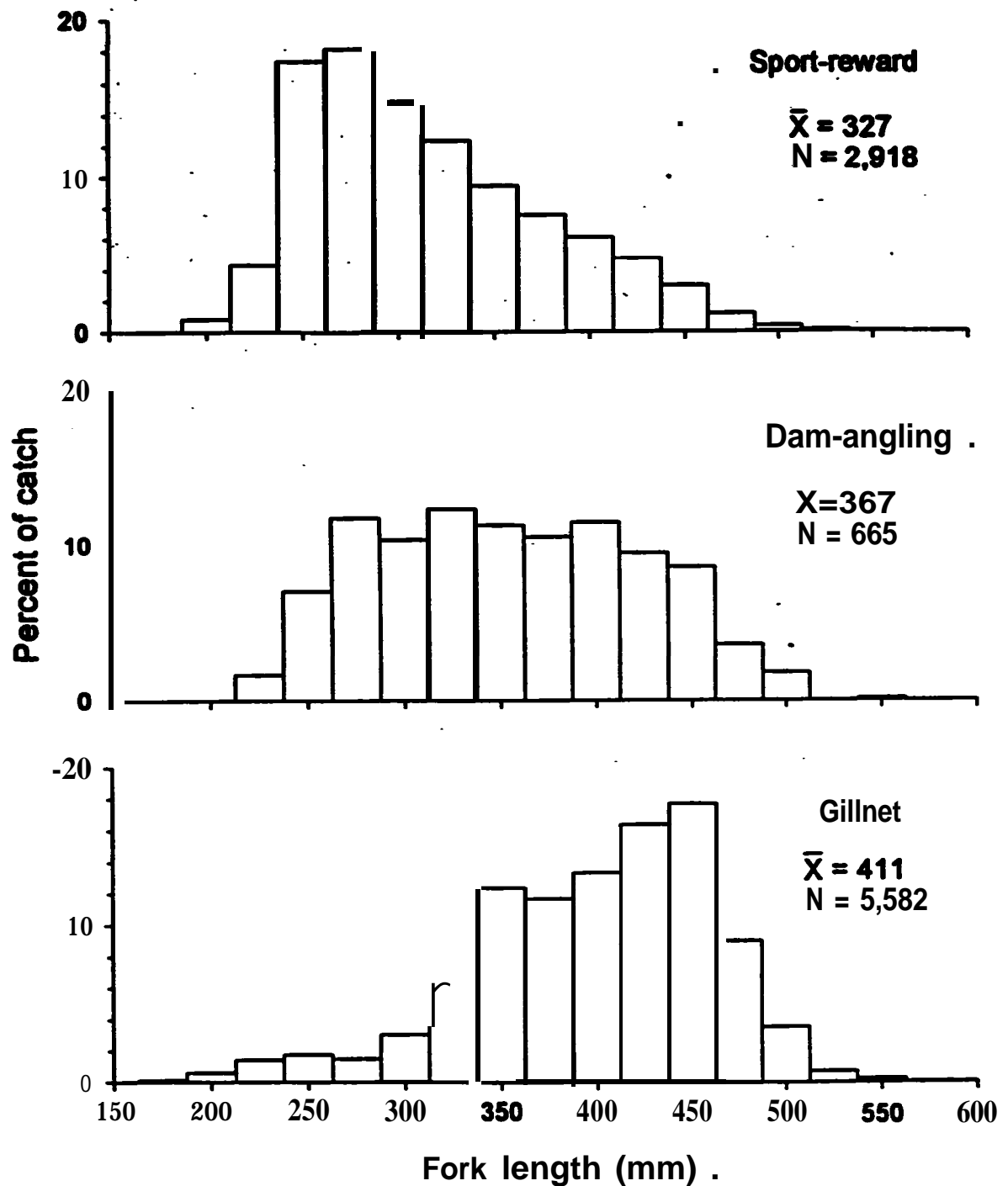


Figure 2. Size composition and mean fork length of northern squawfish in subsamples of fish harvested systemwide in sport-reward, dam-angling, and site-specific gill-net fisheries in 1995. N = subsample size.

Table 3. Mean fork length (mm) of northern squawfish harvested from 1990 through 1995 in the dam-angling, sport-reward, and site-specific gill-net fisheries in the lower Columbia and Snake rivers.

Fishery: location	Mean fork length (mm)					
	1990	1991	1992	1993	1994	1995
Dam angling:						
Bonneville Dam Tailrace	414	417	388	390	376	364
Bonneville Reservoir	407	417	416	415	413	365
The Dalles Reservoir	421	404	380	420	390	343
John Day Reservoir	416	414	417	416	437	389
McNary Reservoir	393	393	356	358	366	323
Ice Harbor Reservoir		375	360	317	407	
Lower Monumental Reservoir		325	309	341		
Little Goose Reservoir		380	346	373	370	
Lower Granite Reservoir				377		
Sport reward:						
Downstream from Bonneville Dam		332	337	316	337	325
Bonneville Reservoir		343	347	312	323	305
The Dalles Reservoir		344	369	369	358	359
John Day Reservoir	377	370	367	370	329	
McNary Reservoir		354	356	358	366	323
Ice Harbor Reservoir		357	360	317	407	
Lower Monumental Reservoir		338	330	307	428	
Little Goose Reservoir		312	347	344	376	
Lower Granite Reservoir		343	345	362	348	322
Site specific:						
Downstream from Bonneville Dam						374
Bonneville Reservoir				371	411	416
The Dalles Reservoir					395	370
John Day Reservoir					366	370
McNary Reservoir					387	363
Ice Harbor Reservoir						386
Lower Monumental Reservoir						345
Little Goose Reservoir						379
Lower Granite Reservoir					377	370

Table 4. Number of northern squawfish and incidentally caught fish by species or family in each fishery in 1995. Northern squawfish <250 mm fork length are considered incidental catch. Incidental catch in the sport-reward fishery was estimated from 8 subsample of returning anglers, and the estimates do not include catches made by non-returning anglers (Scott Smith, WDFW, Pullman, November 1995, personal communication).

Species or family	Sport-reward	Dam-angling ^a	Gill-net ^b
<i>Northern squawfish</i>			
≥250 mm fork length	199,788	5,488	9,484
<250 mm fork length	38,712	0	150
smallmouth bass	13,364	0	228
White sturgeon ^c	4,945	200	1,288
Channel catfish ^c	1,762	0	481
Walleye ^c	1,948	0	184
American shad ^c	593	14	295
Salmonidae^{c d}			
Chinook (adult)	20	--	104
Chinook (juvenile)	13		
Sockeye (adult)	0		1
Sockeye (juvenile)	0		
steelhead (adult)	80		71
Unknown salmon (adult)	18	3	0
Unknown salmon (juvenile)			18
Mountain whitefish ^c	7		34
other	241		8
Cyprinidae (minnows)	15,795		804
Catostomidae (suckers)	4,587		6,604
other	2,929	44	128
Total (all species)	284,802	5,749	19,882
Percent incidental catch	29.8	4.5	57.3

a Salmonids and non-game fish not identified to species.

b Juvenile salmonids not identified to species.

^cWhite sturgeon = *Acipenser transmontanus*, channel catfish = *Ictalurus punctatus*, walleye = *Stizostedion vitreum vitreum*, American shad = *Alosa sapidissima*, Salmonidae = *Oncorhynchus*, *Salmo*, and *Salvelinius* spp., Mountain whitefish = *Prosopium williamsoni*.

d Estimates of salmonids caught by sport-reward anglers do not include fish caught in the Columbia River upstream from the mouth of the Snake River.

Table 5. Comparison of predicted reductions in potential predation of juvenile salmonids relative to predation prior to implementation of the northern squawfish management program. Snake River stocks are juvenile salmonids originating upstream from Lower Granite Dam. Numbers in parentheses represent 95% confidence intervals for estimates of potential predation.

	All Stocks		Snake River stocks	
	Reduction in predation	Year reached	Reduction in predation	Year reached
Potential predation reduction in 1996	36% (28-44%)	-	38% (30-45%)	-
Maximum potential predation reduction with 1995 exploitation levels continued	41% (35-48%)	1998	41% (31-50%)	2003
Maximum potential predation reduction with mean 1991-95 exploitation levels continued	38%(30-45%)	1998	39% (31-46%)	1997

Biological Evaluation

Indices of density and relative abundance of northern squawfish ≥ 250 mm were lower in 1995 than any previous year in areas downstream from Bonneville Dam, and in John Day Reservoir, Lower Monumental Reservoir tailrace; and the upper reach of Lower Granite Reservoir (Figure 3; Appendix Tables B-1 and B-2). Density and relative abundance in Bonneville and The Dalles reservoirs in 1995 was similar to 1994.

Northern squawfish consumption indices in 1995 during spring and summer were lower downstream from Bonneville Dam than when the reach was previously sampled in 1992 and 1994 (Appendix Table B-3 and B-4). Consumption indices in other areas were generally similar to 1994, with the exception of the spring index for the upper reach of Lower Granite Reservoir where consumption doubled from 1994. Changes in relative abundance and consumption resulted in lower indices of predation during both spring and summer in nearly all areas sampled in 1995 relative to previous years (Figures 4 and 5). Predation indices in the tailraces of Bonneville and John Day reservoirs may be biased low because spill prohibited our sampling in the boat restricted zones of The Dalles and McNary Dam tailraces during 1995. Timing of our electrofishing sampling coincided with peaks in downstream passage of juvenile salmonids except during summer at Bonneville Dam (Appendix C).

Variations in year-class strength of northern squawfish downstream from Bonneville Dam and Bonneville Reservoir were similar until 1991, when a strong year class was produced in Bonneville Reservoir (Figure 6). The strongest year class in John Day Reservoir was produced in 1990. In general, year classes were stronger from 1988 through 1991 than in 1986 and 1987.

Proportional stock density (PSD) of northern squawfish has decreased since implementation of the Northern Squawfish Management Program in 1990 (Figure 7). Observed PSDs initially remained stable or increased, as a relatively strong 1985 year class was recruited from stock to quality size. Observed PSDs then generally decreased as relatively weak 1986 and 1987 year classes were recruited to quality size, and relatively strong 1988-91 year classes were recruited to stock size. Observed PSDs were usually lower each year than would have been expected without implementation of the Northern Squawfish Management Program. Values for observed PSDs and PSDs expected with implementation of the management program often differed, however, trends were usually similar. Direction of change between years was the same for 8 of 11 possible comparisons. Differences between observed and expected PSD values generally decreased over time.

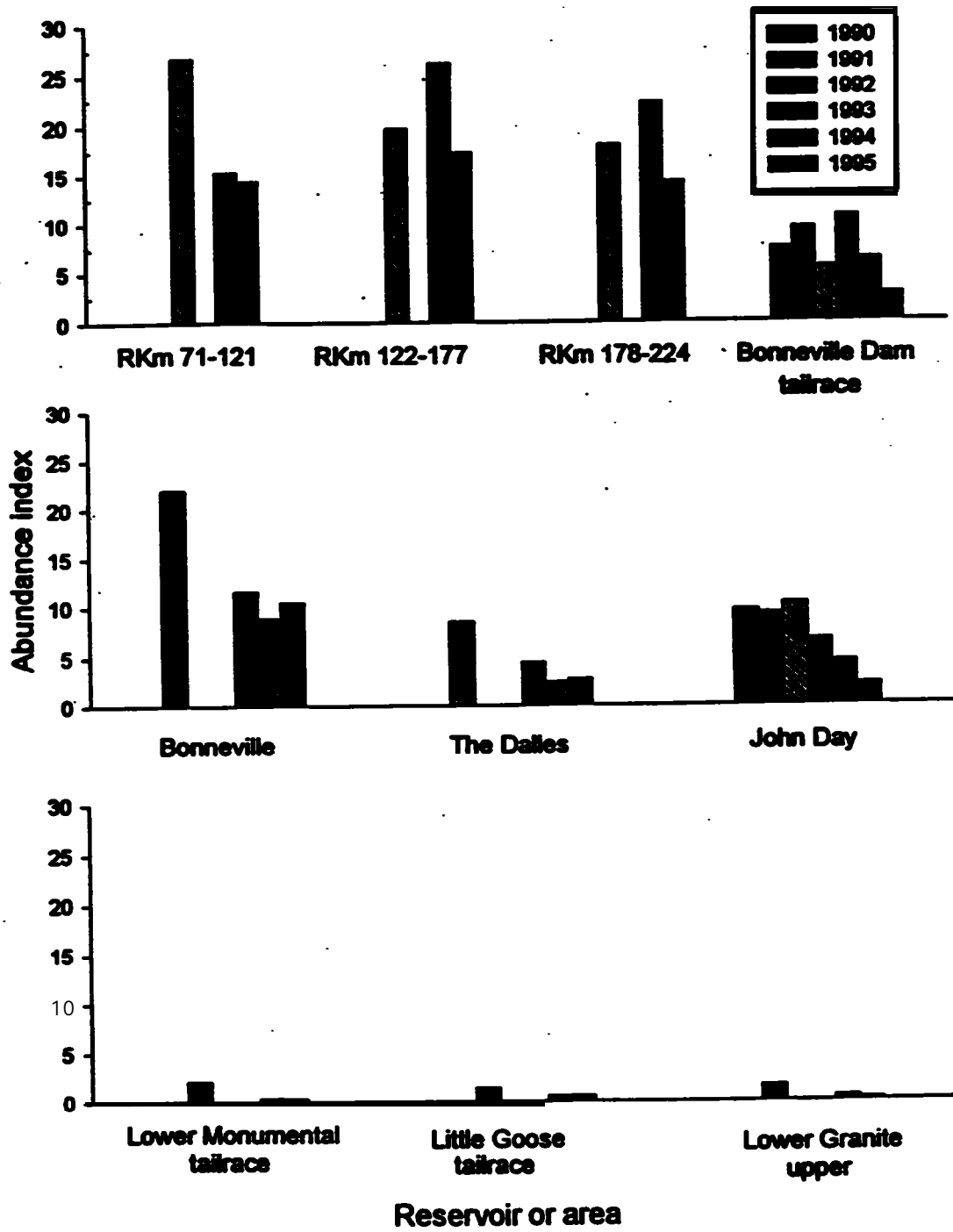


Figure 3. Index of northern squawfish abundance from 1990 through 1995 for sampling locations in the lower Columbia and Snake rivers.

Comparisons of confidence regions for joint estimates of parameters in northern squawfish length-age equations differed among years in some areas (Figure 8). The length-age relationship for northern squawfish collected downstream from Bonneville Dam in 1995 was similar to the previous three years, but different from 1990 and 1991. The length-age relationship for northern squawfish collected in Bonneville Reservoir in 1995 was similar to growth in 1990 and 1994, but different than growth in 1993. In John Day Reservoir, the length-age relationship for 1995 was similar to previous years

The relationship between fecundity and length of northern squawfish in 1995 was significantly different than previous years downstream from Bonneville Dam and in John Day Reservoir (Figure 9). We did not analyze the fecundity-length relationship in Bonneville Reservoir in 1995 due to small sample size.

Mean fecundity of northern squawfish collected downstream from Bonneville Dam averaged 31.8% lower in 1995 relative to 1991-94 (Table 6). Mean relative fecundity downstream from Bonneville Dam averaged 11.5% lower than previous years. Mean fecundity and relative fecundity in Bonneville and John Day reservoirs was also much lower in 1995 relative to 1991-94. However, the number of northern squawfish collected in both reservoirs in 1995 (N=6 in Bonneville Reservoir, N=14 in John Day Reservoir) was too small to make meaningful comparisons with previous years.

