

**DEVELOPMENT OF A SYSTEMWIDE PREDATOR
CONTROL PROGRAM:
STEPWISE IMPLEMENTATION OF A PREDATION INDEX,
PREDATOR CONTROL FISHERIES, AND EVALUATION
PLAN IN THE COLUMBIA RIVER BASIN**

SECTION I: IMPLEMENTATION

1996 ANNUAL REPORT

Prepared by:

Franklin R. Young
Columbia Basin Fish and Wildlife Authority

In Cooperation With

Nez Perce Tribe of Idaho
Oregon Department of Fish and Wildlife
Washington Department of Fish and Wildlife
Pacific States Marine Fisheries Commission
Columbia River Inter-tribal Fish Commission
Confederated Tribes of the Umatilla Indian Reservation
Confederated Tribes of the Warm Springs Reservation of Oregon
Confederated Tribes and Bands of the Yakama Indian Reservation

Prepared for:

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

Project Number 90-077
Contract Number 94BI245 14

November 1997

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1996 EXECUTIVE SUMMARY

by Franklin R Young

We report our results from the sixth 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-size 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 system-wide 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 system-wide fishery using floating trap nets, but found this fishery to be ineffective at harvesting large numbers of northern squawfish on a system-wide 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 (i.e., March through early June). In addition, we initiated a concerted effort to increase public participation in the sport-reward fishery through a series of promotional and incentive activities.

In 1995 and 1996, 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.

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), 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 system-wide (i.e., Columbia River below Priest Rapids Dam and Snake River below Hells Canyon Dam) sport-reward fishery and operate the system for collecting and disposing of harvested northern squawfish.
2. PSMFC (Report B): Process and provide accounting for reward payments to participants in the sport-reward fishery.
3. CRITFC (Report C): Implement a system-wide angling fishery at 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.
6. ODFW (Report E): 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 1996 by report are as follows.

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

1. Objectives for 1996 were to (1) implement a recreational fishery that rewards anglers who harvest northern squawfish (*Ptychocheilus oregonensis*) \geq 11 inches total length, (2) obtain catch data on all fish species caught by fishery participants while targeting northern squawfish, (3) collect length data on the above mentioned species which are returned to registration stations, (4) collect, monitor, and report data on angler participation and catch per angler day during the season, and (5) evaluate promotional, fish handling, and cost analysis aspects of the Northern Squawfish Sport-Reward Fishery.
2. The northern squawfish sport-reward fishery was conducted from April 29 through September 29, 1996. Twelve registration stations were located throughout the lower Snake and Columbia rivers.
3. A total of 157,230 northern squawfish \geq 11 inches were harvested during the 1996 season. A total of 35,485 angler days were spent harvesting these fish. Harvest was slightly above the five-year average of 155,965 while participation was well below the five-year average of 58,853 angler days. Catch per angler day for all anglers during the season was 4.43 and exceeded the five-year average of 3.0 northern squawfish per angler day.
4. The reduction in harvest from 1995 to 1996 can be mainly attributed to a major drop in participation. The level of participation prior to northern squawfish spawning has always been a very important factor in determining overall Northern Squawfish Sport-Reward Fishery (NSSRF) harvest (Klaybor et al. 1993). Participation during this period of the 1996 NSSRF was well below mean 1991-95 levels, most likely a result of very high spring flows in both the Columbia and Snake rivers which made northern squawfish difficult to locate.
5. Fish handling responsibilities were transferred from a private contractor to the WDFW in 1996. The total cost was \$32,835. All collected fish were rendered for an average cost of \$0.20/fish.

Report B
Northern Squawfish Sport-Reward Fishery Payments

1. During 1996, vouchers totaling \$629,538 were paid as rewards for 154,554 fish.
2. A total of 231 vouchers were paid for tagged fish at \$50 per tag for a total of \$11,550.
3. A total of 1,246 promotional coupons were redeemed at \$3 each for a total of \$3,738.
4. A total of \$39,150 was paid out for promotional tournaments.
5. A total of 2,239 anglers received payments.
6. The total for all payments was \$672,426.

Report C
**Controlled Angling for Northern Squawfish at
Selected Dams on the Columbia and Snake Rivers in 1996**

1. Dam angling at eight dams on the lower Snake and Columbia rivers during 1996 resulted in a catch of 5,455 northern squawfish from June through September which was roughly equal to the catch in 1995.
2. Overall catch per angler hour (CPM) was 1.5 in 1996, compared to 0.7 the previous year. Catch rates at Columbia River dams were higher than at Snake River dams, 1.7 and 0.4 CPAH respectively, and showed marked improvement over the previous year (1995: CPAH = 0.8) a trend not observed at Snake River dams (1995: CPAH = 0.5). Total hook-and-line angling effort was reduced in each of the last two years, (1995 : 27% reduction; 1996: 50% reduction) in response to progressive declines in catch rate at Columbia and Snake river dams in 1994 and 1995.
3. Downrigger equipment was used from boats to catch northern squawfish that reside near the river bottom late in the season. At all four dams where they were tested, catch rates using downriggers were higher than conventional hook-and-line angling from boats, with an overall CPAH of 2.5. At Snake River dams, catch rate for boat angling (CPAH = 0.7) was higher than for dam-based angling (CPAH = 0.1). This was not the case at Columbia River dams, where catch rates were 1.3 for boat angling and 1.8 for dam-based angling.
4. Angling effort was supplemented by volunteer angling at Bonneville Dam (NS catch: 153; effort: 257.1 angler hours; CPAH: 0.6), with a total of six sport-angling groups

participating in the program this year. Volunteer effort and catch were roughly half of the 1995 levels.

5. Incidental catch was 2.3% of the total hook-and-line catch, compared to 8.3% the previous year. Game fish (mostly bass *Micropterus spp.*, channel catfish *Ictalurus punctatus*, and walleye *Stizostedion vitreum*) constituted the largest percentage of the incidental catch (46%). No salmonids were caught by hook-and-line in 1996, compared to 5 in 1995.

Report D
Site-Specific Gillnetting for Northern Squawfish Concentrated to
Feed on Hatchery-Released Juvenile Salmonids in the
Lower Columbia River in 1996

1. Small-meshed gill nets were used to catch 6,166 predator-size northern squawfish during March through June 1996. Most of the fish were caught at locations in Bonneville Pool (94%). The mouth of the Klickitat River was the most productive fishing location (3,585 caught). The most productive location outside of Bonneville Pool was at the mouth of the Deschutes River where 232 northern squawfish were caught.
2. The total incidental catch was 7,324 fish, with suckers (*Catostomus spp.*) being the most common (72%) incidentally caught species. Salmonid bycatch (216 adults; 19 juveniles) was minimal despite high concentrations of salmonids in the sampling areas.
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
Development of a Systemwide Predator Control Program:
Indexing and Fisheries Evaluation

1. Objectives were to (1) evaluate northern squawfish exploitation and size composition, and compare catch rate of incidentally-harvested fishes among the three major management fisheries in 1996, (2) estimate reductions in predation on juvenile salmonids since implementation of the fisheries, and (3) evaluate changes from 1990-96 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.

2. Systemwide exploitation of northern squawfish in 1996 was 12.1% for sport-reward, 0.3% for dam-angling, and 0.5% for site-specific gill-net fisheries for a total systemwide exploitation of 12.9%. Total exploitation was lowest in Lower Monumental Reservoir (0.0%) and highest in McNary Reservoir (18.2%). Mean fork length of harvested northern squawfish was 355 mm in the sport-reward, 391 mm in the dam-angling, and 408 mm in the gill-net fisheries. The dam-angling fishery had the lowest percentage (3.6%) of incidental catch relative to the total number of fish caught. Incidental catch was 27.0% in the sport-reward fishery and 54.6% in the gill-net fishery.
3. If exploitation rates remain similar to mean 1991-96 levels, we estimate that potential predation by northern squawfish on juvenile salmonids in 1997 will be approximately 62% of predation levels prior to the implementation of removal fisheries. Further reductions in predation may be small, unless average exploitation in future years is higher than 1994-96 levels.
4. Relative abundance of northern squawfish declined slightly from 1995 in Bonneville Reservoir, Lower Monumental Dam tailrace, and Little Goose Dam tailrace. Mean abundance for 1994-96 was 48-60% of 1990-93 levels among areas sampled at least five years. Indices of consumption were lower than 1995 in all areas except during summer in the tailrace boat-restricted zones of Bonneville and The Dalles dams. Predation indices have declined 69% from pre-1994 levels.
5. Decreases in proportional stock density were greater than could be explained by fluctuations in year-class strength, strongly suggesting that sustained removals may be altering the size structure of predator-sized northern squawfish. We found no evidence that northern squawfish have compensated in growth or fecundity in response to sustained exploitation.

Report A

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

1996 Annual Report

Prepared by:

**Eric C. Winther
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We are particularly thankful to our administrative assistant, Janice Suarez-Pena for her assistance in keeping things running smoothly throughout the year as well as for the many hours she spent assembling this report and reviewing its content.

ABSTRACT

We are reporting on the progress of the Northern Squawfish Sport-Reward Fishery (NSSRF) in the lower Columbia and Snake rivers for April 29 through September 29, 1996. The objectives of this project were to (1) implement a recreational fishery that rewards anglers who harvest northern squawfish (*Ptychocheilus oregonensis*) \geq 11 inches (279 mm) total length, (2) obtain catch data on all fish species caught by fishery participants while targeting northern squawfish, (3) collect length data on the above mentioned species which are returned to registration stations, (4) collect, monitor and report data on angler participation and catch per angler day during the season, and (5) evaluate promotional, fish handling, and cost analysis aspects of the NSSRF.

A total of 157,230 northern squawfish \geq 11 inches were harvested during the 1996 season. A total of 35,485 angler days were spent harvesting these fish. Harvest was slightly above the five-year average of 155,965 while participation was well below the five-year average of 58,853. Catch per angler day for all anglers during the season was 4.43 and exceeded the five-year average of 3.0 northern squawfish per angler day.

Peamouth (*Mylocheilus caurinus*), and smallmouth bass (*Micropterus dolomieu*), were other species most often harvested by NSSRF anglers targeting northern squawfish. Harvest of salmonids (*Onchorhynchus* spp.) by NSSRF anglers targeting northern squawfish remained below limits established by the National Marine Fisheries Service (NMFS).

INTRODUCTION

Northern squawfish (*Ptychocheilus oregonensis*) are the primary predator of juvenile salmonids in the Lower Columbia and Snake River systems (Rieman et al. 1988). Rieman and Beamesderfer (1990) predicted that predation on juvenile salmonids could be reduced by up to 50% with a sustained exploitation rate of 10-20% on northern squawfish >275 mm fork length. The Northern Squawfish Management Program (NSMP) was created in 1990 with the goal of implementing the recommended 10-20% annual exploitation rate on northern squawfish within the program area. One component of the NSMP is the Northern Squawfish Sport-Reward Fishery (NSSRF) which has consistently achieved the highest rate of exploitation within the NSMP during the previous five years (Zimmerman et al. 1995).

The NSSRF encourages recreational anglers to harvest northern squawfish \geq 11 inches (279 mm) total length from within program boundaries on the Columbia and Snake rivers by offering cash rewards. The 1996 NSSRF provided a tiered reward system that paid recreational anglers \$3 each for the first 100 northern squawfish turned in, \$4 each for 101-400, and \$5 each for northern squawfish above 400. Anglers participated in the program by registering at one of 24 registration points (stations + satellites) located throughout the program area and exchanging eligible northern squawfish for a payment voucher at the end of their angling day. The NSSRF provided special promotional and incentive activities to anglers in order to encourage additional angler participation, and surveyed participants in order to collect catch data needed to monitor the effect of the program on other fish species.

With the 1996 season, the annual report for the NSSRF has evolved to a standardized format where we review the major results of the fishery as they relate to our objectives. Our objectives were to (1) implement a recreational fishery that rewards anglers who harvest northern squawfish \geq 11 inches total length, (2) obtain catch data on all fish species caught by fishery participants targeting northern squawfish, (3) collect length data on the above mentioned fish species which were returned to registration stations, (4) collect, evaluate and report data on angler participation and catch per angler day during the season, (5) monitor and evaluate the effectiveness of promotional, fish handling, and efficiency aspects of the NSSRF. Specific findings on objective five are reported in Appendices A-C.

METHODS OF OPERATION

Fishery Operation

Boundaries and Season

The NSSRF was conducted on the Columbia River from the mouth to the boat restricted zone below Priest Rapids Dam, and on the Snake River from the mouth to the boat restricted zone below Hells Canyon Dam (Figure 1). In addition, northern squawfish harvested from backwaters, sloughs, and up to 400 feet inside the mouths of tributaries within this area were also eligible for reward payment. Angler rules for participation remained unchanged from 1995 (Hisata et al. 1995). The 1996 NSSRF was fully implemented from April 29 (week 18) through September 15 (week 37), and was extended at limited stations through September 29 (week 39).

Registration Stations and Satellites

Twelve registration stations (Figure 1) were located on the Columbia and Snake rivers to provide anglers with access to the NSSRF. Washington Department of Fish and Wildlife (WDFW) technicians set up registration stations from 1 p.m. to 9 p.m. daily, where they completed a registration form for each angler which identified the angler and recorded information pertinent to the angler's fishing day. Outside these hours of operation, anglers could self-register using registration boxes located at each station. When registered anglers returned to registration stations, technicians conducted an exit interview and issued pay vouchers for eligible northern squawfish.

In addition to the 12 full-time registration stations used during the 1996 NSSRF, there were also 12 part-time satellites used (Figure 2), which performed the same functions as full-time stations. Satellites operated 1-2 hours per day (using NSSRF vans during off-hours) and were affiliated with a parent registration station as a way to increase their efficiency. Satellites were monitored during the season and those that did not generate sufficient harvest modified their operating schedules or were discontinued in order to keep operating costs in check.

During the two week extension this past season, the NSSRF tried a new concept for operating a type of hybrid registration/satellite station. Two or more stations were combined to form a route that was staffed by a single technician during the NSSRF's standard 1-9 p.m. hours of operation. The technician traveled from the field office to station "A" for a designated time period, then to station "B", and so on. During the extension, the use of these hybrid satellites allowed for better geographic distribution of stations and convenience for anglers while not incurring the costs associated with full time stations.

The codes used by the NSSRF to indicate locations fished by anglers were simplified to reflect reservoir boundaries within the program area (Figure 3) with two exceptions; the area between Bonneville Dam and the mouth (fishing location 1) was referred to as Below Bonneville Dam. The area between McNary Dam and Priest Rapids Dam was divided into three fishing location codes in order to allow accurate reporting of incidentally caught salmonids by anglers targeting northern squawfish. This was necessary for calculating the NSSRF's impact on Snake River salmonid populations.

Returning-Angler Sampling

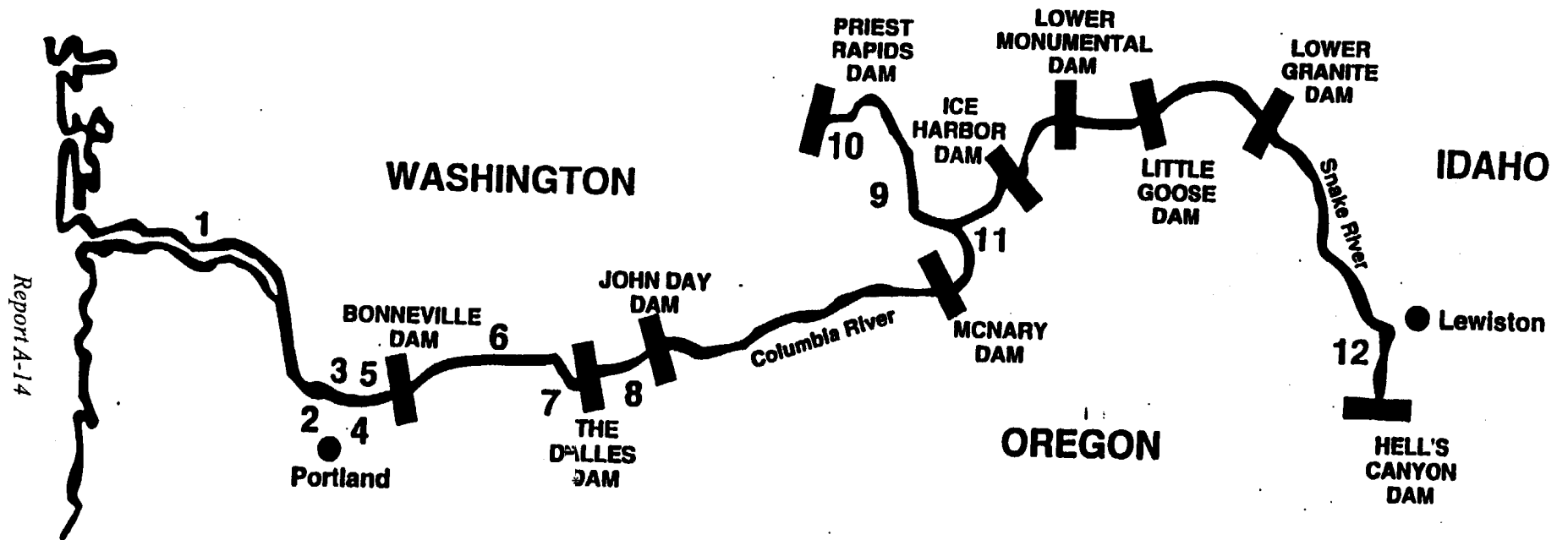
Technicians conducted exit interviews with all returning anglers at each registration station. Anglers were asked if they specifically fished for northern squawfish at any time during their fishing trip. A "no" response ended the exit interview, and with a "yes" response, anglers were asked how many of each type of fish were caught and released while they specifically targeted northern squawfish. A fish was considered "caught" when the angler touched, released or landed the fish, "released" was defined as those fish returned to the water alive.

Non-Returning-Angler Sampling

Technicians surveyed five percent of each week's non-returning anglers by telephone. To attain our 5% goal, a 50% systematic random sample (one in two) of non-returning angler registration forms was taken from all registration stations each week. Each sample was shuffled to randomize registration dates and times. Technicians called anglers from each random sample until they attained the 5% goal (if the 5% goal was not reached during the first pass through the registration forms, technicians continued to re-call anglers that weren't reached during the first attempt until the goal was met). Anglers were asked: "Did you specifically fish for northern squawfish at any time during your fishing trip?" With a "Yes" response, anglers were asked how many of each type of fish were caught and released while they specifically targeted northern squawfish (angler catch and harvest data were not collected from anglers who did not target northern squawfish on their fishing trip). Additionally, anglers were asked: 1) Are you satisfied with the NSSRF?, and 2) How would you rate your interaction with the technician at the registration station? Anglers who registered at a satellite were also asked: "Would you have registered with the NSSRF today if this satellite did not exist?" . .

Non-Returning-Angler Catch and Harvest Estimates

Catch, harvest and effort by river estimates for non-returning anglers targeting northern squawfish were calculated using a simple estimator (20). Salmonid catch and harvest estimates were reported by river. We reported Columbia River salmonid catch from the mouth to the confluence of the Snake and Columbia rivers to emphasize areas where the NSSRF may affect Snake River ESA listed stocks. Fishing location six, (from mouth of Snake River to Priest Rapids Dam) was excluded from our Columbia River salmonid estimate per agreement with NMFS.

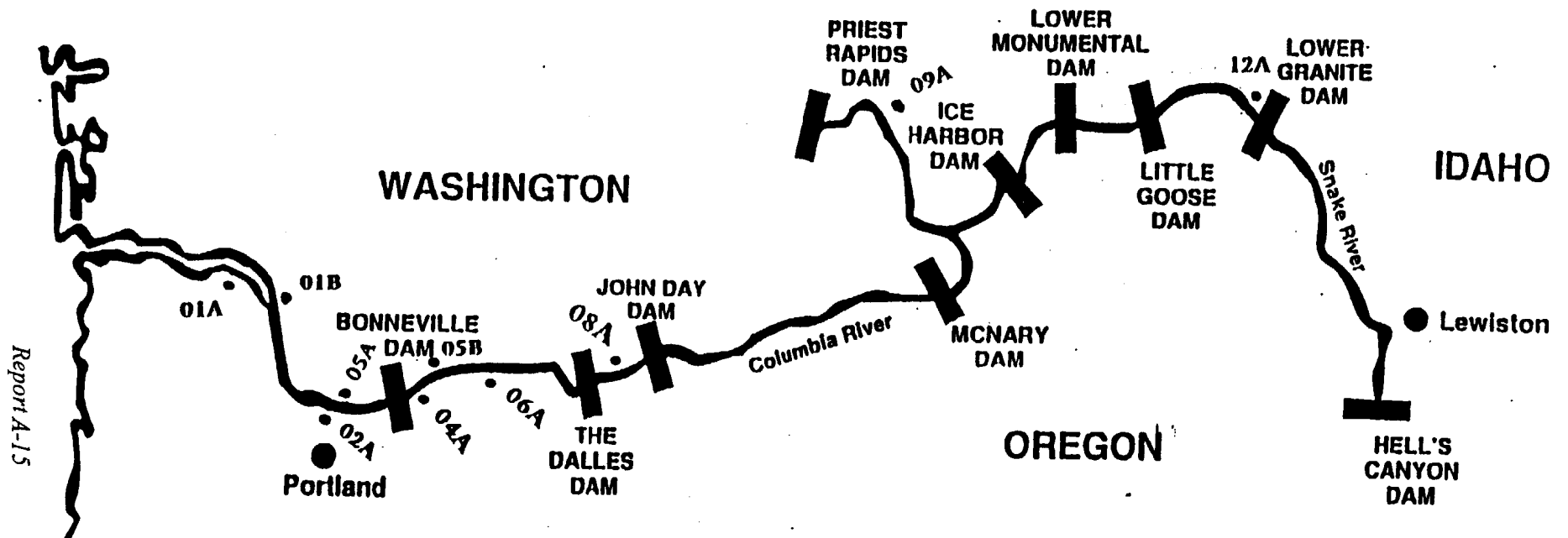


Report A-14

Access Sites:

- | | | |
|--------------------------------------|---------------------------|------------------------------|
| 1. Cathlamet Marina | 5. Hamilton Island | 9. Columbia Point Park |
| 2. M. James Gleason Boat Ramp | 6. Bingen Marina | 10. Vernita Bridge Rest Area |
| 3. Washougal Boat Ramp/Port of Camas | 7. The Dalles Boat Ramp | 11. Hood Park |
| 4. The Fishery at Covert's Landing | 8. Giles French Boat Ramp | 12. Greenbelt Boat Ramp |

Figure 1. 1996 Northern Squawfish Sport-Reward Fishery Registration Stations



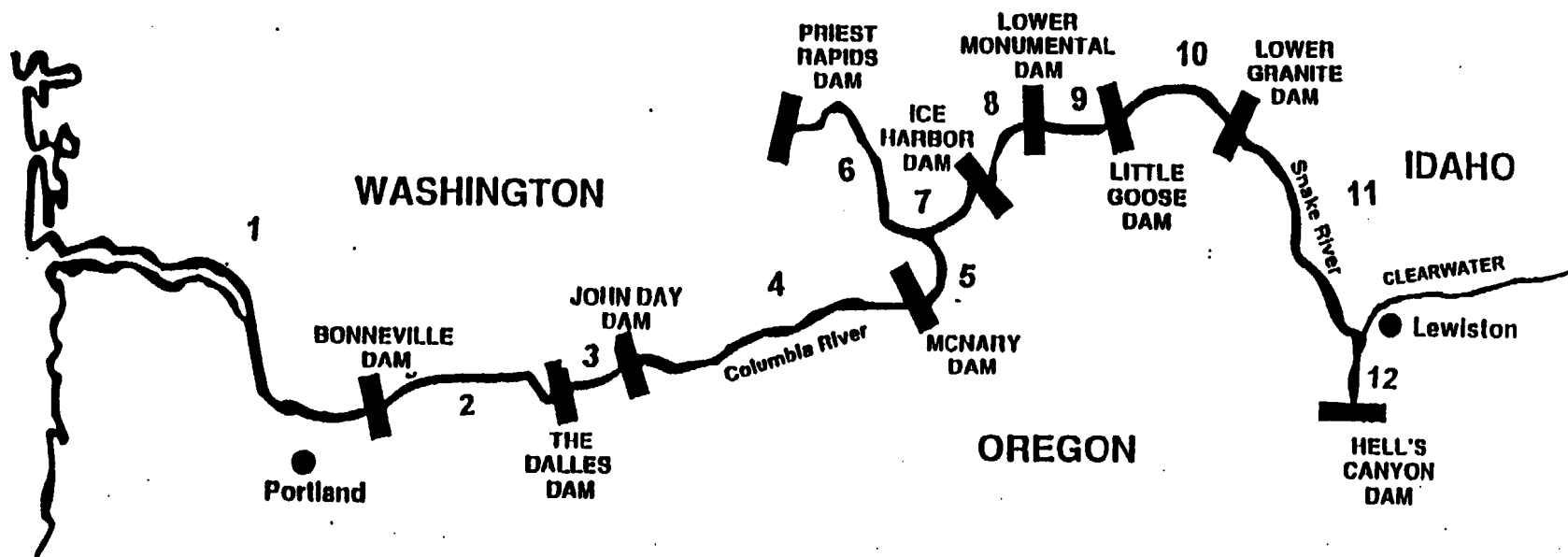
Satellite Sites:

- 01A. Rainier Marina**
- 01B. Kalama Marina**
- 02A. Chinook Landing**

- 04A. Cascade Locks**
- 05A. Beacon Rock**
- 05B. Home Valley**

- 06A. Hood River**
- 08A. Maryhill State Park**
- 09A. Ringold**
- 12A. Boyer Park**

Figure 2. 1996 Northern Squawfish Sport-Reward Fishery Satellites



FISHING LOCATIONS:

- | | |
|---|---|
| 1. Below Bonneville Dam | 7. From Mouth of Snake River to Ice Harbor Dam |
| 2. Between Bonn. Dam & The Dalles Dam | 8. Between Ice Harbor Dam & Lower Monumental Dam |
| 3. Between The Dalles Dam & John Day Dam | 9. Between Lower Monumental Dam & Little Goose Dam |
| 4. Between John Day Dam & McNary Dam | 10. Between Little Goose Dam & Lower Granite Dam |
| 5. Between McNary Dam & Mouth of the Snake River | 11. Between Lower Granite Dam & Mouth of Clearwater |
| 6. From Mouth of Snake River to Priest Rapids Dam | 12. From Mouth of Clearwater to Hells Canyon Dam |

Figure 3. Fishing Locations for 1996.

Northern Squawfish Processing

All reward-size northern squawfish were caudal-clipped (or eviscerated to determine sex) to indicate processing by WDFW technicians. All northern squawfish were placed in insulated coolers and delivered to designated storage facilities at the end of each shift to ultimately be delivered to rendering facilities.

RESULTS AND DISCUSSION

Harvest

The 1996 NSSRF harvested 157,230 northern squawfish \geq 11 inches total length. An additional 22,919 northern squawfish $<$ 11 inches total length were turned in at registration stations. Harvest in 1996 was 21.3% lower than 1995 (Hisata et al. 1995), although slightly above the 5 year average of 155,965. Figure 4 shows the weekly harvest for 1996 compared to the means for each week from the 1991-95 seasons. Mean harvest was 7,147 and peak harvest occurred during week 27 (July 1 through July 7) in 1996. Peak harvest was one week later than in 1995, and higher and slightly later than peak harvest for 1991-95. The lowest weekly harvest was during the first week of the fishery (week 18).

Harvest by registration station ranged from 26,639 at Giles French to 1,953 at Hood Park (Figure 5). This was the second consecutive year that Giles French was the NSSRF's top registration station. Harvest by fishing location for 1996 ranged from 60,454 below Bonneville Dam (fishing location 1) to only 100 northern squawfish for fishing location 5 (Figure 6). The greatest change in harvest between 1995 and 1996 was in The Dalles reservoir (fishing location 3) where harvest for 1996 was 46% less than 1995. Fishing locations 2, 3, 6, and 12 each also showed harvests over 10,000 northern squawfish and their total, combined with that from fishing location 1 comprised 96% of the harvest for all fishing locations. This level of harvest translated to estimated system-wide exploitation of 12.1% (Friesen et al. 1996).

Returning-Angler Data

Northern squawfish \geq 11 inches (153,263) were the most frequently caught species by returning anglers targeting northern squawfish, followed by northern squawfish $<$ 11 inches and peamouth (Table 1). This total is different from the overall total harvest of 157,230 because only fish caught while targeting northern squawfish were included. Thirty-two adult chinook salmon (*Onchorhynchus tshawytscha*), including 15 jacks, and 30 adult steelhead (*Onchorhynchus mykiss*) were caught incidentally from the Columbia River by anglers targeting northern squawfish (Table 2). Additionally, two adult chinook salmon and seven adult steelhead were caught in the Snake River by anglers targeting northern squawfish. The majority of salmonids caught (87%) by anglers targeting northern squawfish were caught below John Day Dam. Incidental salmonid catches by anglers targeting northern squawfish

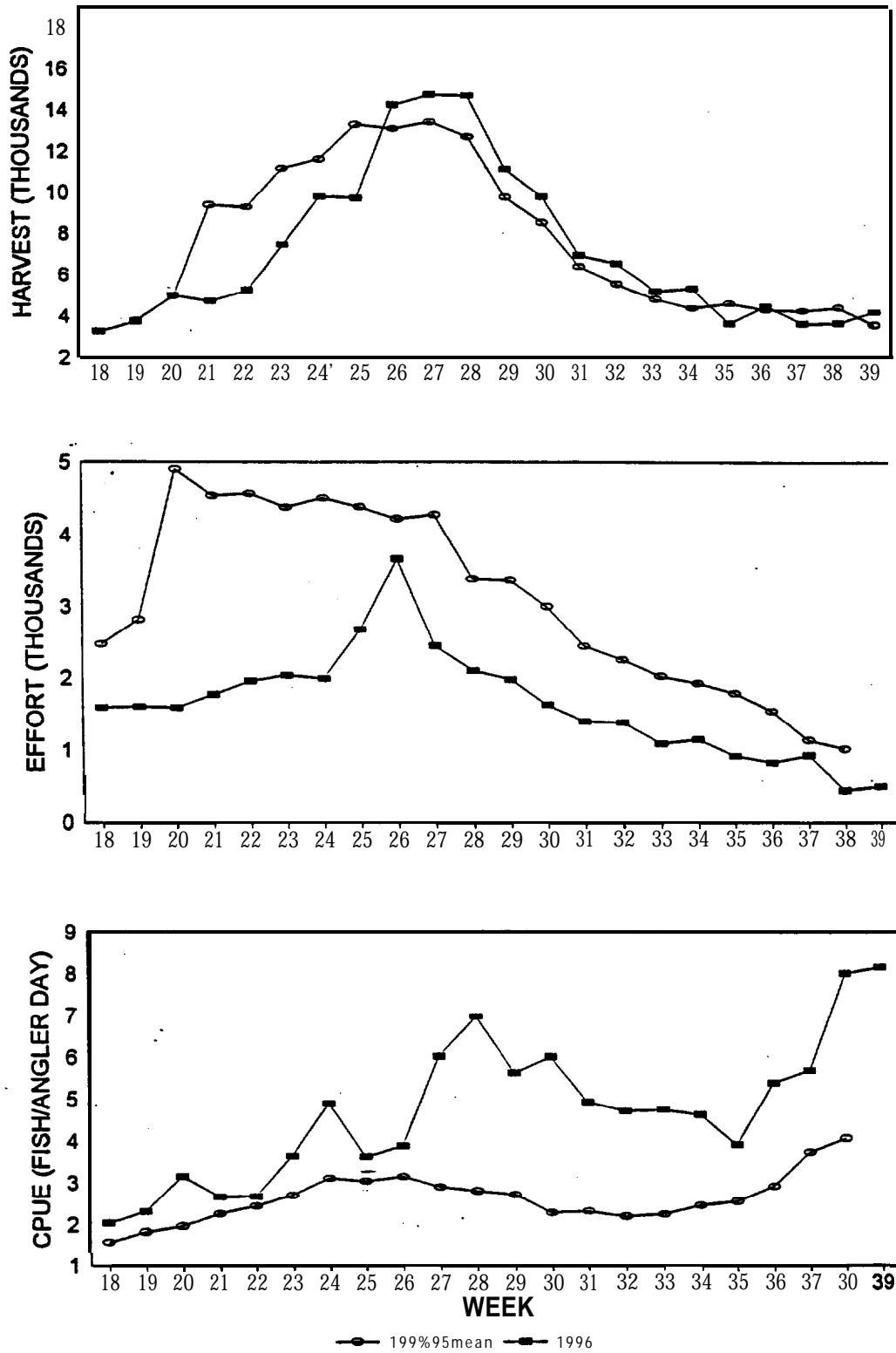


Figure 4. Comparison of northern squawfish harvest, effort (angler day), and CPUE (fish/angler day) by week for 1991-95 means to 1996.

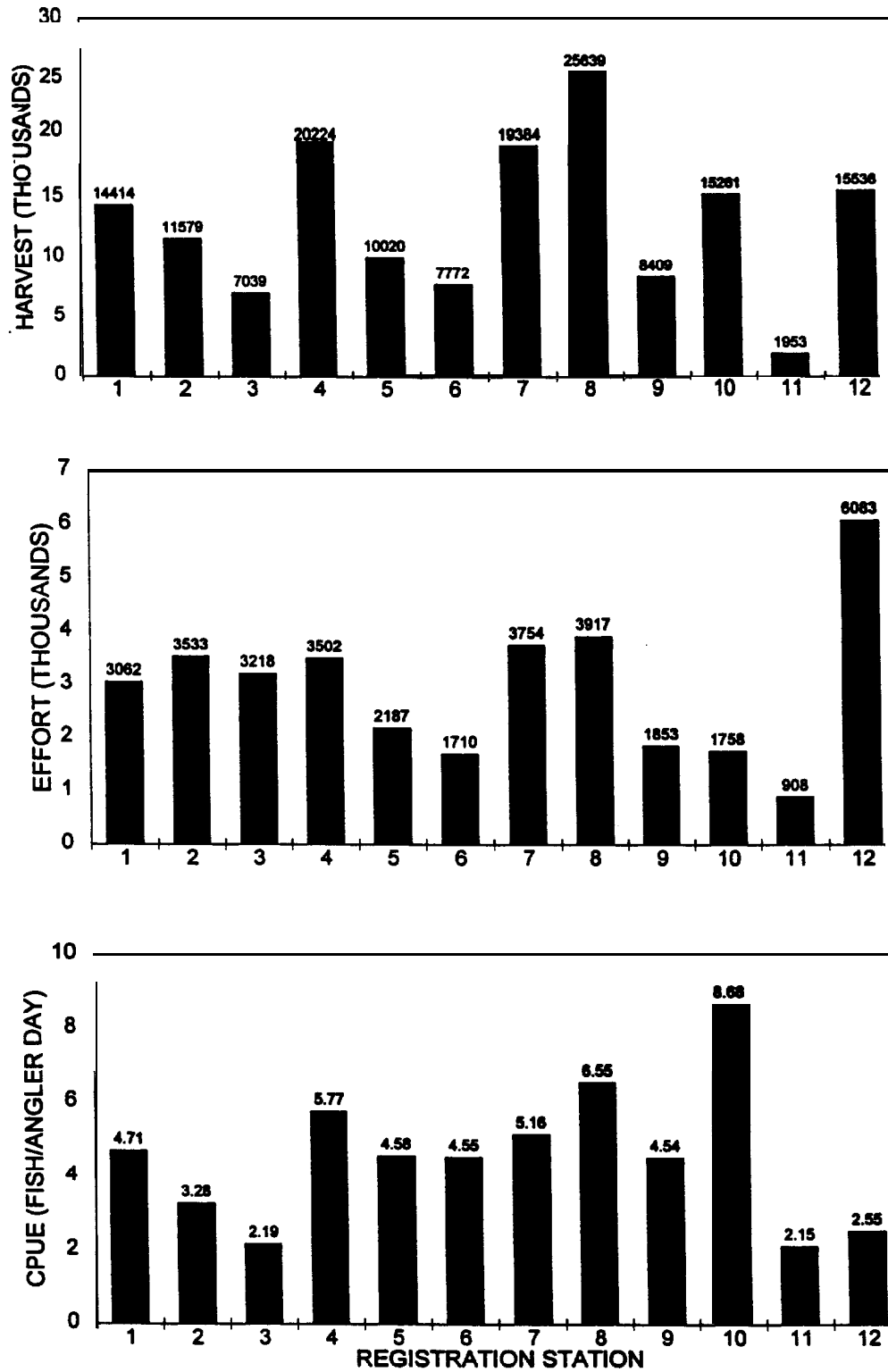


Figure 5.1996 Northern squawfish harvest, effort and CPUE (fish/angler day) by registration station. 1 - Cathlamet, 2 - Gleason, 3 - Washougal 4 - The Fishery, 5 - Hamilton Island, 6 - Bingen, 7 - The Dalles, 8 - Giles French, 9 - Columbia Point, 10 - Vemita, 11 - Hood Park 12 - Greenbelt.

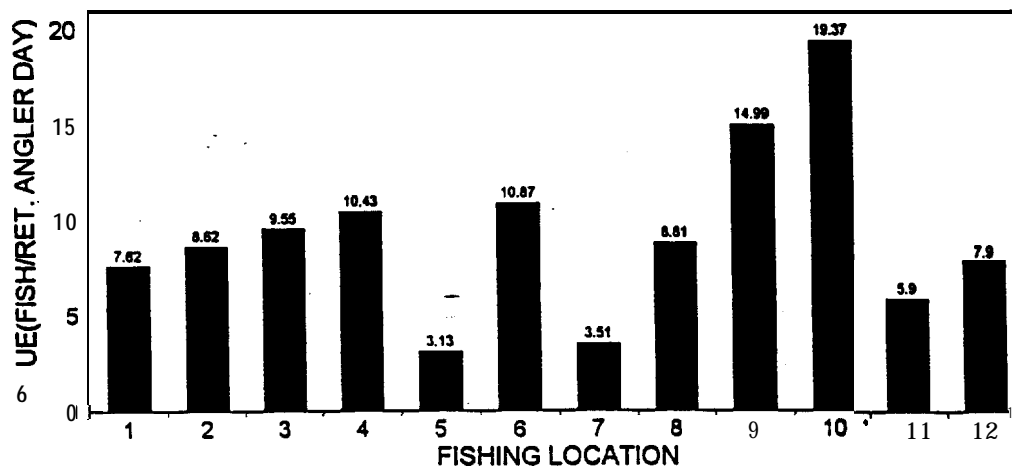
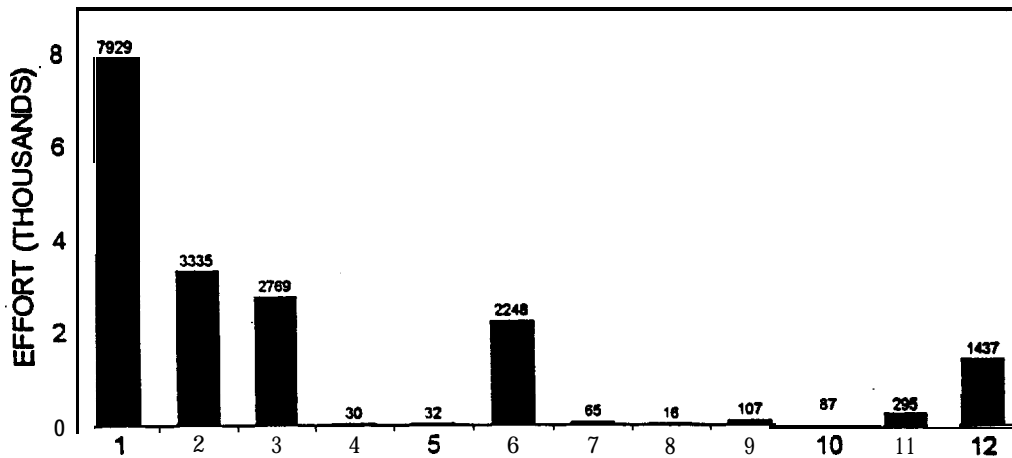
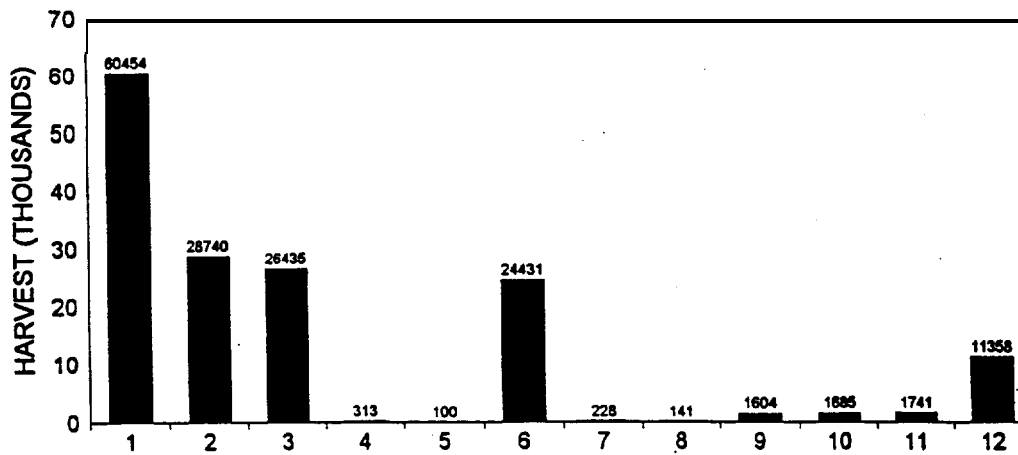


Figure 6. 1996 Northern squawfish harvest, effort (returning angler day) and CPUE (fish/returning angler day) by fishing location in 1996. 1 - Below Bonneville Dam, 2 - Bonneville Reservoir, 3 - The Dalles Reservoir, 4 - John Day Reservoir, 5 - McNary Dam to Mouth of Snake, 6 - Mouth of Snake to Priest Rapids Dam, 7 - Mouth of Snake to Ice Harbor Dam, 8 - Ice Harbor Reservoir, 9 - Lower Monumental Reservoir, 10 - Little Goose Reservoir, 11 - Lower Granite Dam to Clarkston, 12 - Clarkston to Hells Canyon Dam.

Table 1. Catch and harvest of selected species by returning anglers targeting NS and estimated catch and harvest of selected species by non-returning anglers targeting NS.

Returning Anglers

Species	Sample Catch (100%)	Harvest	Percent Harvested
Northern Squawfish > 11"	153,263	153,007	99.83%
Northern Squawfish < 11"	22,919	9,172	40.02%
Peamouth	14,941	3,847	25.75%
Smallmouth Bass	4,639	939	20.24%
White Sturgeon <i>Acipenser transmontanus</i>	3,877	34	0.88%
Walleye <i>Stizostedion vitreum</i>	1,719	750	43.63%
Channel Catfish <i>Ictalurus punctatus</i>	1,566	581	37.10%

N=17,350

Non-Returning Anglers

Species	Sample Catch (5%)	Estimated Catch	Confidence Interval (95%)	Estimated Harvest	Percent Harvested
Northern Squawfish >11"	52	1040	638	920	88.46%
Northern Squawfish <11"	284	5680	1877	400	7.04%
Peamouth	317	6340	1914	700	11.04%
Smallmouth Bass	248	4960	1593	200	4.03%
White Sturgeon	192	3840	1902	20	47.73%
Walleye	44	880	717	420	47.73%
Channel Catfish	52	1040	496	400	38.46%

N=14,095

n=705

were low when compared to the total number of northern squawfish ≥ 11 inches caught in the NSSRF, thus impact on salmonids appears to be minimal.

Non-Returning-Angler Data

Peamouth were estimated to be the most frequently caught species by non-returning anglers targeting northern squawfish, followed by northern squawfish < 11 inches and smallmouth bass (Table 1). An estimated 80 adult chinook salmon (40 jacks) were caught in the Columbia River and 40 juvenile chinook salmon were caught in the Snake River by anglers targeting northern squawfish (Table 2). One hundred percent of the chinook salmon jacks caught in the Columbia River were harvested. All other salmonids caught on the Columbia or Snake rivers by anglers targeting northern squawfish were released alive. The 5% sample used to estimate non-returning angler salmonid catch in 1996 was too small and resulted in large confidence intervals. Due to a low catch rate of salmonids by NSSRF anglers and a small sample size, confidence intervals were nearly twice as large as the estimates (Table 2). We believe a larger, 10-20% sample, will bring our salmonid catch estimates closer to the actual catch and increase the confidence in our estimates.

Non-returning anglers using satellites would not have registered with our program 44% of the time if satellites did not exist, indicating the operation of satellites is very important for increasing effort in the NSSRF. Ninety-eight percent of non-returning anglers reported they were very satisfied with the NSSRF. Non-returning anglers that interacted with the NSSRF technicians in some way reported the interaction was “good” or “very good” 99.7% of the time.

A 1995-1996 incidental species catch comparison (excluding salmonids), of non-returning and returning anglers targeting northern squawfish, shows non-returning anglers caught less fish overall than returning anglers (Hisata et al. 1995) (Table 2). Harvest totals of these same incidentals from 1994 shows a similar pattern but cannot be directly compared to 1995 or 1996 (Smith et al. 1994). Since non-returning anglers catch less of these incidental species, a telephone survey to collect data on these species may not be necessary each year. A periodic sampling of non-returning anglers may be more efficient if we assume non-returning anglers are catching equal or less of these incidental species than returning anglers.

Angler Effort

Total angler effort (total number of registered angler days) for 1996 was 35,485 angler days. This was 27,240 days less than 1995 (Hisata et. al. 1995) and 40% lower than the five year average of 58,852. Returning angler effort totaled 18,350 angler days, 51.7% of total angler days effort. Total number of separate anglers receiving reward payments for 1996 was 2,239 (R. Porter, 1995) compared to 4,249 for 1995. Peak angler effort occurred during week 26 (June 24 to June 30) which was one week later than the peak in 1995 and well below the peak for 1991-95 (Figure 4). Effort by fishing location (returning anglers only) for 1996

ranged from 13,425 below Bonneville Dam to only 23 in the Ice Harbor Pool (Figure 6). Figure 5 shows that the Greenbelt registration station had the highest effort for the 1996 NSSRF and that the next highest station (Giles French) had 64% of the Greenbelt total.

Catch Per Angler Day

Overall CPUE (returning + non-returning anglers) in 1996 was 4.43 Northern squawfish ≥ 11 inches /angler day which exceeded the 1991-95 average of 3.0 northern squawfish/angler day. Overall CPUE was higher each week of the 1996 NSSRF than the mean CPUE for 1991-95 (Figure 4). Catch per unit effort ranged from 19.37 in Little Goose Reservoir (fishing location 10), to 3.13 in fishing location 5 (Figure 6). Anglers utilizing the Vernita Registration Station had the highest CPUE with 8.68 and Hood Park anglers had the lowest with 2.15 (Figure 5).

When we exclude non-returning anglers, CPUE for returning anglers was 8.6 northern squawfish per angler day in 1996, which was up from 6.2 in 1995. The most likely explanation for the higher CPUE in 1996 is that total effort was composed of a higher percentage of anglers at tiers 2 and 3 than in 1995 (as reported in Appendix A). Since tier 1 anglers harvest less northern squawfish per angler than tier 2 and 3 anglers, the overall CPUE shifted upward. Other factors that may have contributed to higher CPUE in 1996 were that anglers spent more hours fishing per day, or that fishing was actually better than in previous years,

SUMMARY

The reduction in harvest from 1995 to 1996 can be mainly attributed to a major drop in participation. The level of participation prior to northern squawfish spawning has always been a very important factor in determining overall NSSRF harvest (Klaybor et al. 1993). Participation during this period of the 1996 NSSRF was well below mean 1991-95 levels, most likely a result of very high spring flows in both the Columbia and Snake rivers which made northern squawfish more difficult to locate. Participation levels throughout the 1996 NSSRF never came close to mean 1991-95 levels. The fact that 1996 harvest remained slightly above the 1991-95 average can be attributed to the NSSRF retaining a cadre of experienced anglers (who catch large numbers of northern squawfish), even though we lost many novice anglers and did not recruit significant numbers of new anglers. If the 1996 NSSRF had maintained a level of effort equal to the 1991-95 average, and if the CPUE remained similar, the NSSRF could have generated its highest harvest to date. Since the majority of lost effort from 1995 to 1996 was from novice anglers (tier 1 anglers), additional measures must be taken to recruit new anglers to the NSSRF in order to generate an increase in effort that could take advantage of the upward trend in CPUE. Past year's experience suggests that the NSMP may best accomplish this through the use of additional advertising and/or by strengthening incentive and promotional activities.

Table 2. Catch and harvest of adult and juvenile salmonids by returning anglers targeting NS and estimated catch and harvest of adult and juvenile salmonids by non-returning anglers targeting NS.

Returning Anglers	Columbia River			Snake River		
	Sample Catch (100%)	Harvest	Percent Harvested	Sample Catch (100%)	Harvest	Percent Harvested
Chinook Salmon (Adult)	17	7	41.18%	2	0	0.00%
Chinook Salmon (Jack)	15	3	20.00%	0	0	0.00%
Chinook Salmon (Juvenile)	5	0	0.00%	0	0	0.00%
Steelhead Adult (Adipose Absent)	18	14	77.78%	6	5	83.33%
Steelhead Adult (Adipose Present)	12	0	0.00%	1	0	0.00%
Steelhead Juvenile(Adipose Absent)	4	0	0.00%	2	0	0.00%
Steelhead Juvenile(Adipose Present)	6	2	33.33%	0	0	0.00%

Columbia River N=1,521
Snake River N=1,785

Non-Returning Anglers	Columbia River					Snake River				
	Sample Catch (5%)	estimate <atch	Confidence Interval (95%)	estimate Harvest	Percent Harvested	Sample Catch (5%)	estimate <atch	Confidence Interval (95%)	estimate Harvest	Percent Harvested
Chinook Salmon (Adult)	2	40	78	0	0.00%	0	0	0	0	0.00%
Chinook Salmon (Jack)	2	40	78	40	100.00%	0	0	0	0	0.00%
Chinook Salmon (Juvenile)	1	20	39	0	0.00%	2	40	82	0	0.00%
Steelhead Adult (Adipose Absent)	0	0	0	0	0.00%	1	20	39	0	0.00%

Columbia River N=9,340 n=46/
Snake River N=3,660 n=183

The trend in weekly CPUE for the 1996 NSSRF, as well as the mean CPUE for 1991-1995 shows an increase in CPUE throughout the season, especially toward the later part of September. Although effort declines considerably by this time, harvest for this late portion of the season generally exceeds the first weeks of the season (weeks 18 & 19). This suggests that extending the season past the end of September may warrant consideration as a way to increase in the total harvest of northern squawfish. Based on these trends, as well as on the likelihood that river conditions will be similar to 1996, we believe that the start of the 1997 season should be delayed until week 21 (May 19). The NSSRF should retain a 22 week season by operating until the end of Week 40 (October 5, 1997) and if harvest justifies it, we should extend the season an additional two weeks into October.

We propose to combine select satellites such as Rainier/Weyerhaeuser, and Hood Park/Ringold/Lyons Ferry (Table 3) in 1997 as a way to increase efficiency, meet the needs of anglers in areas distant from full time stations, and increase harvest of northern squawfish.

Recommendations for the 1997 season are:

1. Increase advertising to recruit additional anglers to the NSSRF.
2. Begin the 1997 NSSRF later than in 1996, from May 19 (week 21), through October 5 (week 40), 1997.
3. Retain the option to extend the NSSRF at selected stations if harvest and CPUE warrant.
4. Improve accuracy of non-returning angler salmonid catch estimates by increasing sample size of telephone survey to 10-20%.
5. Modify non-returning angler survey to exclude incidental species (other than salmonids) and re-sample in 1999 or 2000 to verify that trends have not changed.
6. Implement hybrid satellite sites for Rainier/Weyerhaeuser, and Hood Park/Lyons Ferry.

Table 3. Proposed registration stations, satellite and hybrid satellites for the 1997 NSSRF with the proposed hours of operation for each.

<u>REGISTRATION STATION</u>	<u>SATELLITE SITE</u>	<u>HYBRIDSATELLITE</u>	<u>TIME</u>
1. CATHLAMET		Rainier Marina Weyerhaeuser	12:30-4:30 pm 5:00-8:30 pm
2. GLEASON	Chinook Landing		7:00-9:00 am
3. WASHOUGAL	Marine Park		(***** >
4. THE FISHERY	Cascade Locks		5:30-7:30 pm
5 HAMILTON ISLAND	Home Valley		9:00-10:00 am
6 BINGEN	Hood River		(*****)
7. THE DALLES			
8 GILES FRENCH	Maryhill Park		9:00-11:00 am
9. COLUMBIA POINT		Ringold Lyons Ferry Hood Park	9:00-11:00 am 2:00-5:00 pm 6:00-8:00 pm
10. VERNITA			
11. GREENBELT	Boyer Park		9:00-11:00 am

***** = Open for registration only (northern squawfish are turned in at parent registration station).

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APPENDICES

APPENDIX A
PROMOTIONAL ACTIVITIES
Introduction

The Northern Squawfish Sport-Reward Fishery (NSSRF) 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). Promotional programs and incentives used during the 1996 NSSRF were monitored in order to determine how these activities affected angler effort or the harvest of northern squawfish.

Promotional activities for the 1996 NSSRF retained the primary goal of increasing angler harvest of northern squawfish (Hisata et al. 1995). The objectives under this goal were also similar to those defined in 1995, which were to (1) maintain incentives that encouraged experienced, productive northern squawfish anglers to spend more angler days and/or longer angler days harvesting northern squawfish, (2) continue to recruit new anglers to the NSSRF, (3) continue to provide anglers with information and instruction on catching northern squawfish in order to increase angler efficiency.

Harvest and effort totals for time periods associated with the BPA radio tournaments were monitored during the season using data collected from angler registration forms, exit interviews and the telephone survey. These data were evaluated to determine whether these activities produced positive contributions to the 1996 NSSRF in the form of increased effort or harvest. The 1996 telephone survey was also used to monitor angler satisfaction with the NSSRF and with technicians employed by the NSSRF.

Promotional and Incentive Program Evaluation

Tiered Reward

The 1996 Northern Squawfish Management Program (NSMP) continued to offer the tiered reward system used in 1995 which paid recreational anglers \$3 each for the first 100 northern squawfish ≥ 11 " turned in, then \$4 each for 101-400, and \$5 each for northern squawfish above 400 (Hisata et al. 1995). The tiered reward system was used to encourage the NSSRF's most proficient anglers to expend more effort during the early part of the season as they attempted to reach the higher pay levels. This system was also used to encourage anglers to continue to participate throughout the entire season rather than stopping during the post-spawn period when catch rates traditionally decline.

There were 2,239 different successful anglers (anglers who turned in at least one northern squawfish that was ≥ 11 " total length) during the 1996 NSSRF. These anglers were divided into 1,958 at tier one, 178 at tier two, and 103 at tier three. These numbers represent 87%, 8 % and 5 % of the total respectively. In 1995, out of 4,249 different successful anglers, there were 3,891 (92%) who turned in less than 10 northern squawfish, 234 (5%) who qualified for tier two and 124 (3%) who qualified for tier three. The top angler for the 1996

season turned in 3,089 northern squawfish compared to 1995 when the top angler turned in 3,878 northern squawfish.

Tier 1 anglers harvested 17% (26,280 northern squawfish) of the total in 1996 compared to 20% (39,470 northern squawfish) in 1995. Tier 2 anglers harvested 22% of the total in 1996 (34,443 northern squawfish) and 23% of the total (46,569 northern squawfish) in 1995. Tier 3 anglers harvested 61% (95,077 northern squawfish) of the total in 1996 compared to 57% (113,749 northern squawfish) of the total in 1995. Anglers from the top two tiers accounted for 83% of the total catch in 1996 (129,513 northern squawfish) compared to 80% in 1995 (160,318 northern squawfish).

In 1996, tier 1 anglers harvested an average of three more northern squawfish per season than tier 1 anglers did in 1995. Tier two anglers harvested an average of five less in 1996. Tier three anglers harvested an average of six more in 1996 than in 1995.

The 1996 NSSRF recorded decreases in the total number of angler days spent (35,540 versus 62,725) and in the number of different anglers who participated (2,239 versus 4,249) from 1995. There were decreases in the number of successful anglers at all three tier levels although the percentage of anglers in the top two tier levels shifted slightly upward. Since overall CPUE increased from 3.19 in 1995 to 4.43 in 1996 and the average number of northern squawfish harvested per season by anglers at each tier level increased, it is apparent that the reason the NSSRF harvested less northern squawfish than in 1995 was primarily due to a lack of angler participation.

Bi-Weekly Tournaments

The weekly tournaments used in 1995 were converted to bi-weekly tournaments during the 1996 season as a cost saving measure. The structure of the bi-weekly tournaments remained the same as the weekly tournaments used in 1995 (Hisata et al. 1995) with cash prizes for the longest three northern squawfish turned in per site for each two week period from April 29 through September 29 (excluding the time periods when BPA radio tournaments were held).

There were 263 different anglers who won the 435 prizes available in the bi-weekly tournaments. Of these anglers, 75 anglers won multiple prizes during the course of the season. The most weekly prizes won by a single angler was eight.

Since the bi-weekly tournaments were in effect during virtually the entire season, we were unable to attribute any specific increases in effort to this incentive although anecdotal information from technicians and the results of angler surveys from 1995 indicated that this type of incentive increased participation (Hisata et al. 1995). The change from weekly tournaments in 1995 to bi-weekly tournaments in 1996 did not result in any discernable loss of effort for the NSSRF.

BPA Radio Tournaments

BPA sponsored four large radio tournaments during the 1996 season which followed the pattern set in Clarkston during the 1995 season (Hisata et al. 1995). These tournaments offered daily prizes for the longest northern squawfish turned in for each day of the tournament which were provided by local retail sponsors, and cash grand prizes (\$500 for 1st, \$250 for 2nd, and \$100 for 3rd) which were provided from NSMP reward funds. An additional cash or merchandise prize (provided by the radio station or other daily sponsors) for catching specially tagged northern squawfish was also available. Insurance policies were purchased by the sponsors which would cover the costs of these prizes in case the tagged northern squawfish were caught. Cash grand prizes and special prizes were restricted to one prize per angler. Additional advertising (newspaper advertisements and radio spots) was purchased by BPA to promote the tournament as part of the agreement with the radio stations.

The Clarkston Tournament was co-sponsored by radio station KATW and included the Greenbelt station during the period from June 22-30. In addition to the cash grand prizes, daily sponsors awarded prizes (\$100, \$50, \$25) to anglers turning in the largest three northern squawfish for each day of the tournament. A boat, motor and trailer (valued at \$8,400) was available as a prize to the angler who caught and turned in a specially tagged northern squawfish on June 29 (tagged fish was not caught). During this tournament, there were 1,514 angler days spent and 1,651 northern squawfish harvested. Advertising costs associated with the tournament were \$2,000 for radio and \$2,000 for newspaper.

The Tri-Cities Tournament was co-sponsored by radio station KORD and included the Hood Park, Vernita and Columbia Point stations during the period June 22-30. Daily prize amounts were \$100 for 1st, \$75 for 2nd and \$50 for 3rd places. A 15' travel trailer (valued at \$10,900) was offered to the angler catching and turning in the specially tagged northern squawfish on June 29 (tagged fish was not caught). During this tournament there were 636 angler days spent and 2,625 northern squawfish harvested. Advertising costs associated with this tournament were \$3,000 for radio and \$5,000 for newspaper.

The tournament at The Dalles was co-sponsored by radio station KMCQ and included The Dalles, Giles, and Bingen stations during the period June 22-30. Daily prize amounts were \$75 for 1st, \$25 for 2nd, and \$10 for 3rd places. A boat, motor and trailer (valued at \$8,300) was offered to the angler catching and turning in the specially tagged northern squawfish on June 29 (tagged fish was not caught). Tournament participants spent 1,167 angler days and harvested 6,584 northern squawfish. Advertising costs associated with this tournament were \$1,000 for radio and \$2,000 for newspaper.

The Longview Tournament was co-sponsored by radio station KBAM and included the Cathlamet Registration Station during the period from June 22-30. Daily prize amounts were \$100 for 1st, \$75 for 2nd, and \$50 for 3rd places. If an angler caught the specially tagged

northern squawfish, they would win \$7,500 in cash (tagged fish was not caught). There were 247 angler days spent and 865 northern squawfish harvested. Advertising costs associated with this tournament were \$1,000 for radio and \$1,000 for newspaper.

The NSSRF was unable to secure a radio co-sponsor for the Portland area due to time constraints. Instead a "Grand Bi-Weekly Tournament" was implemented during the period from June 24 through July 7. This tournament included the Gleason, Washougal, The Fishery, and Hamilton Island stations in a modified bi-weekly tournament format. Anglers received the usual \$125, \$75, and \$50 for turning in the longest three northern squawfish during the period at each site. In addition, the overall longest three northern squawfish from the four sites combined received \$500 for 1st, \$250 for 2nd, and \$100 for third from BPA. Results showed 1,204 angler days spent and 5,819 northern squawfish harvested.

Although the tournament period coincided with the NSSRF's peak effort totals and near peak harvest totals (Appendix Figure 1), it must be noted that these tournaments were scheduled to occur near the usual peak of the season and that some increase in effort and harvest levels could be expected at this time of year regardless of whether these BPA tournaments were held. As an additional means of determining the benefit of these tournaments to the NSMP, the number of new anglers recruited to the NSSRF during the tournaments was also monitored. Since the NSSRF inevitably loses some anglers each season to attrition, recruiting new anglers to the NSSRF is important in order to maintain a level of participation that will achieve desired exploitation rates. Overall, there were 1,277 new anglers recruited to the NSSRF during the BPA radio tournaments. These new anglers comprised from 45% (The Dalles tournament) to 66% (the Clarkston tournament) of total anglers participating in the five BPA radio tournaments. In addition, from 15% (Clarkston) to 27% (Longview) of these new anglers continued to participate in the NSSRF after the tournaments were over.

Tagged Northern Squawfish

The tagged northern squawfish promotion which offered \$50 for Oregon Department of Fish and Wildlife (ODFW) tagged northern squawfish was continued during the 1996 season (Smith et al. 1994). Tags continued to be submitted to ODFW for verification using a "Tag Voucher" and verified vouchers were forwarded to Pacific States Marine Fisheries Commission (PSMFC) for payment. A small number of radio tags used by ODFW for radio tracking northern squawfish were also included in this incentive during 1996 (Friesen et al. 1996).

There were 240 tagged northern squawfish which qualified for the \$50 reward that were turned in by 168 different anglers in 1996. This included seven radio tags. The area below Bonneville Dam had the most tags turned in (130) and the area between Ice Harbor Dam and the mouth of the Snake River had the least (1). The Cathlamet station had the most tags turned in (44), while Hood Park had the least (4). The highest number of eligible tags turned in by one angler was 12.

The \$50 tag incentive continues to be a valuable tool for encouraging NSSRF anglers to fish within program boundaries since northern squawfish with eligible tags are primarily found within this area.

Independent Tournaments

There were five independent tournaments which harvested northern squawfish during the 1996 season. Independent tournaments are characterized as being non-NSSRF sponsored events that are planned; organized, and promoted entirely by the sponsoring organization. WDFW provides guidance and temporary (1-2 day) satellite registration stations at the tournament location in order to facilitate collection of northern squawfish, verification of sizes, and issuance of vouchers. These tournaments are encouraged by WDFW since they provide sponsoring groups with a means for redeeming northern squawfish for a fund raising activity and these tournaments increase awareness in the NSSRF at little or no additional cost to the NSMP. The first three tournaments are annual events that have taken place for the last two or three years and their format has remained the same as in 1995 (Hisata et al. 1995).

The Wahkiakum Conservation District (WCD) held its Fourth Annual Squawfish Tournament from June 1 through July 31 at the Cathlamet Registration Station and affiliated satellites. The WCD tournament organizers indicated that they had fewer participants than in 1995 (11 versus 18). They did not keep harvest totals but estimated that their participants harvested approximately 600 northern squawfish ≥ 11 inches during the nine weeks of the tournament.

The Lower Columbia Walleye Club (LCWC) held their "Squawfish Round-UP" in conjunction with its fourth annual Walleye Jamboree on June 29 & 30. There were 60 LCWC tournament participants in 1996 who harvested 39 northern squawfish. This was down from 80 participants and 43 northern squawfish in 1995.

The Big Eddy Marina held a one day northern squawfish tournament on August 24 as a social type activity for houseboat tenants of the marina. This tournament attracted 40 anglers who harvested 18 northern squawfish ≥ 11 inches during the one day of the tournament.

The Kenton Action Plan held a northern squawfish tournament on June 22 and 23 as a fund raiser and community development event. The tournament attracted 30 participants, although there were only two northern squawfish turned in.

The Oregon Bass and Panfishing club held a one-day northern squawfish tournament as a fund raiser on August 24. The event attracted eight anglers who harvested eight northern squawfish ≥ 11 inches.

Each of these independent tournaments produced relatively small results (when compared to BPA sponsored tournaments), however the amount of effort and expense expended by NSSRF staff to get these results was minimal. These tournaments provide an inexpensive option for generating public interest in the NSSRF, contributing additional effort and harvest, and supplying the NSSRF with positive public relations.

Phone survey responses indicated that ninety-eight percent of non-returning anglers

were very satisfied with the NSSRF. The survey also indicated that 99.7% of the non-returning anglers who interacted with NSSRF technicians in some way reported the interaction was “good” or “very good”.

SUMMARY

The objectives for the NSSRF’s 1996 promotional and incentive program were to maintain incentives so that experienced, productive northern squawfish anglers would spend more effort harvesting northern squawfish and to recruit and develop additional productive anglers for the NSSRF by providing them with information and/or instructions for effectively catching northern squawfish.

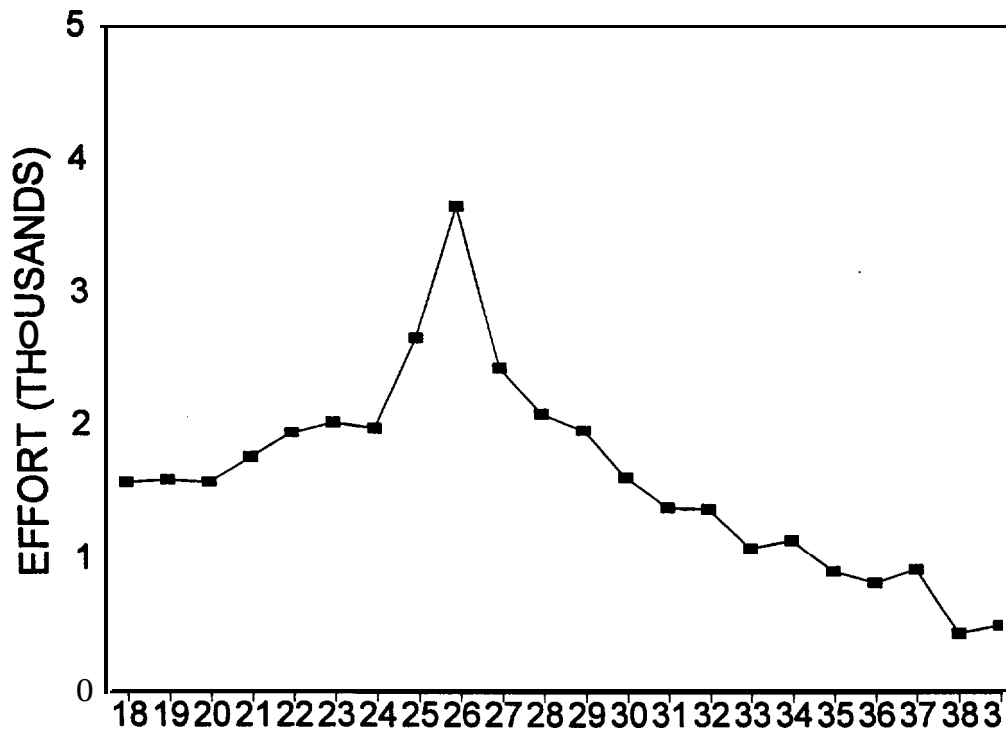
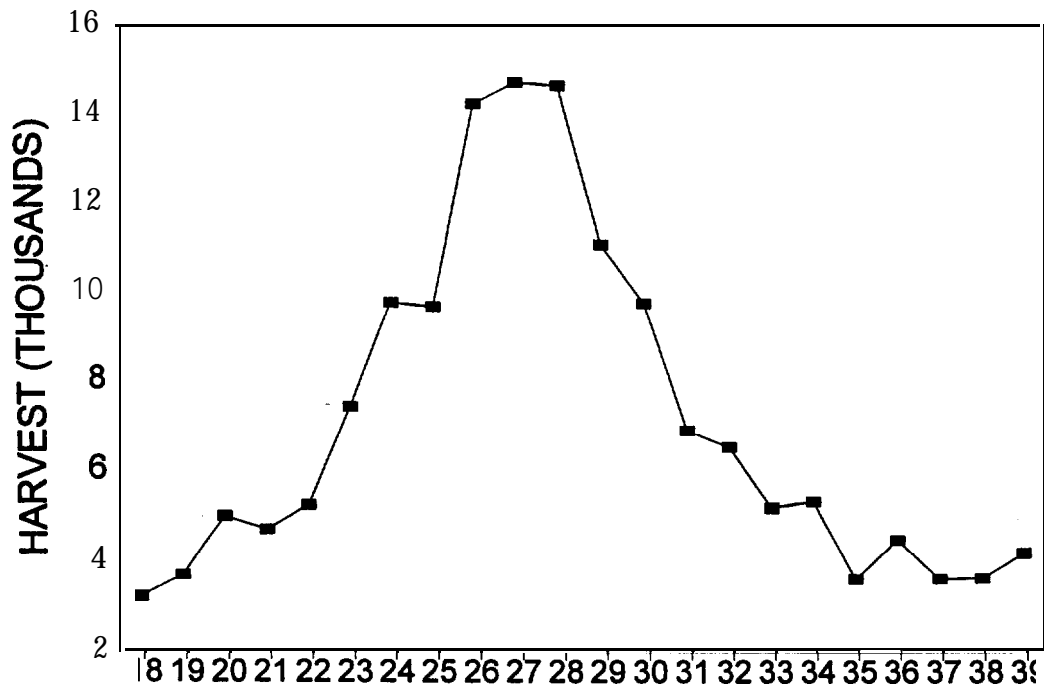
The 1996 NSSRF did achieve a total harvest that was slightly higher than the average from the first five years, the effort total was substantially lower than the 58,853 average, and the CPUE was the highest to date. The tiered reward system continued to encourage anglers to participate for the entire season, although the overall number of participants was down. The BPA radio tournaments continued serve as a means for spurring participation and for recruiting new anglers to the NSSRF. Since overall CPUE remained high, the NSSRF needs to identify additional ways to increase veteran angler participation in 1997, possibly through an increase in advertising

Due to the continued success of incentives used in 1996, the promotional activities planned for the 1997 NSSRF should remain similar. The main components of the 1997 promotional program should continue to be the tiered reward system, the \$50 tag incentive, the bi-weekly tournaments, and improved/expanded BPA radio tournaments. Additional effort should be made to attract new anglers to the NSSRF and to strengthen the NSSRF’s ability to inform and instruct these anglers and the general public about how and where to catch northern squawfish.