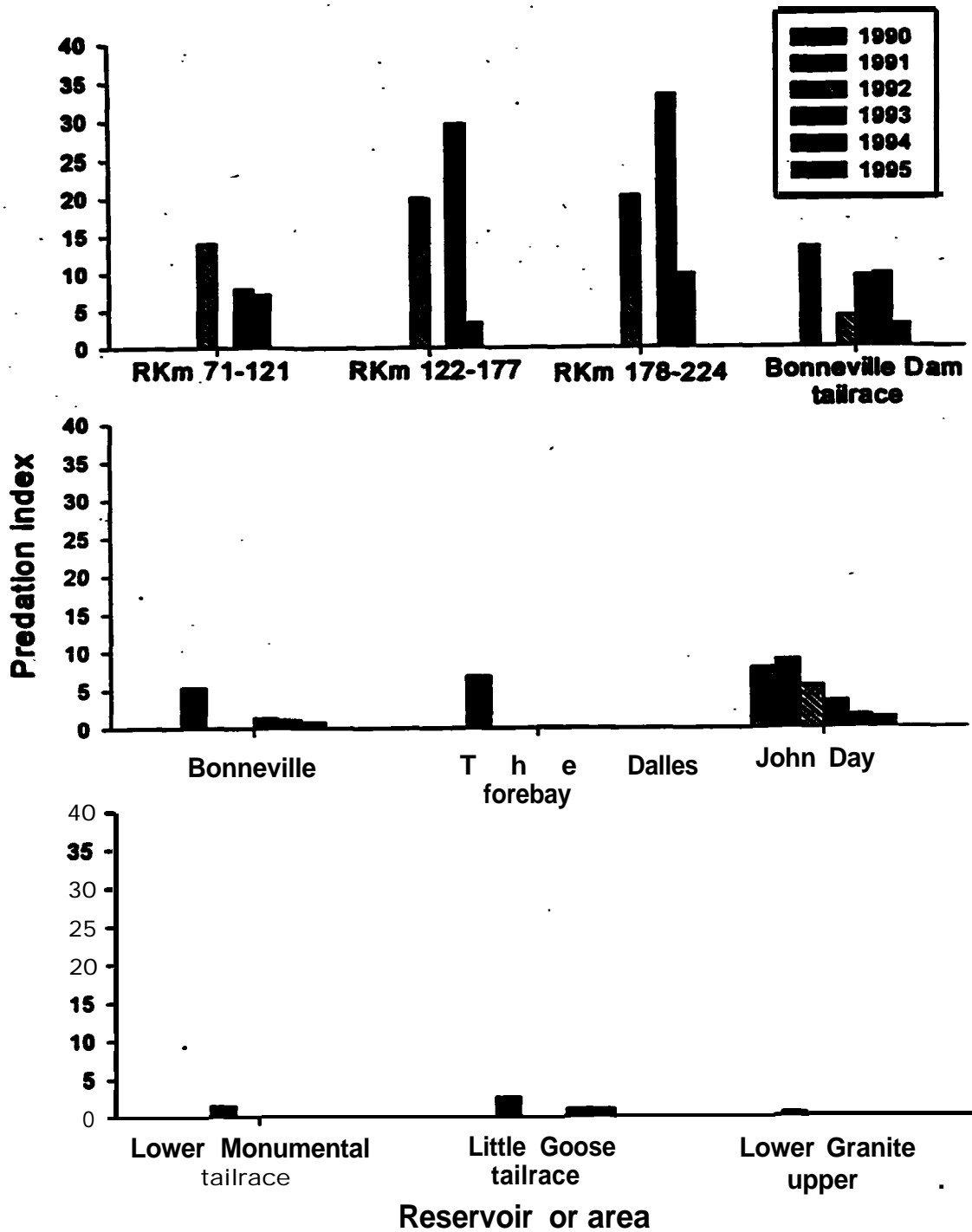


Figure 4. Index of predation by northern squawfish during spring from 1990 through 1995 for sampling locations in the lower Columbia and Snake rivers.

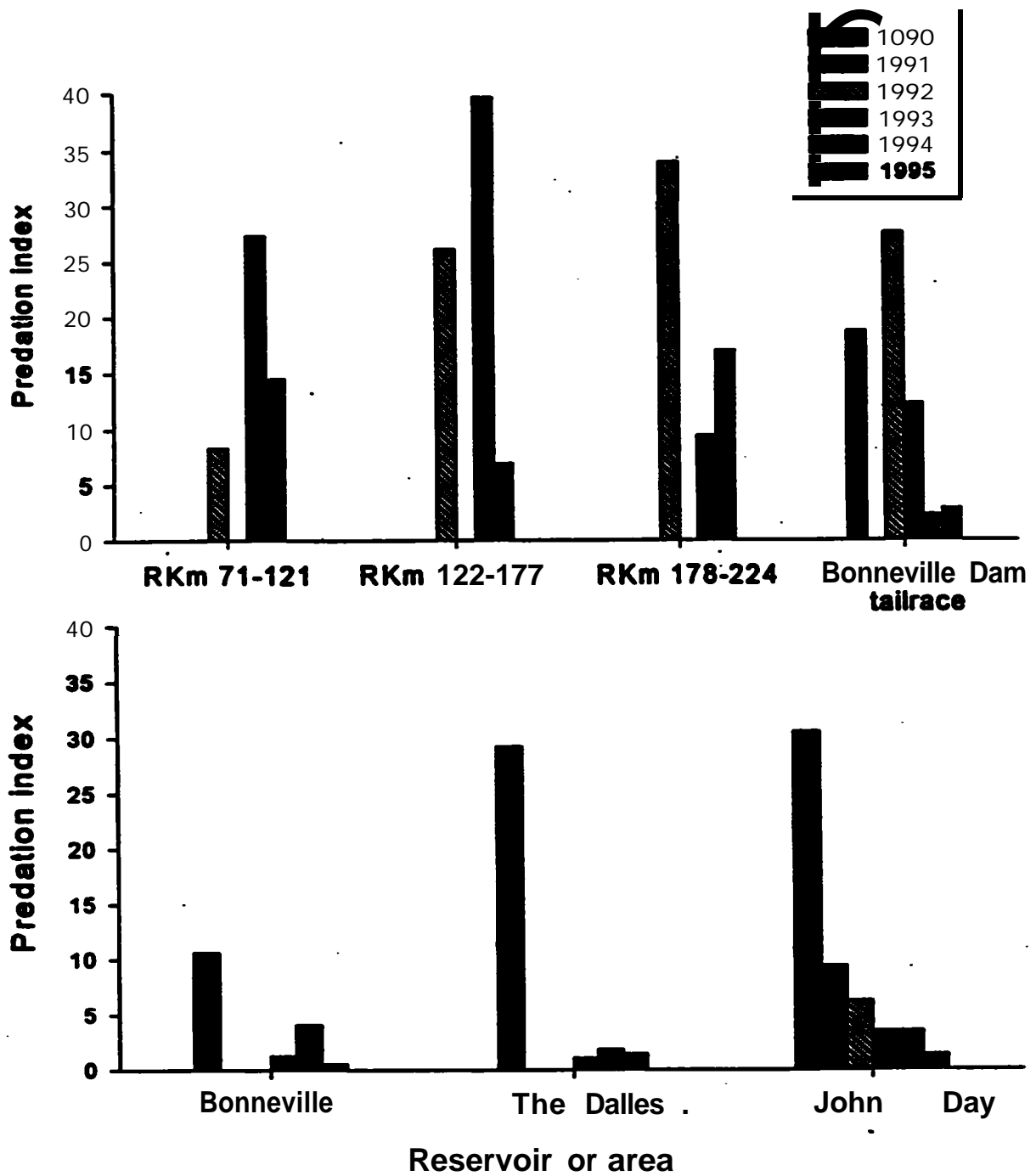


Figure 5. Index of predation by northern squawfish during summer from 1990 through 1995 for sampling locations in the lower Columbia and Snake rivers. Predation indices for The Dalles Reservoir excludes the mid-reservoir.

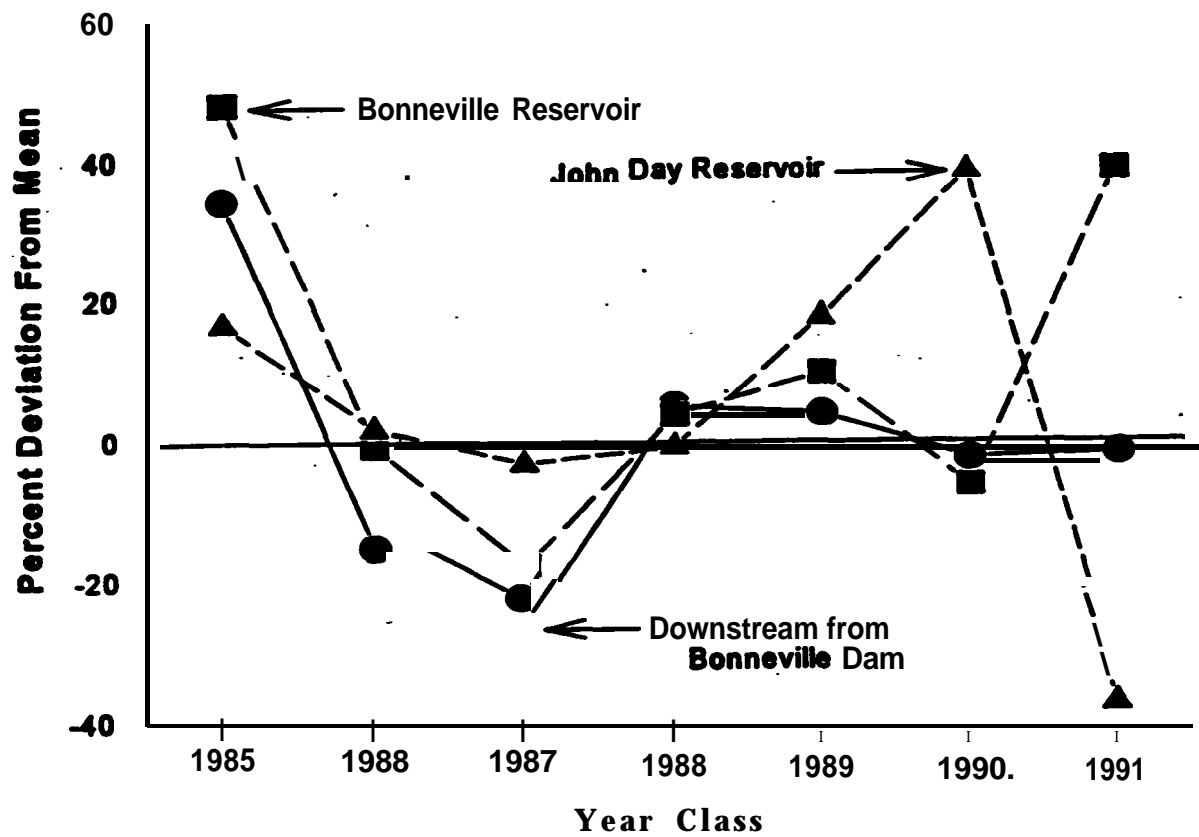


Figure 6. Index of relative year-class strength of northern squawfish in the Columbia River downstream from Bonneville Dam, Bonneville Reservoir, and John Day Reservoir.

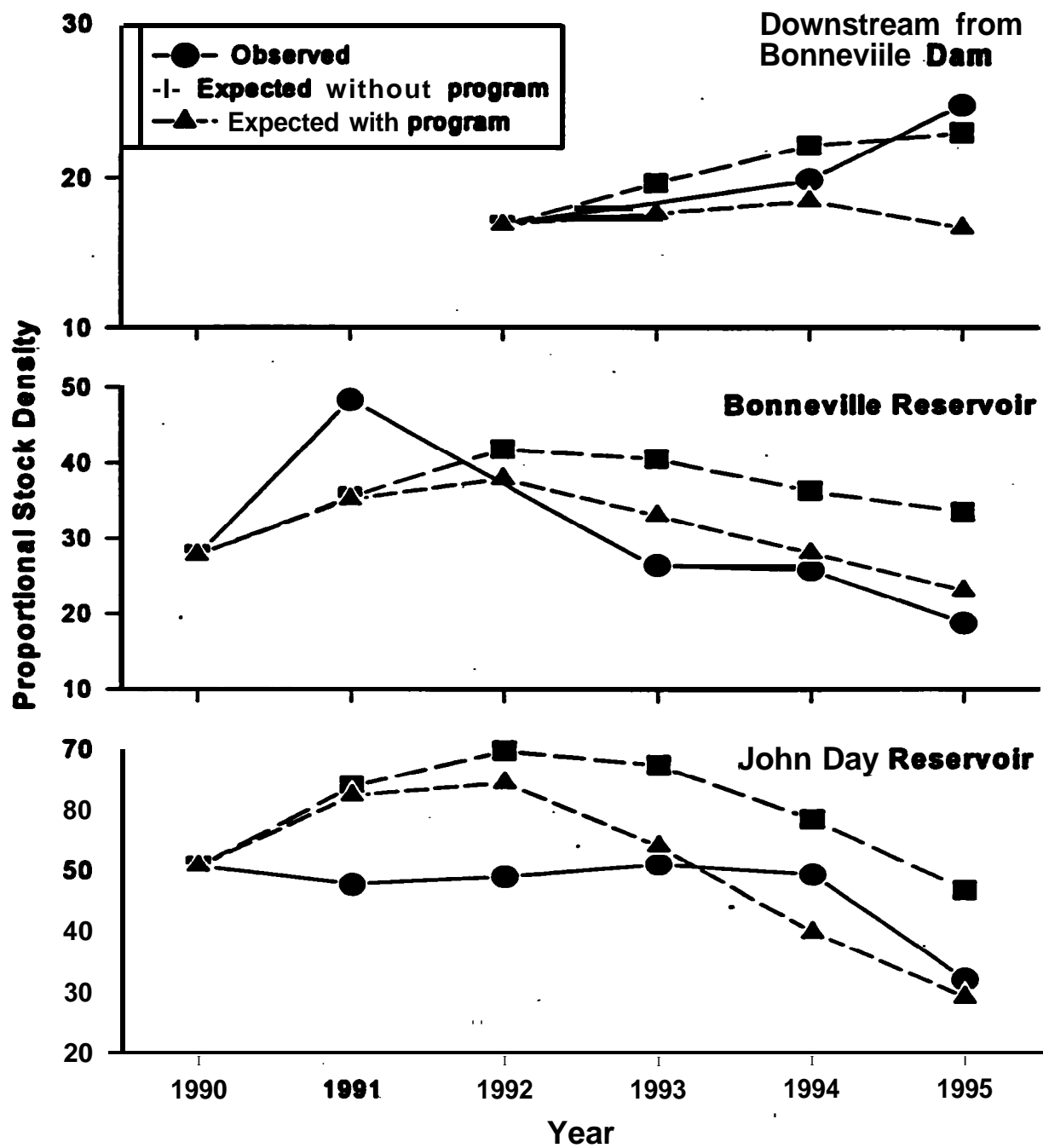


Figure 7. Observed and expected proportional stock density with and without implementation of the Northern Squawfish Management Program from 1990 through 1995 in the Columbia River downstream from Bonneville Dam, Bonneville Reservoir, and John Day Reservoir.