RECOMMENDATIONS

- Recruit additional anglers to the NSSRF through the use of increased advertising.
- Maintain the current tiered reward system for northern squawfish ≥ 11 inches.
- Maintain the current \$50 tagged northern squawfish incentive.
- Maintain the use of a bi-weekly tournament during the entire season.
- Expand the BPA radio tournaments from 1996 to include the Portland area.
- Actively encourage independent tournaments.

Results from the 1996 NSSRF will continue to be assessed prior to the start of the 1997 season and additional changes may be made as necessary according to the wishes of the NSMP.



Appendix Figure A-1. Northern squawfish harvest and effort (angler day) by week in 1996.

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APPENDIX B.

FISH HANDLING

Introduction

The Northern Squawfish Sport-Reward Fishery (NSSRF) 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). The NSSRF received 157,230 northern squawfish (northern squawfish) from anglers participating in the NSSRF during the 1996 season. Prior to 1996, S. P. Cramer and Associates had disposed of northern squawfish carcasses obtained from the NSSRF and from dam angling crews by utilizing both food-grade and render-grade procedures (Pampush and Willis 1995). During the 1996 season, the Washington Department of Fish and Wildlife (WDFW) assumed the responsibility for disposing of these carcasses as a way to improve efficiency and reduce costs to the Northern Squawfish Management Program (NSMP). During 1996, only a render-grade collection network was implemented due to the additional costs and logistical difficulties associated with handling food-grade northern squawfish.

Project Description

WDFW developed a network of storage points and transportation routes that funneled northern squawfish collected from the NSSRF through one of three main fish handling points located in each geographical area. Fish handling points were facilities that provided walk-in coolers, storage barrels and facilities for cleaning fish handling equipment. This network was implemented by WDFW technicians as part of their regular duties operating registration stations and by intermittent technicians who transported northern squawfish from field offices, storage points or registration stations to the fish handling points.

Northern squawfish collected from the Cathlamet station and its associated satellites were kept in a short-term storage facility at WDFW's Longview field office and were transported to the Vancouver field office twice a week. Short-term storage for these fish was provided by using plastic bags and chest freezers as used for the 1991 NSSRF (Hanna et al. 1991). Longview technicians were responsible for cleaning and maintaining fish handling equipment as part of their regular NSSRF duties.

Northern squawfish collected from the Washougal and Gleason stations and their associated satellites, along with any northern squawfish received from Longview were transferred from Vancouver to the Dodson fish handling point on a daily basis as part of the normal commute for the technicians who staffed the registration station at The Fishery. Technicians at The Fishery were responsible for cleaning and maintaining fish handling equipment as part of their regular NSSRF duties.

The fish handling point at Dodson was located within the same facility as The Fishery registration station. The Dodson facility included the standard walk-in cooler used by all fish handling points although WDFW leased an additional portable walk-in cooler that was placed at Dodson during our peak harvest period from May through August. As northern squawfish were brought to Dodson, they were put into 60 gallon plastic garbage bins. These bins were placed in one of the walk-in coolers where they were chilled to approximately 0 degrees Celsius. Northern squawfish that were turned in by anglers at The Fishery registration station were placed directly into the plastic garbage bins used for fish handling and stored in the walk-in cooler. From May through July, WDFW arranged for Darling International to pick up northern squawfish at the Dodson fish handling point. During this period, WDFW scheduled two technicians to be at the Dodson fish handling point to assist Darling personnel with northern squawfish pick-up, and to clean equipment. From the end of July through September, WDFW modified fish handling procedures to improve efficiency by arranging for these technicians to use our fish handling truck to deliver bins of northern squawfish directly to Darling.

Technicians at the Giles French, The Dalles, Bingen and Hamilton Island stations delivered northern squawfish to a short-term storage facility at WDFW's Lyle field office. Technicians assigned to fish handling duties transferred northern squawfish from these stations (in addition to the northern squawfish from the Hamilton Island station) from the Lyle office to the Dodson fish handling point on a daily basis. These technicians were responsible for emptying Northern squawfish into the plastic garbage bins within the walk-in coolers, and for cleaning and maintaining fish handling equipment.

Technicians from Hood Park, Columbia Point and Vernita registration stations delivered Northern squawfish to a walk-in cooler at the fish handling point which also served as the Pasco field office. Northern squawfish were emptied into 55 gallon barrels inside the walk-in cooler. WDFW technicians arranged for Baker Commodities to render the barrels of northern squawfish throughout the season as needed. Fish handling equipment was cleaned and maintained at the Pasco fish handling point by registration station technicians as part of their regular NSSRF duties.

WDFW technicians at the Greenbelt registration station delivered northern squawfish to a fish handling point (Heights Meat Market), which was located near our field office in Clarkston, WA. Northern squawfish were emptied into 55 gallon barrels inside a walk-in cooler. The Heights Meat Market arranged for a renderer to pick-up the barrels throughout the season as part of the walk-in cooler rental. Northern squawfish collected at the Boyer satellite were stored at a short-term storage facility in Pullman and delivered to Clarkston on a weekly basis. Fish handling equipment was cleaned and maintained at the Clarkston field office by the Greenbelt technicians as part of their regular NSSRF duties.

Results and Discussion

Fish handling costs for the 1996 NSSRF totaled \$32,835 and are summarized in Appendix Table B-1. The NSSRF disposed of an estimated 110 tons of northern squawfish in 1996 at an overall average disposal cost of .20 per northern squawfish. The costs of fish handling were \$27,000 lower than the estimated costs prior to the season, even though \$1,965 was spent on equipment (i.e. storage bins, power washer, etc) which will be used for fish handling duties for the next several years. The actual disposal cost per northern squawfish in 1996 should therefore be slightly less than the average of .20/northern squawfish.

The Clarkston processing point handled 10% of the total northern squawfish harvest, Pasco handled 16% and Dodson handled 74%. The costs per fish handling point were \$1,116 for Clarkston, \$2,700 for Pasco and \$28,314 for Dodson. This translates into average disposal costs of .07 per northern squawfish at Clarkston, .11 per northern squawfish at Pasco and .25 per northern squawfish at Dodson.

Fish handling procedures were modified during the season to improve efficiency whenever possible. Changes made to the procedures for disposing of northern squawfish from the Dodson fish handling point saved the NSMP an estimated \$500 in pick-up charges. From the end of July through September, WDFW technicians delivered northern squawfish directly to Darling rather than having them picked up. This allowed the NSSRF to avoid the \$50 charge that Darling assessed for their weekly pick-up, and reduced the price per ton of rendered northern squawfish from \$50 to \$40. Delivering northern squawfish directly to Darling also allowed WDFW to more accurately manage labor costs and avoid inefficiencies associated with the inconsistent pick-up schedule used by Darling.

Fish handling costs associated with transporting northern squawfish daily from the Lyle field office to Dodson may be reduced by utilizing a portable walk-in cooler at Lyle. Savings would be realized in mileage, bridge tolls and labor costs that would more than offset the costs for the portable walk-in cooler.

Due to the time constraints in 1996, no other end uses were found for northern squawfish carcasses other than rendering. Some interest in these carcasses has been indicated by small museums with animal displays, by science class teachers and by animal rehabilitation groups. The amounts wanted are generally small although the NSSRF may potentially dispose of significant numbers of northern squawfish through these types of outlets, given further investigation.

Recommendations

Deliver northern squawfish directly to renderer in Portland rather than having northern squawfish picked up.

- Make use of additional portable walk-in cooler for Lyle area sites.
- Investigate additional end uses for northern squawfish collected from the NSSRF.

Appendix Table B- 1. Fish handling costs for the 1996 northern squawfish sport-reward fishery.

Item	Total
COOLER RENTAL	
The Fishery, walk-in cooler rental	\$3,500.00
Portable refrigeration unit rental	\$3,100.00
Install/remove portable refrigeration unit.	\$350.00
Pasco, walk-in cooler rental	\$2,400.00
FISH HANDLING SUPPLIES	\$1,965.00
RENDERING	
The Fishery	\$2,100.00
Pasco	\$300.00
Clarkston	\$1,822.00
PERSONNEL	
Intermittent technicians	\$9,701.00
VEHICLES	
Dodson truck	\$2,400.00
Dodson truck mileage	\$647.00
Lyle truck	\$1,757.00
Lyle mileage	\$2,793 .00
GRAND TOTAL	\$32.835.00

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APPENDIX C

COST ANALYSIS

Washington Department of Fish and Wildlife conducted a cost analysis of the Northern Squawfish Sport-Reward Fishery (NSSRF) in order to ensure efficiency. The data were used to measure the effect of cost-saving measures implemented in 1996 and to influence management decisions for the 1997 NSSRF. Total expenditures and expenditures per northern squawfish (*Ptychocheilus oregonensis*) were compared between registration stations and between the years of 1995 and 1996. The elements of this cost analysis were based on the evaluation done by Hanna et al. 1992.

Cost per registration station and satellite was calculated by: 1) determining portion of personnel costs associated with each registration and satellite station, 2) determining cost breakdown for field offices and vehicles for each registration station and satellite, and 3) determining amount allotted towards fringe benefits (Old Age Survivors Insurance, retirement, Labor and Industries, etc.) and indirect costs for each registration station. Appendix Table C-1 shows a cost breakdown model used to calculate the expenditures for each registration station and its associated satellites.

Estimated cost per northern squawfish by registration station and satellite was calculated by dividing the total cost of the registration or satellite station by the total northern squawfish harvested at that registration or satellite station.

Cost analysis were improved in 1996 by eliminating incongruities in fringe benefit costs, indirect costs, and vehicle allotments. The format for calculating cost was simplified and standardized so it could be easily recreated in coming years. The 1995 fringe benefits and indirect cost amounts were recalculated in an attempt to produce a relatively viable, but limited, comparison with 1996.

The 1995 figures underestimated the actual costs associated with the registration stations and satellites. With the adjustment implemented to 1995 costs, overall operating costs increased by \$45,777 in 1996. A total of \$30,025 of that figure was the result of a 22-week program in 1996 versus a 21 -week program in 1995. Additional increases were primarily due to inflation (Appendix Table C-2). The registration station comparison of expenditure/northern squawfish increased by \$0.79/northern squawfish due to the overall increase in cost and the decrease in harvest. The average operating cost per registration station (with its associated satellites) in 1996 was **\$56,618.83**. Operating costs ranged from **\$47,375** at Bingen to **\$77,768** at Greenbelt (Appendix Table C-3).

Overall satellite operating costs were \$6,402 less in 1996 than in 1995 (Appendix Table C-4). The increased efficiency of satellites was created by eliminating extremely inefficient satellites from 1995. Likewise the cost per northern squawfish for satellites also decreased by \$39.65 per northern squawfish from 1995. The use of satellites increased the efficiency of the parent station by including fish obtained at a lower cost per northern squawfish, which decreased the overall cost per northern squawfish (Appendix Table 3). The average operating

Appendix Table C- 1. Sample breakdown of the costs used to calculate the total expenditure for each registration station, 1996.

ITEM	QUANTITY	UNIT COST	TOTAL COST
REGISTRATION STATION			
PERSONNEL:			
Fisheries Biologist 2	1.5 mo.		\$ 3,616.67
Scientific Technician II	5 mo.		\$ 11,459.96
Scientific Technician I	5 mo.		\$ 9,796.85
FRINGE BENEFITS:			\$ 5,145.83
SUPPLIES:			\$ 185.57
Indirect Costs:			\$ 16,559.83
WDFW rate 19%			
FIELD STATION RENTAL:	5 mo.	\$ 160.00	\$ 800.00
VEHICLE:			
Lease	5 mo.	\$ 180.00	\$ 900.00
Mileage	3696 mi.	\$ 0.165	<u>\$ 609.84</u>
TOTAL			\$49,074.55
SATELLITE			
PERSONNEL:			
Scientific Technician I	5 mo.		\$ 4,486.02
VEHICLE:			
Mileage	5544 mi.	\$ 0.14	<u>\$ 356.40</u>
TOTAL			\$ 4,842.42
GRAND TOTAL			\$ 53,916.97

Appendix Table C-2. Expenditure per registration station for 1995 and 1996. (Registration station costs include its associated satellites).

Registration Station	1995		1996	
	Expenditures	Harvest	Expenditures	Harvest
Cathlamet (0 1)	\$59,665.08	7,175	\$62,676.85	14,414
M. J. Gleason (02)	\$59,943.04	11,510	\$53,916.97	11,579
Camas/Washougal(O3)	\$50,470.46	8,659	\$49,584.97	7,039
Covert's Landing (04)	\$54,555.62	30,154	\$53,106.67	20,224
Hamilton Island (05)	\$45,963.10	11,936	\$56,882.39	10,020
Bingen (06)	\$48,521.79	11,555	\$47,375.13	7,772
The Dalles (07)	\$42,920.45	22,895	\$48,572.56	19,384
Giles French (08)	\$54,015.72	45,790	\$58,922.18	25,639
Columbia Point (09)	\$51,532.58	12,418	\$57,673.49	8,409
Vernita Bridge (10)	\$43,991.63	15,577	\$57,382.82	15,261
Hood Park (11)	\$51,103.89	3,750	\$52,25 1.56	1,953
Greenbelt (12)	<u>\$67,654.37</u>	<u>15,645</u>	<u>\$77,768.50</u>	15,536
TOTAL:	\$630,337.73	197,064	\$676,114.09	157,230

Appendix Table C-3. Total expenditure per registration station location and expenditure per NS removed for 1996.

Registration Station	Total Expenditure incl. Satellite	Total Harvest incl. Satellite	Expenditure Per NS incl. Satellite	Expenditure Per NS minus Satellite
Cathlamet	\$62,676.85	14,414	\$4.35	\$ 6.10
M. J. Gleason	53,916.97	11,579	4.66	6.15
Camas/Washougal	49,584.97	7,039	No Satellite	7.04
Covert's Landing	53,106.67	20,224	2.63	2.67
Hamilton Island	56,882.39	10,020	5.68	5.81
Bingen	47,375.13	7,772	6.10	6.03
The Dalles	48,572.56	19,384	No Satellite	2.51
Giles French	58,922.18	25,639	2.30	2.31
Columbia Point Park	57,673.49	8,409	6.86	6.95
Vernita	57,382.82	15,261	No Satellite	3.76
Hood Park	52,25 1.56	1,953	26.75	44.32
Greenbelt	<u>77,768.50</u>	<u>15,536</u>	<u>5.01</u>	4.95
TOTAL	\$676,114.09	157,230	\$ 7.15	\$ 8.22

Appendix Table C-4. Expenditure per satellite for 1995 and 1996.

Resistration Station	Expenditures	1995 Harvest	Expenditures	1996 Harvest	
01:	John Day	\$1,690.09	3	NIA	N/A
	Rainier	\$3,174.74	1,411	\$3,516.28	3,432
	Willow Grove	\$2,225.10	157	N/A	N/A
	Kalama	N/A	N/A	\$5,079.52	654
	Weyerhaeuser	N/A	N/A	\$2,191.46	1,815
	Scappoose	\$2,477.10	92	N/A	NIA
02:	Chinook	\$3,419.74	2,456	\$4,842.42	3,593
	Marine Park	\$2,395.70	145	N/A	N/A
	Ridgefield	\$2,117.58	53	N/A	N/A
04:	Cascade Locks	\$5,940.48	2,768	\$3,712.10	1,739
	Beacon Rock	\$2,448.66	2,294	N/A	N/A
05:	Home Valley	\$2,613.66	967	\$2,501.10	658
06:	Hood River	\$4,105.29	383	\$1,144.92	99
08:	Maryhill	\$4,484.29	4,923	\$6,731.20	3,079
09:	Ringold	\$4,517.56	1,213	\$7,106.04	1,137
11:	Umatilla	\$4,589.56	747	N/A	NIA
	Lyons Ferry	N/A	N/A	\$2,086.26	821
12:	Boyer Park	<u>\$3,973.56</u>	<u>1,046</u>	<u>\$4,860.40</u>	<u>795</u>
TOTAL:		\$50,173.11	18,858	\$43,771.70	17,860

cost per satellite station was \$3,979.18. Operating cost ranged from \$1,145 at Hood River to \$7,106 at Ringold. Some satellites show a large increase in expenditures which can be attributed to an increase in the NSSRF's total weeks of operation.

RECOMMENDATIONS FOR 1997

1. Increase efficiency of Hood Park registration station by converting to a combined station with Lyons Ferry and Ringold.
- 2) Utilize associated satellites even more by modifying hours to further increase effectiveness.

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Report B

Northern Squawfish Sport Reward Payments - 1996

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February, 1997

Report B-48

The Pacific States Marine Fisheries commission provided fiscal services for payment of the squawfish sport rewards. Anglers registered and subsequently checked in their catch at the Washington Department of Fish and Wildlife field stations where they received a voucher for all eligible fish checked in. Standard vouchers were issued for all fish over 11 inches that were not tagged. The number of fish turned in were recorded on the voucher 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 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. This year rewards were paid on a tiered structure of from \$3.00 - \$5.00 per fish.. Anglers received a reward of \$3.00 per fish for their first 100 fish, then \$4.00 per fish up to 400 fish when the reward went to \$5.00 per fish for all fish caught in excess of 400. PSMFC maintained an accounting during the season by computer for all anglers submitting vouchers to properly determine their tier payment level for all fish submitted for payment. A cut off date of October 30, 1996 was established as the final date vouchers needed to be postmarked to receive payment from PSMFC. Vouchers representing 154,554 fish were paid on standard vouchers representing rewards of \$629,538. A Coupon good for one free \$3.00 reward was provided to anglers this season. The coupon could be used with one or more qualifying fish to obtain credit for one additional fish toward the tiered reward structure and an additional \$3 reward. A total of 1,246 coupons were redeemed during the season.

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 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 depending on the payment tier for that angler. A total of 23 1 tag vouchers were received and paid in 1996.

Biweekly tournaments were held at each of the 12 registration stations throughout the season. The three largest fish checked in at each station during each two week period received rewards of \$125, \$75 and \$50 respectively. In addition, special 9 day tournaments were held in different parts of the river from June 22 through July 28, 1996. Prizes of \$500, \$250 and \$100 were paid for the three biggest fish caught as well as daily merchandise awards by the radio station sponsors.

The attached table summarizes the payments, vouchers and tournament winnings during the 1996 season.

All IRS Form 1099-Misc. statements were sent to the qualifying anglers for tax purposes the third week in January 1997. Appropriate reports and copies were provided to the IRS by the end of February 1997.

1996 SPORT REWARD PAYMENTS SUMMARY

The following is a summary of the vouchers received and paid as of November 13, 1996.

	<u>\$ Amount</u>
TOTAL DOLLARS PAID OUT:	\$672,426
Total Fish Paid (including tags, not coupons) 154,554	\$629,538
Fish Paid at Tier 1: 53,110	\$159,330
Fish Paid at Tier 2: 47,407	\$189,628
Fish Paid at Tier 3: 53,806	\$269,030
Tags Returned: 231	\$11,550
Coupons Returned: 1,246	\$3,738
Total Bi-weekly Tournaments (all stations): 10.50	\$31,500
BPA Grand Tournament 6/22/96 - 6/30/96 stations 1, 6-12:	\$6,800
BPA Grand Tournament 7/15/96 - 7/28/96 stations 2-5 (combined):	\$850
Total Tournament Payments:	\$39,150

Number of Separate Anglers: **2,239**

 Anglers at Tier 3: **103**

 Anglers at Tier 2: **178**

 Anglers at Tier 1: **1,958**

Anglers with 10 fish or less:

 Anglers with 1-2 fish:

Number of Pred-A-Cards ordered and/or issued: **1,201**

Top Anglers: *(Note: Does not include tournament winnings)*

1. Ulyess Woody	Fish: 3,089	Coupons: 1	Tags: 1	\$14,999
2. Thomas Papst	Fish: 2,622	Coupons: 1	Tags: 4	\$12,814
3. Steven Owre	Fish: 2,508	Coupons: 1	Tags: 7	\$12,396
4. Daniel Keilwitz	Fish: 2,288	Coupons: 1	Tags: 5	\$11,197

Report C

**Controlled Angling for Northern Squawfish at Selected
Dams on the Columbia and Snake Rivers
in 1996**

Prepared by

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

Report C-51

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Personnel from the U.S. Army Corps of Engineers (USACE) 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).

The project supporting visitor services at Bonneville Dam was carried out with the help of Pat Berry (USACE) and Laura Berg, Scott Welch, and Rick Taylor (CRITFC). The informational handouts provided to visitors were courtesy of Bonneville Power Administration, Columbia River Inter-Tribal Fish Enforcement, and Columbia River Inter-Tribal Fish Commission (CRITFC). The taxidermic display was courtesy of CRITFC. Most of all, we would like to thank Scherri Sotomish for her excellent work in making the presentations at Bonneville Dam Visitor's Center.

This report was prepared by (in alphabetical order) Ken Collis, Jack McCormack, Kathy McRae, and Scherri Sotomish. We thank Keith Hatch, Roy Beaty, Jed Volkman, Colleen Fagan, and Blaine Parker for their comments on an earlier draft of this report.

ABSTRACT

Field crews used hook-and-line to catch northern squawfish (*Ptychocheilus oregonensis*; NS) at eight mainstem dams on the lower Columbia and Snake rivers from June through September 1996. A total of 5,455 predator-size (≥ 250 mm fork length) northern squawfish were caught in 1996, which was roughly equal to the catch in 1995. The catch per angler hour (CPAH) for hook-and-line angling was 1.5 in 1996, compared to 0.7 the previous year. Catch rates at Columbia River dams were higher than at Snake River dams, 1.7 and 0.4 CPAH respectively, and showed marked improvement over the previous year (1995 : CPAH = 0.8), a trend not observed at Snake River dams (1995: CPAH = 0.5). Total hook-and-line angling effort was reduced in each of the last two years, (1995: 27% reduction; 1996: 50% reduction) in response to progressive declines in catch rate at Columbia and Snake river dams in 1994 and 1995.

Downrigger equipment was used from boats to catch northern squawfish that reside near the river bottom late in the season. At all four dams where they were tested, catch rates using downriggers were higher than conventional hook-and-line angling from boats, with an overall CPAH of 2.5. At Snake River dams, catch rate for boat angling (CPAH = 0.7) was higher than for dam-based angling (CPAH = 0.1). This was not the case at Columbia River dams, where catch rates were 1.3 for boat angling and 1.8 for dam-based angling. Angling effort was supplemented by volunteer angling at Bonneville Dam (NS catch: 153; effort: 257.1 angler hours; CPAH: 0.6), with a total of six sport-angling groups participating in the program this year. Volunteer effort and catch were roughly half of 1995 levels. 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.

Incidental catch was 2.3% of the total hook-and-line catch, compared to 8.3% the previous year. Game fish (mostly bass *Micropterus* spp., channel catfish *Ictalurus punctatus*, and walleye *Stizostedion vitreum*) constituted the largest percentage of the incidental catch (46%). No salmonids were caught by hook-and-line in 1996, compared to 5 in 1995.

INTRODUCTION

The eight hydroelectric dams on the lower Columbia and Snake rivers have converted a once free-flowing river into a series of reservoirs, prolonging 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 on juvenile salmonids, northern squawfish *Ptychocheilus oregonensis* have been targeted by the Columbia River Northern Squawfish Management Program (NSMP) for controlled removal from the lower Columbia and Snake rivers 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; Collis et al. 1996). Over the past six years, hook-and-line angling crews have caught over 115,000 predator-size (≥ 250 mm fork length; Vigg et al. 1991) northern squawfish at eight dams on the lower Columbia and Snake rivers. Our objectives in 1996 were to: 1) remove northern squawfish from areas near dams using hook-and-line angling; 2) minimize the incidental catch of salmonids, white sturgeon *Acipenser transmontanus*, and other fish; and 3) improve our effectiveness in carrying out these fisheries.

METHODS

Study Area

In 1996, dam angling was conducted at eight U.S. Army Corps of Engineer (USACE) dams on the lower Columbia and Snake rivers (Figure 1). Removal activities were confined to the boat-restricted zones (BRZ) at these dams, with most of our effort focused in the tailraces.

Crew Scheduling

Most of the hook-and-line angling effort was implemented at Columbia River dams (Tables 1 and 2), where catch rates in previous years have been consistently higher than at Snake River dams. 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 2). When feasible, crews working on the Columbia River rotated between dams to increase productivity (i.e., catch success) (Table 2).

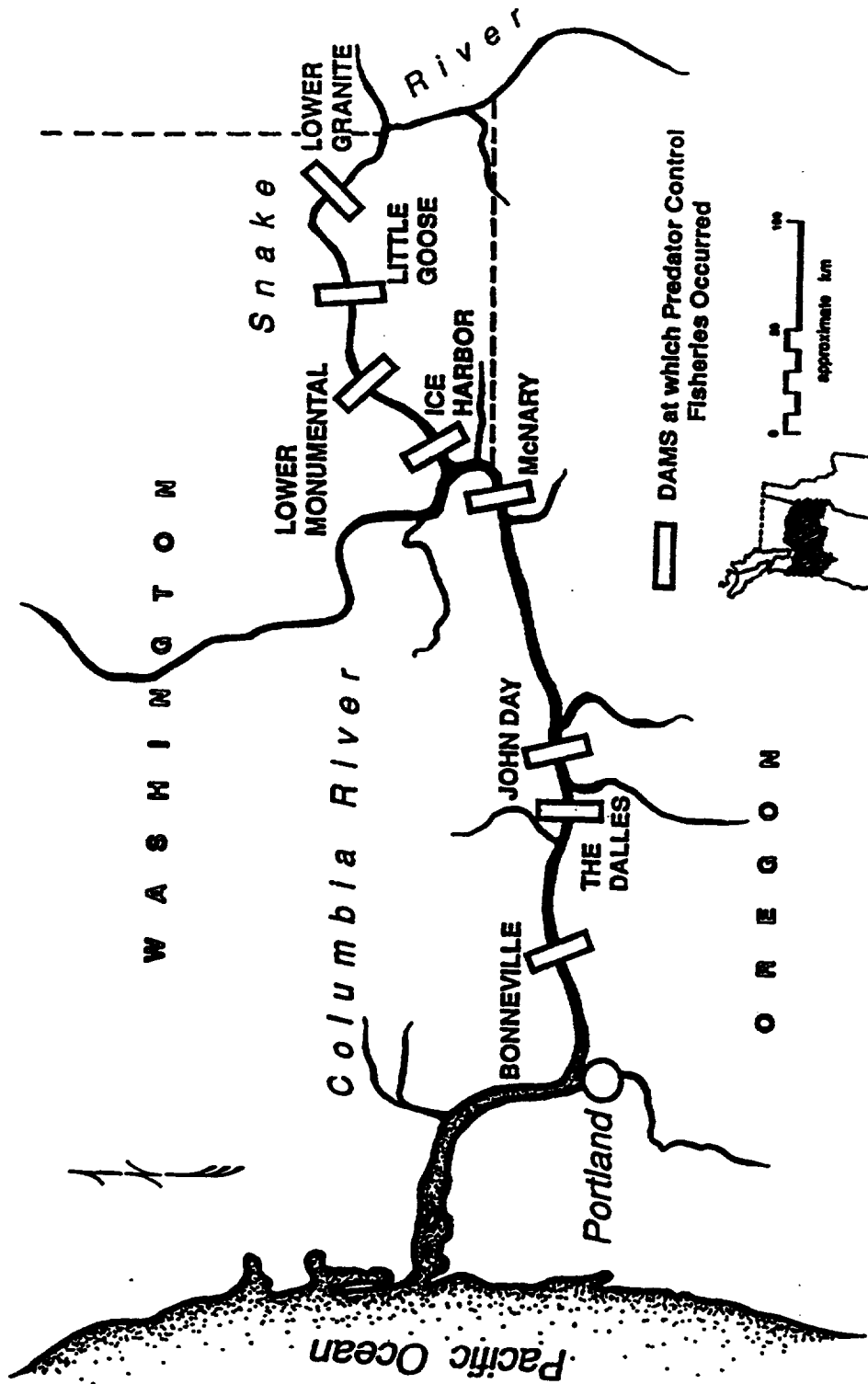


Figure 1. Dams where controlled angling operations for northern squawfish were conducted in 1996.

Table 1 Distribution of hook-and-line angling effort at Columbia and Snake river dams in 1996.

River and dam	River km	Season	Number of crew-days worked
Columbia River			
Bonneville	233	June 14 - Aug 28	47
The Dalles	310	July 2-Aug 28	30
John Day	348	June 5-Sept 4	44
McNary	470	June 17 Sept 4	50
Snake River			
Ice Harbor	16	July 1 - July 16	2
Lower Monumental	68	July 2-Aug 28	5
Little Goose	113	June 18-Aug 29	11
Lower Granite	172	June 10-Sept 4	19

Volunteer anglers augmented the effort of our technicians at Bonneville Dam (Table 2). During the 1996 season, six sport-angling groups volunteered to work at least one four-hour shift each from mid-June through early August (Table 2). As many as eight individuals per group signed up to work either morning or evening shifts scheduled from Friday through Sunday.

Field Procedures

Hook-and-line angling equipment and techniques, including measures to minimize incidental catch, were essentially the same as those used the previous five years (Parker et al. 1993). Boats were again used to access areas within the BRZ outside the reach of dam-based anglers.

Angling with downriggers occurred in the tailraces of John Day and McNary dams on the Columbia River and Lower Granite and Little Goose dams on the Snake River. Both electronic and low speed, hand crank downriggers were used. One downrigger was mounted on each side of the boat gunnel near the transom. Fishing lures were attached (with downrigger clips) to 10 pound downrigger weights and fished within one foot of the bottom of the river using electronic depth-finders. Leader length behind the downrigger weights varied from 15 to 30 feet. A variety of lures were used, but the most effective was a two-inch Rapala. The lures were either fished by maneuvering the boat from side to side across the current or by anchoring and letting the downrigger fish the current.

Table 2. Methods applied by crew type and organization for removal of northern squawfish at Columbia and Snake river dams in 1996.

Crew type and organization	Dam(s)	Dates (crew-days)
Dam-based Angling		
Technicians^a		
CTUIR	McNary	June 17 - Sept 4 (32)
CTWS	Bonneville, McNary, The Dalles	June 17 - Aug 28 (64)
NPT	Ice Harbor, Lower Monumental, Little Goose, Lower Granite	June 10 - Sept 4 (23)
YIN	John Day, McNary	June 11 - Sept 4 (43)
Volunteer Crews		
Beaverton Steelheaders	Bonneville	June 15 - Aug 3 (3)
Portland Steelheaders	Bonneville	June 22 - July 13 (2)
Sandy Steelheaders	Bonneville	June 14 - Aug 2 (4)
Tigard Steelheaders	Bonneville	July 27 (1)
Tom McCall Steelheaders	Bonneville	June 29 (1)
Tualatin Valley Steelheaders	Bonneville	July 6 (1)
Boat Angling		
Technicians'		
CTUIR	McNary	June 17 - Aug 29 (28)
CTWS	The Dalles	Aug 19 - Aug 26 (2)
NPT	Lower Monumental, Little Goose, Lower Granite	July 22 - Sept 4 (17)
YIN	John Day	June 5 - Aug 27 (9)
Downrigging		
Technicians'		
CTLJIR	McNary	July 18 - Sept 3 (13)
CTWS	McNary	Aug 1 (1)
NPT	Little Goose, Lower Granite	July 31 - Aug 19 (9)
YIN	John Day, McNary	Aug 1 - Aug 15 (3)

^a 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

Harvested northern squawfish were either kept in on-site freezers or coolers for rendering or were sacrificed and returned to the river. All tagged fish recovered were recorded and reported to the appropriate agencies. All other incidentally caught fish were immediately released back into the river.

Data Collection and Analysis

In 1996, data were collected as in previous years (Parker et al. 1993) using hand-held computers and transmitted daily via modem to the 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 bi-weekly 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.

RESULTS AND DISCUSSION

Northern Squawfish Catch

In 1996, hook-and-line anglers caught 5,455 predator-size northern squawfish¹ in 3,666 hours of fishing, for a seasonal CPAH of 1.5 (Table C-3). 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

The 1996 angling effort was concentrated at Columbia River dams where, over the years, catch rates have been consistently higher than at Snake River dams (Appendix Table B-1). Crews at Columbia River dams caught 5,220 northern squawfish in 3,022 hours of effort for an

¹ Based on sub-sampling of dam-angling northern squawfish catch by ODFW, 1.3% of our catch were fish < 250 mm. All catch results presented herein have not been adjusted to account for this discrepancy.

overall CPAH of 1.7 (Table C-3). Anglers at Snake River dams caught 235 northern squawfish in 645 hours of effort, resulting in a CPAH of 0.4 (Table 3).

At Columbia River dams, the largest catch (2,184) and highest CPAH (2.1) were at McNary and John Day dams, respectively (Table 3). The greatest angling effort (1,372 angler hours) was expended at McNary Dam (Table 3). On the Snake River, the highest CPAH (0.5) was at Little Goose Dam. The largest catch (112) and greatest angler effort (307 angler hours) were at Lower Granite Dam (Table 3). With the exception of McNary Dam, relative catch rates indicate that more effort could have been expended at Columbia River dams to maximize productivity (Figure 2).

At all dams, angling effort was focused in the more productive tailrace areas, rather than in the forebay (Table 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; Collis et al. 1996).

Temporal Effects

Hook-and-line angling catch (5,455) in 1996 was slightly higher than in 1995 (5,299; Appendix Table B-1). The overall CPAH for hook-and-line angling more than doubled from 1995 (CPAH = 0.7) to 1996 (CPAH = 1.5; Appendix Table B-1). In 1996, hook-and-line angling effort was reduced 50% from 1995 levels in response to declines in catch rate at Columbia and Snake river dams in previous years (Appendix Table B-1).

Generally, the increases in catch and catch rate in 1996 occurred at Columbia River dams (Appendix Table B-1). Catch and catch rate at Snake River dams in 1996 did not change appreciably from the previous year; effort at these dams remained relatively unproductive compared to Columbia River dams (Appendix Table B-1). The biggest increase in catch rate from 1995 to 1996 occurred at The Dalles Dam (1995 CPAH = 0.4; 1996 CPAH = 1.8), followed by McNary Dam (1995 CPAH = 0.6; 1996 CPAH = 1.6; Appendix Table B-1). The crews working at these dams were highly experienced (i.e., many had fished from the dams from two to six years), and each crew was successful in finding and exploiting fishing “hot spots” at their respective dams.

As in past years, hook-and-line angling in 1996 was augmented by volunteers from local sport-angling groups. A total of 6 groups and 58 individuals participated in the program in 1996 (Table 2), compared to 12 groups and 143 individuals in 1995. In 1996, all volunteer angling was conducted at Bonneville Dam, the most convenient site for the Portland-area groups. This year’s volunteers caught 153 northern squawfish in 257.1 hours of effort for a CPAH of 0.6 (Table 6). 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 NSMP.

Table 3. Northern squawfish (NS) catch, effort, and catch per angler hour (CPAH) for dam-based angling, boat angling, and downrigging at Columbia and Snake river dams in 1996.

River and dam	Dam-based angling			Boat angling			Downrigging			Totals		
	NS	Effort	CPAH	NS	Effort	CPAH	NS	Effort	CPAH	NS	Effort	CPAH
Columbia River												
Bonneville	1135	692.8	.6	—	—	—	—	—	—	1135	692.8	1.6
The Dalles	618	304.8	2.0	5	33.7	0.1	--	--	--	623	338.5	1.8
John Day	1244	548.1	2.3	28	66.3	0.4	6	3.7	1.6	1278	618.0	2.1
McNary	1031	671.0	1.5	872	611.9	1.4	281	89.6	3.1	2184	1372.4	1.6
Total	4028	2216.6	1.8	905	711.8	1.3	287	93.3	3.1	5220	3021.6	1.7
Snake River												
Ice Harbor	0	56.3	0.0	--	--	--	--	--	--	0	56.3	0.0
Lower Monumental	7	47.3	0.1	20	28.1	0.7	--	--	--	27	75.5	0.4
Little Goose	21	138.1	0.2	52	52.8	1.0	23	15.5	1.5	96	206.4	0.5
Lower Granite	25	174.8	0.1	55	104.3	0.5	32	27.6	1.2	112	306.7	0.4
Total	53	416.5	0.8	127	185.3	2.7	55	61.1	1.3	235	644.8	0.4
Grand total	4081	2633.0	1.5	1032	897.0	1.2	342	136.3	2.5	5455	3666.4	1.5

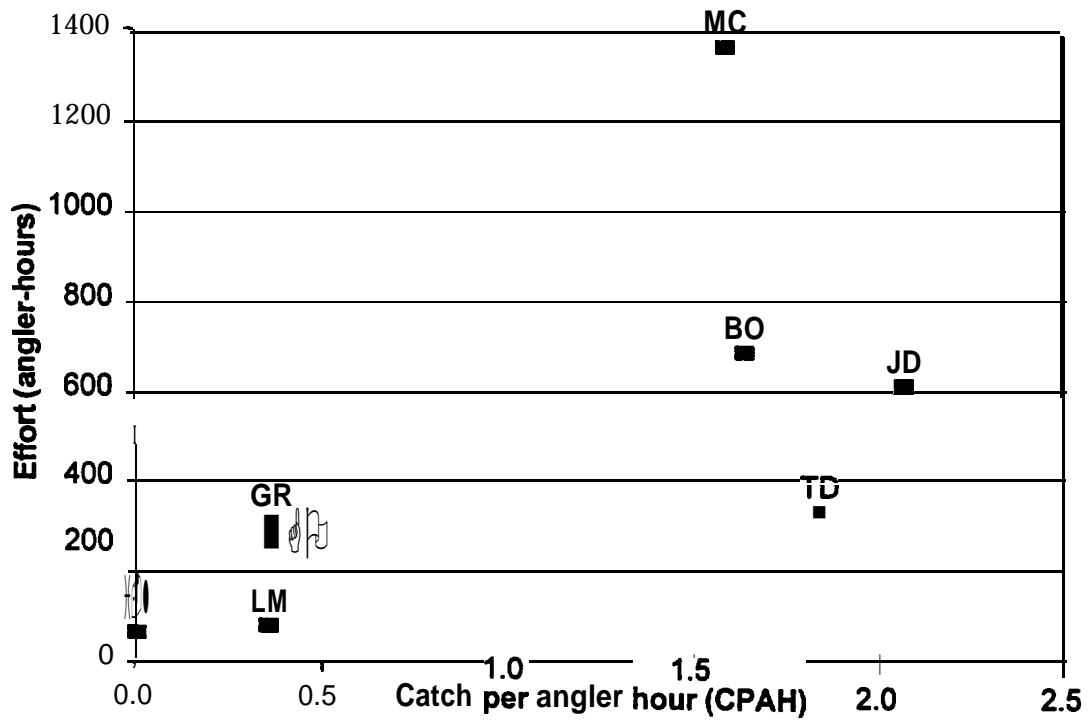


Figure 2. Seasonal catch per angler hour (CPAH) and total hours fished at Columbia and Snake River dams in 1996. BO = Bonneville; TD = The Dalles; JD = John Day; MC = McNary; IH = Ice Harbor; LM = Lower Monumental; GO = Little Goose; GR = Lower Granite.

Table 4. Northern squawfish (NS) catch, angler hours (effort), and catch per angler hour (CPAH) in tailrace and forebay fishing sites at Columbia and Snake river dams in 1996.

River and dam	Tailrace			Forebay		
	NS	Effort	CPAH	NS	Effort	CPAH
Columbia River						
Bonneville	897	560.4	1.6	238	132.3	1.8
The Dalles	623	338.5	1.8	—	—	—
John Day	1,278	618.0	2.1	—	—	—
McNary	2,184	1,372.4	1.6	—	—	—
Total	4,982	2,889.3	1.7	238	132.3	1.8
Snake River						
Ice Harbor	0	56.3	0.0	—	—	—
Lower Monumental	27	75.5	0.4	—	—	—
Little Goose	96	197.7	0.5	0	8.7	0.0
Lower Granite	112	294.7	0.4	0	12.0	0.0
Total	235	624.2	0.4	0	20.7	0.0
Grand total	5,217	3,513s	1.5	238	153.0	1.5

In 1996, monthly northern squawfish catch, effort, and CPAH were highest in July at Columbia River dams (Figure 3). At Snake River dams, catch and catch rate were highest in August, whereas effort was greatest in July (Figure 3). In general, weekly catch rates at Columbia River dams indicate that angling between late June and mid-August was the most productive (Figure 4). The 1996 weekly totals of catch, effort, and CPAH at Snake and Columbia river dams are listed in Appendix Tables A-1 and A-2. Comparisons among years (1991-1996) of weekly CPAH 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. (Table 5), as was the case last year (Collis et al. 1996). No obvious trend in productivity by diel period was observed at Snake River dams in 1996 (Table 5).

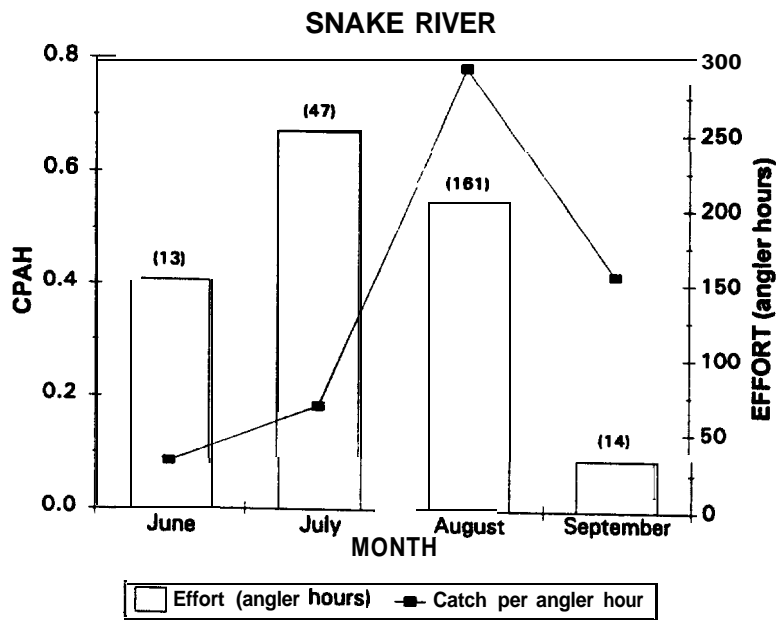
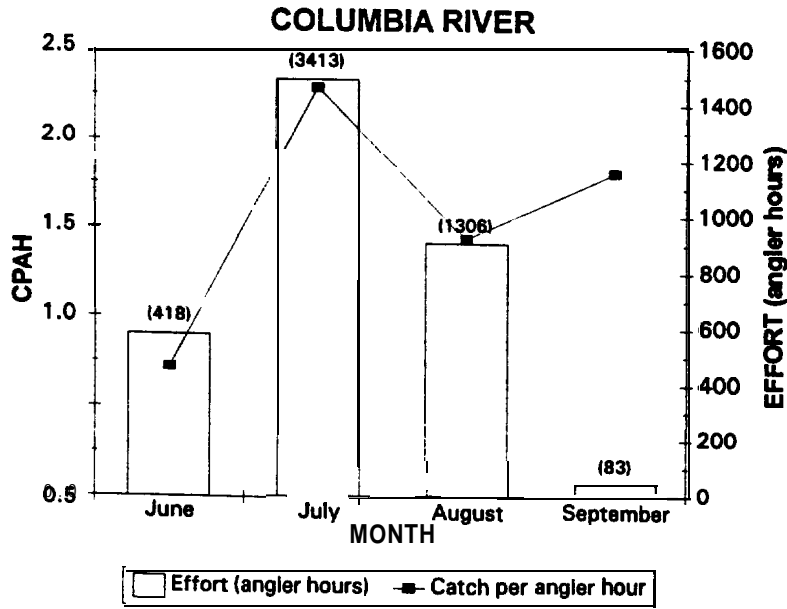


Figure 3. Monthly northern squawfish catch (in parentheses), catch per angler hour (CPAH), and effort at Columbia and Snake river dams in 1996.

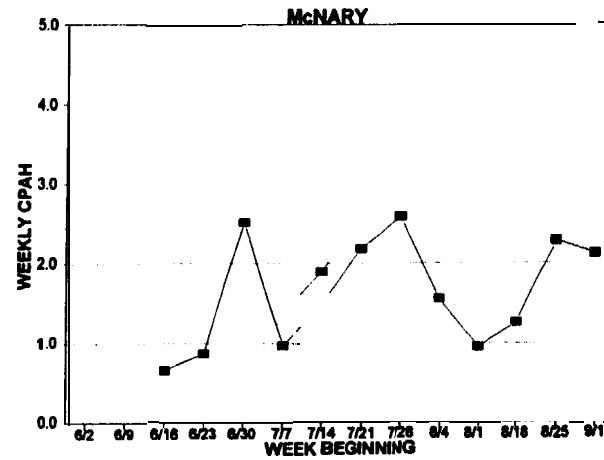
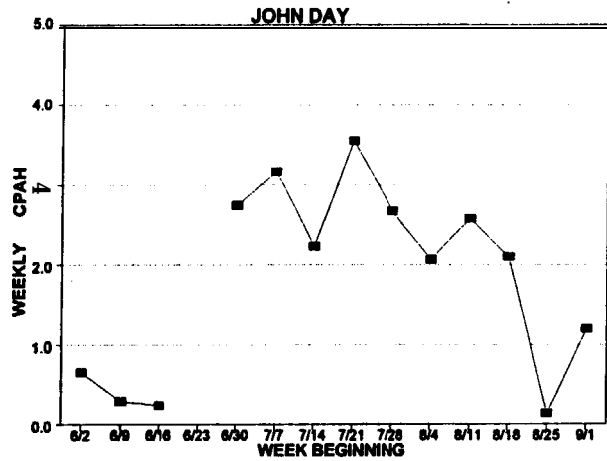
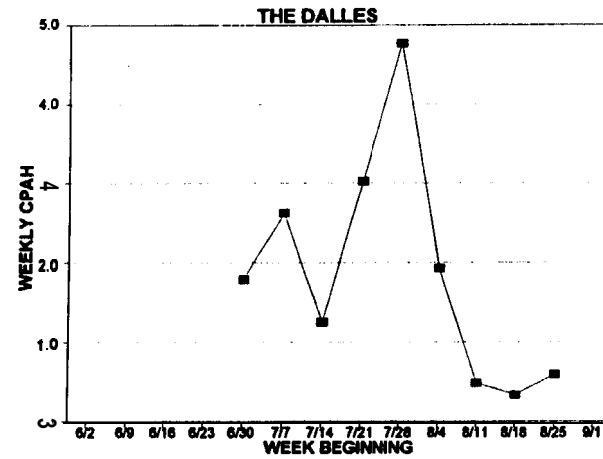
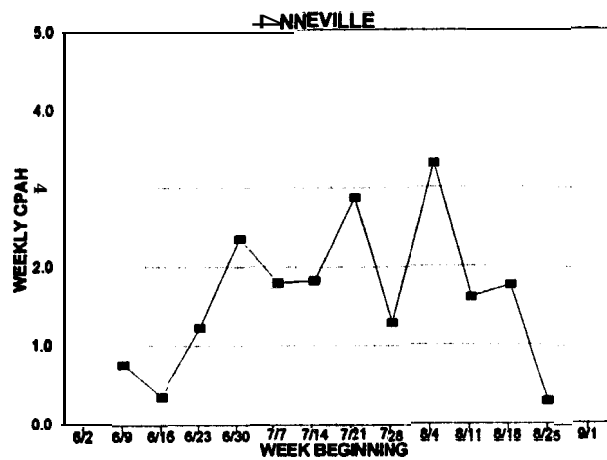


Figure 4. Weekly average catfish per angler hour (CPAH) of northern squawfish at Columbia River dams in 1996.

Table 5. Northern squawfish (NS) catch, angler hours (effort), and catch per angler hour (CPAH) for dam-based and boat angling (combined) during four different diel periods at Columbia and Snake river dams in 1996.

River and dam	0001-0600			0601-1200			1201-1800			1801-2400		
	NS	Effort	CPAH	NS	Effort	CPAH	NS	Effort	CPAH	NS	Effort	CPAH
Columbia River												
Bonneville	52	54.3	1.0	16	65.0	0.2	139	70.5	2.0	928	502.9	1.8
The Dalles	92	42.3	2.2	25	13.8	1.8	373	177.4	2.1	133	104.9	1.3
John Day	517	262.9	2.0	5	15.0	0.3	44	46.6	0.9	712	293.6	2.4
McNary	197	139.4	1.4	607	398.1	1.5	674	513.2	1.3	706	321.8	2.2
Total	858	498.9	1.7	653	491.9	1.3	1,230	807.7	1.5	2479	1,223.2	2.0
Snake River												
Ice Harbor	0	19.8	0.0	0	22.3	0.0	0	14.2	0.0	--	--	
Lower Monumental	0	14.5	0.0	15	41.3	0.4	12	19.7	0.6	--	--	
Little Goose	0	14.2	0.0	54	117.8	0.5	42	74.5	0.6	--	--	
Lower Granite	3	54.7	0.1	74	143.8	0.5	33	96.8	0.3	2	11.4	0.2
Total	3	103.1	0.0	143	325.1	0.4	87	205.2	0.4	2	11.4	0.2
Grand total	861	602.0	1.4	796	817.0	1.0	1,317	1,012.8	1.3	2,481	1,234.6	2.0

Angling Gear and Techniques

A variety of gear and techniques were used in 1996 to increase productivity. These different methods allowed greater flexibility in adapting to changes in the distribution, feeding habits, and other behaviors of northern squawfish that affect their catchability. In 1996, boats were once again used to remove northern squawfish from areas within the BRZ but outside the reach of dam-based anglers. Catch rates for boat angling were higher than dam-based angling at Snake River dams, where the opposite was true at Columbia River dams (Table 3). The data from Columbia River dams should be viewed with some caution, however, due to minimal boat angling effort (with the exception of McNary Dam) at those dams. In 1996, downriggers were used from boats to catch northern squawfish that reside near the river bottom late in the season. Limited effort (136.3 angler hours) produced a catch of 342 predator-size northern squawfish and a CPAH of 2.5 (Table 3). At all four dams where the new gear was tested, catch rates using downriggers were higher than with conventional hook-and-line angling from boats and produced an overall catch rate that was greater than both dam-based and boat angling (Table 3).

Table 6. Northern squawfish (NS) catch, angler hours (effort), and catch per angler hour (CPAH) for technicians and volunteers at Columbia River dams in 1996.

Dam	Technicians			Volunteers			Totals		
	NS	Effort	CPAH	NS	Effort	CPAH	NS	Effort	CPAH
Bonneville	982	435.7	2.3	153	257.0	0.6	1135	692.8	1.6
The Dalles	618	304.8	2.0	--	--		-	--	
John Day	1,244	548.1	2.3	--		--	-	--	
McNary	1,031	671.0	1.5	-		--	-	--	
Total	3,875	1,959.5	2.0	153	257.0	0.6	1,135	692.8	1.6

Catch rates varied by angler at each dam (Figure 5), probably due to differences in angler ability or technique, bait selection (Table 7) and choice of fishing site (*see Spatial Effects*). Overall, catch rates were highest using hard plastic lures (CPAH = 2.0) followed by soft plastic lures (CPAH = 1.6) which were also used most often by anglers (Table 7).

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.

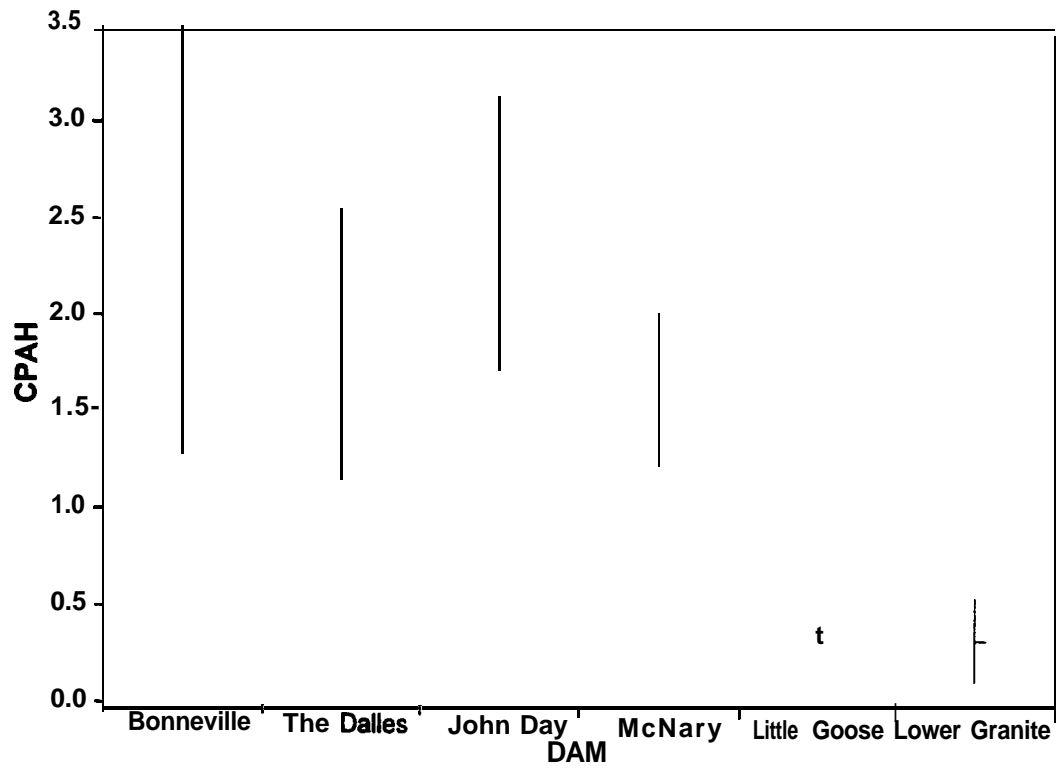


Figure 5. Range in catch per angler hour (CPAH) for individual anglers at each dam. Volunteer angling crews and anglers who worked fewer than 50 hours are not included. Average catch per angler hour at each dam is indicated by a horizontal mark.

Table 7. Northern squawfish (NS) catch, angler hours (effort), and catch per angler hour (CPAH) for baits used at Columbia and Snake river dams in 1996.

Dam	Totals by dam				Totals by river system			
	Bait	NS	Effort	CPAH	Bait	NS	Effort	CPAH
Bonneville	HML	5	1.9	2.7	Columbia River			
	HPO	443	174.0	2.5	CL0	1	0.3	3.0
	SPO	655	490.9	1.3	HPO	1070	502.3	2.1
	NBO	32	26.0	1.2	HML	6	3.0	2.0
The Dalles	HML	1	0.4	2.5	SPO	3981	2385.6	1.7
	HPO	226	105.6	2.1	NBO	162	130.3	1.2
	SPO	382	179.1	2.1	Snake River			
	NBO	14	53.4	0.3	HPO	59	49.6	1.2
John Day	SPO	1201	497.4	2.4	NBO	17	31.6	0.5
	NBO	9	11.1	0.8	SPO	116	238.2	0.5
	HPO	68	109.6	0.6	CL0	43	320.1	0.1
McNary	CL0	1	0.3	3.0	HML	0	5.3	0.0
	HPO	333	113.2	2.9	Grand total			
	NBO	107	39.8	2.7	HPO	1129	551.9	2.0
	SPO	1743	1218.2	1.4	SPO	4097	2623.8	1.6
	HML	0	0.8	0.0	NBO	179	161.9	1.1
Ice Harbor	SPO	0	51.3	0.0	HML	6	8.4	0.7
	HML	0	2.3	0.0	CL0	44	320.4	0.1
	CL0	0	2.7	0.0				
Lower Monumental	SPO	25	44.4	0.6	Bait descriptions:			
	CL0	2	27.0	0.1	HPO = Hard Plastic (such as Rat-L-Traps, Rapalas, and other plugs)			
	NBO	0	1.7	0.0	SPO = Soft Plastic (such as grubs, tubes, fish-like grubs)			
	HPO	0	1.4	0.0	MIS = Miscellaneous (items not in either of the above categories)			
	HML	0	1.0	0.0	NBO = Natural Bait (such as salmon smolts, lamprey, worms)			
Little Goose	HPO	24	16.6	1.5	CL0 = Combination Lures (any combination of the classes listed above)			
	SPO	40	40.6	1.0	HML = Hard Metal Lures (such as spoons, spinners, Zonars)			
	NBO	11	13.4	0.8				
	CL0	21	135.9	0.2				
Lower Granite	HPO	35	31.7	1.1				
	SPO	51	102.0	0.5				
	NBO	6	16.5	0.4				
	CL0	20	154.5	0.1				
	HML	0	2.0	0.0				

As in previous years, we expect that high discharge rates and juvenile salmonid passage affected our catch rates of northern squawfish at Columbia River dams in **1996**. Although cursory, our data provide some support for this hypothesis. In mid-June, when discharge rates were at their peak at Columbia River dams, our catch rates were relatively low (Figure 6). As discharge rates declined from mid- to late June, our catch rates increased (Figure 6). Certainly, other factors may contribute to the observed increase in catch rate (e.g., increases in water temperature or angler ability), therefore these data need to be interpreted with some caution. Also, peaks in catch rate of northern squawfish often coincide with periods of increased juvenile salmonid passage early in the season at Bonneville and McNary dams and late in the season at John Day Dam (Figure 6). Not enough data was available at other dams to complete this comparison.

Incidental Catch

Incidental catch was 2.3% of the total hook-and-line catch (Appendix Tables A-3 and A-4; Figure 7) compared to 8.3% the previous year (Collis et al. 1996; Appendix Figure B-5 for among year comparisons in catch composition). Game fish (mostly bass *Micropterus* spp., channel catfish *Ictalurus punctatus*, and walleye *Stizostedion vitreum*) constituted the largest percentage (46%) of the incidental catch for hook-and-line angling (Appendix Tables A-3 and A-4; Figure 7). No salmonids were caught by hook-and-line in 1996 (Appendix Table A-4), compared to 5 in 1995 (Collis et al. 1996). See Appendix Tables A-5 through A-S for incidental catch summaries for individual dams.

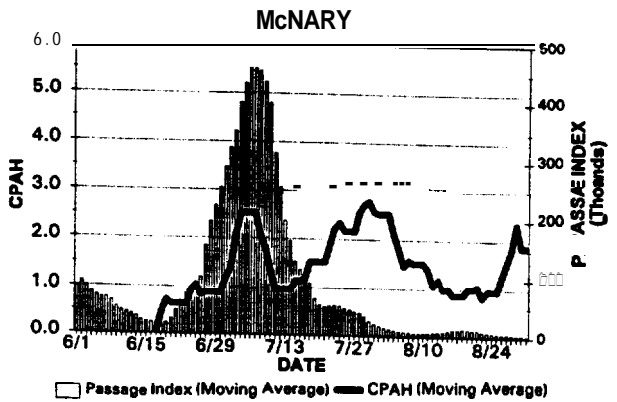
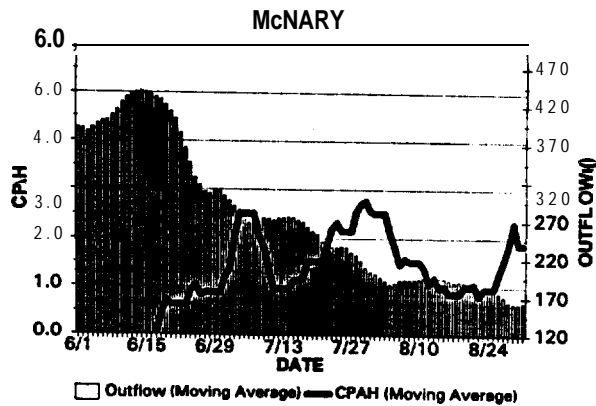
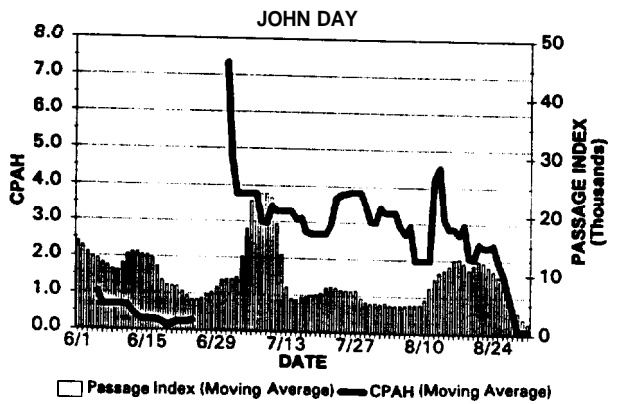
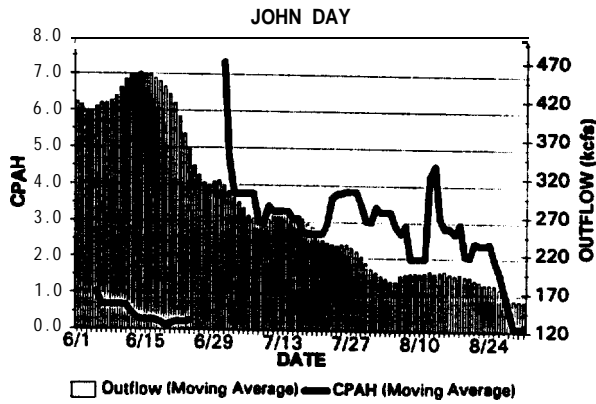
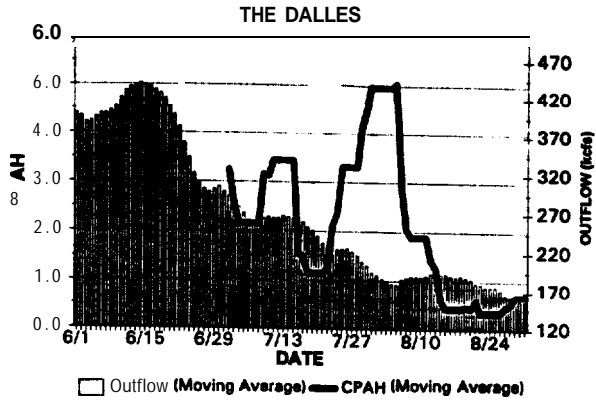
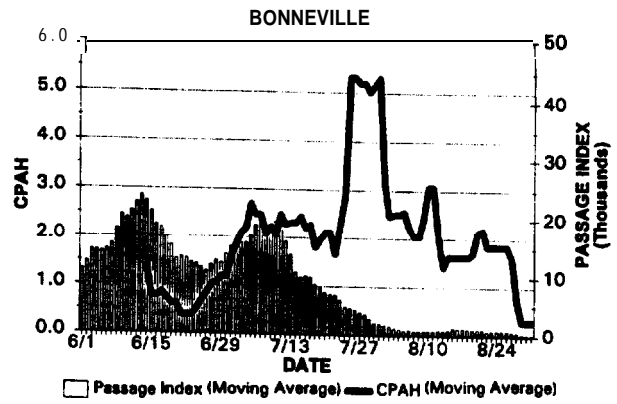
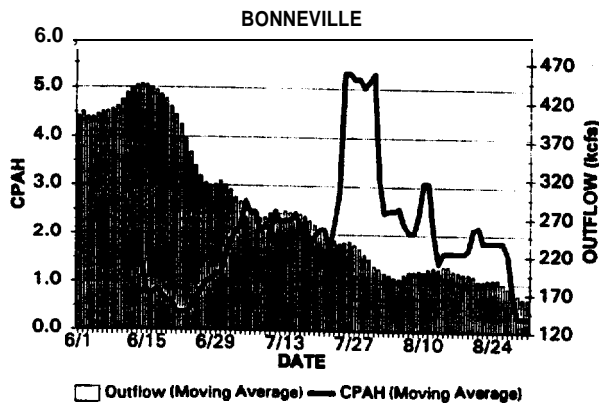
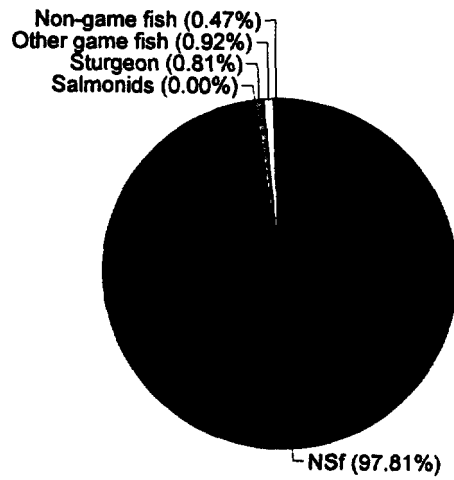


Figure 6. Northern squawfish catch per angler hour (CPAH), project outflow, and smolt passage indices at Columbia River dams in 1996. Passage data were not available for The Dalles Dam.

COLUMBIA RIVER



SNAKE RIVER

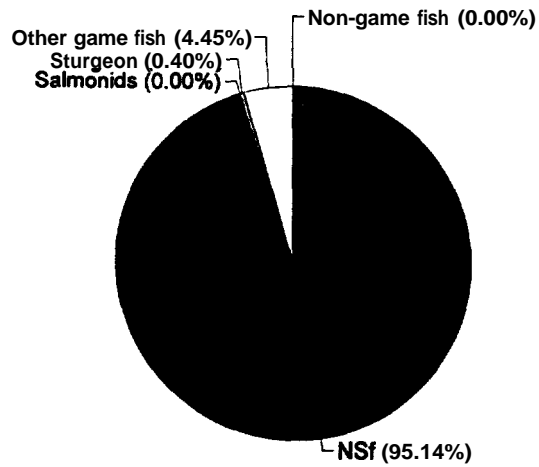


Figure 7. Percentage of total catch of northern squawfish (NS), salmonids, sturgeon, other game fish (bass, channel catfish and walleye), and non-game fish (American shad and others) for hook-and-line angling at Columbia and Snake river dams in 1996.

RECOMMENDATIONS FOR 1997

1. **Reduce dam-angling efforts overall and focus them more in time (late June through mid-August) and space (Columbia River dams) to become effective.**

Due to continued declines in catch and catch rate at Snake River dams, we propose to discontinue angling on the Snake River. At Columbia River dams, we plan to use in-season catch reports and mostly mobile angling crews to shift angler effort to the most productive dams and times.

2. **Continue to use angling methods such as downriggers and boat angling to allow greater flexibility in adapting to changes in the distribution, feeding habits, and other behaviors that affect catchability of northern squawfish.**

The distribution of northern squawfish near dams varies by season and with changes in dam operations. Late in the season (July-August), northern squawfish are found near the river bottom. Due to high flows near dams, these areas can not be fished effectively using conventional hook-and-line angling. We plan to use downriggers to target northern squawfish that reside near the river bottom late in the season. Furthermore, boats will be used to remove northern squawfish from areas within the BRZ but outside the reach of dam-based anglers. This should be particularly effective during periods of increased spill when northern squawfish reside in more protected shoreline areas away from the dam.

3. **Continue to administer a volunteer angling program at Bonneville Dam. The level of participation will likely depend on in-season success in catching northern squawfish at that dam.**

Volunteer angling efforts are productive in catching northern squawfish at a low cost. Furthermore, the volunteer program provides participants with an opportunity to learn about the NSMP in general, and to work cooperatively with tribal people.