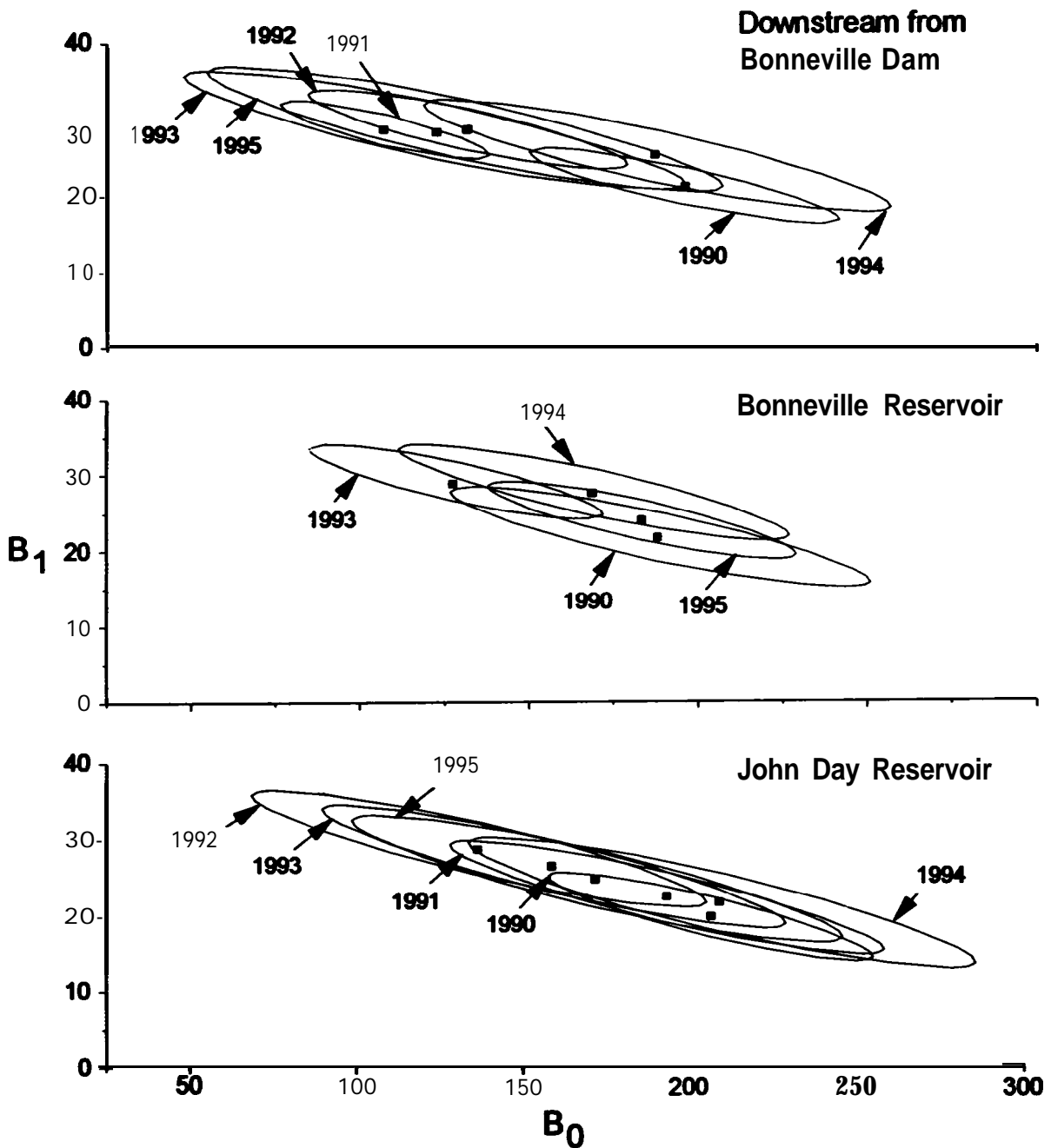


Figure 8. Joint 95% family confidence regions for estimates of length-age equation parameters (B_1 = slope and B_0 = y-intercept) for female northern squawfish in the Columbia River downstream from Bonneville Dam (ages 5-14), Bonneville Reservoir (ages 5-14), and John Day Reservoir (ages 5-13) from 1990-95. Data were not available for Bonneville Reservoir in 1991 and 1992. Parameter pairs are considered significantly different if point estimates (solid squares) are not within the confidence region for another year.

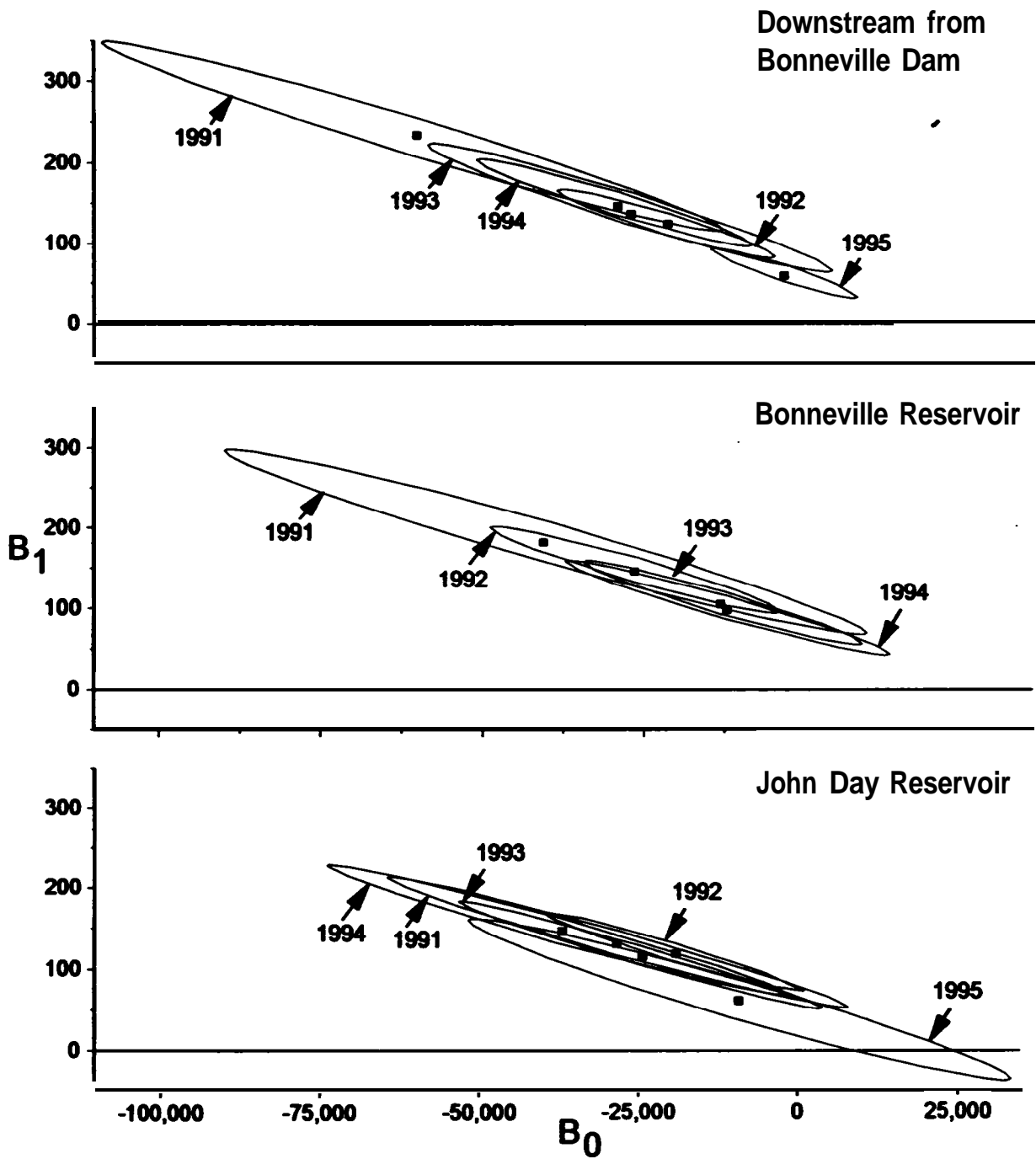


Figure 9. Joint 95% family confidence regions for estimates of fecundity-length equation parameters (B_1 = slope and B_0 = y-intercept) for northern squawfish in the Columbia River downstream from Bonneville Dam (1991-95), Bonneville Reservoir (1991-94), and John Day Reservoir (1991-95). Parameter pairs are considered significantly different if point estimates (solid squares) are not within the confidence region for another year.

Table 6. Mean fecundity (number of developed eggs per female), mean relative fecundity (number of developed eggs per gram of body weight), and sample size (N) of northern squawfish in the Columbia River downstream from Bonneville Dam, and Bonneville and John Day reservoirs from 1991-95.

Location, parameter	1991	1992	1993	1994	1995
Downstream from Bonneville Dam					
Meanfecundity	34,806	23,437	24,288	27,812	18,363
Mean relative fecundity	36.58	30.59	34.41	36.47	30.37
N	52	77	33	75	126
Bonneville Reservoir					
Meanfecundity	35,796	33,338	30,405	28,688	18,550
Mean relative fecundity	43.52	34.94	31.86	31.91	22.27
N	45	110	103	101	6
John Day Reservoir					
Mean fecundity	30,619	31,504	26,088	27,638	16,840
Mean relative fecundity	28.11	31.62	24.83	24.93	18.97
N	81	119	96	60	14

DISCUSSION

High exploitation rates downstream from Bonneville Dam, and in The Dalles and McNary reservoirs in 1995 contrii to the highest systemwide exploitation rate since implementation of the Northern Squawfish Management Program. The sport-reward fisher accounted for the majority of systemwide exploitation, whereas exploitation in the dam-angling fishery in 1995 was an order of magnitude lower than all previous years. The site-specific fishery made a major contribution to exploitation in Bonneville Reservoir where gillnetting effort and harvest were greatest.

Reductions in potential predation on stocks of outmigrating Snake River salmonids may reach 38% in 1996 and could reach 41% if exploitation remains at 1995 levels. The benefit of reduced predation on Snake River stocks is particularly important given their status under the Endangered Species Act. Efforts to reduce potential predation by increasing exploitation of northern squawfish in 1995 were at least somewhat successful, and should be continued in 1996.

The indices of predation on spring-migrating juvenile salmonids by northern squawfish were lower in all sampling areas in 1995 relative to the previous five years. In Bonneville Reservoir, lower predation was attributable to lower consumption indices as abundance indices of northern squawfish from 1993-95 have not changed. In Lower Granite Reservoir, lower predation reflected lower abundance of northern squawfish as the consumption index for the upper reservoir was higher than previous years. This was the only sampling area in which our spring index of consumption was markedly higher than previous years. Low predation indices downstream from Bonneville Dam were attributable to lower abundance and consumption relative to previous years. We collected northern squawfish digestive tracts during times of peak juvenile salmonid abundance at most sampling areas in 1995. Therefore, we cannot attribute lower consumption indices to mistimed sampling.

Decreases in PSD were greater than could be explained by fluctuations in year-class strength, and indicate that sustained removals may be altering the size structure of predator-sized northern squawfish. Although trends in observed PSD were usually similar to trends in expected PSD, observed and expected values often differed, especially in the early years of the management program. This is due in part to the fact that estimates of expected PSD incorporate estimates of annual mortality and age-specific lengths. Annual variations in natural mortality and growth are unpredictable; we therefore used estimates of annual mortality developed prior to sustained removals, and pooled 1990-95 growth data to estimate age-specific lengths. These data should be representative of long-term averages, but will not reflect annual variation around those averages. Differences between observed and expected values should therefore become smaller over a period of years, as annual variations "average out."

We found no evidence of increased growth among northern squawfish *in response* to sustained harvest. Although length-age relationships varied among years, no overall increase in growth was apparent in any area or reservoir. The magnitude of variation in growth estimates from 1990 through 1995 underscored the difficulty in detecting growth compensation by northern squawfish.

Northern squawfish have not compensated for sustained harvests by increasing fecundity. Our estimates of fecundity in 1995 were in fact lower than previous years. A decline in the mean size of northern squawfish collected for fecundity analysis in 1995 contributed to the observed differences in mean fecundity and the fecundity-length relationship between 1995 and previous years. This was particularly true of samples from Bonneville and John Day reservoirs where sample sizes were also very small. However, an adequate sample size was obtained downstream from Bonneville Dam in 1995 and the mean weight of northern squawfish was 14.8% lower than in previous years' samples. We observed an even greater decline (29.2%) in mean gonad weight of ripe females collected downstream from Bonneville Dam in 1995.

REFERENCES

- Bagenal, T.B. 1968. Fecundity. Pages 160-169 *in* W.E. Ricker, editor. *Methods for assessment of fish production in freshwater* International Biological Programme Handbook 3, Blackwell Scientific Publications, Oxford, England.
- Beamesderfer, RC., and B.E. Rieman 1988. Size selectivity and bias in estimates of population statistics of smallmouth bass, walleye, and northern squawfish in a Columbia River reservoir- *North American Journal of Fisheries Management* 8:505-510.
- Beamesderfer, RC., B.E. Rieman, J.C. Elliott, AA Nigro, and D.L. Ward. 1987. **Distribution, abundance, and population dynamics of northern squawfish, walleye, smallmouth bass, and channel catfish in John Day Reservoir, 1986.** Oregon Department of Fish and Wildlife, Contract DE-AI79-82BP35097. 1986 Annual Report to Bonneville Power Administration, Portland, Oregon.
- Knutsen, C.J., D.L. Ward, T.A. Friesen, and M.P. Zimmerman. 1995. Development of a systemwide predator control program: indexing and fisheries evaluation. Oregon Department of Fish and Wildlife Contract DE-AI799OBPO7084. 1994 Annual Report to the Bonneville Power Administration, Portland, Oregon.
- Mesa, M.G., SD. Duke, and D.L. Ward. 1990. Spatial and temporal variation in proportional stock density and relative weight of smallmouth bass in a reservoir. *Journal of Freshwater Ecology* 5:323-339.

- Neter, J., W. Wasserman and M.H. Kutner. 1985. Applied linear statistical models, 2nd edition. Irwin Press, Homewood, Illinois.**
- Parker, RM., M.P. Zimmerman, and D.L. Ward. 1994. Development of a systemwide predator control program: indexing and fisheries evaluation. Oregon Department of Fish and Wildlife, Contract number DE-AI799OBPO7096. 1992 Annual Report to the Bonneville Power Administration, Portland, Oregon.**
- Parker, RM., M.P. Zimmerman, and D.L. Ward. 1995. Variability in biological characteristics of northern squawfish in the lower Columbia and Snake rivers. Transactions of the American Fisheries Society 124:335-346.**
- Petersen, J.H., D.B. Jepsen, R.D. Nelle, RS. Shively, R.A. Tabor, and T.P. Poe. 1991. Systemwide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. U.S. Fish and Wildlife Service, Contract DE-AI79-9OBPO7096. 1990 Annual Report to the Bonneville Power Administration, Portland, Oregon.**
- Vigg, S., CC. Burley, D.L. Ward, C. Mallette, S. Smith, and M. Zimmerman. 1990. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River basin. Oregon Department of Fish and Wildlife, Contract DE-BI79-9OBPO7084. 1990 Annual Report to the Bonneville Power Administration, Portland, Oregon.**
- Ward D.L., J.H. Petersen, and J. J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the lower Snake River. Transactions of the American fisheries Society 124:321-334.**
- Ward D.L., M.P. Zimmerman, RM. Parker, and S.S. Smith. 1991. Development of a systemwide predator control program: indexing, fisheries evaluation, and harvesting technology development. Oregon Department of Fish and Wildlife, Contract number DE-BI79-9OBPO7084. 1991 Annual Report to the Bonneville Power Administration, Portland, Oregon.**
- Zimmerman, M.P., C. Knutsen, D.L. Ward, and K. Anderson. 1995. Development of a systemwide predator control program: indexing and fisheries evaluation. Oregon Department of Fish and Wildlife, Contract DE-AI79-9OBPO7084. 1993 Annual Report to the Bonneville Power Administration, Portland, Oregon.**

APPENDIX A

Exploitation of Northern Squawfish by Reservoir and Fishery from 1991-95

Appendix Table A-1. Exploitation rates (%) of northern squawfish ≥ 250 mm for the sport-reward fishery from 1991-95.

Area or reservoir	1991	1992	1993	1994	1995
Downstream from:					
Bonneville Dam	7.9	11.5	6.1	13.7	16.2
Bonneville	13.4	4.1	2.1	2.2	3.5
The Dalles	6.1	6.3	7.0	9.8	15.0
John Day	4.3	3.5	2.4	3.2	0.0 ^a
McNary	3.3	5.6	16.0	14.0	22.5
Ice Harbor	3.9	-- ^b	-- ^b	-- ^b	-- ^b
Lower Monumental	10.0	1.8	3.1	0.8	0.0 ^a
Little Goose	5.0	12.0	3.3	6.1	2.9
Lower Granite	16.8	14.7	12.6	8.7	6.4
Systemwide	8.3	9.4	6.8	10.9	13.5

^a Northern squawfish harvested, but no tags recovered.