4. **Continue to recruit and hire experienced hook-and-line anglers and provide them with in-season information to help improve their effectiveness.**

Angler ability and experience are important factors in catch success. We will attempt to hire experienced technicians and to provide them with in-season information (e.g., reports showing the relative productivity of different baits, sites, and time periods at each dam) that will help to maximize our productivity in catching northern squawfish. We will encourage information exchange among crews by scheduling different crews to work together and by organizing in-season meetings.

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APPENDIX A

1996 Tabular Data

Appendix Table A-1. Northern squawfish (NS) catch, angler hours (effort), and catch per angler hour (CPAH) for dam-based and boat angling (combined), by statistical week, at Snake River dams in 1996.

Statistical week: dates	Ice Harbor			Lower Monumental			Little Goose			Lower Granite		
	NS	Effort	CPAH	NS	Effort	CPAH	NS	Effort	CPAH	NS	Effort	CPAH
23: 6/03/96 — 6/09/96	—	—	—	—	—	—	—	—	—	—	—	—
24: 6/10/96 — 6/16/96	—	—	—	—	—	—	—	—	—	1	40.4	0.0
25: 6/17/96 — 6/23/96	—	—	—	—	—	—	8	46.7	0.2	—	—	—
26: 6/24/96 — 6/30/96	—	—	—	—	—	—	4	43.0	0.1	0	22.9	0.0
27: 7/01/96 — 7/07/96	0	28.4	0.0	0	16.5	0.0	3	22.8	0.1	—	—	—
28: 7/08/96 — 7/14/96	—	—	—	—	—	—	—	—	—	9	63.9	0.1
29: 7/15/96 — 7/21/96	0	27.9	0.0	2	24.7	0.1	6	23.5	0.3	2	17.5	0.1
30: 7/22/96 — 7/28/96	—	—	—	—	—	—	—	—	—	8	12.8	0.6
31: 7/29/96 — 8/04/96	—	—	—	—	—	—	—	—	—	17	15.2	1.1
32: 8/05/96 — 8/11/96	—	—	—	—	—	—	60	50.3	1.2	—	—	—
33: 8/12/96 — 8/18/96	—	—	—	—	—	—	—	—	—	51	59.1	0.9
34: 8/19/96 — 8/25/96	—	—	—	—	—	—	—	—	—	10	41.3	0.2
35: 8/26/96 — 9/01/96	—	—	—	25	34.2	0.7	15	20.2	0.7	—	—	—
36: 9/02/96 — 9/08/96	—	—	—	—	—	—	—	—	—	14	33.7	0.4
Total	0	56.3	0.0	27	75.4	0.4	96	206.5	0.5	112	306.8	0.4

Appendix Table A-2. Northern squawfish (NS) catch, angler hours (effort), and catch per angler hour (CPAH) for dam-based and boat angling (combined), by statistical week, at Columbia River dams in 1996.

Statistical week: dates	Bonneville			The Dalles			John Day			McNary		
	NS	Effort	CPAH	NS	Effort	CPAH	NS	Effort	CPAH	NS	Effort	CPAH
23: 6/03/96 -- 6/09/96	—	—	—	—	—	—	23	35.2	0.7	—	—	—
24: 6/10/96 -- 6/16/96	44	58.4	0.8	—	—	—	16	55	0.3	—	—	—
25: 6/17/96 -- 6/23/96	24	68.2	0.4	—	—	—	8	33.3	0.2	60	91	0.7
26: 6/24/96 -- 6/30/96	126	102.5	.2	—	—	—	—	—	—	117	34.5	0.9
27: 7/01/96 -- 7/07/96	258	09.7	2.4	45	25.2	1.8	120	43.7	2.7	291	115.8	2.5
28: 7/08/96 -- 7/14/96	163	90.8	1.8	54	20.6	2.6	192	60.7	3.2	123	126.4	1.4
29: 7/15/96 -- 7/21/96	113	61.9	1.8	63	50.3	1.3	218	97.7	2.2	251	168.1	1.5
30: 7/22/96 -- 7/28/96	141	49.1	2.9	134	44.3	3.0	285	80.3	3.6	358	163.9	2.2
31: 7/29/96 -- 8/04/96	54	41.8	1.3	191	40.1	4.8	123	46.0	2.7	287	110.9	2.6
32: 8/05/96 -- 8/11/96	91	27.4	3.3	81	42.0	1.9	22	10.7	2.1	208	133.1	1.6
33: 8/12/96 -- 8/18/96	52	32.3	1.6	18	36.9	0.5	86	33.3	2.6	27	33.3	1.0
34: 8/19/96 -- 8/25/96	65	36.9	1.8	13	38.6	0.3	163	77.5	2.1	96	76.3	1.3
35: 8/26/96 -- 9/01/96	4	13.8	0.3	24	40.6	0.6	4	29.5	0.1	201	88.6	2.3
36: 9/02/96 -- 9/08/96	—	—	—	—	—	—	18	15.0	0.2	65	30.6	2.1
Total	1,135	692.8	1.6	623	338.6	1.8	1,278	618.0	2.1	2,184	1,372.6	1.6

Appendix Table A-3. Monthly species composition of the combined dam- and boat-angling catch at Columbia and Snake river dams in 1996.

Dam and month	Percent NS* in total catch	Percent by-catch in total catch	Percent of total catch						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
Columbia River									
June	94.14	5.86	0.00	1.80	0.45	0.45	0.23	2.03	0.90
July	99.42	0.58	0.00	0.17	0.15	0.00	0.15	0.06	0.06
August	94.91	5.09	0.00	2.03	1.82	0.51	0.15	0.00	0.58
September	98.81	1.19	0.00	1.19	0.00	0.00	0.00	0.00	0.00
Total	97.81	2.19	0.00	0.81	0.60	0.17	0.15	0.21	0.26
Snake River									
June	72.22	27.78	0.00	0.00	0.00	27.78	0.00	0.00	0.00
July	94.00	6.00	0.00	2.00	0.00	4.00	0.00	0.00	0.00
August	98.17	1.83	0.00	0.00	0.61	1.22	0.00	0.00	0.00
September	93.33	6.67	0.00	0.00	6.67	0.00	0.00	0.00	0.00
Total	95.14	4.86	0.00	0.40	0.81	3.64	0.00	0.00	0.00
Grand Total									
June	93.29	6.71	0.00	1.73	0.43	1.52	0.22	1.95	0.87
July	99.34	0.66	0.00	0.20	0.14	0.06	0.14	0.06	0.06
August	95.26	4.74	0.00	1.82	1.69	0.58	0.13	0.00	0.52
September	97.98	2.02	0.00	1.01	1.01	0.00	0.00	0.00	0.00
Total	97.69	2.31	0.00	0.79	0.61	0.32	0.14	0.20	0.25

*Northern squawfish

Appendix Table A-4. Monthly by-catch for the combined dam- and boat-angling by condition at release at Columbia and Snake river dams in 1996. 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			Catfish			Walleye			Shad	Other
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3		
Columbia River																					
June	444	26	0	0	0	0	7	0	0	1	2	0	0	2	0	0	1	0	0	9	4
July	3433	20	0	0	0	0	5	0	0	1	5	0	0	0	0	0	4	0	1	2	2
August	1376	70	0	0	0	0	6	0	0	22	24	0	1	7	0	0	2	0	0	0	8
September	84	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Total	5337	117	0	0	0	0	18	0	0	25	31	0	1	9	0	0	7	0	1	11	14
Snake River																					
June	18	5	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
July	50	3	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0
August	164	3	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0
September	15	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Total	247	12	0	0	0	0	1	0	0	0	2	0	0	9	0	0	0	0	0	0	0
Grand Total																					
June	462	31	0	0	0	0	7	0	0	1	2	0	0	7	0	0	1	0	0	9	4
July	3483	23	0	0	0	0	6	0	0	1	5	0	0	2	0	0	4	0	1	2	2
August	1540	73	0	0	0	0	6	0	0	22	25	0	1	9	0	0	2	0	0	0	8
September	99	2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Total	5584	129	0	0	0	0	19	0	0	25	33	0	1	18	0	0	7	0	1	11	14

Appendix Table A-5. Monthly species composition of the combined dam- and boat-angling catch at Columbia River dams in 1996.

Dam and month	Percent NS ^a in total catch	Percent by-catch in total catch	Percent of total catch						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
Bonneville									
June	95.57	4.43	0.00	3.45	0.00	0.00	0.00	0.49	0.49
July	99.72	0.28	0.00	0.00	0.00	0.00	0.00	0.28	0.00
August	95.00	5.00	0.00	4.58	0.00	0.00	0.00	0.00	0.42
Total	98.01	1.99	0.00	1.55	0.00	0.00	0.00	0.26	0.17
The Dalles									
July	97.60	2.40	0.00	0.60	1.00	0.00	0.80	0.00	0.00
August	76.84	23.16	0.00	5.65	12.99	1.13	1.13	0.00	2.26
Total	92.16	7.84	0.00	1.92	4.14	0.30	0.89	0.00	0.59
John Day									
June	83.93	16.07	0.00	0.00	0.00	0.00	0.00	12.50	3.57
July	99.89	0.11	0.00	0.00	0.00	0.00	0.11	0.00	0.00
August	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	99.22	0.78	0.00	0.00	0.00	0.00	0.08	0.54	0.16
McNary									
June	95.68	4.32	0.00	0.54	1.08	1.08	0.54	0.54	0.54
July	99.61	0.39	0.00	0.23	0.00	0.00	0.00	0.00	0.16
August	97.49	2.51	0.00	1.03	0.29	0.74	0.00	0.00	0.44
September	98.48	1.52	0.00	1.52	0.00	0.00	0.00	0.00	0.00
Total	98.60	1.40	0.00	0.54	0.18	0.32	0.05	0.05	0.27

^anorthern squawfish

Appendix Table A-6. Monthly by-catch for the combined dam- and boat-angling by condition at release for Columbia River dams in 1996. 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			Catfish			Walleye			Shad	Other
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3		
Bonneville																					
June	203	9	-	-	-	-	7	0	0	0	0	0	0	-	-	-	-	-	-	1	1
July	715	2	-	-	-	-	0	0	0	0	0	0	0	-	-	-	-	-	-	2	0
August	240	12	-	-	-	-	1	0	0	10	0	0	0	-	-	-	-	-	-	0	1
Total	1158	23	-	-	-	-	8	0	0	10	0	0	0	-	-	-	-	-	-	3	2
The Dalles																					
July	499	12	-	-	-	-	3	-	-	-	5	0	0	0	0	0	4	-	-	-	-
August	177	41	-	-	-	-	4	-	-	-	22	0	1	2	0	0	2	-	-	-	-
Total	676	53	-	-	-	-	7	-	-	-	27	0	1	2	0	0	6	-	-	-	4
John Day																					
June	56	9	-	-	-	-	0	0	0	0	-	-	-	-	-	-	-	-	0	7	2
July	933	1	-	-	-	-	0	0	0	0	-	-	-	-	-	-	-	-	1	0	0
August	281	-	-	-	-	-	0	0	0	0	-	-	-	-	-	-	-	-	0	0	0
September	18	-	-	-	-	-	0	0	0	0	-	-	-	-	-	-	-	-	0	0	0
Total	1288	10	-	-	-	-	0	0	0	0	-	-	-	-	-	-	-	-	1	7	2
McNary																					
June	185	8	-	-	-	-	0	-	-	1	2	-	-	2	-	-	1	-	-	1	1
July	286	5	-	-	-	-	2	-	-	1	0	-	-	0	-	-	0	-	-	0	2
August	678	17	-	-	-	-	1	-	-	6	2	-	-	5	-	-	0	-	-	0	3
September	66	1	-	-	-	-	0	-	-	1	0	-	-	0	-	-	0	-	-	0	0
Total	2215	31	-	-	-	-	3	-	-	9	4	-	-	7	-	-	1	-	-	1	6

Appendix Table A-7. Monthly species composition of the combined dam- and boat-angling catch at Snake River dams in 1996.

Dam and month	Percent NS ^a in total catch	Percent by-catch in total catch	Percent of total catch						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
Ice Harbor									
July	0.00	100.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
Total	0.00	100.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
Lower Monumental									
July	66.67	33.33	0.00	0.00	0.00	33.33	0.00	0.00	0.00
August	96.15	3.85	0.00	0.00	0.00	3.85	0.00	0.00	0.00
Total	93.10	6.90	0.00	0.00	0.00	6.90	0.00	0.00	0.00
Little Goose									
June	75.00	25.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00
July	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	96.00	4.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00
Lower Granite									
June	50.00	50.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00
July	97.30	2.70	0.00	0.00	0.00	2.70	0.00	0.00	0.00
August	96.83	3.17	0.00	0.00	1.59	1.59	0.00	0.00	0.00
September	93.33	6.67	0.00	0.00	6.67	0.00	0.00	0.00	0.00
Total	95.73	4.27	0.00	0.00	1.71	2.56	0.00	0.00	0.00

^anorthern squawfish

Appendix Table A-8. Monthly by-catch for the combined dam- and boat-angling by condition at release for Snake River dams in 1996. 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.

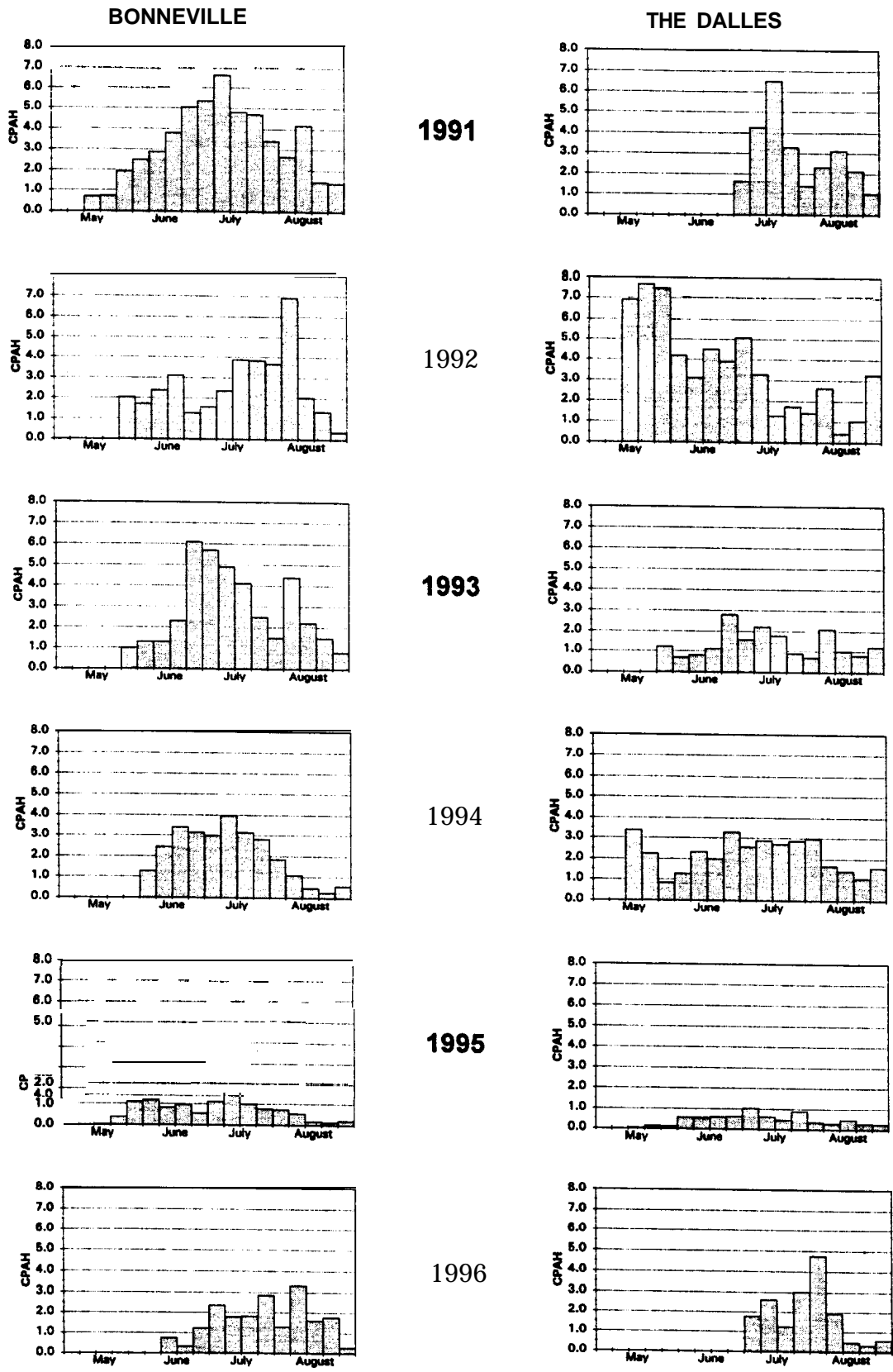
Dam and month	Total catch (all species)	Total by-catch	Salmonids			Sturgeon			Bass		Catfish		Walleye			Shad	Other
			2	3	L	2	3	L	2	3	2	3	1	2	3		
Ice Harbor																	
July	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Total	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Lower Monumental																	
July	3	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
August	26	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Total	29	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Little Goose																	
June	16	4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
July	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	100	4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
Lower Granite																	
June	2	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
July	37	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
August	63	2	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
September	15	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Total	117	5	0	0	0	0	0	0	2	0	0	3	0	0	0	0	0

APPENDIX B

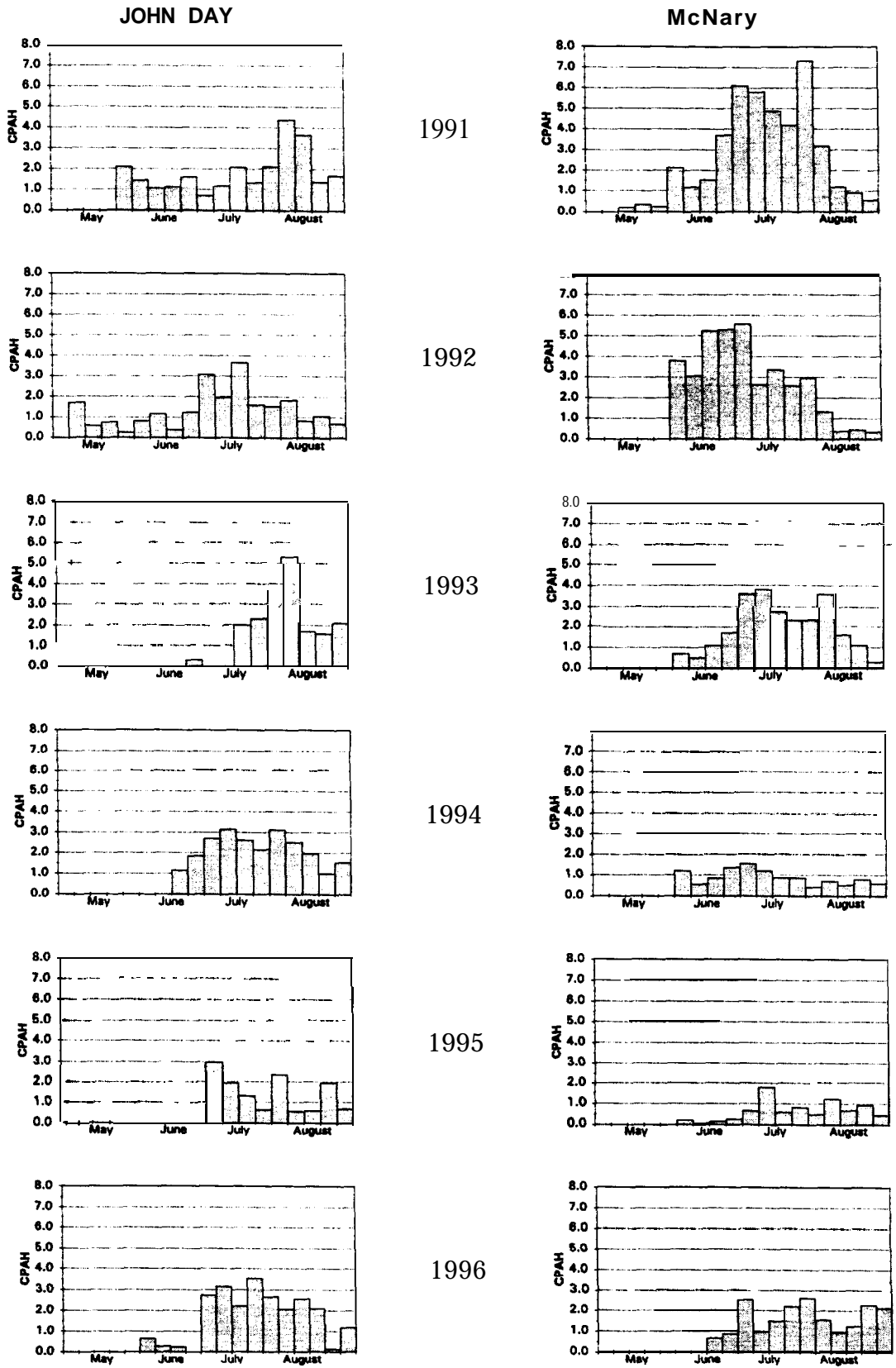
Among-Year Comparisons

Appendix Table B-1. Northern squawfish (NS) catch, effort, and catch per angler hour (CPAH) for hook-and-line angling at Columbia and Snake river dams, 1991-1996.

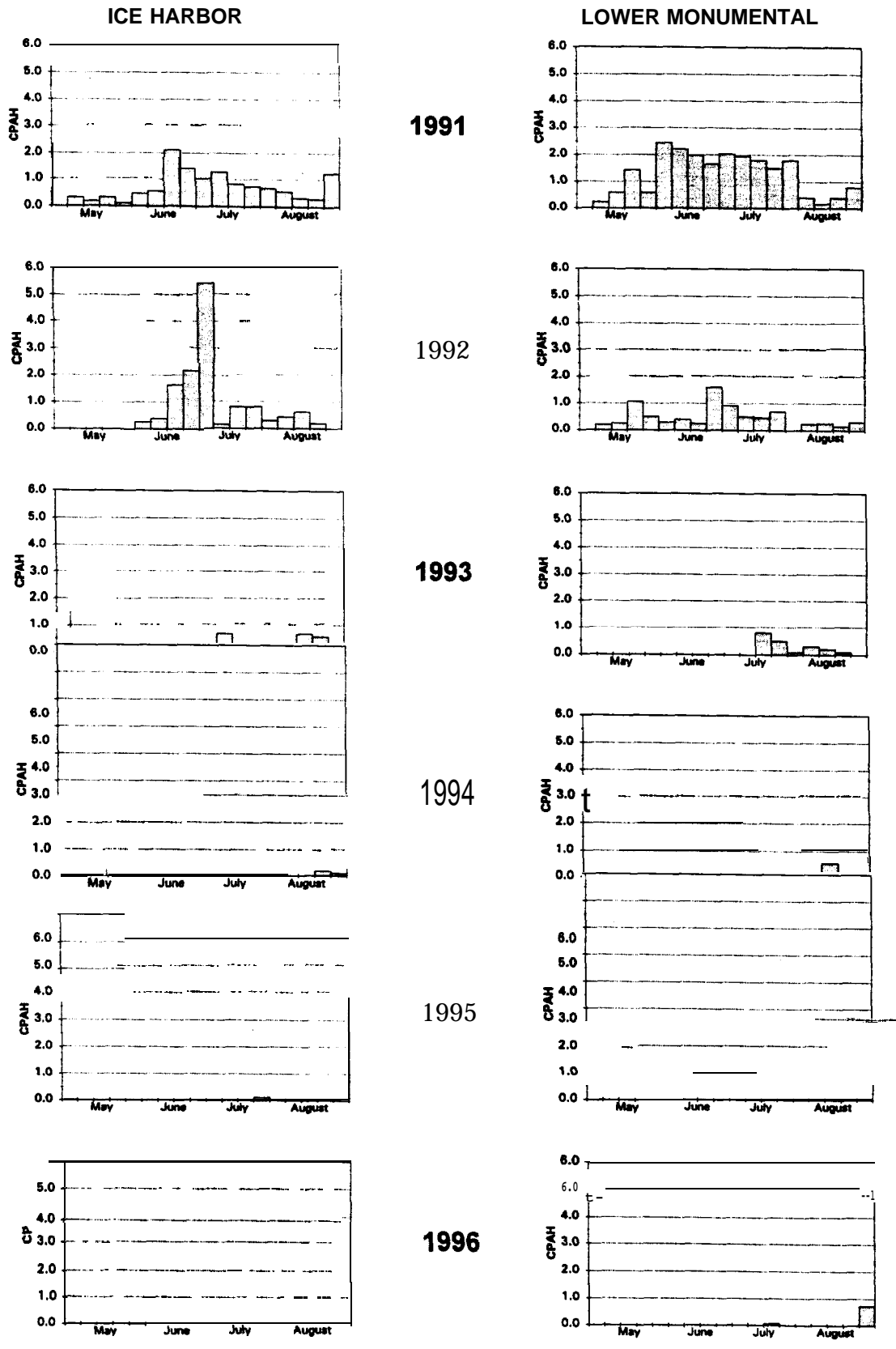
		COLUMBIA RIVER DAMS					SNAKE RIVER DAMS					GRAND TOTALS
		Bonneville	The Dalles	John Day	McNary	Season	Ice Harbor	Lower Mon.	Little Goose	Lower Granite	Season	
1991	NS	8131	3674	5004	8348	25157	1486	3313	4915	4480	14194	39351
	Effort	2621	1333	2816	3416	10186	2052	2471	2140	2448	9112	19298
	CPAH	3.1	2.8	1.8	2.4	2.5	0.7	1.3	2.3	1.8	1.6	2.0
1992	NS	4814	7561	3427	7297	23099	278	475	1664	2352	4769	27868
	Effort	1781	2496	2775	2523	9575	298	943	3062	2880	7183	16758
	CPAH	2.7	3.0	1.2	2.9	2.4	0.9	0.5	0.5	0.8	0.7	1.7
	NS	5836	2712	2509	5148	16205	122	105	100	678	1005	17210
	Effort	1991	1992	1561	2780	8324	404	396	378	734	1911	10235
	CPAH	2.9	1.4	1.6	1.9	1.9	0.3	0.3	0.3	0.9	0.5	1.7
1994	NS	5238	4393	3083	2556	15270	23	27	92	685	827	16097
	Effort	2232	2064	1649	2966	8910	141	55	203	692	1092	10002
	CPAH	2.3	2.1	1.9	0.9	1.7	0.2	0.5	0.5	1.0	0.8	1.6
1995	NS	2422	409	950	1002	4783	9	1	186	320	516	5299
	Effort	2823	920	777	1670	6190	80	38	183	798	1099	7289
	CPAH	0.9	0.4	1.2	0.6	0.8	0.1	0.0	1.0	0.4	0.5	0.7
1996	NS	1135	623	1278	2184	5220	0	27	96	112	235	5455
	Effort	693	338	618	1372	3022	56	75	206	307	645	3666
	CPAH	1.6	1.8	2.1	1.6	1.7	0.0	0.4	0.5	0.4	0.4	1.5
Total	NS	27576	19372	16251	26535	89734	1918	3948	7053	8627	21546	111280
	Effort	12141	9144	10196	14727	46207	3031	3979	6172	7859	21042	67249
	CPAH	2.3	2.1	1.6	1.8	1.9	0.6	1.0	1.1	1.1	1.0	1.7



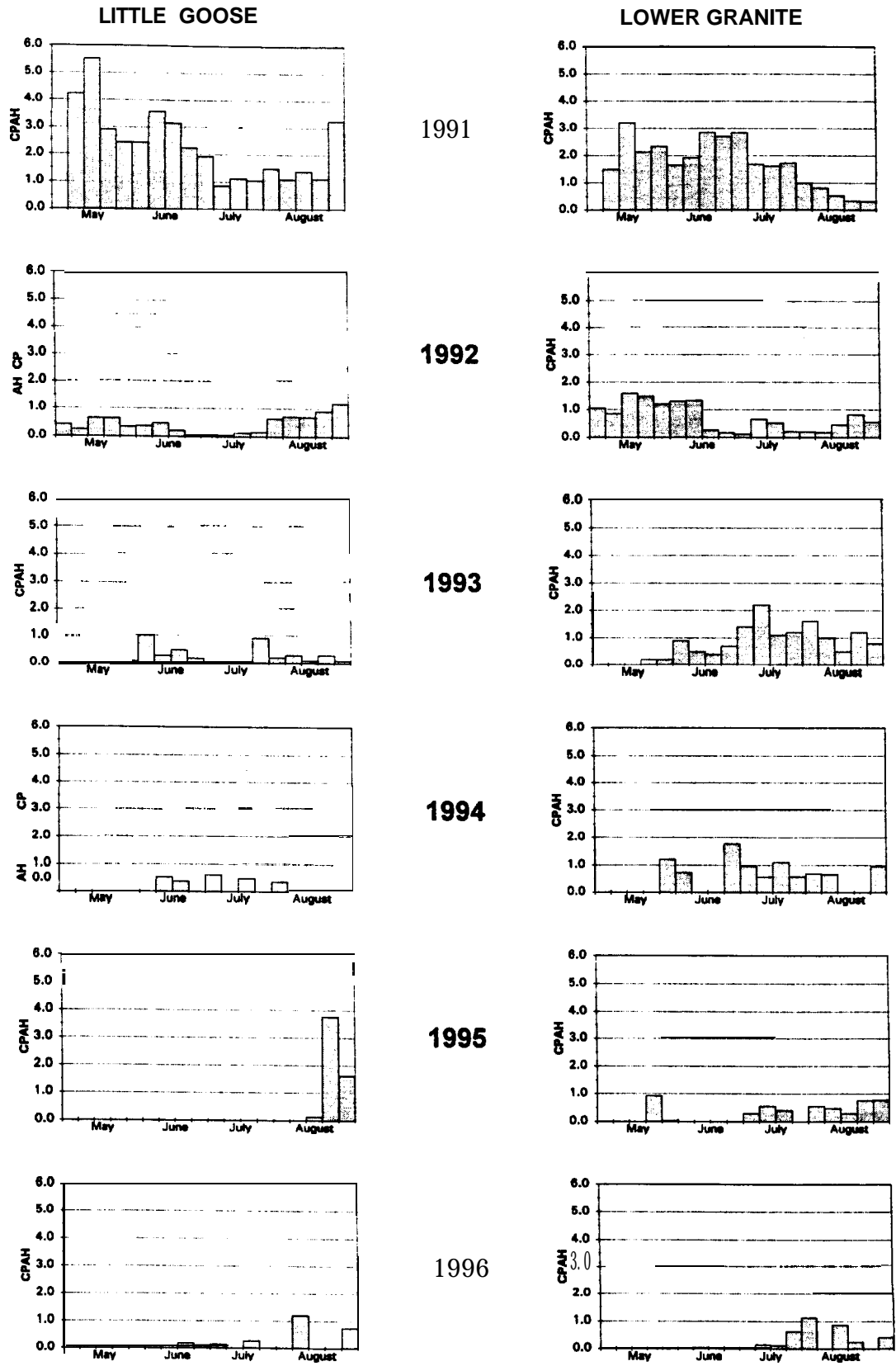
Appendix Figure B-1. Monthly northern squawfish catch per angler hour (CPAH) at Bonneville and The Dalles dams for 1991 through 1996.



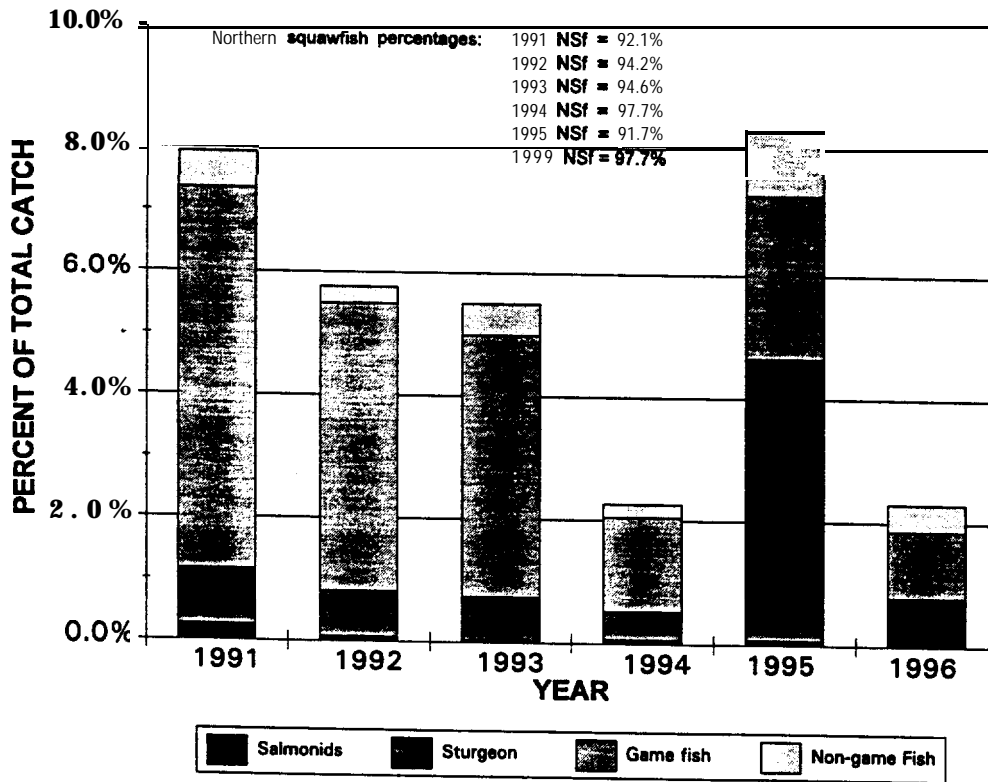
Appendix Figure B-2. Monthly northern squawfish catch per angler hour (CPAH) at John Day and McNary dams for 1991 through 1996.



Appendix Figure B-3. Monthly northern squawfish catch per angler hour (CPAH) at Ice Harbor and Lower Monumental dams for 1991 through 1996.



Appendix Figure B-4. Monthly northern squawfish catch per angler hour (CPAH) at Little Goose and Lower Granite dams for 1991 through 1996.



Appendix Figure B-S. Catch composition for hook-and-line angling at Columbia and Snake river dams, 1991 through 1996.

APPENDIX C

**Support of Visitor Services at
Bonneville Dam**

PROJECT OBJECTIVE

Our objectives were to (1) develop and present a program that increases public awareness of the projects implemented by Columbia River Inter-Tribal Fish Commission (CRITFC) and its member tribes as part of the Columbia River Northern Squawfish Management Program (NSMP), and (2) inform the public about tribal involvement in salmon management, in general.