^b No northern squawfish were tagged.

Appendix Table A-2. Exploitation rates (%) of northern squawfish ≥ 250 mm for the dam-angling fishery from 1991-95.

Area or reservoir	1991	1992	1993	1994	1995
Downstream from:					
Bonneville Dam	0.2	0.2	0.0^a	0.1	0.2
Bonneville	1.8	2.8	2.2	3.7	0.0^a
The Dalles	4.4	1.0	0.0^a	0.0^a	0.0^a
John Day	9.0	10.9	8.1	2.6	0.0^a
McNary	1.9	0.0^a	0.5	0.0^a	0.0^a
Ice Harbor	13.6	--^b	--^b	--^b	--^b
Lower Monumental	17.0	6.0	0.0^a	0.0^a	4.6
Little Goose	13.4	6.1	3.3	3.1	2.8
Lower Granite	0.0^a	0.0^a	0.0^a	0.0^a	0.0^a
Systemwide	3.0	2.7	1.3	1.1	0.3

^a Northern squawfish harvested, but no tags recovered.

^b No northern squawfish were tagged.

Appendix Table A-3. Dates for each sampling period in 1995.

Period	Dates	Period	Dates
1	before April 2	14	June 26 - July 2
2	Apr 3-Apr 9	15	July 3-July 9
3	April 10-April 16	16	July 10 -July 16
4	April 17-April23	17	July 17 - July 23
5	April 24-April 30	18	July 24 - July 30
6	May 1-May 7	19	July31 -August6
7	May 8-May 14	20	August 7-August 13
8	May 15-May 21	21	August 14 - August 20
9	May 22-May 28	22	August 21-August 27
10	May 29-June 4	23	August 28 - September 3
11	June 5-June 11	24	September 4 - september 10
12	June 12 -June 18	25	September 11 - September 17
13	June 19 - June 25	26	September 18 - September 24

Appendix Table A-4. Exploitation of northern squawfish downstream from Bonneville Dam in 1995. T = number marked. M = number marked at large. Misc. = marked fish recaptured outside the program area or fisheries.

Time period	Recaptures					M	Exploitation		
	T	Sport	Dam	Net	Misc.		Sport	Dam	Net
1				--					
2	81			--					
3	125			--		81			
4	326			--		206			
5				--		532			
6		3		--	1	532	0.0056		
7	50			1	-	528			0.0019
8		4		--	-	577	0.0069		
9	14	4		--	1	573	0.0070		
10				--		582			
11		7		--		582	0.0120		
12		9		--		575	0.0157		
13		7		--		566	0.0124		
14		7		--		559	0.0125		
15		8		--		552	0.0145		
16		6		--		544	0.0110		
17		10	1	--	1	538	0.0186	0.0019	
18		3		--		526	0.0057		
19		4		--	1	523	0.0076		
20				--		518	--		
21		3		--	--	518	0.0058		
22		3		--		515	0.0058		
23		2		--		512	0.0039		
24		5		--		510	0.0098		
25				--		505			
26				--		505			
Total	5 %	85	1	1	4		0.1549	0.0019	0.0019
Adjusted for tag loss							0.1623	0.0020	0.0020

Appendix Table A-5. Exploitation of northern squawfish in Bonneville Reservoir in 1995. T = number marked. M = number marked at huge. Misc. = marked fish recaptured outside the program area or fisheries.

Time period	Recaptures					M	Exploitation		
	T	Sport	Dam	Net	Misc.'		Sport	Dam	Net
1								--	--
2	350				1			--	--
3						349		--	--
4						349		--	--
5				1		349		--	0.0029
6				5	--	348		--	0.0144
7				2	--	343		--	0.0058
8		1		2	2	341	0.0029	--	0.0059
9		2		2	1	336	0.0060	--	0.0060
10		2		1	--	331	0.0060	--	0.0030
11		1		2	--	328	0.0030	--	0.0061
12		2		1	--	325	0.0062	--	0.003 1
13		1		3	2	322	0.003 1	--	0.0093
14	--	--			2	316		--	--
15		--			1	314		--	--
16		--			4	313		--	--
17		1			3	309	0.0032	--	--
18					--	305		--	--
19					--	305		--	--
20	--				--	305		--	--
21	--				--	305		--	--
22	--				--	305		--	--
23	--				--	305		--	--
24	--	1			--	305	0.0033	--	--
25						304		--	--
26						304		--	--
Total	350	11	0	19	16		0.0338	0.0000	0.0564
Mjusted for tag loss							0.0354	0.0000	0.0591

Appendix Table A-6. Exploitation of northern squawfish in The Dalles Reservoir in 1995. T = number marked. M = number marked at large. Misc. = marked fish recaptured outside the program area or fisheries.

T i i period	Recaptures					M	Exploitation		
	T	Sport	Dam	Net	Misc.		Sport	Dam	Net
1	8			--	--			--	--
2	34			--	--	8		--	--
3				--	--	42		--	--
4				--	--	42		--	--
5				--	--	42		--	--
6	56			--	--	42		--	--
7				--	--	98		--	--
8				--	--	98		--	--
9				--	--	98		--	--
10		2		1	--	98	0.0204	--	0.0102
11				--	--	95		--	--
12		1		--	--	95	0.0105	--	--
13		2		--	--	94	0.0213	--	--
14		1		--	--	92	0.0109	--	--
15				--	1	91		--	--
16		3		--	1	90	0.0333	--	--
17		3		--	--	86	0.9349	--	--
18				--	--	83		--	--
19				--	--	83		--	--
20	--			--	--	83		--	--
21				--	--	83	--	--	--
22	--			--	--	83		--	--
23				--	--	83		--	--
24		1		--	--	83	0.0120	--	--
25				--	--	82		--	--
26				--	--	82		--	--
Total	98	13	0	1	2		0.1433	0.0000	0.0102
Adjusted for tag loss							0.1502	0.0000	0.0107

Appendix Table A-7. Exploitation of northern squawfish in John Day Reservoir in 1995. T = number marked. M = number marked at large. Misc. = marked fish recaptured outside the program area or fisheries.

Time Period	T	Recaptures			M	Exploitation	
		sport	Dam	Misc.		Sport	Dam
1	3	--		--		--	--
2	6	--		--	3	--	--
3	11	--		--	9	--	--
4	6	--		--	20	--	--
5		--		--	26	--	--
6	5	--		--	26	--	--
7	9	--		--	3	1	--
8	4	--		--	40	--	--
9		--		1	44	--	--
10		--		--	43	--	--
11		--		--	43	--	--
12		--		--	43	--	--
13		--		--	43	--	--
14		--		--	43	--	--
15	-	--		--	43	--	--
16		--		--	43	--	--
17		--		--	43	--	--
18		--		--	43	--	--
19		--		1	43	--	--
20		--		--	42	--	--
21		--		--	42	--	--
22		--		--	42	--	--
23		--		--	42	--	--
24		--		--	42	--	--
25		--		--	42	--	--
26		--		--	42	--	--
Total	44	0	0	2		0.0000	0.0000
Adjusted for tag loss						0.0000	0.0000

Appendix Table A-8. Exploitation of northern squawfish in McNary Reservoir in 1995. T = number marked. M = number marked at large. Misc. = marked fish recaptured outside the program area or fisheries.

Time Period	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	2			--	--		
2				--	2		
3	20			--	2		
4				--	22		
5				--	22		
6		1		--	22	0.0455	
7				--	21		
8	6			--	21		
9	23			--	27		
10		1		--	50	0.0200	
11	174	1		--	49	0.0204	
12		3		--	222	0.0135	
13		5		--	219	0.0228	
14		5		--	214	0.0234	
15		3		--	209	0.0144	
16		4		1	206	0.0194	
17		1		--	201	0.0050	
18				--	200		
19				--	200		
20		1		--	200	0.0050	
21		3		--	199	0.0151	
22				--	1%		
23		1		--	1%	0.005 1	
24		1		--	195	0.005 1	
25				--	194		
26				--	194		
Total	225	30	0	1	--	0.2146	0.0000
Adjusted for tag loss						0.2249	0.0000

Appendix Table A-9. Exploitation of northern squawfish in Lower Monumental Reservoir in 1995. T = number marked. M = number marked at large. Misc. = marked fish recaptured outside the program area or fisheries.

Time Period	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		snort	Dam
1		--	--	--		--	--
2	-	--	--	--			--
3	15	--	--	--		--	--
4		--	--	--	15	--	--
5		--	--	--	15	--	--
6		--	--	--	15	--	--
7		--	--	--	15	--	--
8		--	--	--	15	--	--
9	10	--	--		15	--	--
10		--	--	--	25	--	--
11		--	--	--	25	--	--
12		--	--	--	25	--	--
13		--	--	1	25	--	--
14		--	--	--	24	--	--
15		--	--	--	24	--	--
16		--	--	--	24	--	--
17		--	--	--	24	--	--
18		--	--	1	24	--	--
19		--	--	--	23	--	--
20			--	--	23	--	--
21			--	--	23	--	--
22			1	--	23	--	0.0435
23			--	--	22	--	--
24			--	--	22	--	--
25			--	--	22	--	--
26			--	--	22	--	--
Total	25	0	1	2	--	0.0000	0.0435
<i>Adjusted for tag loss</i>						0.0000	0.0456

Appendix Table A-10. Exploitation of northern squawfish in Little Goose Reservoir in 1995. T = number marked. M = number marked at large. Misc. = marked fish recaptured outside the program area or fisheries.

Time Period	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1		--	--				--
2		--	--				--
3	27	--	--				--
4		--	--		27		--
5		--	--	1	27		--
6		--	--		26		--
7		--	--		26		--
8		--	--		26		--
9		--	--		26		--
10	12	--	--		26		--
11		--	--		38		--
12		--	--		38		--
13		--	--		38		--
14		--	--		38		--
15		--	--		38		--
16		--	--		38		--
17		--	--		38		--
18		--	--		38		--
19		--	--	1	38		--
20		--	--		37		--
21		--	1		37		0.0270
22		--	--		36		--
23		--	--		36		--
24		1	--		36	0.0278	--
25		--	--		35		--
26		--	--		35		--
Total	39	1	1	2		0.0278	0.0270
<i>Adjusted fix tag loss</i>						0.0291	0.0283

Appendix Table A-1 1. Exploitation of northern squawfish in Lower Granite Reservoir in 1995. T = number marked. M = number marked at large. Misc. = marked fish recaptured outside the program area or fisheries.

Time Period	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1		--				--	--
2		--				--	--
3	1	--					
4		--			1	--	--
5	49	--			1	--	--
6		1			50	0.0200	--
7		--			49	--	--
8		--			49	--	--
9		--			49	--	--
10		--			49	--	--
11		--			49	--	--
12		--			49	--	--
13		--			49	--	--
14		--			49	--	--
15		--			49	--	--
16		--			49	--	--
17		--			49	--	--
18		--			49	--	--
19		--			49	--	--
20		--			49	--	--
21		1	--		49	0.0204	--
22		1	--		48	0.0208	--
23					47	--	--
24					47	--	--
25					47	--	--
26					47	--	--
Total	50	3	0	0		0.0612	0.0000
<i>Adjusted for tag loss</i>						0.0642	0.0000

Appendix Table A-12. Exploitation of northern squawfish systemwide in 1995. T = number marked. M = number marked at large. Misc. = marked fish recaptured outside the program area or fisheries.

T i e period	Recaptures					M	Exploitation		
	T	Sport	Dam	Net	Misc.		Sport	Dam	Net
1	13				--			--	
2	471				--	13	-	--	
3	199				--	484	-	--	
4	332				--	683	-	--	
5	49			1	1	1015	-	--	0.0010
6	61	6		5	--	1062	0.0056	--	0.0047
7	59			3	--	1112	-	--	0.0027
8	10	6		2	1	1168	0.0051	--	0.0017
9	47	9		2	--	1169	0.0077	--	0.0017
10	12	5		2	--	1205	0.0041	--	0.0017
11	174	9		2	--	1210	0.0074	--	0.0017
12		15		1	--	1373	0.0109	--	0.0007
13		18		3	--	1357	0.0133	--	0.0022
14		15			--	1336	0.0112	--	
15		13			--	1321	0.0098	--	
16		17			2	1308	0.0130	--	
17		18	1		1	1289	0.0140	0.0008	
18		3			1	1269	0.0024	--	
19		6			1	1265	0.0047	--	
20	-	1			--	1258	0.0008	--	
21		7	1		--	1257	0.0056	0.0008	
22	-	4	1		--	1249	0.0032	0.0008	
23		3			--	1244	0.0024	--	
24		9			--	1241	0.0073	--	
25					--	1232		--	
26					--	1232	--	--	
Total	1427	164	3	21	7	--	0.1286	0.0024	0.0181
<i>Adjusted for tag loss</i>							0.1348	0.0025	0.0189

APPENDIX B

Density, Abundance, Consumption, and Predation Indices from 1990-95 for Sampling Locations in the Lower Columbia and Snake Rivers

Appendix Table B-1. Indices of northern squawfish density from 1990 through 1995 for sampling zones in the lower Columbia and Snake rivers. Rkm = river kilometer. BRZ = boat restricted zone.

Location, zone	Density index					
	1990	1991	1992	1993	1994	1995
Below						
Bonneville Dam						
Rkm 71-121			1.691		0.972	0.911
Rkm 122-177			1.573		2.091	1.389
Rkm 178-224			1.412		1.744	1.125
Tailrace	5.750	6.859	3.432	9.625	2.926	2.235
Tailrace BRZ	13.709	19.000	12.913	14.520	18.875	4.571
Bonneville Reservoir						
Forebay	5.711			2.229	2.371	2.354
Mid-reservoir	2.102			1.179	0.690	1.022
Tailrace	0.512			1.103	0.600	1.088
Tailrace BRZ	5.465			1.500	6.750	
The Dalles Reservoir						
Forebay	1.104			1.216	0.554	0.565
Tailrace	2.750			0.714	0.650	1.556
Tailrace BRZ	21.541			10.800	5.500	3.500
JohnDay Reservoir						
Forebay	0.715	0.656	1.252	0.634	0.692	0.267
Mid-reservoir	0.265	0.240	0.339	0.163	0.116	0.053
Tailrace	0.764	0.750	0.106	0.451	0.265	0.325
Tailrace BRZ	14.727	17.933	9.235	13.333	2.400	
Lower Monumental Res.						
Tailrace		1.524			0.331	0.105
Tailrace BRZ		16.312			1.200	3.875
Little Goose Reservoir						
Tailrace		1.625			0.484	0.063
Tailrace BRZ		28.294			6.418	10.250
Lower Granite Reservoir						
Upper-reservoir		1.855			0.541	0.225

Appendix Table B-2. Indices of northern squawfish abundance from 1990 through 1995 in the lower Columbia and Snake rivers. RKm = river kilometer. BRZ = boat restricted zone.

Location, zone	Abundance index					
	1990	1991	1992	1993	1994	1995
Below						
Bonneville Dam						
RKm 71-121			26.8		15.4	14.5
RKm 122-177			19.7		26.2	17.4
RKm 178-224			17.9		22.1	14.2
Tailrace	4.5	5.4	2.7	7.6	2.3	1.8
Tailrace BRZ	3.0	4.1	2.8	3.1	4.1	1.0
Bonneville Reservoir						
Forebay	5.5			2.1	2.3	2.3
Mid-reservoir	15.2			8.5	5.0	7.4
Tailrace	0.4			0.8	0.5	0.8
Tailrace BRZ	0.9			0.2	1.1	
The Dalles Reservoir						
Forebay	1.4			1.6	0.7	0.5
Tailrace	2.7			0.7	0.6	1.5
Tailrace BRZ	4.4			2.2	1.1	0.7
John Day Reservoir						
Forebay	1.4	1.3	2.5	1.2	1.4	0.5
Mid-reservoir	5.2	4.7	6.6	3.2	2.3	1.0
Tailrace	1.4	1.4	0.2	0.9	0.5	0.6
Tailrace BRZ	1.6	1.9	1.0	1.4	0.3	
Lower Monumental Res.						
Tailrace		1.3			0.3	0.1
Tailrace BRZ		0.8			0.1	0.2
Little Goose Reservoir						
Tailrace		0.7			0.2	<0.1
Tailrace BRZ		1.7			0.4	0.6
Lower Granite Reservoir						
upper-reservoir		1.6			0.5	0.2

Appendix Table B-3. Indices of northern squawfish consumption of juvenile salmonids from 1990 through 1995 during spring in the lower Columbia and Snake rivers. RKm = river kilometer. BRZ = boat restricted zone.

Location, zone	Consumption index					
	1990	1991	1992	1993	1994	1995
Below						
Bonneville Dam						
RKm 71-121			0.5		0.5	0.5
RKm 122-177			1.0		1.1	0.2
RKm 178-224			1.1		1.5	0.7
Tailrace	1.2		0.5	0.8	3.2	0
Tailrace BRZ	2.7		1.0	1.1	0.6	1.7
Bonneville Reservoir						
Forebay	0.6			0.7	0.2	0.3
Mid-reservoir	0.0			0.0	0.2	0.0
Tailrace	0.3			0.0	0.0	0.2
Tailrace BRZ	2.3					
The Dalles Reservoir						
Forebay	0.8			0.1	0.1	0.0
Tailrace	0.7			0.0		
Tailrace BRZ	0.9			0.0		
John Day Reservoir						
Forebay	1.5	1.9	1.9	1.5	1.0	1.7
Mid-reservoir	0.0	0.5	0.0	0.0	0.0	0.0
Tailrace	1.5	0.9	0.0	2.0	0.3	0.8
Tailrace BRZ	2.5	1.5	0.9		0.7	
Lower Monumental Res.						
Tailrace		0.6			0.7	0.0
Tailrace BRZ		0.7				1.3
Little Goose Reservoir						
Tailrace		0.7			1.9	1.4
Tailrace BRZ		1.2			1.5	1.6
Lower Granite Reservoir						
uppe resevoir		0.3			0.6	1.2

Appendix Table B-4. Indices of northern squawfish consumption of juvenile salmonids from 1990 through 1995 during summer in the lower Columbia and Snake rivers. Rkm = river kilometer. BRZ = boat restricted zone.

Location, zone	Consumption index					
	1990	1991	1992	1993	1994	1995
Below						
Bonneville Dam						
RKm 71-121		--	0.3		1.8	1.5
RKm 122-177		--	1.3		1.5	0.4
RKm 178-224		--	1.9		0.4	1.2
Tailrace	0.5	--	2.1	1.2	0.4	0.9
Tailrace BRZ	5.5	--	7.8	1.0	2.1	1.3
Bonneville Reservoir						
Forebay	1.8	--	--	0.5	0.3	0.0
Mid-reservoir	0.0	--	--	0.0	0.0	0.0
Tailrace	0.0	--	--	0.0	0.0	0.8
Tailrace BRZ	0.8	--	--	1.0	3.2	
The Dalles Reservoir						
Forebay	1.0		--	0.0	0.0	0.0
Tailrace	0.0	--	--	0.0	0.8	0.0
TailraceBRZ	6.4		--	0.5	1.2	2.2
John Day Reservoir						
Forebay	2.4	3.1	0.7	0.6	1.2	2.0
Mid-reservoir	0.9	0.0	0.0	0.6	0.6	0.0
Tailrace	2.6	0.0	0.0	0.0	0.0	0.6
Tailrace BRZ	11.7	2.8	4.6	0.6	1.9	

Appendix Table B-5 Indices of northern squawfish predation of juvenile salmonids from 1990 through 1995 during spring in the lower Columbia and Snake rivers. Rkm= river kilometer. BRZ = boat restricted zone.

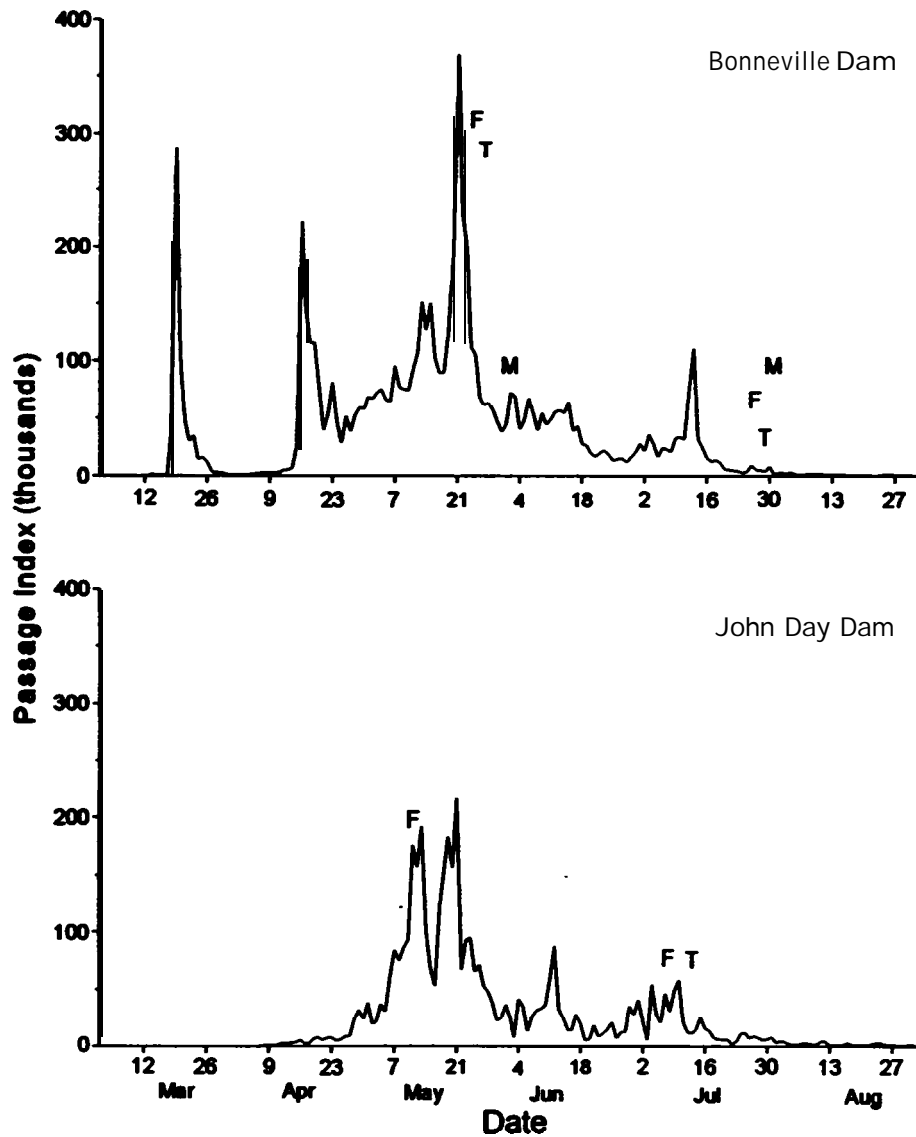
Location, zone	Predation index					
	1990	1991	1992	1993	1994	1995
Below						
Bonneville Dam						
RKm 71-121			14.0		8.0	7.3
RKm 122-177			20.0		29.7	3.5
RKm 178-224			20.2		33.3	9.9
Tailrace	5.5		1.4	6.1	7.4	1.4
TailraceBRZ	8.0		2.8	3.5	2.5	1.7
Bonneville Reservoir						
Forebay	3.3			1.5	0.3	0.7
Mid-reservoir	0.0			0.0	1.0	0.0
Tailrace	0.1	--		0.0	0.0	0.2
TailraceBRZ	2.0					
The Dalles Reservoir						
Forebay	1.1			0.2	0.1	0.0
Tailrace	1.9			0.0		
TailraceBRZ	3.9			0.0		
John Day Reservoir						
Forebay	2.1	2.4	4.7	1.9	1.3	0.9
Mid-reservoir	0.0	2.4	0.0	0.0	0.0	0.0
Tailrace	1.9	1.3	0.0	1.7	0.2	0.5
TailraceBRZ	3.9	2.9	0.9		0.2	
Lower Monumental Res.						
Tailrace		0.8			0.2	0.0
TailraceBRZ		0.6				0.3
Little Goose Reservoir						
Tailrace		0.5			0.4	<0.1
Tailrace BRZ		2.0			0.6	1.0
Lower Granite Reservoir						
upper-resevoir		0.5			0.3	0.2

Appendix Table B-6. Indices of northern squaw&h predation of juvenile salmonids from 1990 through 1995 during summer in the lower Columbia and Snake rivers. Rkm = river kilometer. BRZ = boat restricted zone.

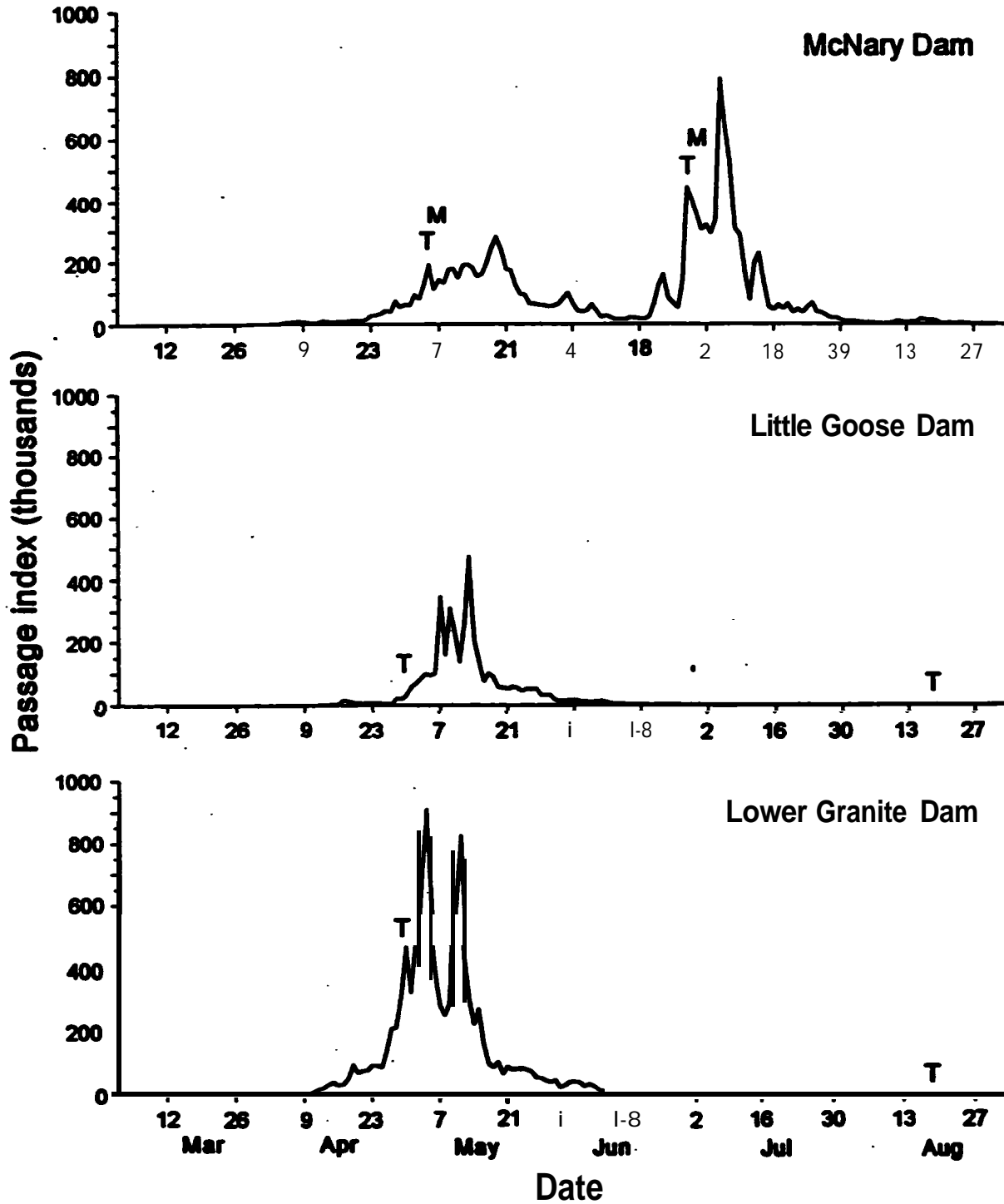
Location, zone	Density index					
	1990	1991	1992	1993	1994	1995
Below						
Bonneville Dam					-	
Rkm 71-121		--	8.3		27.3	14.5
Rkm 122-177		--	26.1		39.6	7.0
Rkm 178-224		--	33.9		9.5	17.0
Tailrace	2.3	--	5.7	9.1	1.0	1.6
Tailrace BRZ	16.4	--	21.8	3.2	1.3	1.3
Bonneville Reservoir						
Forebay	9.9	--	--	1.1	0.6	0.0
Mid-reservoir	0.0	--	--	0.0	0.0	0.0
Tailrace	0.0	--	--	0.0	0.0	0.6
Tailrace BRZ	0.7	--	--	0.2	3.5	-
The Dalles Reservoir						
Forebay	1.4	--	--	0.0	0.0	0.0
Tailrace	0.0	--	--	0.0	0.5	0.0
Tailrace BRZ	27.8	--		1.1	1.4	1.5
John Day Reservoir						
Forebay	3.4	4.0	1.7	0.7	1.6	1.0
Mid-reservoir	4.7	--	0.0	1.9	1.4	0.0
Tailrace	3.8	--	0.0	0.0	0.0	0.4
TailraceBRZ	18.6	5.4	4.6	0.9	0.5	-

APPENDIX C

**Timing of Consumption Index Sampling with Passage Indices
at Lower Columbia and Snake River Dams in 1995**



Appendix Figure! C-1. Timing of consumption index sampling with respect to juvenile salmonid passage indices at Bonneville and John Day dams in 1995 Sample times for forebay (F), tailrace (T), and areas downstream from Bonneville Dam tailrace (M) are shown.



Appendix Figure C-2. Timing of consumption index sampling with respect to juvenile salmonid passage indices at McNary, Little Goose, and Lower Granite dams in 1995. Sample times for tailrace (T) and the mid-reservoir of John Day Reservoir (M) are shown.

APPENDIX D

Response of Smallmouth Bass to Sustained Removals of Northern Squawfish

Introduction

A large-scale management program for northern squawfish (*Ptychocheilus oregonensis*) began in 1990 to increase survival of juvenile salmonids in the Columbia River Basin (Parker et al. 1995; Beamesderfer et al., in press). The program consists of both public and agency-operated fisheries that target northern squawfish exceeding 275 mm in fork length approximately the size at which northern squawfish become important predators on juvenile salmonids (Poe et al. 1991). The goal of the program is to sustain annual exploitation of "predator-sized" northern squawfish at 10-20%, which may reduce losses of juvenile salmonids by as much as 50% (Rieman and Beamesderfer 1990). Approximately 950,000 northern squawfish were removed by this program from 1990 through 1995. Estimates of annual exploitation in the lower Columbia and Snake rivers ranged from 8.5% to 15.6%.