PROJECT DESCRIPTION

The program, approximately 25 minutes long, featured a video, slide show, various exhibits, and informational hand-outs. It was presented at the visitor center at Bonneville Dam, mostly on weekends from July through August. The presentation was given by Scherri Sotomish, a Nez Perce Tribal member who has been working as a fishery technician on this project for three years.

The 8-minute video described a site-specific gillnet fishery conducted by CRITFC and its member tribes which removed bigmouth minnows (a.k.a. northern squawfish) from areas where they concentrated to feed on hatchery-released juvenile salmonids. The video was shot on a night following a hatchery release at the Klickitat River in 1994. The video footage showed (1) how gillnets are set to catch bigmouth minnows, (2) large numbers of predator-size bigmouth minnows being removed from gillnets, and (3) freshly eaten juvenile salmonids in the guts of bigmouth minnows dissected to determine diet composition. The video also contained interviews with tribal technicians and student volunteers that worked together on site-specific gillnetting crews. This and other footage helped provide a historical, cultural, and personal perspective on the problems caused by bigmouth minnow predation and other causes for declining salmon runs.

A slide show described a hook-and-line fishery conducted by the tribes which removed bigmouth minnows from areas near dams on the lower Columbia and Snake rivers where predation rates on juvenile salmonids are high. The slide presentation described the sites where controlled dam-based angling occurs, the angling techniques and baits used to catch bigmouth minnows, and the volunteer angling program that utilizes volunteers from local sportsfishing groups to assist tribal technicians at Bonneville Dam. In addition, the presentation included information about management activities proposed by the tribes to increase salmon survival, specifically a project that investigates avian predation on juvenile salmonids and the tribal salmon restoration plan entitled, *Wy-Kan-Ush-Mi Wa-Kish- Wit*, Spirit of the Salmon: The Columbia River Anadromous Fish Restoration Plan of the Nez Perce, Umatilla, Warm Springs, and Yakama tribes.

The exhibits on display at the Bonneville Dam Visitors Center included a taxidermic display showing bigmouth minnows preying on salmon smolts and a sample of commonly used

baits to catch bigmouth minnows. Informational handouts were made available, as was a sign-up sheet for visitors attending the presentation. The informational handouts included:

- a pamphlet on the Northern Squawfish Sport-Reward Fishery (conducted by Washington Department of Fish and Wildlife as part of the Columbia River Northern Squawfish Management Program)
- a pamphlet on CRITFE (the Columbia River Inter-Tribal Fisheries Enforcement)
- CRITFC annual reports for 1995 and 1996
- *Wana Chinook Tymoo* (a CRITFC publication dedicated to cultural- and fishery-related issues)
- an executive summary of the tribal salmon restoration plan entitled, *Wy-Kan-Ush-Mi Wa-Kish- Wit, Spirit of the Salmon: The Columbia River Anadromous Fish Restoration Plan of the Nez Perce, Umatilla, Warm Springs, and Yakama Tribes.*

RESULTS

Morning and afternoon presentations were given from July through August (Appendix Table C-1). A total of 45 presentations were made with 640 people attending, for an average of 14 visitors per presentation. To establish what time of day drew bigger audiences, we compared the number of visitors per program during mornings and afternoons (Appendix Table C-1). The 15 morning programs were attended by 184 people (approximately 12 visitors per program), whereas 456 visitors attended the 30 afternoon programs (approximately 15 visitors per program). These figures suggest that, on average, afternoon programs were attended by bigger audiences.

Appendix Table C-1. Weekly counts of the number of presentations and visitors, by morning and afternoon sessions.

Week	Morning		Afternoon		Total	
	# programs	# visitors	# programs	If visitors	# programs	# visitors
July 14 - July 20	1	4	3	30	4	34
July 21 - July 27	0	0	3	32	3	32
July 28 - August 3	0	0	1	12	1	12
August 4 - August 10	2	11	7	103	9	114
August 11 - August 17	3	38	15	232	18	270
August 18 - August 24	1	19	6	82	7	101
August 25 - August 31	1	41	2	36	3	77
Total	8	113	37	527	45	640

From the sign-up sheet for visitors interested in receiving copies of *Wana Chinook Tymoo*, we were able to get an overview of the state or country of origin of visitors attending the presentations (Appendix Table C-2). Of the 317 people/groups that signed up, 119 (37%) were from the Pacific Northwest (Oregon, Washington, and Idaho), 183 (58%) were from the other 47 states, 15 (5%) were international visitors (e.g., Poland, France, Israel). This indicates that this program was successful in reaching a wide audience living both inside and outside the Columbia River Basin.

Appendix Table C-2. Geographical distribution of visitors that signed up to receive *the Wana Chinook Tymoo*.

Week	United States			Total
	Oregon, Washington, Idaho	Other 47 states	International	
July 14 - July 20	13	32	0	45
July 21 - July 27	14	15	1	30
July 28 -August 3	11	22	3	36
August 4 - August 10	16	32	4	52
August 11 -August 17	29	34	4	67
August 18 - August 24	16	25	1	42
August 25 -August 31	20	23	2	45
Total	119	183	15	317

Based on feedback provided by visitors attending presentations and rangers working for the U.S. Army Corps of Engineers at the Bonneville Dam visitors center, this project was successful in educating the public about (1) the plight of Columbia River salmon and (2) the NSMP and other tribal fish-management programs implemented to increase salmon survival. Commonly asked questions by visitors were:

1. Are bigmouth minnows edible?
2. What is being done with the bigmouth minnows once they are caught?
3. How significant is the bigmouth minnow problem compared to other sources salmon mortality?
4. How can someone volunteer to help on this project?
5. How do you know the NSMP is working?

RECOMMENDATIONS FOR 1997

1. Continue to give informative programs on the efforts by CRITFC and its member tribes to decrease predation on juvenile salmonids by bigmouth minnows.
2. Continue to improve presentation methods and revise the presentation **materials as** appropriate.
3. Create a pamphlet containing information about all the management fisheries that make up the NSMP and include results from previous years.
4. Continue to keep track of the number of talks given and the number of visitors in attendance (including time of day) and use that information to schedule talks to reach the widest audience possible.
5. Improve on efforts to keep track of where visitors are from by having a guest book at the entrance to the auditorium where the presentations are made.
6. Give talks at other dams and to other interested organizations or groups, such as sportsfishing groups, public schools, and perhaps local merchants that sell fishing supplies.

Report D

**Site-Specific Gillnetting for Northern Squawfish Concentrated to
Feed on Hatchery-Released Juvenile Salmonids in the
Lower Columbia River in 1996**

Prepared by

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Report D-97

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ABSTRACT

Field crews used small-meshed gill nets to catch northern squawfish *Ptychocheilus oregonensis* from areas where they concentrate to feed on hatchery-released juvenile salmonids *Oncorhynchus* spp. in the lower Columbia River from March through June, 1996. A total of 6,166 predator-size (≥ 250 mm fork length) northern squawfish was caught in 1996, which was 65% of the total gill-net catch the previous year. The catch per net hour (CPNH) for site-specific gillnetting was 2.1 in 1996, compared to 3.9 in 1995. In 1996, most (94%) fish were caught at locations in Bonneville Pool, as in the previous two years. The mouth of the Klickitat River continues to be the most productive fishing location in terms of total gillnet catch (3,585), despite a decline in CPNH from 5.7 in 1995 to 2.4 in 1996. Outside Bonneville Pool, the highest catch and CPNH were at the Deschutes River, with a gillnet catch of 232 predator-size northern squawfish and a CPNH of 1.9. Once again, gill nets caught large fish (average fork length = 408.2 mm) relative to other management fisheries.

The total incidental catch was 7,324 fish, with suckers *Catostomus* spp. being the most common (72%) of the incidentally caught species. Salmonid by-catch (216 adults; 19 juveniles) was minimal, despite high concentrations of salmonids in the sampling areas. 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 (NSMP) was implemented to increase survival of out-migrating juvenile salmonids *Oncorhynchus* spp. by reducing predation by northern squawfish *Ptychocheilus oregonensis* in the lower Columbia and Snake rivers. The program goal is to sustain a 10-20% annual exploitation rate on predator-size (≥ 250 mm fork length; Vigg et al. 1991) northern squawfish, which over several years may result in a 50% or greater reduction in predation on juvenile salmonids (Rieman and Beamesderfer 1990). Various management fisheries were implemented as part of the NSMP, one of which was a tribal site-specific gill-net fishery.

Northern squawfish can be effectively removed from areas where hatchery-reared juvenile salmonids are released in the spring using small-meshed gill nets (Collis et al. 1995a; Collis et al. 1995b; Collis et al. 1996). Over the past three years, site-specific gill-net crews have caught over 24,000 predator-size northern squawfish at various locations in the lower Columbia and Snake rivers.

In 1996, the Columbia River Inter-Tribal Fish Commission (CRITFC) and its member tribes continued to investigate the step-wise implementation of a site-specific fishery using small-mesh gill nets to catch northern squawfish concentrated to feed on juvenile salmonids released from hatcheries. Our objectives in the current study were to 1) focus removal efforts at sampling locations that were productive in previous years, 2) investigate additional locations where northern squawfish might concentrate to feed on hatchery-released juvenile salmonids, and 3) continue to develop methods that increase our catch of predator-size northern squawfish while further reducing impacts to salmonids.

METHODS

Study Area

In 1996, the site-specific gillnet fishery was conducted at locations' between the mouth of the Kalama River and Priest Rapids Dam tailrace on the Columbia River (Figures 1 and 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.

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

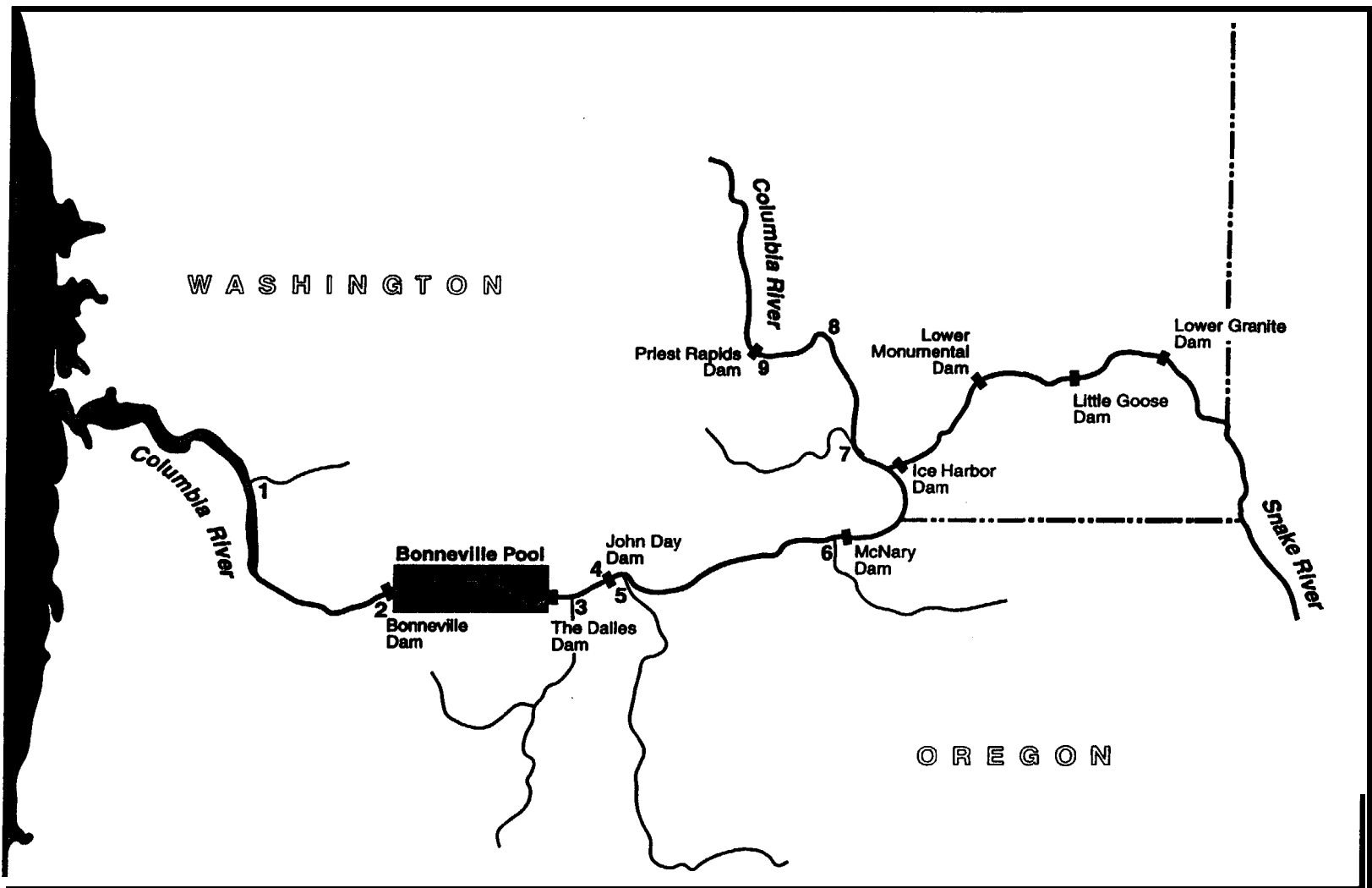


Figure 1. Sampling locations above and below Bonneville Pool (see Figure 2 for sampling locations in Bonneville Pool), 1996. Locations are: 1 = Kalama River; 2 = Tanner Creek; 3 = Deschutes River; 4 = John Day Dam; 5 = John Day River; 6 = Umatilla River; 7 = Yakima River; 8 = White Bluffs; and 9 = Priest Rapids.

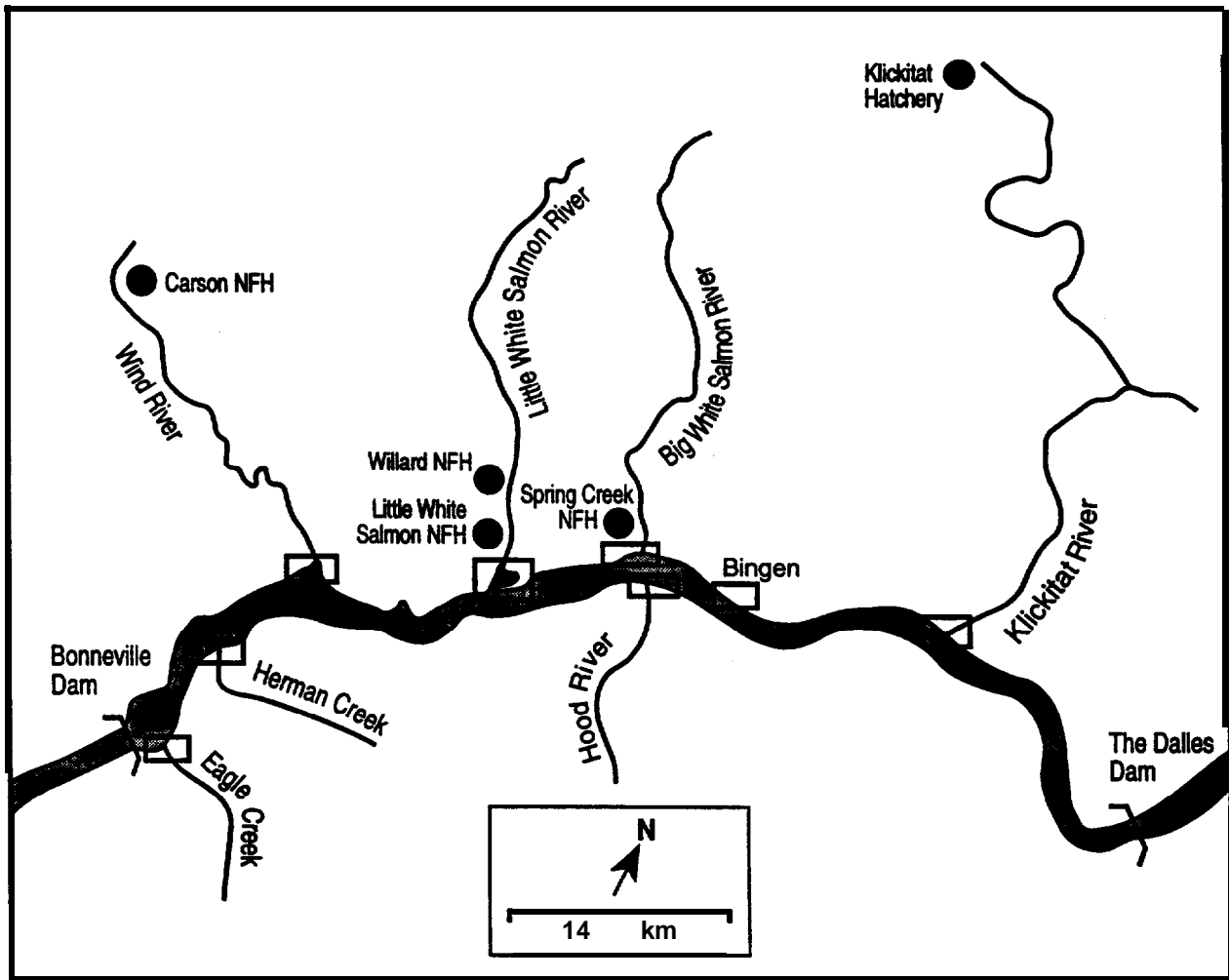


Figure 2. Sampling locations (shown in boxes) in Bonneville Pool, 1996. Locations are (left to right) Eagle Creek, Herman Creek, Wind River, Drano Lake, Spring Creek, Hood River, Bingen Marina, and Klickitat River.

Crew Scheduling

The Fish Passage Center and hatchery managers provided hatchery-release information used in determining crew schedules. Criteria used for crew scheduling were; 1) date and location of hatchery release, 2) estimated time of arrival of the released fish at the sampling location, 3) size and number of fish released, 4) previous success in catching northern squawfish, 5) incidental catch rate of salmonids at a sampling location, 6) site-specific hydrologic conditions, and 7) 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 1996, four boat crews sampled from March 14 through June 30. Crews generally worked at a location from one hour after sunset to one hour after sunrise. Crews often moved to another location the same night when 1) fishing success was lower than in recent nights at a nearby location or 2) operational criteria (Collis et al. 1995b; see below) established to limit salmonid catch were reached.

Technicians were assisted by student volunteers enrolled in a cooperative education program at Mt. Hood Community College. In 1996, five volunteers worked one night per week throughout the season for college credit and work experience in Fisheries Science.

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 1-2 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 back into the river. Operational criteria established to minimize potential impacts to salmonids were essentially the same as those used the previous two years (Collis et al. 1996; Collis et. al 1995b).

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-size (2250 mm fork length) northern squawfish. We compared catch and CPNH for different areas and time periods. Means are expressed as $X \pm SE$.

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 tin clips. Adults were identified to species. Specific notes on condition were recorded 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.

RESULTS & DISCUSSION

Northern Squawfish Catch

In 1996, we caught a total of 6,209 northern squawfish, the majority (99.3%) of which were predator-size (Table 1). Overall, gill nets were fished for 2,878 net-hours and caught 6,166 predator-size northern squawfish, for a CPNH of 2.1 fish/hr. The seasonal catch rate declined from 1995 (CPNH = 3.9; Collis et al. 1996), largely due to a decrease in harvest at the Klickitat River (see discussion below). Among-year comparisons of catch and effort for site-specific gillnetting are provided in Appendix A.

Gill-netting effort was distributed in pools or reaches (Figure 3) and at locations (Table 1) according to the CPNH in that area. As in 1995, the highest catch (5,822) and CPNH (2.3) was in Bonneville Pool as compared to the other locations sampled (Figure 3). Of the remaining pools, catch and CPNH was highest in The Dalles Pool (Figure 3), with a catch of 232 northern squawfish and a CPNH of 1.9. The productivity (as measured by total catch) of Bonneville and The Dalles pools relative to other areas was largely due to the productivity of the Klickitat River and the Deschutes River, respectively.

As in previous years, the mouth of the Klickitat River was the most productive location in terms of total gillnet catch (3,585); however, catch rate has declined there for two consecutive years (1994: CPNH = 10.1; 1995: CPNH = 5.7; 1996: CPNH = 2.4). Over the past three years, more than 17,000 northern squawfish have been removed from the mouth of the Klickitat River, which may, with harvests from other program fisheries in Bonneville Pool, help explain the decline in catch rate at that location. Furthermore, a low pool elevation in 1995 prevented us from fishing the most productive sites, and high, turbid water conditions in 1996 likely affected both the distribution of northern squawfish and our ability to fish nets effectively at that location.

Table 1. Northern squawfish (NS) catch, effort, and catch per net hour (CPNH) for the Site-specific Gillnet Fishery on the Columbia River in 1996.

Location	Effort (net hours)	Northern squawfish catch		CPNH ^a
		(<250 mm)	(≥250 mm)	
Wind River	361.6	2	924	2.6
Spring Creek	63.7	1	165	2.6
Klickitat River	1,484.0	27	3,585	2.4
Drano Lake	402.9	9	833	2.1
Deschutes River	121.5	2	232	1.9
Herman Creek	28.7	0	48	1.7
Kalama River	13.6	2	21	1.5
Bingen Marina	191.6	0	221	1.2
Eagle Creek	18.5	0	20	1.1
John Day River	35.2	0	33	0.9
Umatilla River	30.2	0	23	0.8
Tanner Creek	20.9	0	17	0.8
Hood River	33.0	0	26	0.8
White Bluffs	15.0	0	6	0.4
Priest Rapids	9.5	0	4	0.4
John Day Dam	26.0	0	7	0.3
Yakima River	22.5	0	1	0.0
Totals	2878.4	43	6,166	2.1

^a CPNH for NS ≥250 mm fork length

The Deschutes River was the most productive (northern squawfish catch = 232; CPNH = 1.9) location fished outside of Bonneville Pool (Table 1). Unlike previous years, Snake River locations were not sampled in 1996, because they had been relatively unproductive in previous years and were expensive (i.e., costs per northern squawfish removed) areas in which to work.

As in previous years, the highest monthly catch and effort during 1996 were in May (Figure 4). Catch rates increased slightly throughout the season, reaching a high of 2.5 in June (Figure 4). In 1995, catch rates increased from March to April and progressively declined thereafter, which directly corresponded with the number of hatchery fish released each month (Collis et al. 1996). In 1996 we observed that catch rates did not show this relationship, but seemed to be indirectly related to river turbidity and flow, which was unusually high at most locations at the onset of sampling and showed a gradual and progressive decline throughout the sampling season.

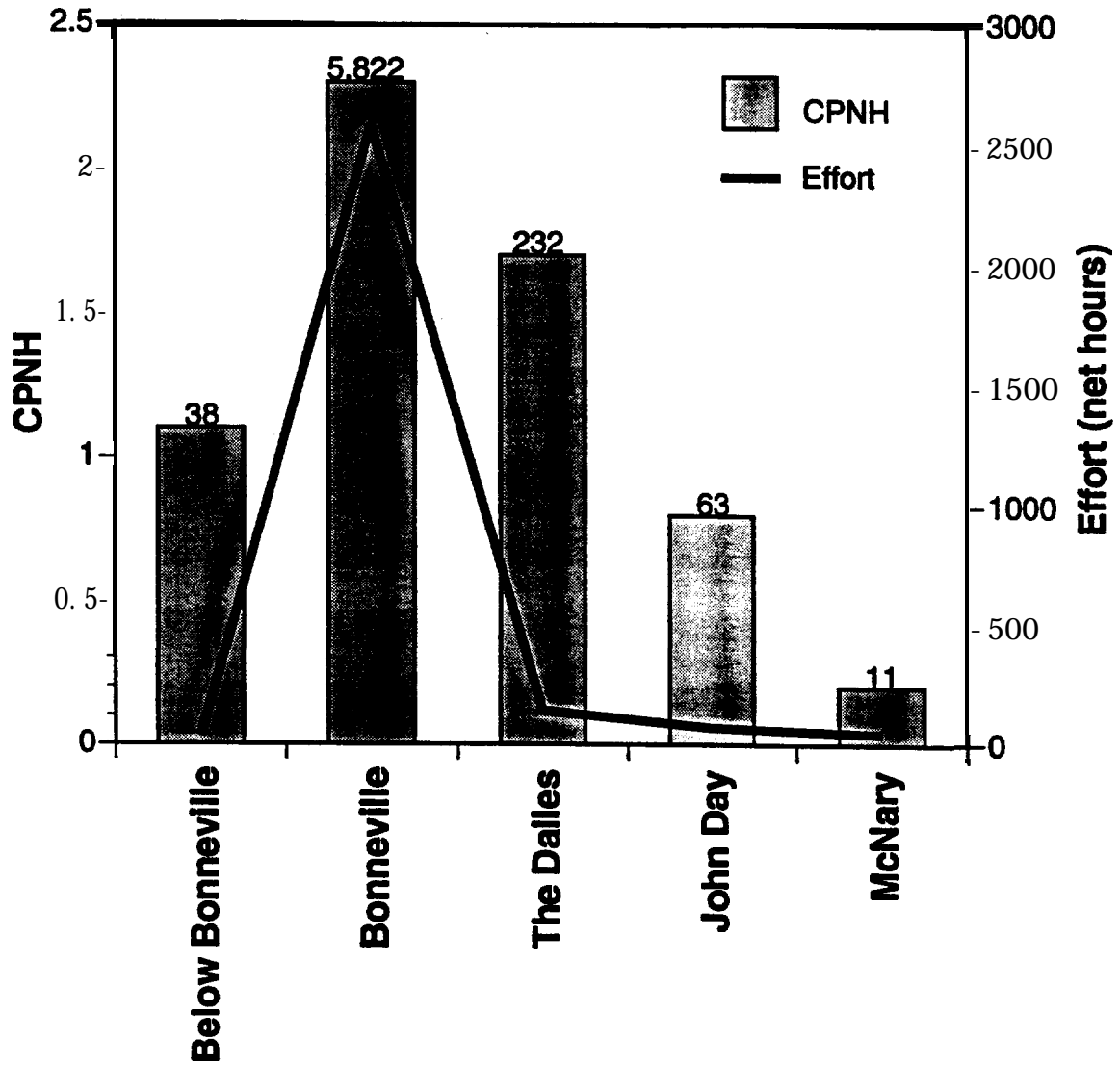


Figure 3. Northern squaw-fish catch (values above bars), effort, and catch per net hour (CPNH) on the Columbia River below Bonneville Dam and in lower Columbia River reservoirs, 1996.

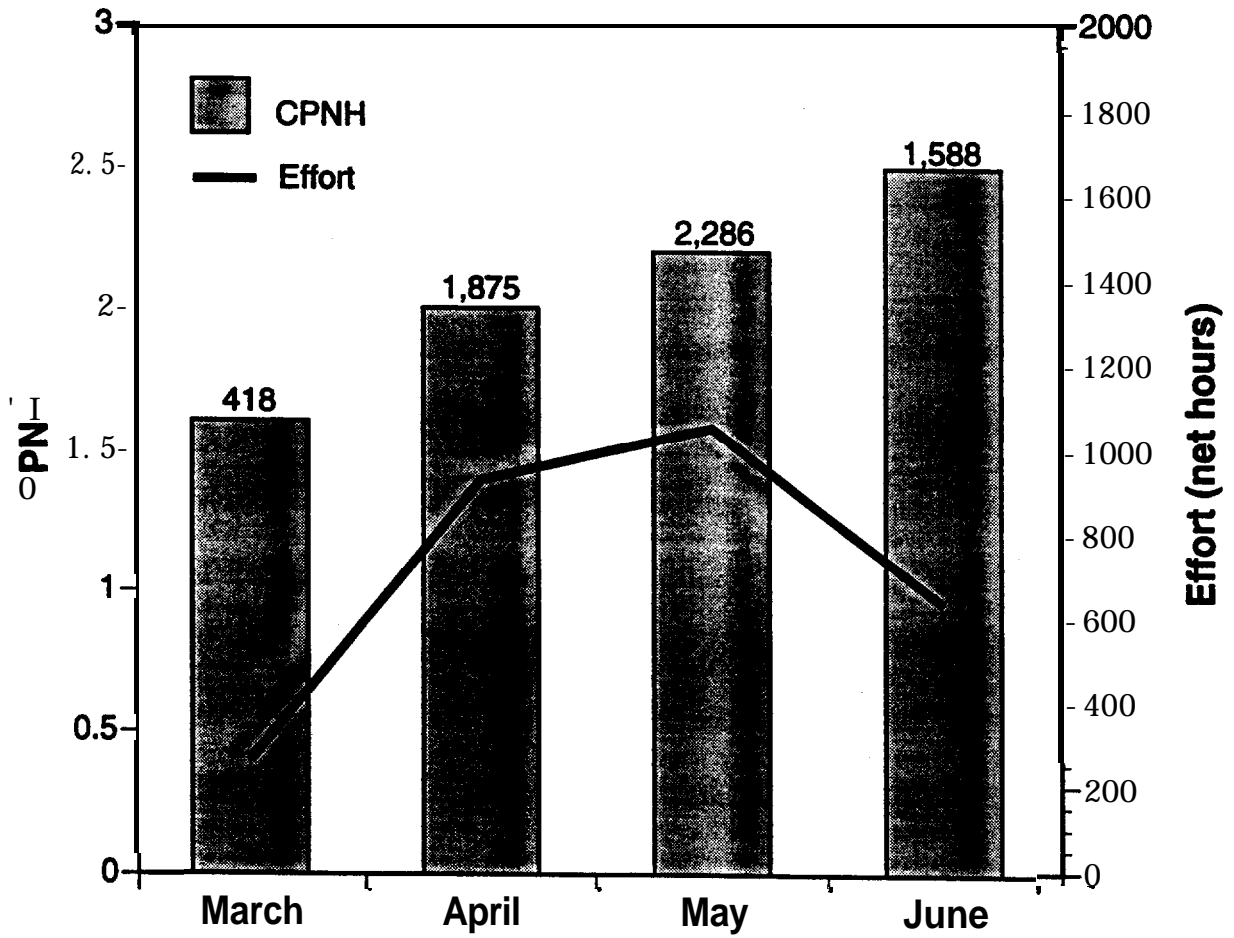


Figure 4. Northern squawfish catch (values above bars), effort, and catch per net hour (CPNH) by month, 1996.

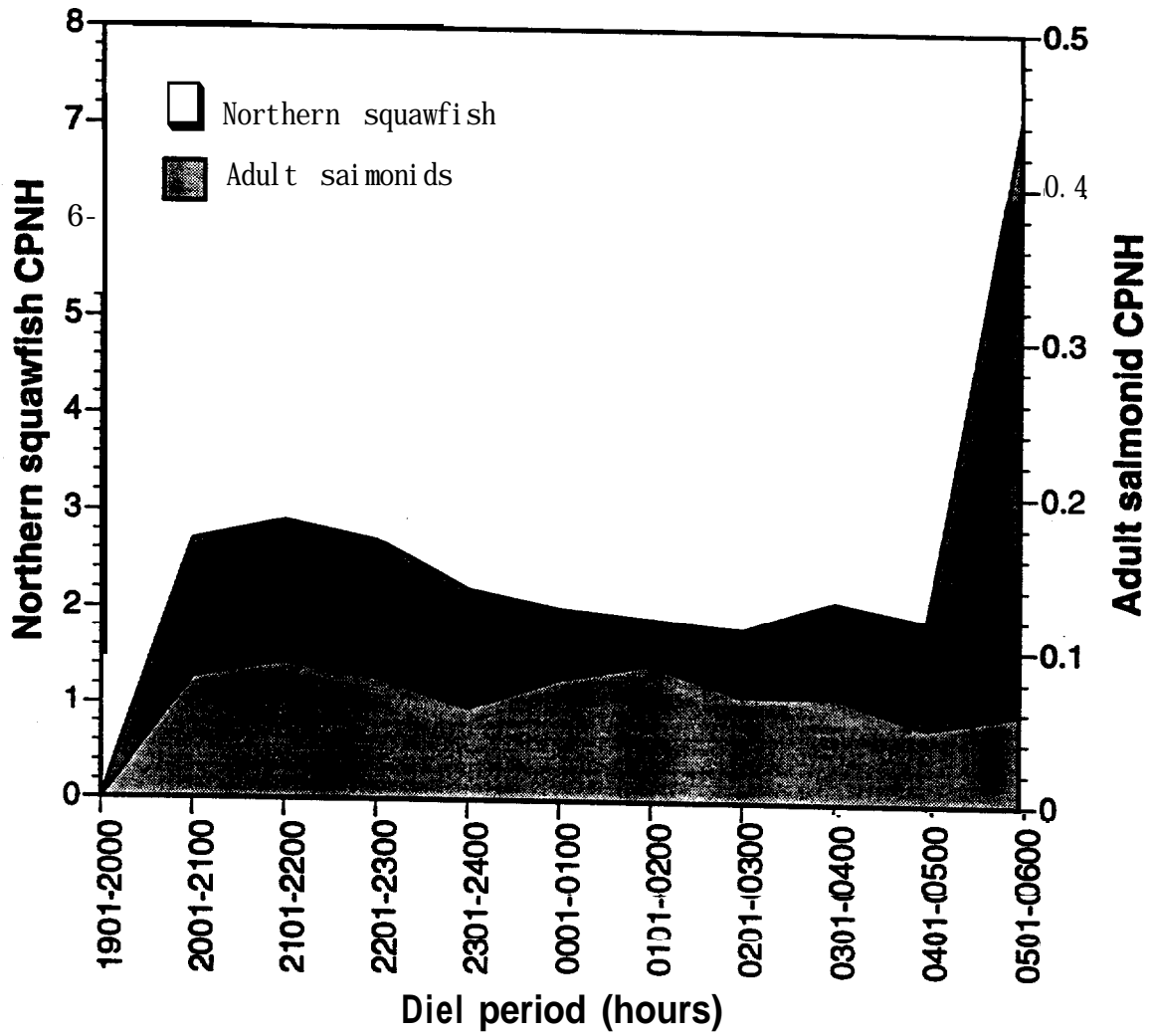


Figure 5. Catch per net hour (CPNH) of northern squawfish and adult salmonids in gill nets during different diel periods in 1996.