Although predation by native northern squawfish has been well documented throughout the lower Columbia River Basin (Rieman et al. 1991; Ward et al. 1995), other predators such as introduced smallmouth bass (*Micropterus dolomieu*) are also present. Smallmouth bass are distributed throughout the lower Columbia and Snake rivers, with densities highest in Snake River reservoirs (Zimmerman and Parker 1995). Smallmouth bass abundance ranged from under 40% of northern squawfish abundance in John Day Reservoir (Beamesderfer and Rieman 1991) to more than 100% of northern squawfish abundance in Lower Granite Reservoir (Curet 1993). Smallmouth bass were responsible for only 7% of the total predation on juvenile salmonids in John Day Reservoir (Rieman et al. 1991). However, in some areas and times of year, smallmouth bass may be more important predators than northern squawfish (Tabor et al. 1993).

The effects of large-scale removals of northern squawfish on predation by smallmouth bass are unknown and difficult to predict. Johnson (1977) and Hayes et al. (1992) found that populations of yellow perch (*Perca flavescens*) were enhanced by intensive removals of white sucker (*Catostomus commersoni*), however, removals were far more intensive (80-85% of adult white suckers), and competition between yellow perch and white sucker was strongly indicated. Although diets of smallmouth bass and northern squawfish overlap (Poe et al. 1991), differences in distribution between the two species may limit competition. Densities of smallmouth bass are generally greatest in forebays immediately upstream from dams and in midreservoir areas (Zimmerman and Parker 1995), whereas northern squawfish densities are

generally greatest in **tailraces** immediately downstream from dams, and lowest in midreservoir areas (Ward et al. 1995).

Our objective was to describe the response of smallmouth bass to sustained removals of northern squawfish. We examined smallmouth bass density, consumption of juvenile salmonids, population structure, and growth and mortality over a period of years coinciding with the Northern Squawfish Management program. Information comparing smallmouth bass populations before and after sustained removals of northern squawfish will help assess the effectiveness of the removal program in reducing predation on juvenile salmonids.

Methods

Data Collection and Summary

We sampled from 1990 through 1995 to collect information on smallmouth bass in the lower Columbia and Snake rivers. We sampled each year in the forebay (immediately upstream from the dam), midreservoir, and tailrace (immediately downstream from the next dam) of John Day Reservoir, and in the tailrace immediately downstream from Bonneville Dam. We sampled in the forebay, midreservoir, and tailrace of Bonneville Reservoir each year except 1992. We sampled the tailrace of Lower Monumental and Little Goose reservoirs, and the upper reach of Lower Granite Reservoir in 1991, 1994 and 1995. Finally, we sampled three reaches of the Columbia River downstream from Bonneville Dam tailrace in 1992, 1994 and 1995. Each sampling reach was 6 km long, and was subdivided into 24 nearshore sampling sites of equal length.

We used boat electrofishing, and sampled 4-8 boat-days in each reach between early April and mid-September to collect smallmouth bass. Sampling was stratified so that efforts in spring (April-June) and summer (July-September) were approximately equal to accommodate differences in water temperature and in species of juvenile salmonids present (Ward et al. 1995). We sampled at least six randomly selected sites each boat-day between 3 am. and 11 am. Effort at each site consisted of a 15-minute electrofishing run with continuous output of approximately 4 A

We measured fork length (mm) and weight (g), and collected scales from all smallmouth bass captured. Stomach contents from smallmouth bass that were 200 mm fork length or longer were pumped with a modified Seaburg stomach sampler (Seaburg 1957). All stomach samples were kept on ice and later frozen until subsequent laboratory analysis.

In the laboratory, stomach contents were ~~thawed~~, and weighed to the nearest 0.01 g. To speed processing of samples, we first digested them with a solution of lukewarm tapwater, 2% (wet weight) pancreatin (8x porcine digestive enzyme), and

1% (wet weight) sodium sulfide. The solution was poured into sample bags until contents were submersed, and the bags were sealed and contents mixed to ensure all food was in contact with the solution. Samples were placed in a desiccating oven at 40°C for 24 hours. Digested samples were poured through a 425-µm sieve and rinsed with tap water. Diagnostic bones of prey fish were examined under a dissecting microscope and identified to the lowest possible taxon (Hansel et al. 1988). We enumerated prey fish consumed by adding the number of paired diagnostic bones to remaining unpaired bones.

We used standard methods to determine ages of smallmouth bass from scales (Jearld 1983). Data were pooled so that for each reservoir and the Columbia River downstream from Bonneville Dam, fish were grouped by 25-mm fork length intervals, and scales from 20 individuals were selected randomly from each group to be aged.

Although we sampled all reaches in both spring and summer, data were often pooled to achieve adequate sample sizes or to simplify data analyses. We pooled catch and effort data to produce yearly estimates of density for each reach, however, differences in water temperatures between seasons precluded pooling of consumption data. Population structure data were pooled to produce yearly estimates for each reservoir and for the Columbia River downstream from Bonneville Dam. Growth and mortality data were pooled similarly, except that we obtained sufficient sample sizes only for Bonneville, John Day, and Lower Granite reservoirs, and for the Columbia River downstream from Bonneville Dam.

Density

We used catch per 15-minute electrofishing run (CPUE) as an index of smallmouth bass density for each reach. Beamesderfer and Rieman (1988) found that electrofishing captured the widest size range of smallmouth bass; Zimmerman and Parker (1995) concluded that electrofishing CPUE was a good indicator of smallmouth bass density. We calculated mean CPUE and 95% confidence intervals for each reach each year.

Consumption of Juvenile salmonids

We developed an index to compare consumption of juvenile salmonids by smallmouth bass among years. Our consumption index was analogous to the consumption index for northern squawfish developed by Ward et al. (1995), which was highly correlated with direct estimates of consumption, and was easily obtained so that laboratory effort was minimized.

Beyer et al. (1988) calculated the days to 99% digestion (T90) for northern squawfish as

$$T90_i = 47.792 \cdot M_i^{0.61} \cdot T_i^{1.60} \cdot W_i^{-0.27},$$

where

M_i = meal size (g) at time of ingestion of salmonid prey item i ,
 T = water temperature ($^{\circ}\text{C}$), and
 W = predator weight (g).

From this equation, Ward et al. (1995) determined that daily consumption rate (C) of juvenile salmonids by northern squawfish could be expressed as

$$C = 0.0209 \cdot T^{1.60} \cdot W^{0.27} \cdot \sum_{i=1}^n M_i^{-0.61}.$$

However, this requires measurement of meal size M , which is time consuming and difficult. Ward et al. (1995) tested several potential indices by substituting some easily measured parameters for meal size, and found a consumption index (CI) that was highly correlated with direct estimates of consumption:

$$CI = 0.0209 \cdot T^{1.60} \cdot W^{0.27} \cdot S \cdot GW^{-0.29}$$

where

S = mean number of salmonids per sample of northern squawfish, and
 GW = mean total gut weight.

Rogers and Burley (1990) determined the T_{90} for smallmouth bass to be

$$T_{90} = 24.542 \cdot M_i^{0.29} \cdot e^{-0.15T} \cdot W^{-0.23}$$

Following the method of Ward et al. (1995), a potential index of juvenile salmonid consumption for smallmouth bass would therefore be

$$CI = 0.0407 \cdot e^{0.15T} \cdot W^{0.23} \cdot (S \cdot GW^{-0.29}).$$

We tested how well difference in consumption indices related to differences in direct estimates of consumption rate. Consumption indices and consumption rates were both computed for reaches sampled in 1995, and the correlation between the index and the direct estimate was examined.

We used the simple meal turnover-time method of Tabor et al. (1993) to estimate smallmouth bass consumption rate of juvenile salmonids in 1995:

$$C = (R \cdot P \cdot W) / SW;$$

where

R = daily ration (% body weight/day),
P = proportion of diet (by weight) that is sahnnonid prey, and
SW = mean sahnnonid prey weight (g) before digestion.

Daily ration (R) was estimated as

$$R = (M \cdot n) / (T90_i \cdot N);$$

where

M= average size of ingested meal (% body tight),
n = number of fish that contain food in the stomach and
N = total Mmber of fish examined.

An estimate of original meal weight of fishes was based on lengths of prey fishes. Identity and original fork lengths of prey fishes were determined from diagnostic bones (Hansel et al. 1988), then original weights were estimated from length-wtght regressions (Vigg et al. 1991). Original weights of other prey items were estimated by adjusting the observed non-fish weight with the same ratio used for fish weight.

We **adjusted estimates of consumption** rate for diel feeding periodicity. Vigg et al. (1991) found that smallmouth bass consumed 32% of their daily ration during the hours we sampled.

Population Structure

We used proportional stock density (PSD) to compare size structure of **smallmouth bass population among years** (PSD= 100 • number of fish of at least quality length/number of fish of at least stock length; Anderson 1980). Stock and quality sizes were defined as 180 mm and 280 mm total length, respectively (Anderson and Gutreuter 1983), where total length = 1.04 • fork length (Carlander 1977). We computed 95% confidence intervals for each PSD estimate (Gustafson 1988) and used **chi-square analyses to compare PSD among years.**

We used mean relative weight (**Wr**) to compare fish condition among years (**Wr**= 100 • weight/Ws; ws is the length-specific standard weight of smallmouth bass). The **standard weight equation defined by Kolander et al. (1993) for smallmouth bass at least 150 mm total length is**

$$\log_{10}(Ws) = -5.239 + 3.200 \cdot \log_{10}(\text{total length}).$$

We computed 95% confidence **intervals** for each estimate of mean **Wr.**

Growth and Mortality

We used length-at-age data to compare growth rate among years and reservoirs. We plotted observed length at ages for each reservoir and visually inspected each plot for trends in growth over time.

To evaluate total instantaneous mortality and annual mortality rates, we developed catch curves for each reservoir (Richer 1975). We tested the descendi limb of the catch curves (estimates of total instantaneous mortality) for homogeneity of slopes among years.

Results

Density

Catch rate of smallmouth bass varied considerably among reaches and years (Appendix Figure D-1), with catch generally highest in John Day Reservoir and in the Snake River. Catch rate consistently increased over time at one of four reaches downstream from Bonneville Dam, however, we found no evidence of an increase in catch rate at any of the nine reaches upstream from Bonneville Dam. Catch rate consistently decreased at two of three reaches in the Snake River.

Consumption of juvenile salmonids

Our proposed consumption index for smallmouth bass,

$$CI = 0.0407 \cdot e^{0.15T} \cdot W^{0.23} \cdot (S \cdot GW^{-0.29}),$$

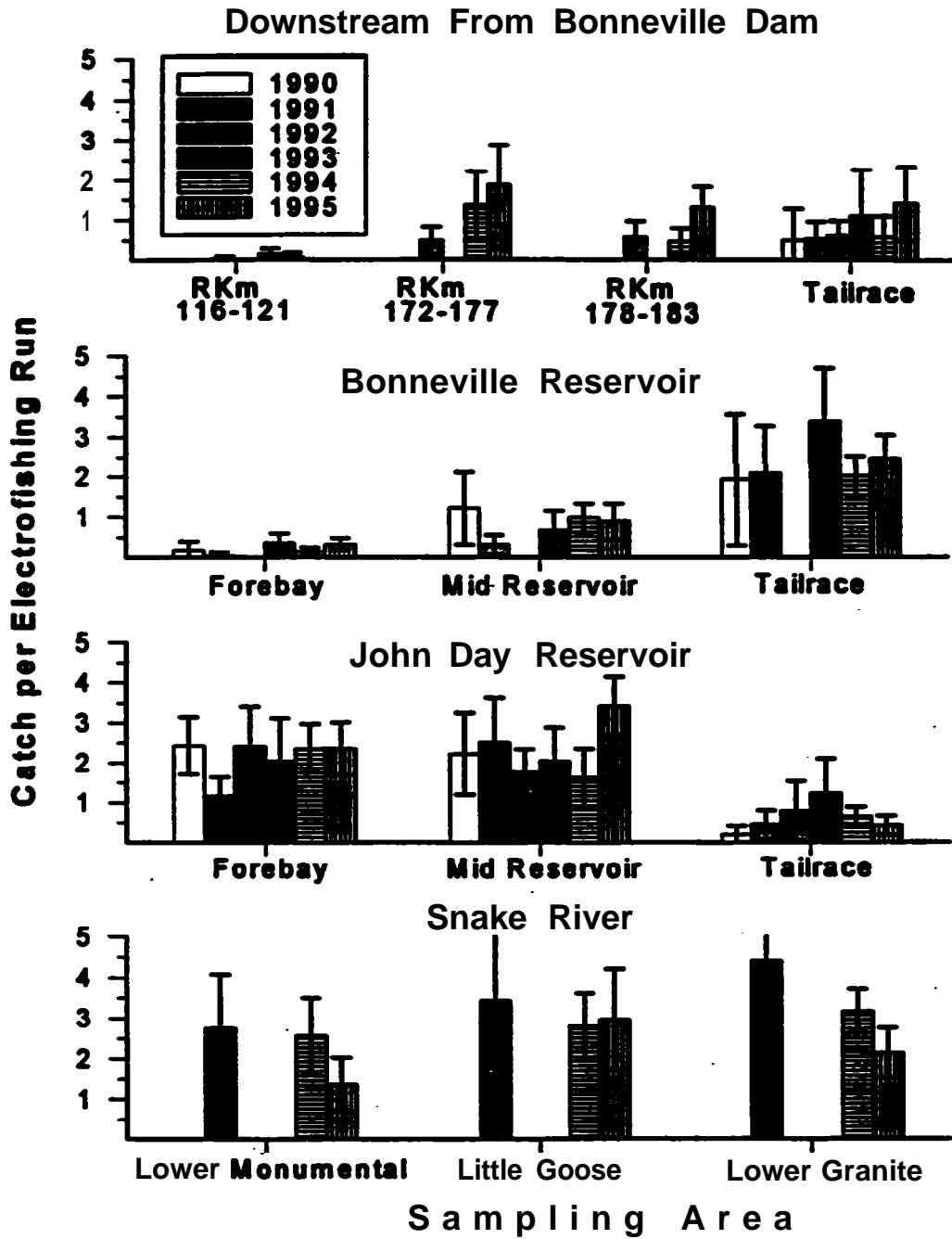
was highly correlated with the direct estimate of consumption (Appendix Figure D-2). We therefore used this index to evaluate consumption of juvenile salmonids by smallmouth bass.

Consumption of juvenile salmonids was highly variable among reaches and seasons, but was generally low (Appendix Tables D-1 and D-2). Although consumption indices for spring were especially low, we found consistent evidence of predation on juvenile salmonids in Snake River reservoirs, and to a lesser extent in the forebay of John Day Reservoir. In summer, consumption was highest in the forebay of John Day Reservoir, and in the reach from Rkm 178- 183, downstream from Bonneville Dam. We found no trend of increasing consumption by smallmouth bass over time.

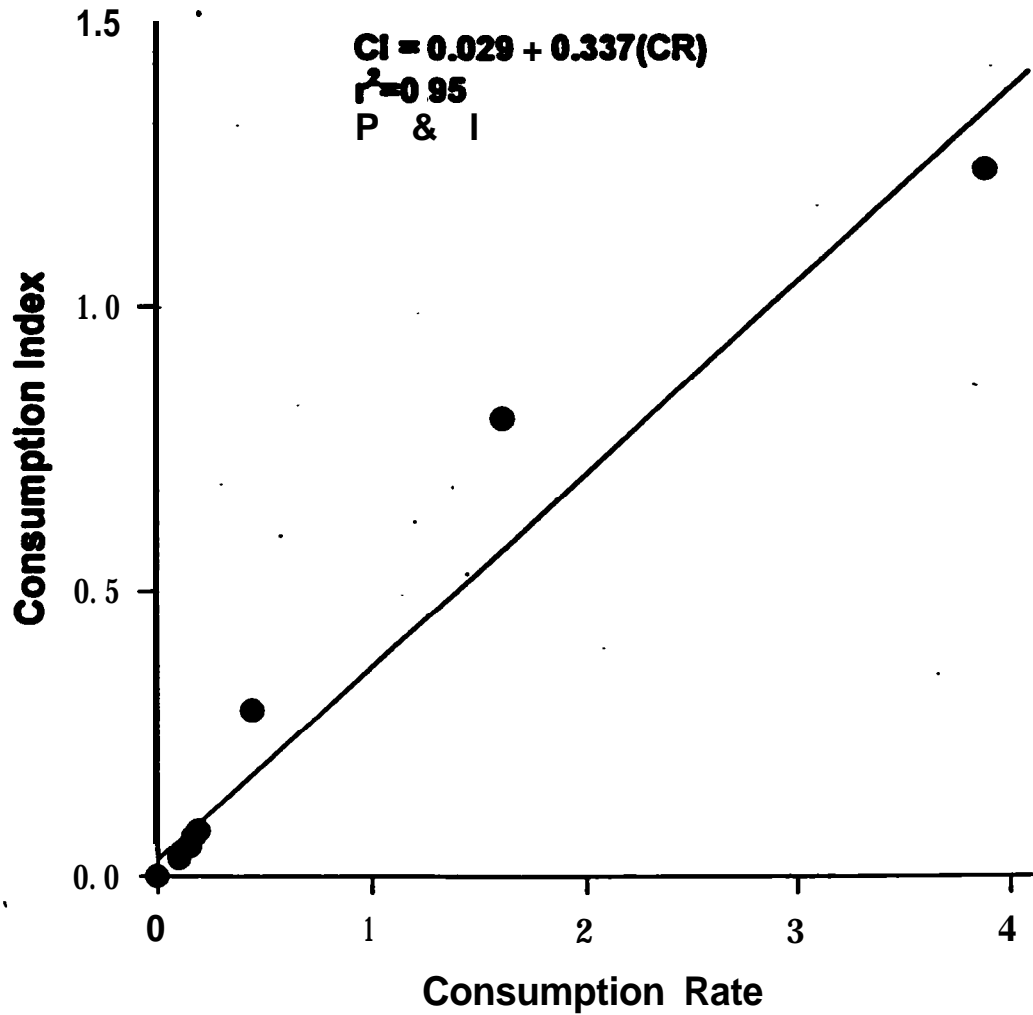
Population Structure

Proportional stock density of smallmouth bass varied considerably among reservoirs and years (Appendix Figure D-3), but was generally higher in the Columbia River than in the Snake River. In John Day Reservoir, PSD was relatively stable except for a one-year increase in 1991. Annual variation in PSD was generally greater in other reservoirs. We found no trend of increasing or decreasing PSD over time for any reservoir.

Relative weight of smallmouth bass was also highly variable, but was generally higher in the Columbia River than in the Snake River (Appendix Figure D-4). Relative weight was usually highest in Bonneville Reservoir or in the Columbia River downstream from Bonneville Dam. We found no trend of increasing or decreasing relative weight over time for any reservoir.



Appendix Figure D-1. Relative density of smallmouth bass 200 mm fork length and larger in the lower Columbia and Snake rivers, 1990-95, as determined by catch per 15-minute electrofishing run. Vertical bars represent 95% confidence intervals.



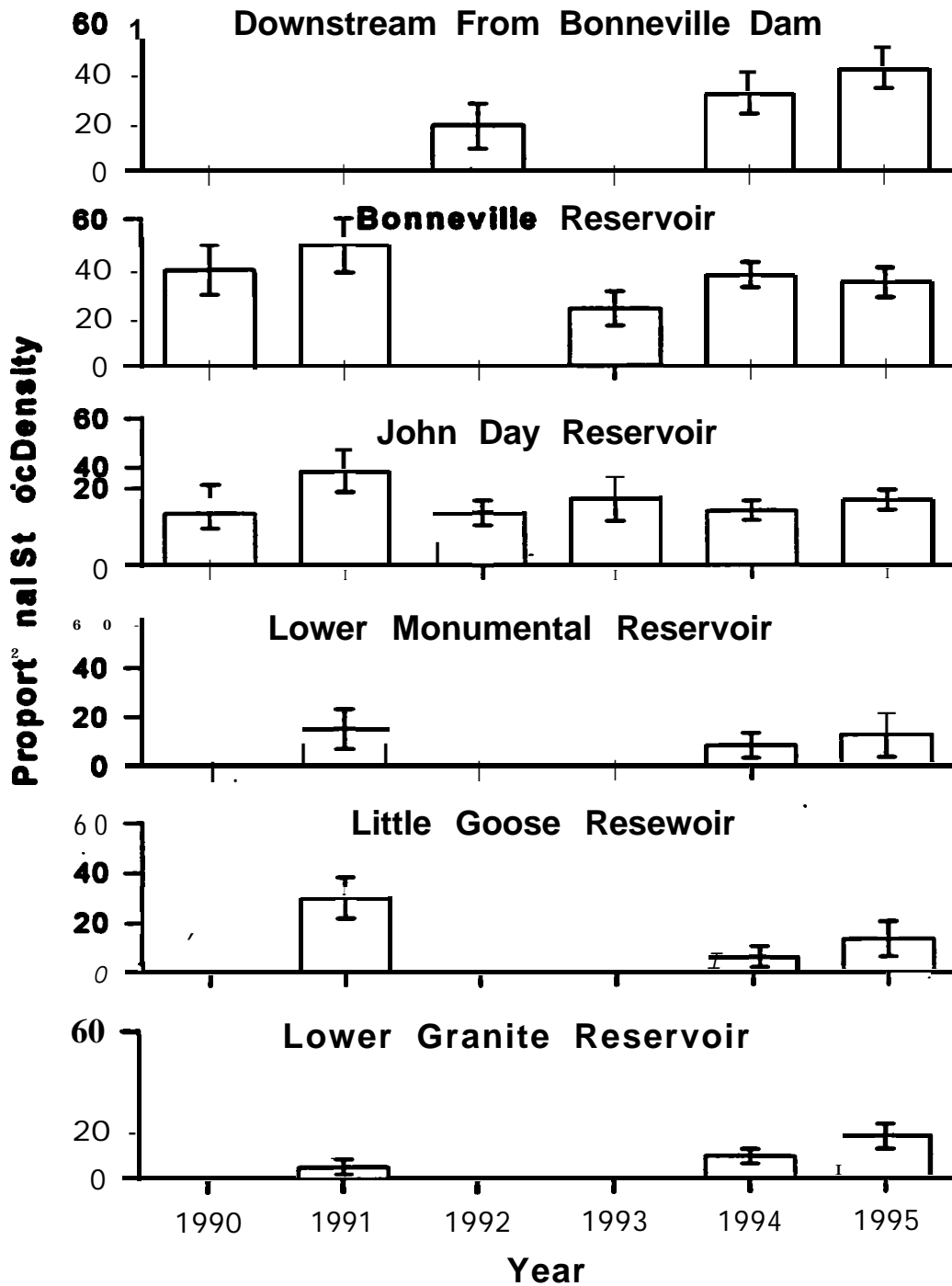
Appendix Figure D-2. Relationship between proposed consumption index for smallmouth bass (CI) and direct estimate of consumption rate (CR); CR = number of juvenile salmonids per smallmouth bass per day.

Appendix Table D-1. Index of salmonid consumption by smallmouth bass in the lower Columbia and Snake rivers during spring, 1990-95. CI = consumption index, N = sample size.

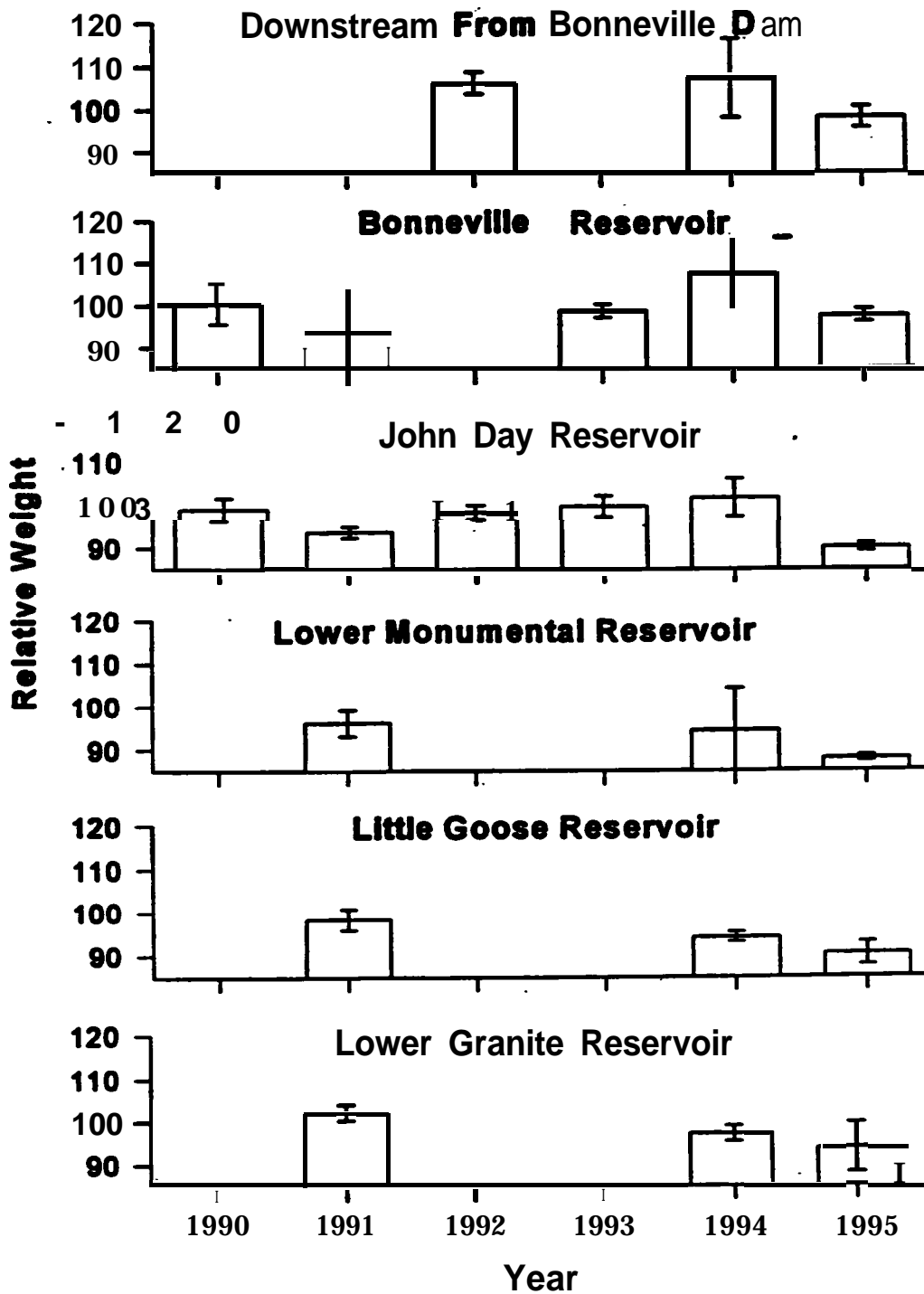
Reservoir, reach	1990		1991		1992		1993		1994		1995	
	CI	N	CI	N	CI	N	CI	N	CI	N	CI	N
Downstream from												
Bonneville Dam												
RKm 116121	-	-	-	-	0.0	1	-	-	0.0	0	0.0	2
RKm 172-177	-	-	-	-	0.1	12	-	-	0.0	23	0.1	47
RKm 178-183	-	-	-	-	0.0	5	-	-	0.3	10	0.0	33
Tailrace	0.5	5	-	-	0.0	4	0.0	4	0.0	7	0.0	26
Bonneville												
Forebay	0.0	0	-	-	-	-	0.0	2	0.0	5	0.1	12
Mid-reservoir	0.0	0	-	-	-	-	0.0	1	0.0	47	<0.1	30
Tailrace	0.0	10	-	-	-	-	0.0	21	0.0	58	0.0	99
John Day												
Forebay	0.1	6	0.0	41	0.1	39	0.0	37	0.1	75	0.0	76
Mid-reservoir	0.0	17	0.0	33	0.0	14	0.0	27	0.0	45	0.0	127
Tailrace	0.0	0	0.0	4	0.0	1	0.0	3	0.0	27	0.0	11
Lower												
Monumental												
Tailrace	-	-	0.0	74	-	-	-	-	0.1	23	0.0	25
LittleGoose												
Tailrace	-	-	<0.1	63	-	-	-	-	0.1	9	<0.1	78
Lower Granite												
upper reservoir	-	-	0.1	57	-	-	-	-	0.2	48	0.1	94

Appendix Table D-2. Index of salmonid consumption by smallmouth bass in the lower Columbia and Snake rivers during summer, 1990-95. CI = consumption index, N = sample size.

Reservoir, reach	1990		1991		1992		1993		1994		1995	
	CI	N	CI	N	CI	N	CI	N	CI	N	CI	N
Downstream from BonnevilleDam												
RKm 116-121	--		--		0.0	0	--		0.0	6	0.0	2
RKm 172-177	--		--		0.0	7	--		0.2	22	0.3	18
RKm 178-183	--		--		0.4	13	--		0.3	9	0.8	17
Tailrace	0.0	2	--		0.0	2	0.2	10	0.0	14	0.0	8
Bonneville												
Forebay	0.0	0	--		--		0.0	2	0.4	8	0.0	13
Mid-reservoir	0.0	3	--		--		0.0	14	0.0	32	0.0	9
Tailrace	0.0	3	--		--		0.0	36	0.1	77	<0.1	97
John Day												
Forebay	0.3	10	0.5	43	0.2	35	0.7	55	0.2	137	0.3	92
Mid-reservoir	0.3	13	0.0	40	0.0	4	0.1	65	0.0	35	0.0	182
Tailrace	0.0	10	0.1	13	0.0	6	0.0	23	0.0	19	0.0	22
LOWER												
Monumental Tailrace	--		--		--		--		--		0.0	34
LittleGoose												
Tailrace	--		--		--		--		--		0.0	38
Lower Granite												
Upper reservoir	--		--		--		--		--		0.0	81



Appendix Figure D-3. Proportional stock density of smallmouth bass in the lower Columbia and Snake rivers, 1990-1995. Vertical bars represent 95% confidence intervals.



Appendix Figure D-4 Relative weigh of smallmouth bass in the lower Columbia and Snake rivers, 1990-95. Vertical bars represent 95% confidence intervals.

Growth and Mortality

observed fork lengths at ages varied more among reservoirs than among years within reservoirs (Appendix Figure D-5). Lengths at age were generally highest downstream from Bonneville Dam and in Bonneville Reservoir, and lowest in Lower Granite Reservoir. We found no evidence of faster growth over time.