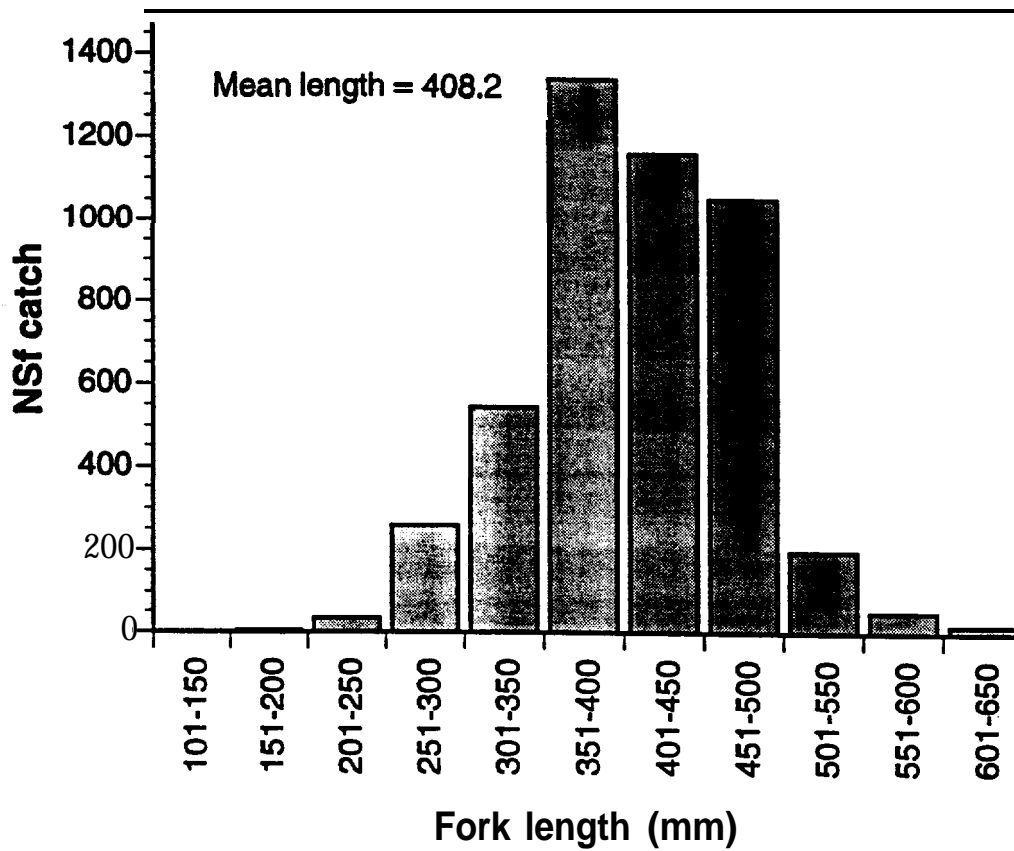


Figure 6. Size distribution of northern squawfish (NS) caught in gill nets in the Columbia River in 1996.

Catch rates of northern squawfish increased from 1900 to 2 100 and remained relatively constant until near dawn (0500), at which time CPNH increased three-fold to 7.1 northern squawfish per net hour (Figure 5). This diurnal pattern was unlike the patterns observed the previous two years (Collis et al. 1996; Collis et al. 1995b), when catch rate appeared to correspond with diel fluctuations in juvenile salmonid densities, as noted elsewhere (Mains and Smith 1964). High turbidity in 1996 may have increased juvenile salmonid migration rates during daylight hours (Northcote 1984) which may have affected foraging activity and catchability of northern squawfish at dawn.

In 1996, site-specific gillnetting caught larger northern squawfish ($X = 408.2 \pm 1.0$ mm; Figure 6) than other management fisheries (D. Ward, ODFW, personal communication), as was the case in previous years (Zimmerman et al. in press; Knutsen et al. 1995).

Incidental Catch

In 1996, 7,324 fish (54% of the total catch) were incidentally caught in gill nets (Table 2). As in previous years, suckers (*Catostomus* spp.) were the most common incidentally caught species, comprising 71% and 39% of the total and incidental catch in 1996, respectively (Table 2; Figure 7; Collis et al. 1994; Collis et al. 1995a, Collis et al. 1996).

We caught 235 salmonids (2% of total catch) in 1996 (Table 3). The salmonid catch increased 17% from the salmonid catch (196) the previous year (Collis et al. 1996). The majority (92%) of the salmonid gillnet catch was adults, 82% of which were likely to survive at release (Table D-3). Of the total adult salmonid catch, 51% were chinook salmon *Oncorhynchus tshawytscha* and 41% were steelhead *O. mykiss* (Table 3).

Catch rates of adult salmonids remained relatively constant for different diel periods in 1996 (Figure 5). In previous years, catch rates of adult salmonids were constant until dawn, at which time they dropped to near zero (Collis et al. 1996; Collis et al. 1995b). Perhaps catch rates did not decline at dawn in 1996 because high turbidity affected the ability of adult salmonids to detect and avoid gill nets.

Table 2. Species composition for the Site-specific Gillnet Fishery in 1996.

Species	Total
Northern squawfish <i>Ptychocheilus oregonensis</i>	6,209 ^a
Sucker <i>Catostomus</i> spp.	5,257
White sturgeon <i>Acipenser transmontanus</i>	581
Peamouth <i>Mylocheilus caurinus</i>	297
Salmonids <i>Oncorhynchus</i> spp.	235
Walleye <i>Stizostedion vitreum</i>	193
Bass <i>Micropterus</i> spp.	179
Common carp <i>Cyprinus carpio</i>	154
American shad <i>Alosa sapidissima</i>	128
Channel catfish <i>Ictalurus punctatus</i>	109
Unidentified ^b	105
Chiselmouth <i>Acrocheilus alutaceus</i>	57
Mountain whitefish <i>Prosopium williamsoni</i>	49
Yellow perch <i>Perca flavescens</i>	14
Crappie <i>Pomoxis</i> spp.	6
Bluegill <i>Lepomis macrochirus</i>	2
Brown trout <i>Salmo trutta</i>	1
Total	13,576

^a Includes northern squawfish <250 mm.

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

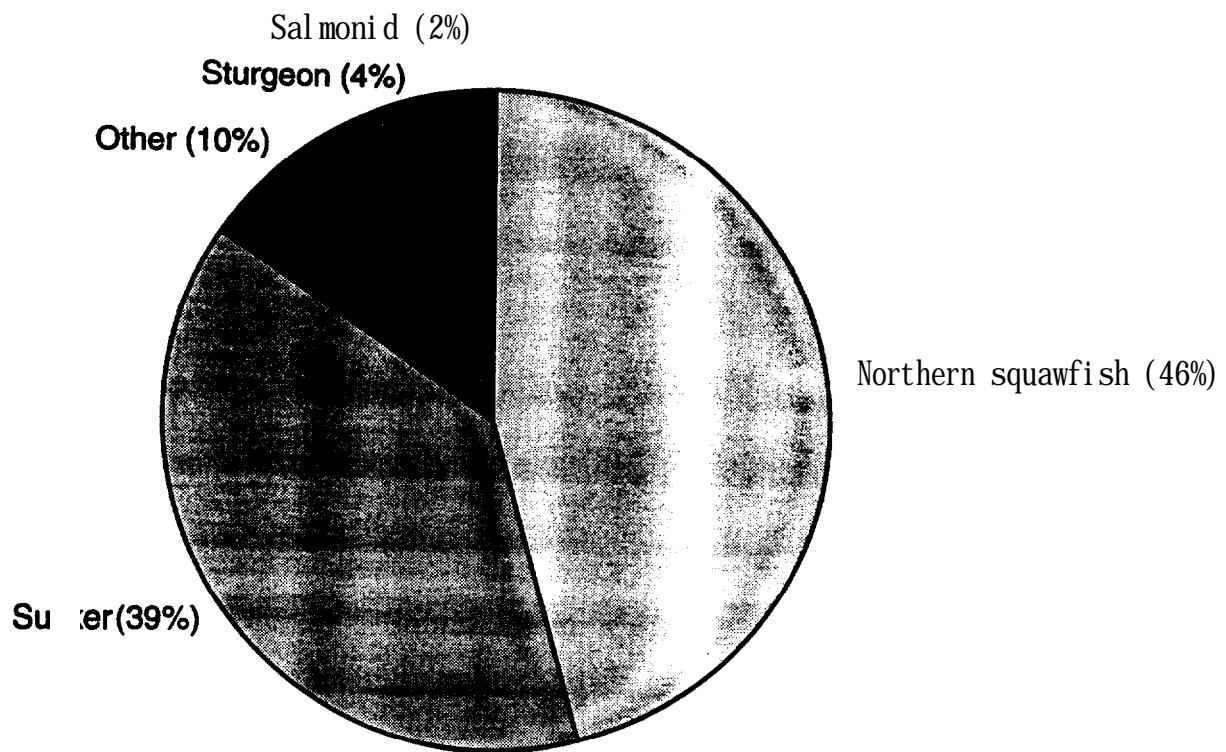


Figure 7. Percent of total catch of northern squawfish and incidentally caught species for gill nets in 1996.

Table 3. Salmonid by-catch by species and condition at release for the Site-specific Gillnet Fishery in 1996. 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.

Location	Adult salmonids												Juv. salmonids ^a		
	Chinook			Steelhead			Sockeye			Other ^a			1	2	3
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Kalama River	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0
Tanner Creek	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Eagle Creek	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Herman Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind River	27	0	0	4	0	3	0	0	0	1	0	0	1	0	0
Drano Lake	40	2	0	13	1	0	0	0	0	1	0	1	0	0	0
Spring Creek	7	1	0	2	0	0	0	0	0	3	0	0	0	0	1
Hood River	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bingen Marina	0	0	0	0	0	0	0	0	0	2	0	2	1	0	0
Klickitat River	24	0	2	42	3	3	0	0	0	1	1	1	3	0	2
Deschutes River	3	0	0	1	0	0	0	0	0	4	0	0	0	0	0
John Day Dam	0	0	0	3	0	1	0	0	0	0	0	0	0	0	1
John Day River	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
Umatilla River	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
White Bluffs	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Yakima River	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
Total						8	1	0	0	12	1	4	15	0	4

^a Not identified to species

RECOMMENDATIONS FOR 1997

- 1. Continue to focus effort at the most productive times and locations as determined in-season and in previous years.**

Based on three years of gillnetting, the lower Columbia River (particularly Bonneville Pool) is the most productive area to conduct site-specific gillnetting for northern squawfish. We will continue to focus our effort there and monitor in-season catch rates in order to schedule crews at the most productive times and locations.

- 2. Investigate new locations where we have evidence of potentially high catch rates of northern squawfish.**

Although most of our effort will be focused at locations previously sampled, we plan to investigate some new locations in 1997. These investigations will be based on in-season information on northern squawfish distribution and abundance available from Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, and other sources.

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

Northern squawfish have been successfully harvested 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 d&netting to develop more productive and efficient removal methods.

- 4. Continue to identify ways to reduce by-catch 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 by-catch of salmonids, particularly listed stocks.

- 5. Continue to recruit and hire experienced technicians and provide them with in-season information to help improve their effectiveness.**

Technician ability and experience are important factors in catch success. We will attempt to hire experienced technicians and to provide them with in-season information to maximize productivity. We will encourage information exchange among crews by scheduling different crews to work together and by organizing in-season meetings.

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APPENDIX A

Among-Year Comparisons

Appendix Table A-1. Northern squawfish (NS) catch, effort, and catch per net hour (CPNH) for the Site-specific Gill-net Fishery, 1993-1996.

		COLUMBIA RIVER POOLS						SNAKE RIVER POOLS					GRAND TOTALS
		Below Bonneville	Bonneville	The Dalles	John Day	McNary	Season	Ice Harbor	Lower Monumental	Little Goose	Lower Granite	Season	
1993	NS	--	1772	--	--	--	1772	--	--	--	--	--	1772
	Effort (h)	--	394	--	--	--	394	--	--	--	--	--	394
	CPUE	--	4.5	--	--	--	4.5	--	--	--	--	--	4.5
1994	NS	--	8890	5	42	10	8947	--	5	--	72	77	9024
	Effort (h)	--	1195	18	43	67	1323	--	17	--	102	120	1442
	CPUE	--	7.4	0.3	1.0	0.2	6.8	--	0.3	--	0.7	0.6	6.3
1995	NS	263	8668	25	136	57	9149	231	22	22	60	335	9484
	Effort (h)	166	1844	19	139	45	2214	112	26	13	66	217	2431
	CPUE	1.6	4.7	1.3	1.0	1.3	4.1	2.1	0.8	1.7	0.9	1.5	3.9
1996	NS	38	5822	232	63	11	6166	--	--	--	--	--	6166
	Effort (h)	35	2584	121	91	47	2878	--	--	--	--	--	2878
	CPUE	1.1	2.3	1.9	0.7	0.2	2.1	--	--	--	--	--	2.1
Total	NS	301	25152	262	241	78	26034	231	27	22	132	412	26446
	Effort (h)	201	6018	158	274	158	6809	112	43	13	168	337	7146
	CPUE	1.5	4.2	1.7	0.9	0.5	3.8	2.1	0.6	1.7	0.8	1.2	3.7

SECTION II. EVALUATION

Cooperators

Columbia Basin Fish and Wildlife Authority

Pacific States Marine Fisheries Commission

Oregon Department of Fish and Wildlife

Report E

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

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ABSTRACT

Predator control fisheries aimed at reducing predation on juvenile salmonids by northern squawfish *Ptychocheilus oregonensis* were implemented for the seventh consecutive year in the mainstem Columbia and Snake rivers. In this report, we (1) evaluate northern squawfish exploitation and size composition, and compare catch rate of incidentally-harvested fishes among the three major management fisheries in 1996, (2) estimate reductions in predation on juvenile salmonids since implementation of the fisheries, and (3) evaluate changes from 1990-96 in relative abundance, consumption, size and age structure, growth, and fecundity of northern squawfish.

Systemwide exploitation of northern squawfish ≥ 250 mm fork length was 12.1% for sport-reward, 0.3% for dam-angling, and 0.5% for site-specific gill-net fisheries. Total exploitation was lowest in Lower Monumental Reservoir (0.0%) and highest in McNary Reservoir (18.2%). Mean fork length of harvested northern squawfish was 355 mm in the sport-reward, 391 mm in the dam-angling, and 408 mm in the gill-net fisheries. The dam-angling fishery had the lowest percentage (3.6%) of incidental catch relative to the total number of fish caught. Incidental catch was 27.0% in the sport-reward fishery and 54.6% in the gill-net fishery.

If exploitation rates remain similar to mean 1991-96 levels, we estimate that potential predation by northern squawfish on juvenile salmonids in 1997 will be approximately 62% of

predation levels prior to the implementation of removal fisheries. Further reductions in predation may be small, unless average exploitation in future years is higher than 1994-96 levels.

Relative abundance of northern squawfish declined slightly from 1995 in Bonneville Reservoir, Lower Monumental Dam tailrace, and Little Goose Dam tailrace. Mean abundance for 1994-96 was 48-60% of 1990-93 levels among areas sampled at least five years. Indices of consumption were lower than 1995 in all areas except during summer in the tailrace boat-restricted zones of Bonneville and The Dalles dams. Predation indices have declined 69% from pre- 1994 levels.

Decreases in proportional stock density were greater than could be explained by fluctuations in year-class strength, strongly suggesting that sustained removals may be altering the size structure of predator-sized northern squawfish. We found no evidence that northern squawfish have compensated in growth or fecundity in response to sustained exploitation.

INTRODUCTION

The goal of the Columbia River Northern Squawfish Management Program (NSMP) is to reduce mainstem mortality of juvenile salmonids attributed to predation by northern squawfish *Ptychocheilus oregonensis*. We established baseline levels of predation and described northern squawfish population characteristics prior to the implementation of sustained predator control fisheries by estimating northern squawfish abundance, consumption, and predation in Columbia River reservoirs (1990; Vigg et al. 1990), Snake River reservoirs (1991; Ward et al. 1993) and the unimpounded lower Columbia River downstream from Bonneville Dam (1992; Parker et al. 1994). We sampled Columbia River impoundments again in 1993 to evaluate changes from 1990 (Zimmerman et al. 1995). From 1994-96, we sampled in areas where sufficient numbers of northern squawfish could be collected to compare changes in predation among years (Knutson et al. 1995; Zimmerman et al. in press). In this report we describe our activities and findings for 1996, and wherever possible, evaluate changes from previous years.

Our objectives in 1996 were to (1) evaluate the relative efficiency of each northern squawfish fishery by comparing exploitation rate, size composition, and incidental catch, (2) estimate reductions in predation on juvenile salmonids since the implementation of the NSMP, and (3) evaluate changes through 1996 in relative abundance, size 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 and Loss Estimates

Field Procedures

Three northern squawfish fisheries were conducted in 1996. The sport-reward fishery was implemented by the Washington Department of Fish and Wildlife (WDFW) from April 29-September 29 throughout the lower Columbia and Snake rivers. The dam-angling fishery was implemented by the Columbia River Inter-Tribal Fish Commission (CRITFC), Confederated Tribes of the Warm Springs Reservation of Oregon (CTWS), Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes and Bands of the Yakama Indian Nation (YIN), and the Nez Perce Tribe (NPT) from June 5-September 4 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, NPT, and CTWS from March 14-June 30 downstream from Bonneville Dam and in Bonneville, The Dalles, John Day, and McNary reservoirs.

We tagged and released northern squawfish to estimate exploitation rates for each fishery. We used electrofishing boats and gill nets to collect northern squawfish from March 25-June 20. We allocated equal sampling effort 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 the mouth through RKm 229, excluding Ice Harbor Reservoir. Northern squawfish greater than 240 mm fork length were tagged with a serially-numbered spaghetti tag and given a secondary mark (left pelvic fin clip). Tags were recovered from each fishery from April 22-September 29.

Data Analysis

We used mark-and-recapture data to compare exploitation rates of northern squawfish > 250 mm fork length among fisheries and reservoirs in 1996. Weekly estimates of exploitation for each fishery were calculated by dividing the number of tagged northern squawfish recovered by the number of tagged fish at large and summed to yield total exploitation rates (Beamesderfer et al. 1987). We also adjusted exploitation estimates for tag loss (4.2%), determined by the recovery of secondary-marked fish without tags.

We calculated 95% confidence intervals for the number of tagged fish recovered each week. We calculated confidence intervals for variables distributed in a Poisson distribution from Ricker (1975) for weeks when tagging and fishing occurred simultaneously. After tagging was complete, we calculated confidence intervals using the formula

$$m \pm 1.96 \sqrt{m/n} \quad (\text{if } mn > 30)$$

where

n = the number of sampling periods (weeks) remaining, and

m = the mean number of tagged fish recovered per week (Elliott 1977).

Using this method, bounds were identical for all remaining weeks. We summed estimates for each week to give overall confidence limits.

We calculated mean fork length and compared length-frequency distributions among fisheries. We also compared incidental catch among fisheries for 1996 by determining the percent of the total catch composed of fish other than northern squawfish ≥ 250 mm fork length (incidental catch).

We used the “Loss Estimate Spreadsheet Model” (Zimmerman et al. 1995) to estimate predation on juvenile salmonids relative to predation prior to implementation of the NSMP. 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 the effects of removals if all variables except exploitation were held constant.

We estimated the potential relative predation in 1997 based on observed exploitation rates, and the eventual minimum potential predation assuming continuing exploitation at mean 1991-96 levels. Because inputs to the model included three potential relationships between age of northern squawfish and consumption, and three estimates of exploitation (point estimate plus confidence limits), we computed nine estimates of relative predation for each year. We report the maximum, median, and minimum estimates.

Biological Evaluation

Field Procedures

To evaluate changes in relative abundance and consumption for northern squawfish, we used boat electrofishing to collect biological data from April 29-August 9 in the following areas: downstream from Bonneville Dam (RKm 117-121, RKm 171-177, and RKm 178-183), Bonneville Dam tailrace, Bonneville Reservoir, The Dalles Reservoir forebay, John Day Dam tailrace, John Day Reservoir, Little Goose Dam tailrace, Lower Granite Dam tailrace, and upper Lower Granite Reservoir (RKm 221-229). Sampling methods and gear specifications were as described in previous reports (Vigg et al. 1990; Ward et al. 1993; Parker et al. 1994; Zimmerman et al. 1995; Knutsen et al. 1995; Zimmerman et al. in press). Digestive tracts from all northern squawfish ≥ 250 mm fork length were preserved using methods described by Ward et al. (1995).

We collected biological data from all northern squawfish collected by electrofishing and from subsamples of fish harvested by the sport-reward and dam-angling fisheries to evaluate changes in population structure, growth, and reproduction. We determined fork length (mm), total body weight (g), sex (male, female or undetermined), and maturity (undeveloped or immature,

developing, ripe, or spent), and collected gonad (ripe females only) and scale samples. Fork length data for northern squawfish harvested by the site-specific gillnet fishery were provided by CRITFC.

Laboratory Procedures

We examined digestive tract 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 Ward et al. (1995). 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 standardized 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 1990-96 for all sampling areas.

The following formula was developed as a consumption index (CI) by Ward et al. (1995):

$$CI = 0.0209 T^{1.60} \cdot MW^{0.27} \cdot (S \cdot GW^{-0.61})$$

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 (Ward et al. 1995). Spring (May-June) and summer (July-September) consumption indices were compared from 1990-96 for all sampling areas. 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. 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.

Because fishery exploitation rates increase with 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; Anderson 1980) where $PSD = 100 \cdot (\text{number of fish at least quality length} / \text{number of fish at least stock length})$ to compare size structure of northern squawfish populations among years 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 and 380 mm fork length, respectively (Beamesderfer and Rieman 1988; Parker et al. 1995).

Comparisons of PSDs among years may be biased by fluctuating year-class strengths that influence the number of stock-size fish (Mesa et al. 1990) and 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 (Knutson et al. 1995). We then compared observed and expected PSDs.

To evaluate changes in growth rate after implementation of the NSMP, we used observed length-at-age data for female northern squawfish from the Columbia River downstream from Bonneville Dam and Bonneville, John Day, and Lower Granite 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, and ages 6 through 11 in Lower Granite Reservoir). We compared growth among years 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 calculated mean fecundity (number of developed eggs per female) and mean relative fecundity (number of developed eggs per gram of body weight) for northern squawfish from the Columbia River downstream from Bonneville Dam, and Bonneville, John Day, and Lower Granite reservoirs. We determined parameters for the regression of fecundity on fork length and compared relationships among years for each area using joint 95% family confidence regions for estimates of parameter pairs (Neter et al. 1985).

RESULTS

Fishery Evaluation and Loss Estimates

We tagged and released 1,430 northern squawfish throughout the lower Columbia and Snake rivers in 1996. A total of 162 tagged fish were recaptured in the three fisheries: 152 in the sport-reward fishery, four in the dam-angling fishery, and six in the site-specific gill-net fishery.

Total exploitation of northern squawfish in 1996 was 12.9%, and ranged from 0.0% in Lower Monumental Reservoir to 18.2% in McNary Reservoir (Figure 1; **Appendix A**). Exploitation of northern squawfish by the sport-reward fishery was 12.1% in 1996. Sport-reward exploitation increased from 1995 in Bonneville, The Dalles, Little Goose, and Lower Granite reservoirs, decreased downstream from Bonneville Dam, and did not change in John Day and Lower

Monumental reservoirs (Figure 1; **Appendix Table A-1**). Dam-angling exploitation was 0.3%, and 1996 exploitation rates declined in all areas except John Day Reservoir (Figure 1; **Appendix Table A-2**). Exploitation by the site-specific gill-net fishery totaled 0.5% and declined or remained the same in all areas (Figure 1; **Appendix Table A-3**). A sufficient number of tagged fish were captured in 1996 ($n > 30$) to calculate 95% confidence intervals for exploitation estimates (all fisheries combined) downstream from Bonneville Dam and systemwide.

Mean fork length of northern squawfish harvested systemwide in 1996 was 355 mm in the sport-reward fishery, 391 mm in the dam-angling fishery, and 408 mm in the site-specific fishery (Figure 2). Mean fork length increased from 1995 in the sport-reward (8.6%) and dam-angling (6.5%) fisheries, and decreased slightly (0.7%) in the site-specific fishery.

Mean sizes of northern squawfish harvested in specific areas by the sport-reward fishery in 1996 were within the range for other years, except fish harvested downstream from Bonneville Dam and in Lower Granite Reservoir were larger than in any other year (Table 1). Mean fork length of northern squawfish harvested by the dam-angling fishery in 1996 was higher than 1995 in Bonneville Dam tailrace and John Day Reservoir, and lower than any other year in Bonneville Reservoir. Sample size of northern squawfish harvested by the dam-angling fishery in The Dalles Reservoir was inadequate to estimate mean fork length. Mean fork length of northern squawfish harvested by the gill-net fishery in 1996 was higher than 1995 downstream from Bonneville Dam and in John Day Reservoir, lower in Bonneville and McNary reservoirs, and similar to 1995 in the Dalles Reservoir. Sample sizes were small (<200) for all locations except Bonneville Reservoir.

In 1996, the various fisheries reported 65,814 incidentally-caught fish including northern squawfish <250 mm fork length (Table 2). The incidental catch rate was 27.0% in the sport-reward fishery, 3.6% in the dam-angling fishery, and 54.6% in the gill-net fishery. Northern squawfish <250 mm, other cyprinids, smallmouth bass, catostomids, and white sturgeon were the most common incidentally-caught fish. Salmonids made up only 0.3% of the total catch and 1.2% of the incidental catch for all fisheries combined. The proportion of predator-sized (≥ 250 mm fork length) northern squawfish relative to the total number of northern squawfish harvested was highest in the dam-angling fishery (98.7%) and lowest in the sport-reward fishery (87.1%).

Results from the “Loss Estimate Spreadsheet Model” indicate that potential predation by northern squawfish on juvenile salmonids in 1997 may range from 45% to 75% of pre-program levels, with a median estimate of 62% (Figure 3). Continued exploitation at mean 1991-96 levels will not result in further reductions in predation; predation will remain similar to 1997 levels unless exploitation is increased.

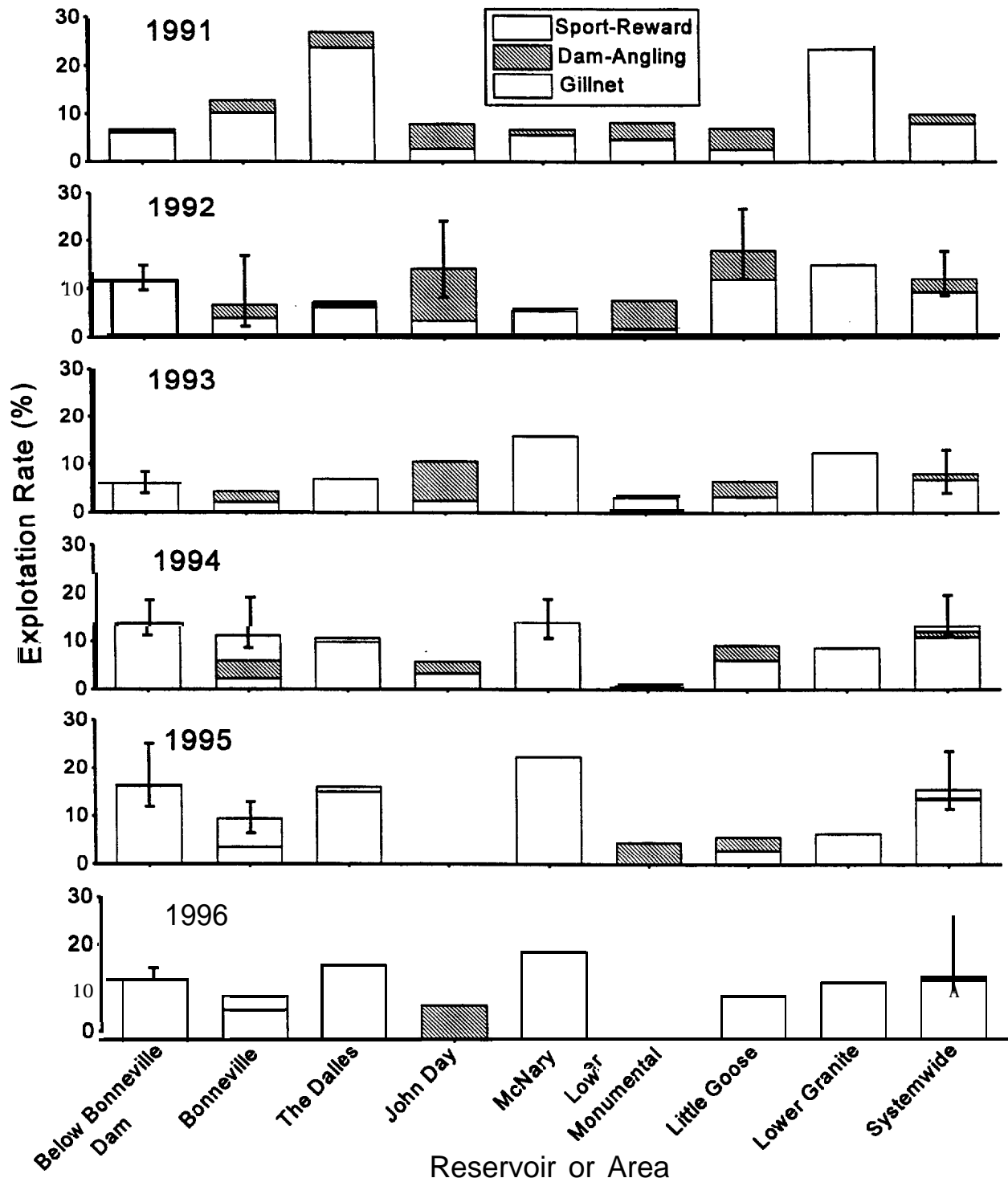


Figure 1. Exploitation of northern squawfish ≥ 250 mm fork length by fishery and area, 1991-96. Confidence intervals for all fisheries combined (96%; vertical bars) are included where a sufficient number of tagged northern squawfish were recaptured to estimate upper and lower bounds.

Table 1. Mean fork length (mm) of northern squawfish harvested from 1990-96 in the lower Columbia and Snake rivers by the sport-reward, dam-angling, and site-specific gill-net fisheries.

Fishery: Location	Mean fork length (mm)						
	1990	1991	1992	1993	1994	1995	1996
Dam Angling:							
Bonneville Dam Tailrace	414	417	388	390	376	365	370
Bonneville Reservoir	407	417	416	415	413	366	363
The Dalles Reservoir	421	404	380	420	390	343	--
John Day Reservoir	416	414	417	416	437	389	418
McNary Reservoir	393	393	375	408	--	--	--
Ice Harbor Reservoir	--	375	369	414	--	--	--
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	345
Bonneville Reservoir	--	343	347	312	323	305	344
The Dalles Reservoir	--	344	369	369	358	359	349
John Day Reservoir	377	370	367	370	329	--	--
McNary Reservoir	--	354	356	358	366	323	359
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	375
Gill Net:							
Downstream from Bonneville Dam	--	--	--	--	--	374	391
Bonneville Reservoir	--	--	--	371	411	416	409
The Dalles Reservoir	--	--	--	--	395	396	397
John Day Reservoir	--	--	--	--	366	370	403
McNary Reservoir	--	--	--	--	387	363	353
Ice Harbor Reservoir	--	--	--	--	--	386	--
Lower Monumental Reservoir	--	--	--	--	--	345	--
Little Goose Reservoir	--	--	--	--	--	379	--
Lower Granite Reservoir	--	--	--	--	377	370	--

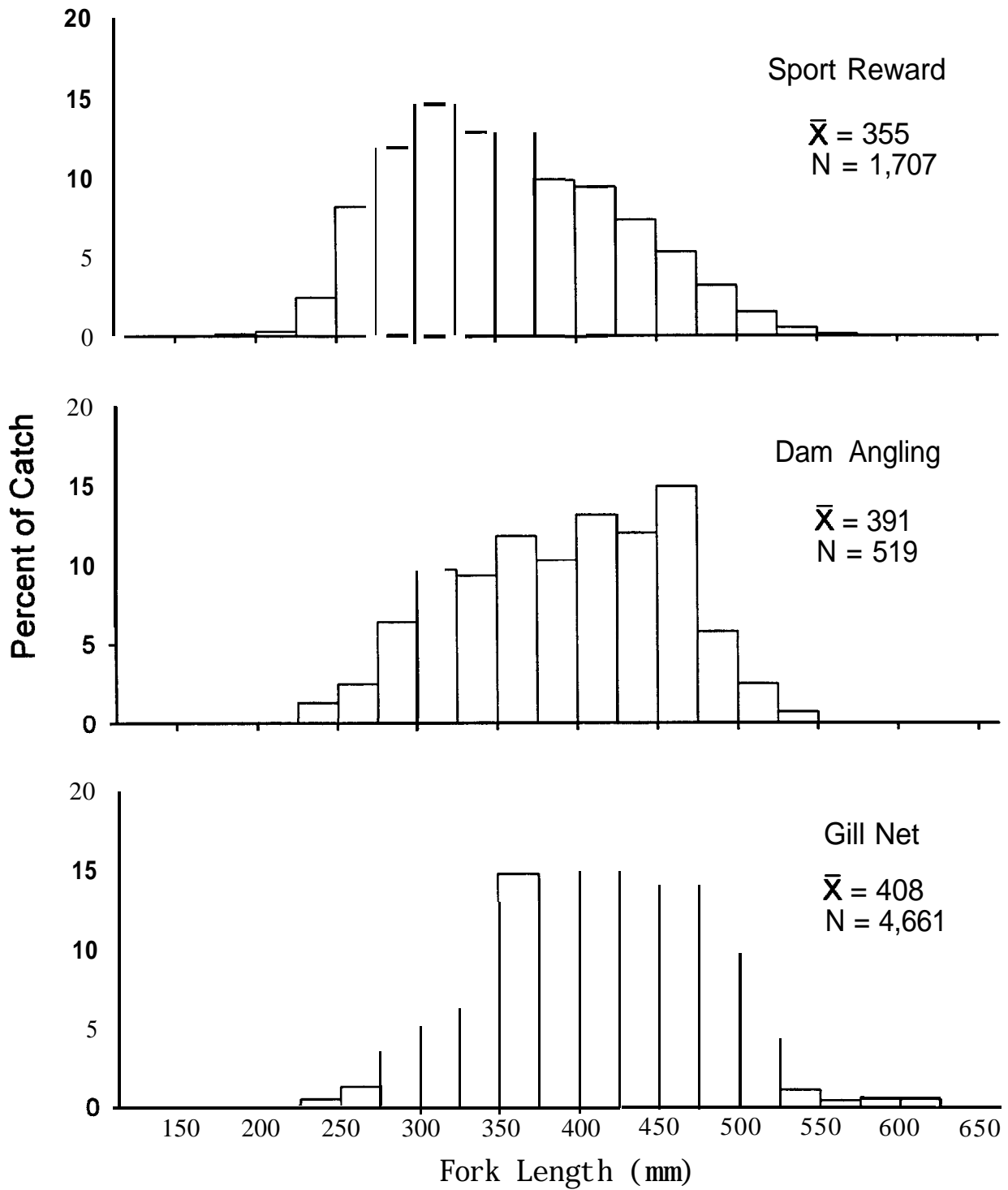


Figure 2. Size composition and mean fork length of northern squawfish from subsamples of fish harvested systemwide by sport-reward, dam-angling, and site-specific gill-net fisheries during 1996. N = subsample size.