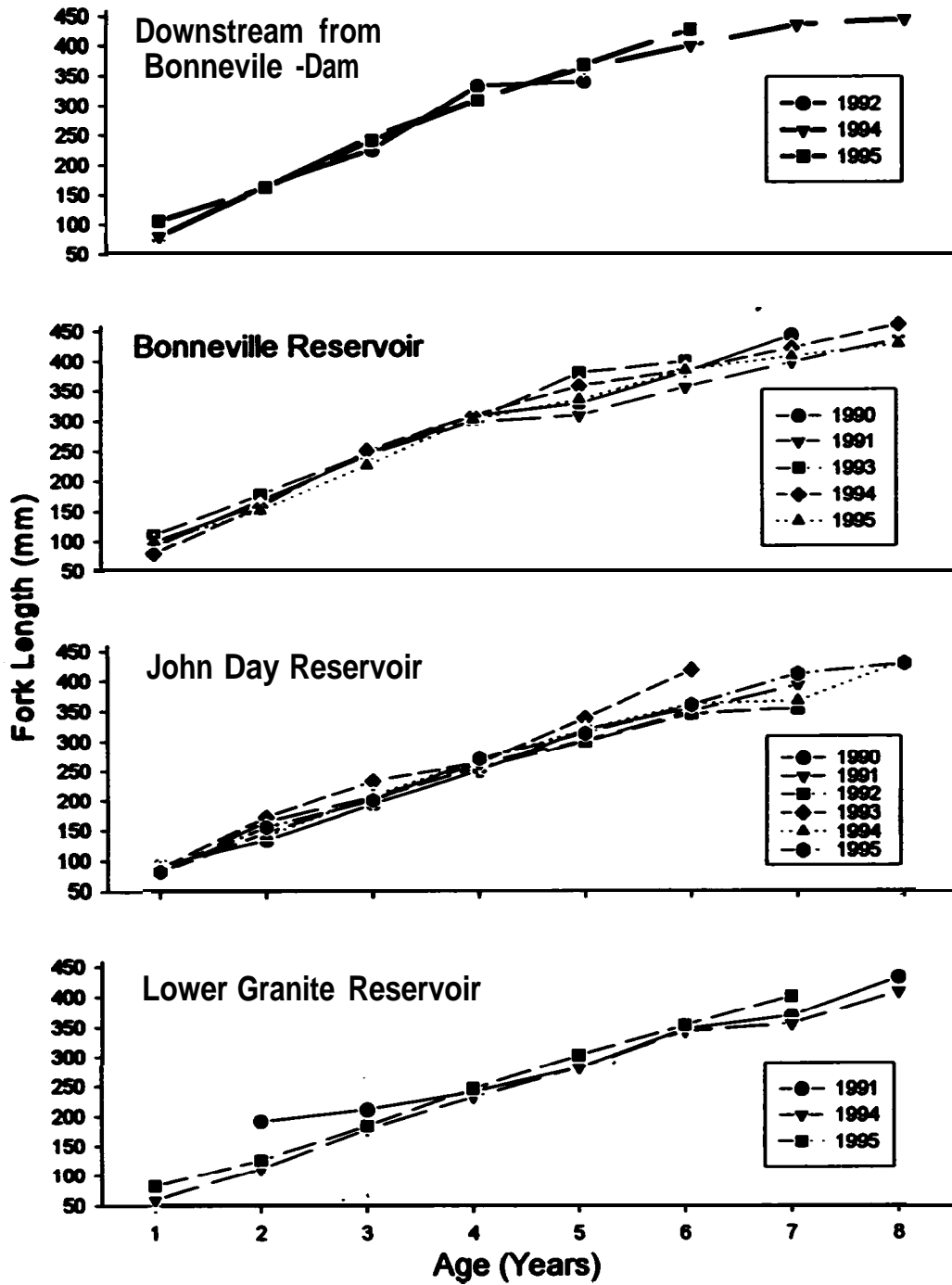
Estimates of annual mortality of smallmouth bass consistently exceeded 50% throughout the Columbia River basin (Appendix Table D-3). We found no evidence of decreased mortality over time. Differences among years in slopes of the descending limbs of catch curves (estimates of total instantaneous mortality) were not significant for the Columbia River downstream from Bonneville Dam ($P=0.38$), Bonneville Reservoir ($P=0.85$), John Day Reservoir ($P=0.79$), or Lower Granite Reservoir ($P=0.93$).

Discussion

We have found no evidence of any smallmouth bass response to sustained removals of northern squawfish. No trends in smallmouth bass density, consumption of juvenile salmonids, population structure, or growth and mortality have been realized since implementation of the Northern Squawfish Management Program.

The first evidence of any response by smallmouth bass would likely be changes in diet, which could then lead to changes in growth (Johnson 1977, Hayes et al. 1992). Data from John Day Reservoir (ODFW, unpublished data) indicate that the diet of smallmouth bass remains similar to that prior to northern squawfish removals (Poe et al. 1991). Sculpins (*Cottus* spp.) remain the most common fish in the diet, and crustaceans (primarily crayfish *Pasifisticus* spp.) remain the most common non-fish prey item.

Of the population characteristics we examined, size structure may be the most likely to exhibit measurable change within the period studied. Small changes in growth, survival, and recruitment may all contribute to and, therefore, be more apparent as changes in size structure. After a single-year removal of 80% of a white sucker population, Hayes et al. (1992) reported small changes in size structure of yellow perch for three years, and a much larger change in the fourth year. Although annual exploitation rates of northern squawfish were much lower, removals have been sustained for five years in most areas, with little evidence of changing size structure of smallmouth bass. However, the highest levels of sustained exploitation have occurred downstream from Bonneville Dam and in Lower Granite Reservoir, the only two areas where smallmouth bass PSD has increased. Further research is needed to determine if these trends in PSD continue, or if they result from variations in year-class strength prior to sustained removals of northern squawfish.



Appendix Figure D-5. Observed fork length at age for smallmouth bass downstream from Bonneville Dam, and in Bonneville, John Day, and Lower Granite reservoirs.

Appendix Table D-3. Estimates of annual mortality (%) for smallmouth bass in the Lower Columbia and Snake rivers. Estimates are for ages 3-6 unless otherwise noted.

Reservoir	Year					
	1990	1991	1992	1993	1994	1995
Downstream from Bonneville Dam	-		62'		63	57
Bonneville	69	57		62	62*	69
John Day	64	55^b	57*	60*	68	58
Lower Granite	-	57*			72	58

^a Ages 3-5.

^b Ages 4-6.

E&mess of the Northern Squawfish Management Program relies partially on the response of other predators to sustained removals of northern squawfish. Smallmouth bass are the most abundant and widespread predator other than northern squawfish in the lower Columbia and Snake rivers, and therefore have the highest potential for reducing benefits of the management program. The lack of response to date by smallmouth bass increase confidence in the hypothesis that sustained removals of northern squawfish increases survival of juvenile salmonids.

References

- Anderson, RO. 1980. Proportional stock density (PSD) and relative weight (W_r): interpretive indices for fish populations and communities. Pages 27-33 in S. Gloss and B. Shupp, editors. Practical fisheries management: more with less in the 1980s. American Fisheries Society, New York Chapter, Ithaca, New York.
- Anderson, RO., and S.J. Gumuter 1983. Length, weight, and associated structural indices. Pages 283-300 in L.A Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.
- Beamesdefer, RC., and B.E. Rieman. 1988. Size selectivity and bias in estimates of population statistics of smallmouth bass, walleye, and northern squawfish in a Columbia River reservoir. North American Journal of Fisheries Management 8:505-510.

- Beamesderfer, RC., and B.E. Rieman. 1991. Abundance and distribution of northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:439-447.**
- Beamesderfer, RCP., D.L. Ward, and AA Nigro. In press. A unique predator control program on northern squawfish in the Columbia River. Canadian Journal of Fisheries and Aquatic Sciences.**
- Beyer, J.M., M.G. Lucchetti, and G. Gray. 1988. Digestive tract evacuation in northern squawfish (*Ptychocheilus oregonensis*) Canadian Journal of Fisheries and Aquatic Sciences 45:548-553.**
- Carlander, K.D. 1977. Handbook of freshwater fishery biology, volume 2. Iowa State University Press, Ames.**
- Curet, T.S. 1993. Habitat use, food habits and the influence of predation on subyearling chinook salmon in Lower Granite and Little Goose Reservoirs, Washington. Master thesis, University of Idaho, Moscow.**
- Gustafson, K-A 1988. Approximating confidence intervals for indices of fish population size structure. North American Journal of Fisheries Management 8:139-141.**
- Hansel, H.C., SD. Duke, P.T. Lofy., and G.A Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of prey species. Transactions of the American Fisheries Society 117:55-62.**
- Hayes, D-B., W. W. Taylor, and J.C. Schneider. 1992. Response of yellow perch and the benthic invertebrate community to a reduction in the abundance of white suckers. Transactions of the American Fisheries Society 121:36-53.**
- Jearld, W.E. 1983. Age determination. Pages 301-323 in L.A Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.**
- Johnson, F.H. 1977. Responses of walleye (*Stizostedion vitreum vitreum*) and yellow perch (*Perca flavescens*) to removal of white sucker (*Catostomus commersoni*) from a Minnesota Lake, 1966. Journal of the Fisheries Research Board of Canada 34: 1633-1642.**
- Kolander, T.D., D.W. Willis, and B.R Murphy. 1993. Proposed revision of the standad weight (W.) equation for smallmouth bass. North American Journal of Fisheries Management 13:398-400.**

- Neter, J., W. Wasserman and M.H. Kutner. 1985. Applied linear statistical models, 2nd edition. Irwin Press, Homewood, Illinois.**
- Parker, R.M., M.P. Zimmerman, and D.L. Ward. 1995. Variability in biological characteristics of northern squawfish in the lower Columbia and Snake rivers. Transactions of the American Fisheries Society 124:335-346.**
- Poe, T.P., H.C. Hansel, S. Vigg, D.E. Palmer, and L.A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.**
- Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.**
- Rieman, B.E., and R.C. Beamesderfer. 1990. Dynamics of a northern squawfish population and the potential to reduce predation on juvenile salmonids in a Columbia River reservoir. North American Journal of Fisheries Management 10:228-241.**
- Rieman, B.E., R. C. Beamesderfer, S. Vigg, and T.P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:448-458.**
- Rogers, J.B., and C.C. Burley. 1990. A sigmoid model to predict gastric evacuation rates of smallmouth bass (*Micropterus dolomieu*) fed juvenile salmon. Canadian Journal of Fisheries and Aquatic Sciences 48:933-937.**
- Seaburg, K.G. 1957. A stomach sampler for live fish. Progressive Fish Culturist 19: 137-139.**
- Tabor, R.A., R.S. Shively, and T.P. Poe. 1993. Predation on juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. North American Journal of Fisheries Management 13:831-838.**
- Vigg, S., T.P. Poe, L.A. Prendergast, and H.C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.**
- Ward, D.L., J. H. Petersen, and J.J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the lower Snake River. Transactions of the American Fisheries Society 124:321-334.**

Zimmerman, M.P., and R.M. Parker. 1995. Relative density and distribution of smallmouth bass, channel catfish, and walleye in the lower Columbia and Snake rivers. Northwest Science 69: 19-28.

APPENDIX E

Digestive Tract Contents of Northern Squawfish and Smallmouth Bass in 1995 and Comparison of Fish Diets between Northern Squawfish and Smallmouth Bass in 1994-95

We examined digestive tract contents of 8 17 northern squawfish and 1,485 smallmouth bass collected during standardized electrofishing in 1995 (Appendix Table E. 1). The systemwide occurrence of salmonids in digestive tracts was 15.3% for northern squawfish and 2.4% for smallmouth bass, which was nearly identical to results from 1993-94 (Knutsen et al. 1995). The occurrence of ingested juvenile salmonids during spring was highest for northern squawfish caught in Little Goose Reservoir (90.8%) and smallmouth bass caught in Lower Granite Reservoir (11.7%), whereas during summer it was highest for northern squawfish in Bonneville Reservoir (22.2%) and smallmouth bass downstream from Bonneville Dam tailrace (13.5%).

We pooled data from 1994 and 1995 to compare fish diets of northern squawfish and smallmouth bass. To increase sample sizes, data from individual reservoirs were pooled to compare diets among three areas — downstream from Bonneville Dam, Columbia River reservoirs, and Snake River reservoirs. Salmonids comprised at least 80% of the fish in northern squawfish digestive tracts, and salmonids and sculpins together accounted for at least 94% of all northern squawfish prey in all areas (Appendix Table E-2). In contrast, salmonids comprised 24% of fish in smallmouth bass digestive tracts in Snake River sampling sites, and 11% downstream from Bonneville Dam and in lower Columbia River reservoirs. Sculpins were the most common fish in smallmouth bass digestive tracts. Fish other than salmonids and sculpins were far more prevalent in smallmouth bass than northern squawfish and comprised over 40% of the fish eaten by smallmouth bass downstream from Bonneville Dam and in the Snake River. Excluding salmonids and sculpins, cyprinids were the most common fish in smallmouth bass digestive tracts in all areas. The increase in the percentage of centrarchids (including smallmouth bass) and catfish in smallmouth bass from below Bonneville Dam to the Snake River was consistent with the increase in relative abundance of smallmouth bass and catfish in the lower Columbia and Snake rivers (Zimmerman and Parker 1995).

Appendix Table E-1. Number of northern squawfish and smallmouth bass digestive tracts examined from the lower Columbia and Snake rivers in 1995 (N) and the percent of digestive tracts that contained food, fish, and juvenile salmonids. Sampling periods were spring (April 25 - June 1) and summer (June 27 - August 18).

Period: Reservoir or area	Northern squawfish				smallmouth bass				
	N	% Food	% Fish	% Sal.	N	% Food	% Fish	% Sal.	
spring:									
Below Bonneville									
Dam tailrace	7	8	50.0	18.0	9.0	82	76.2	32.9	2.4
Bonneville Dam									
tailrace	42	45.2	31.0	31.0	26	61.5	23.1	0	
Bonneville	136	54.4	10.3	5.2	141	62.4	27.7	1.4	
The Dalles	22	31.8	4.6	4.6	101	41.6	15.8	1.0	
John Day	21	52.4	28.6	28.6	214	53.3	12.2	0	
Lower Monumental	7	57.1	57.1	2.9	25	28.0	8.0	0	
Little Goose	65	96.9	90.8	90.8	78	52.6	21.8	1.3	
Lower Granite	16	75.0	56.3	56.3	94	64.9	36.2	11.7	
summer:									
Below Bonneville									
Dam tailrace	5	6	41.1	14.3	7.1	37	62.2	40.5	13.5
Bonneville Dam									
tailrace	27	44.4	29.6	22.2	8	87.5	62.5	0	
Bonneville	182	39.6	1.7	1.7	119	73.1	26.1	0.8	
The Dalles	84	19.1	4.8	3.6	111	82.9	17.1	0	
John Day	30	26.7	13.3	10.0	296	71.0	16.9	4.1	
Lower Monumental	28	25.0	0	0	34	50.0	20.6	0	
Little Goose	19	36.8	10.5	5.3	38	76.3	7.9	0	
Lower Granite	4	50.0	0	0	81	77.8	17.3	0	

Appendix Table E-2. Sample size and percentage of salmonids, cottids, and other fish families in northern squawfish and smallmouth bass digestive tracts containing identifiable fish in three reaches of the lower Columbia and Snake rivers from 1994-95. Reaches are downstream from Bonneville Dam (DBD), lower Columbia River reservoirs (COL), and lower Snake River reservoirs(SNK).

sample size, family	Northern squawfish			Smallmouth bass		
	DBD	COL	SNK	DBD	COL	SNK
N (digestive tracts)	611	1,099	261	224	1,710	430
N (fish)	243	220	227	156	475	164
N (identifiable fish)	227	201	214	126	353	126
% Salmonidae	85.0	82.6	98.1	11.1	10.8	23.8
% cottidae	9.7	11.4	0	47.6	66.9	30.2
% other taxa	5.3	6.0	1.9	41.3	22.3	46.0
% cyprinidae	2.2	3.0	0.5	16.7	15.3	15.1
% catostomidae	0	5.5	0	15.8	1.7	8.7
% Ictaluridae	0	0	0	0	0.2	11.9
% Percopsidae	0.4	0.5	0	3.2	1.4	0
% Gastelosteidae	2.2	1.5	0	4.8	0.6	0
% Centrarchidae	0	0	1.4	0.8	1.7	10.3
% other	0.5	0.5	0	0	1.4	0

References

- Knutsen, C.J., D.L. Ward, T.A Friesen, and M.P. Zimmerman. 1995. Development of a systemwide predator control program: Indexing and fisheries evaluation. Oregon Department of Fish and Wildlife, Contract DE-AI79-9OBPO7084. 1994 Annual Report to the Bonneville Power Administration, Portland, Oregon.**
- Zimmerman, M.P., and RM. Parker. 1995. Relative density and distribution of smallmouth bass, channel catfish, and walleye in the lower Columbia and Snake rivers. Northwest Science 69: 19-28.**