Biological Evaluation

Density indices for northern squawfish in 1996 were generally similar to those of 1995 (**Appendix Table B-1**). Total (all sampling areas combined) density increased slightly downstream from Bonneville Dam, in John Day Reservoir, and in the upper portion of Lower Granite Reservoir, and decreased in Bonneville, The Dalles, Lower Monumental, and Little Goose Reservoirs. Density indices for seven of the 19 areas sampled were the lowest recorded since biological evaluation began in 1990.

Relative abundance of northern squawfish declined slightly in Bonneville Reservoir, and in the tailrace zones of Lower Monumental and Little Goose reservoirs in 1996 relative to previous years (Figure 4; **Appendix Table B-2**). Abundance in the remaining areas were similar to or slightly higher than abundance in 1994-95. Mean abundance in Bonneville Dam tailrace, and Bonneville, The Dalles, and John Day reservoirs (areas sampled at least five years) was 48-60% lower from 1994-96 than 1990-93.

Consumption in spring was lower in 1996 relative to previous years in all locations (**Appendix Table B-3**). Consumption in summer was also lower than previous years except in the boat restricted zones of Bonneville Dam tailrace and The Dalles Reservoir tailrace (**Appendix Table B-4**). We found no juvenile salmonids in the digestive tracts of northern squawfish collected at seven of 14 summer sampling sites, which resulted in consumption indices of zero for these sites. Among areas sampled at least five years, mean consumption from 1994-96 was 2-4% lower in spring and 13-64% lower in summer than 1990-93.

Predation indices in spring 1996 were lower than all prior years in every location (Figure 5; **Appendix Table B-5**). Predation in summer 1996 was higher than predation in 1994-95 in most tailrace and forebay areas, but was generally lower than predation prior to 1994 (Figure 6; **Appendix Table B-6**). The mean decline in predation from pre- to post-1994 levels ranged from 40% downstream from Bonneville Dam to 86% in Little Goose Dam tailrace. The mean decline in all areas was 69%. Timing of consumption/predation sampling coincided with peaks in downstream passage of juvenile salmonids in all sampling areas during spring, and at John Day Dam (forebay and tailrace), McNary Dam (tailrace), and McNary Reservoir (mid-reservoir) during summer (**Appendix C**).

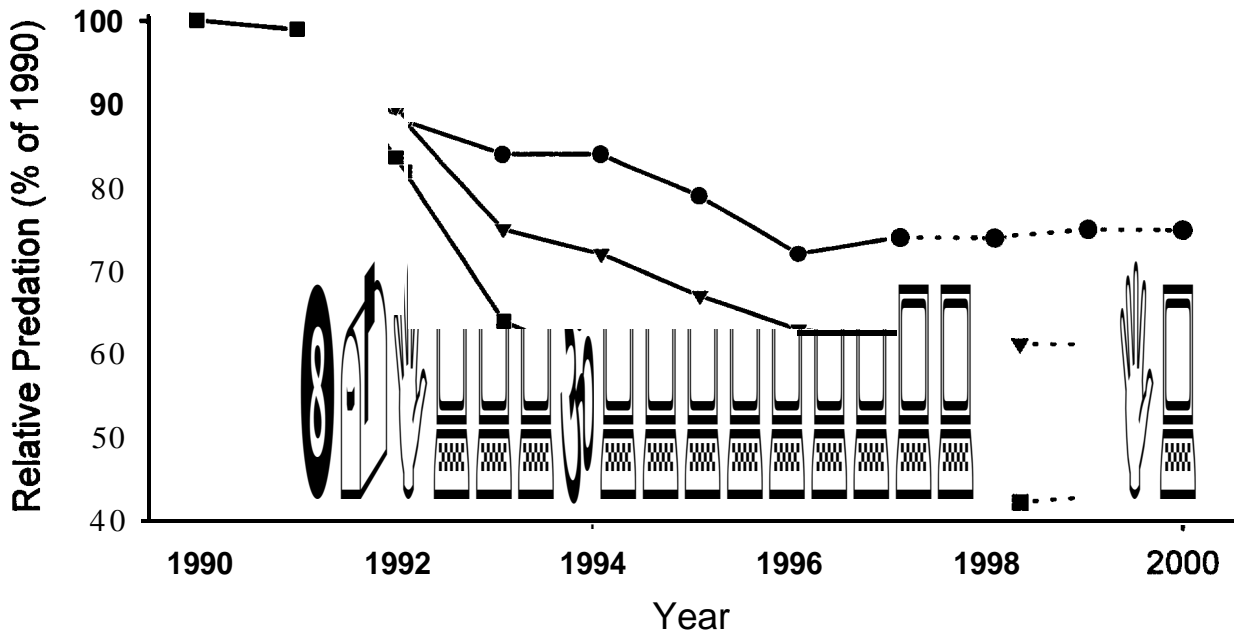


Figure 3. Maximum (circles), median (triangles), and minimum (squares) estimates of potential predation on juvenile salmonids by northern squawfish relative to predation prior to implementation of the northern squawfish management program. Dashed lines indicate predation in future years if exploitation is maintained at mean 1991-96 levels.

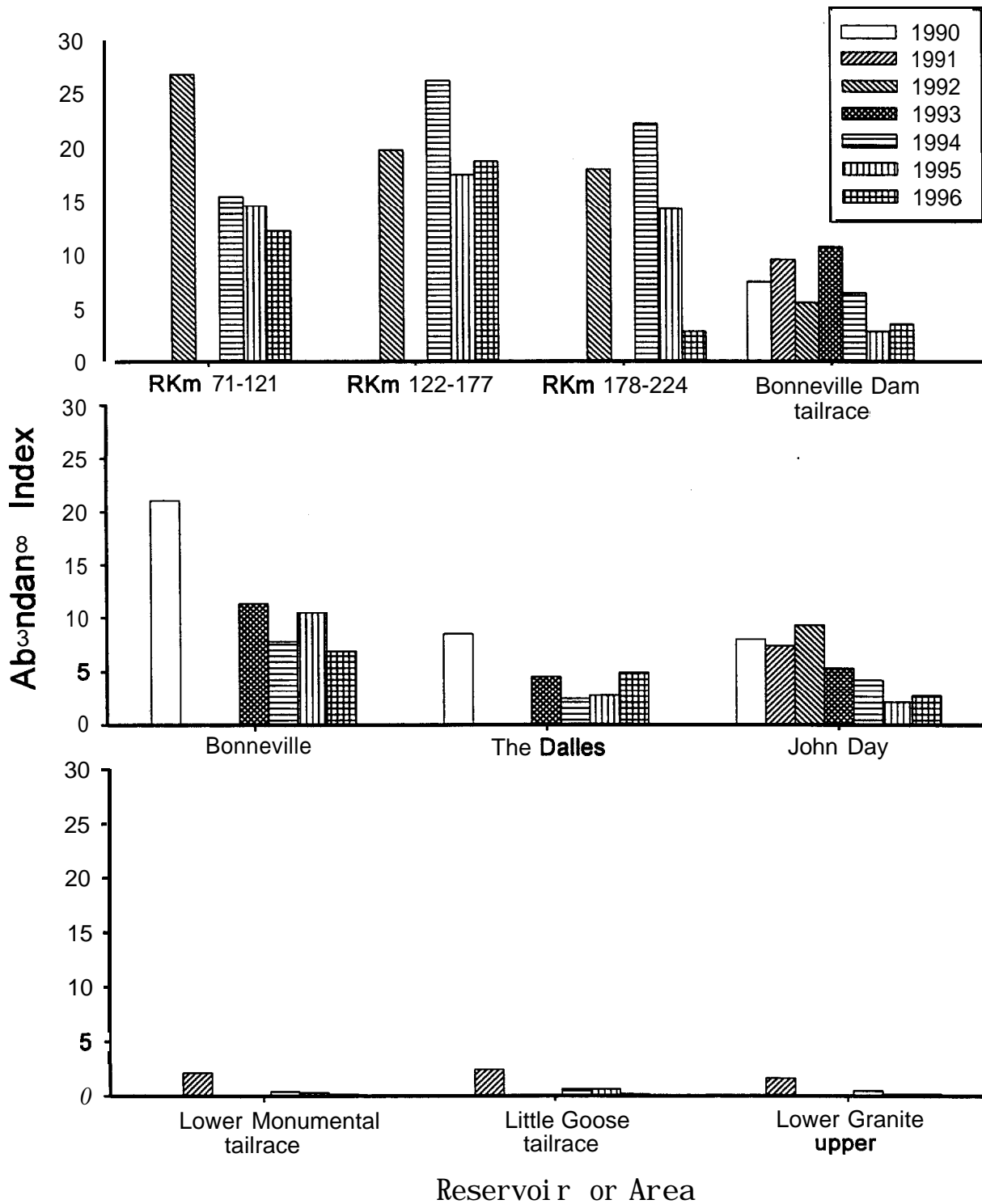


Figure 4. Index of northern squawfish abundance from 1990-96 for sampling locations in the lower Columbia and Snake rivers. RKm = river kilometer.

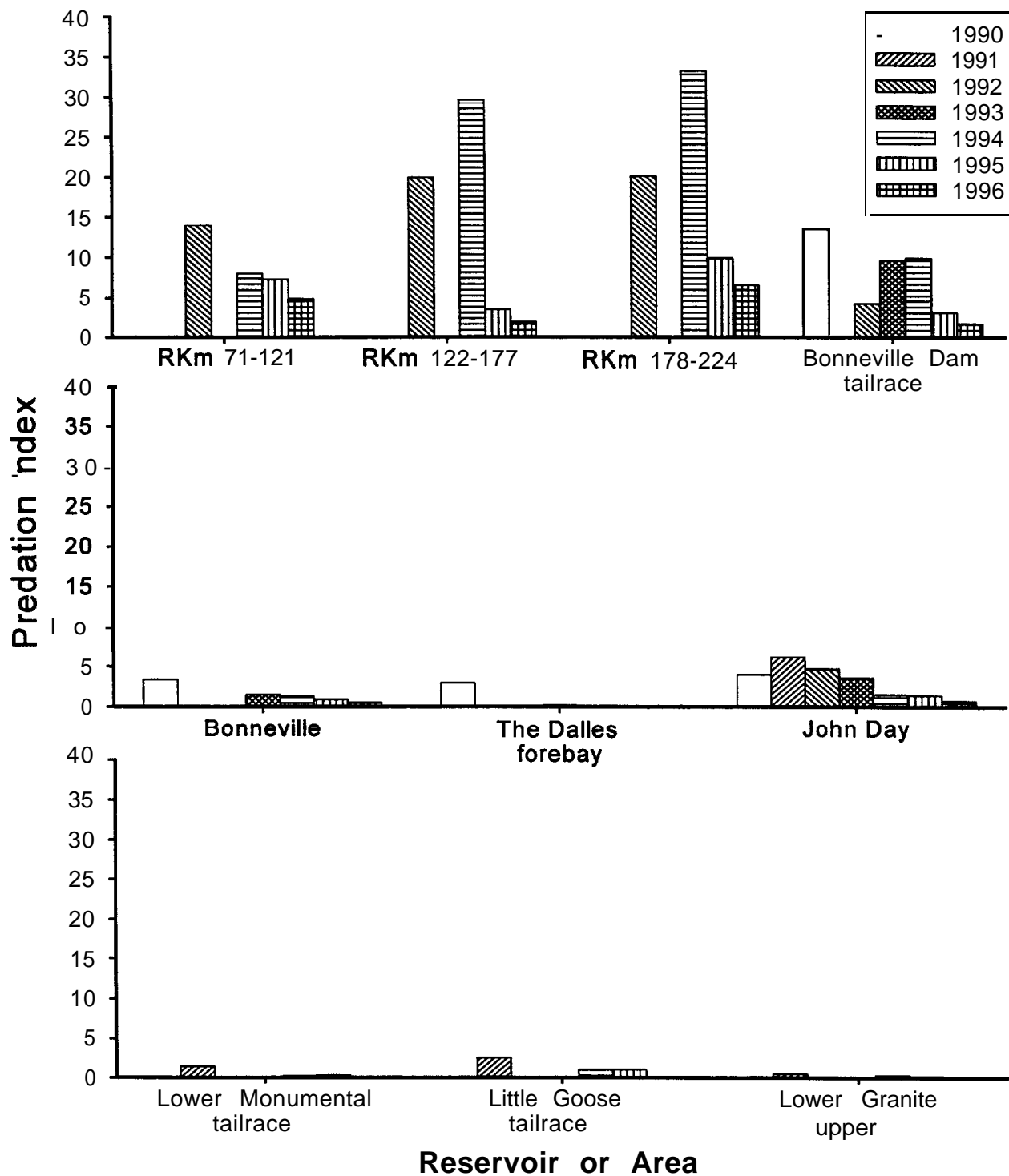


Figure 5. Index of predation by northern squawfish during spring from 1990-96 for sampling locations in the lower Columbia and Snake rivers. Rkm = river kilometer.

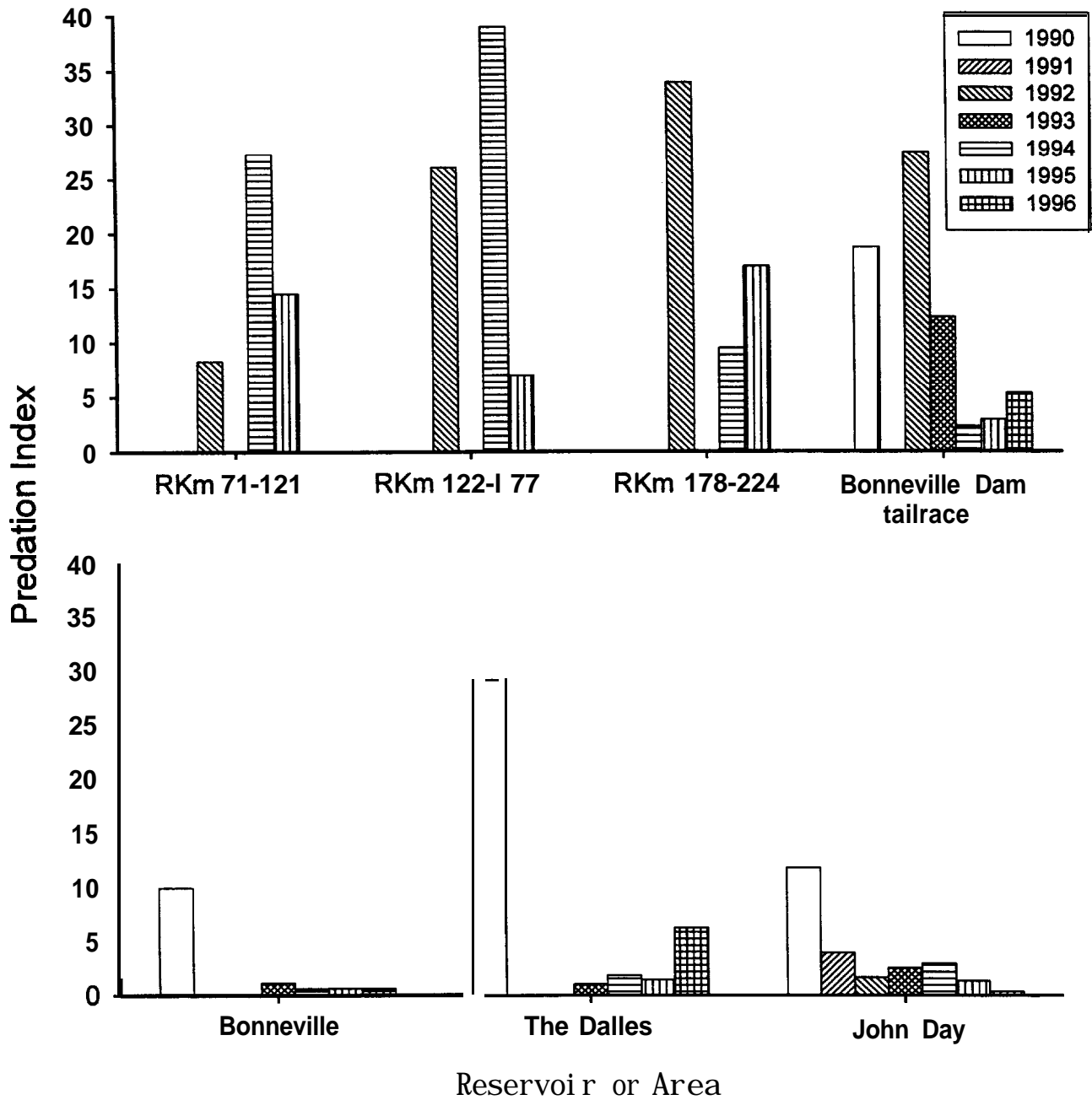


Figure 6. Index of predation by northern squawfish during summer from 1990-96 for sampling locations in the lower Columbia and Snake rivers. Predation indices for The Dalles Reservoir excludes the mid-reservoir. R.Km = river kilometer.

Year-class strength of northern squawfish was highly variable; however, variations were generally similar among areas (Figure 7). Differences among areas were less than 25% except in 1987. Year classes were generally stronger from 1989-92 than in 1987 and 1988.

Proportional stock density of northern squawfish has generally decreased since implementation of the NSMP (Figure 8). 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 strong 1989-91 year classes were recruited to stock size. In Bonneville and John Day reservoirs, observed PSDs were lower than PSDs expected without implementation of the management program. After 1993, observed PSDs were very similar to PSDs expected with implementation of the NSMP. Observed PSDs followed expected trends downstream from Bonneville Dam except in 1995, when the observed PSD was higher than expected.

Estimates of mean fecundity and mean relative fecundity in each reservoir or reach increased from 1995 to 1996; however, fecundity in 1996 was generally similar to or less than fecundity from 1991-94 (Table 3). Although regression parameters for fecundity-fork length relationships differed among years, there was no evidence that fecundity of northern squawfish increased from 1991-96 (Table 4).

Regression parameters for length-age relationships differed among some years for female northern squawfish downstream from Bonneville Dam, and in Bonneville and John Day Reservoirs, but were similar among years in Lower Granite Reservoir (Table 5). There was no trend in increasing growth from 1990-96 in any area, despite differences in growth among a few years.

DISCUSSION

Rieman and Beamesderfer (1990) predicted that sustained exploitation of northern squawfish > 275 mm fork length at an annual rate of 10-20% would reduce losses of juvenile salmonids to predation by 50%. Total systemwide exploitation by the three fisheries in 1996 was 12.9%, the third consecutive year that exploitation has exceeded 10%. Systemwide exploitation from 1991-95 averaged 11.7% (Zimmerman et al. in press). As in previous years, sport-reward exploitation greatly exceeded exploitation by other fisheries. The dam-angling and site-specific gill-net fisheries, while contributing less to exploitation, harvested localized concentrations of northern squawfish which may have aggregated to feed on juvenile salmonids (Beamesderfer and Rieman 1991; Poe et al. 1991; Collis et al. 1995). These fisheries also harvested larger northern squawfish than the sport-reward fishery, and captured a much smaller number of other species.

If exploitation rates remain similar to mean 1991-96 levels, it is likely that no further reductions in potential predation will be realized. Predation will remain at approximately 62% of pre-program levels. Exploitation rates lower than mean 1991-96 levels will result in increases in

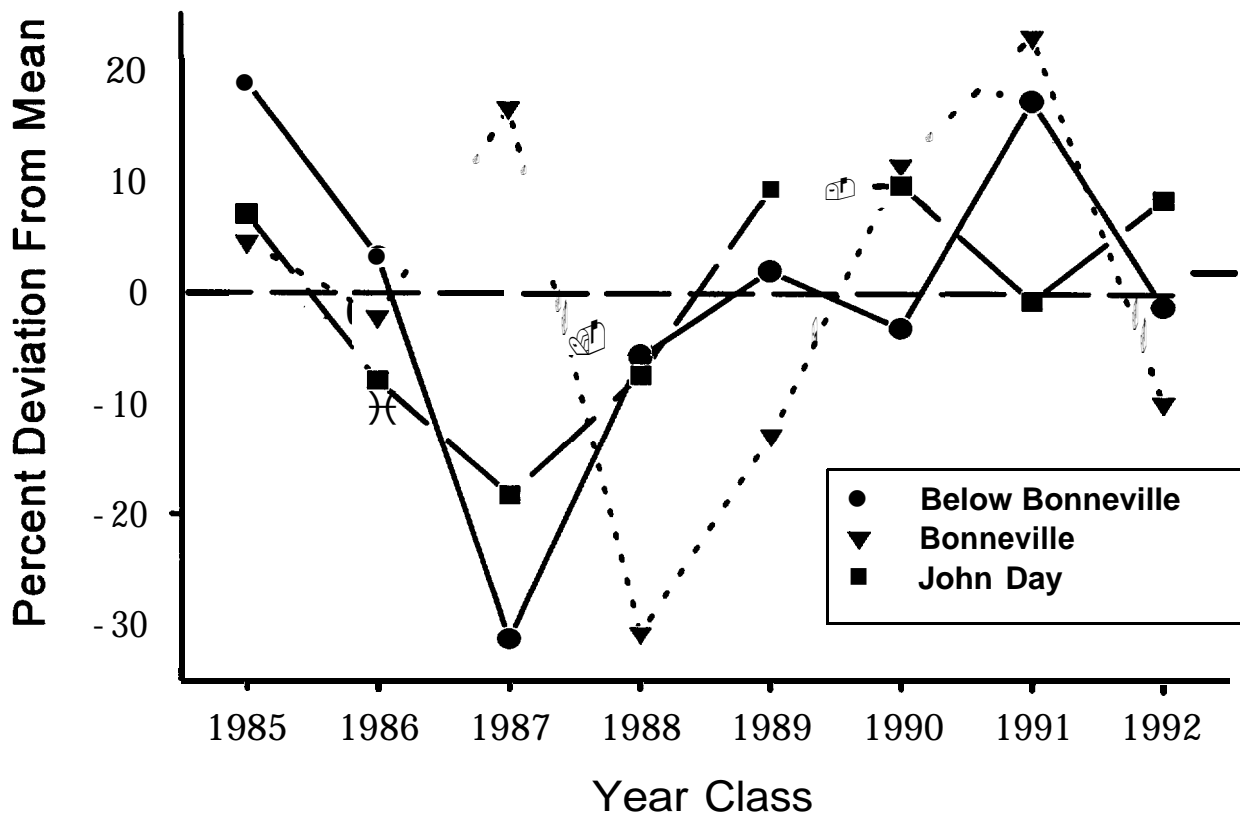


Figure 7. Index of relative year-class strength of northern squawfish in the Columbia River downstream from Bonneville Dam, in Bonneville Reservoir, and in John Day Reservoir.

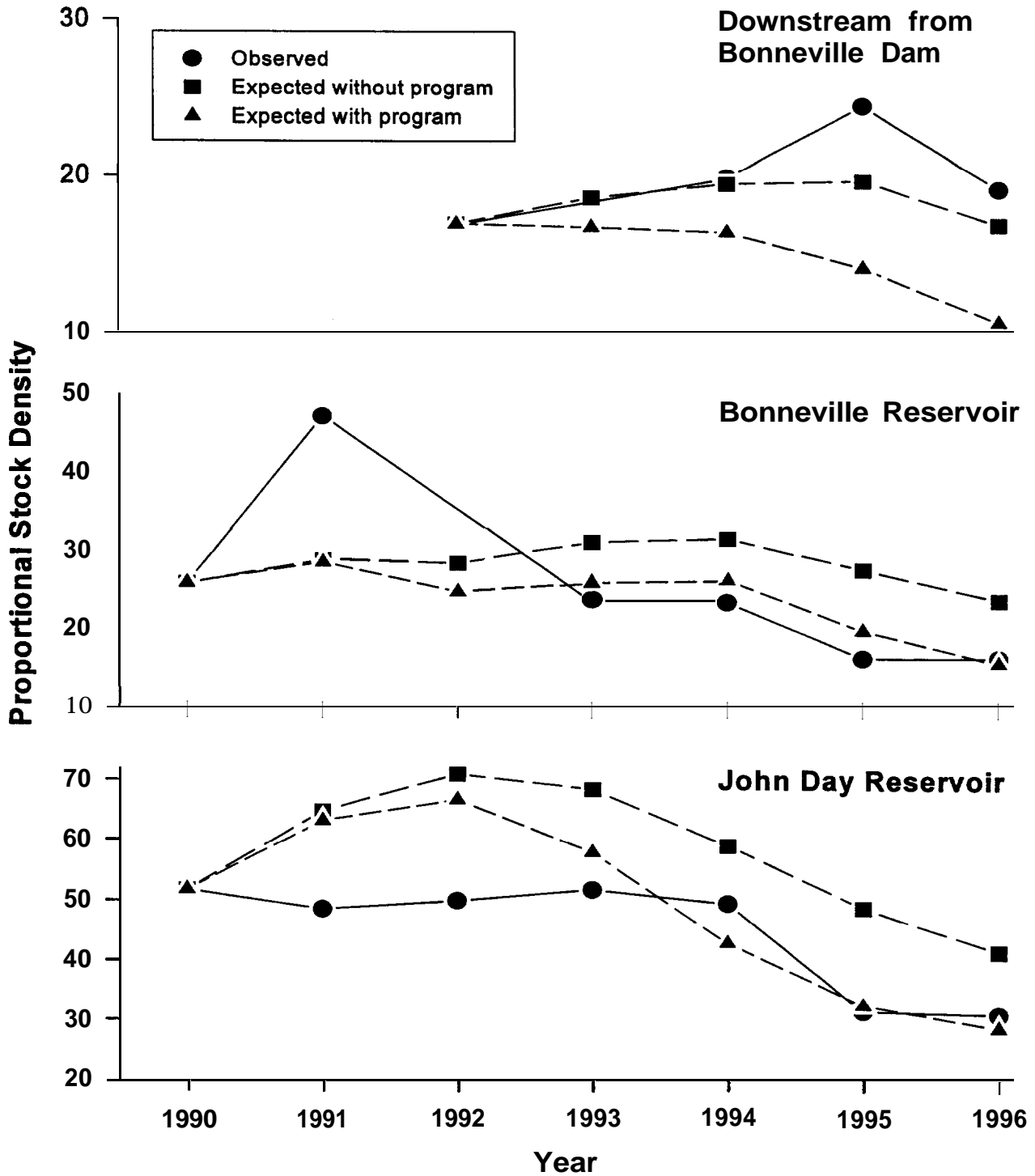


Figure 8. Observed and expected proportional stock density with and without implementation of the Northern Squawfish Management Program from 1990-96 in the Columbia River downstream from Bonneville Dam, in Bonneville Reservoir, and in John Day Reservoir.

Table 3. Mean fecundity (number of developed eggs per female), mean relative fecundity (MRF; number of developed eggs per gram of body weight), and sample size (N) of northern squawfish in selected areas of the Columbia and Snake rivers, 1991-96.

Location, parameter	1991	1992	1993	1994	1995	1996
Downstream from Bonneville Dam						
Mean fecundity	37,500	25,069	22,410	26,717	18,865	24,047
MRF	40.01	38.74	37.68	37.37	31.32	40.79
N	59	247	267	84	121	39
Bonneville Reservoir						
Mean fecundity	31,225	33,640	30,444	29,313	18,550	26,413
MRF	45.17	35.96	32.15	32.43	22.27	33.90
N	37	105	101	100	6	47
John Day Reservoir						
Mean fecundity	30,699	32,026	26,016	27,638	17,792	36,487
MRF	28.90	32.40	24.72	24.93	20.80	31.05
N	66	109	95	60	12	51
Lower Granite Reservoir						
Mean fecundity	23,251	24,851	32,472	21,926	23,991	25,795
MRF	30.29	27.51	27.79	34.28	21.80	29.23
N	44	30	17	5	5	65

Table 4. Differences among years in joint 95% family confidence regions for parameter pairs of the regression of fecundity on fork length (mm) of northern squawfish. * = significant difference between years; ns = no difference between years.

Location, Year	Statistical Significance						Parameters	
	1991	1992	1993	1994	1995	1996	Slope	Intercept
Downstream from Bonneville Dam								
1991	--						254.6	-66,804
1992	*	--					106.5	-15,081
1993	*	ns	--				127.1	-23,421
1994	*	*	*	--			180.7	-41,757
1995	*	*	*	*	--		67.6	-6,037
1996	*	ns	*	ns	*	--	172.3	-36,648
Bonneville Reservoir								
1991	--						229.7	-58,353
1992	ns	--					145.5	-26,444
1993	*	ns	--				105.4	-13,113
1994	*	*	ns	--			98.5	-11,666
1996	ns	ns	*	*	--	--	172.0	-40,410
John Day Reservoir								
1991	--						110.8	-19,152
1992	*	--					114.0	-16,682
1993	ns	*	--				115.5	-24,036
1994	ns	ns	ns	--			146.8	-36,626
1995	ns	*	ns	ns	--		96.0	-21,367
1996	*	ns	*	*	*	--	196.9	-51,113
Lower Granite Reservoir								
1991	--						152.7	-34,631
1992	ns	--					161.8	-40,845
1996	ns	ns	--	--	--	--	133.6	-27,357

Table 5. Differences among years in joint 95% family confidence regions for parameter pairs of the regression of fork length (mm) on age of female northern squawfish. * = significant difference between years; ns = no difference between years.

Location, Year	Statistical Significance							Parameters	
	1990	1991	1992	1993	1994	1995	1996	Slope	Intercept
Downstream from Bonneville Dam									
1990	--							21.2	195.9
1991	*	--						28.8	106.5
1992	*	*	--					28.8	131.5
1993	*	ns	ns	--				28.4	122.1
1994	ns	*	ns	*	--			25.3	187.1
1995	ns	ns	ns	ns	ns	--		28.8	131.1
1996	*	*	ns	ns	ns	ns	--	26.0	152.1
Bonneville Reservoir									
1990	--							21.7	188.0
1993	*	--	--	--				28.8	127.4
1994	*	--	--	*	--			27.6	168.9
1995	ns	--	--	*	*	--		24.0	183.2
1996	ns	--	--	*	*	ns	--	22.6	192.2
John Day Reservoir									
1990	--							20.0	206.3
1991	ns	--						22.4	193.0
1992	*	ns	--					28.6	136.2
1993	*	ns	ns	--				26.4	158.6
1994	ns	ns	*	ns	--			21.5	208.8
1995	ns	ns	ns	ns	ns	--		24.6	171.6
1996	ns	ns	ns	ns	ns	ns	--	23.0	192.7
Lower Granite Reservoir									
1991	--	--	--					32.5	92.3
1993	--	ns	--	--				29.6	108.7
1995	--	ns	--	ns	--	--		26.8	149.4
1996	--	ns	--	ns	--	ns	--	31.3	124.7

potential predation. Because exploitation from 1994-96 was higher than exploitation from 1991-93, further reductions in predation may be feasible. These reductions will be small (1% to 4%) unless average exploitation is higher than 1994-96 levels.

Reducing the number of large northern squawfish may improve salmonid survival if remaining northern squawfish do not consume salmonids at a higher rate (Beamesderfer et al. 1990). Declining abundance and consumption of northern squawfish contributed to declines in predation on juvenile salmonids from 1990-96 in all areas. Our results indicate that northern squawfish are not consuming more juvenile salmonids in response to decreased abundance of northern squawfish. Density (and therefore abundance and predation) indices for the tailrace boat-restricted zones of The Dalles, Lower Monumental, and Little Goose reservoirs may be biased low because river conditions during 1996 limited our sampling of these areas.

Decreases in PSD were greater than could be explained by fluctuations in year-class strength, and indicate that sustained removals are changing the size structure of predator-sized northern squawfish. Observed and expected PSD values often differed in the early years of the NSMP, in part because estimates of expected PSD incorporate estimates of natural mortality and growth. Annual variations in mortality and growth are unpredictable; we therefore used estimates of natural mortality developed prior to sustained removals, and pooled 1990-96 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 PSD values have become smaller over a period of years, as annual variations in mortality and growth “average out.”

If northern squawfish compensate for sustained exploitation with increased growth or fecundity rates, relative benefits of the NSMP will be diminished (Beamesderfer et al. 1996). While our estimates of fecundity and growth of female northern squawfish differed in some years, there was no evidence that northern squawfish are compensating for decreased abundance by increasing consumption and consequently growing faster, or by increasing fecundity.

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APPENDIX A

Exploitation of Northern Squawfish by Reservoir and Fishery, 199 1-96

Appendix Table A-1. Exploitation rates (%) of northern squawfish > 250 mm fork length for the sport-reward fishery, 1991-1996.

Area or Reservoir	1991	1992	1993	1994	1995	1996
Downstream from Bonneville Dam	7.6	11.4	6.0	13.6	16.1	12.7
Bonneville	10.9	4.0	2.1	2.2	3.5	6.1
The Dalles	23.6	6.2	7.0	9.8	14.9	15.5
John Day	2.8	3.4	2.4	3.2	0.0 ^b	0.0 ^b
McNary	5.3	5.6	15.9	14.0	22.4	18.2
Ice Harbor	1.0	-- ^b	-- ^b	-- ^b	-- ^b	-- ^b
Lower Monumental	4.5	1.8	3.1	0.8	0.0 ^a	0.0 ^a
Little Goose	2.4	11.9	3.3	6.1	2.9	8.9
Lower Granite	20.0	15.0	12.5	8.7	6.4	11.7
Systemwide	8.5	9.3	6.8	10.9	13.4	12.1

^a Northern squawfish harvested, but no tags recovered.

^b No northern squawfish tagged.

Appendix Table A-2. Exploitation rates (%) of northern squawfish > 250 mm fork length for the dam-angling fishery, 1991-1996.

Area or Reservoir	1991	1992	1993	1994	1995	1996
Downstream from Bonneville Dam	0.9	0.2	0.0 ^b	0.1	0.2	0.0 ^b
Bonneville	2.7	2.8	2.2	3.7	0.0 ^b	0.0 ^b
The Dalles	3.3	1.0	0.0 ^b	0.0 ^b	0.0 ^b	0.0 ^b
John Day	5.2	10.8	8.1	2.6	0.0 ^b	7.0
McNary	1.1	0.0 ^b	0.1	0.0 ^b	0.0 ^b	0.0 ^b
Ice Harbor	3.4	-- ^b	-- ^b	-- ^b	-- ^b	-- ^b
Lower Monumental	3.1	5.9	0.0 ^a	0.0 ^b	4.5	0.0 ^a
Little Goose	4.2	6.0	3.3	3.1	2.8	0.0 ^a
Lower Granite	<0.1	0.0 ^b	0.0 ^b	0.0 ^b	0.0 ^b	0.0 ^a
Systemwide	2.2	2.7	1.3	1.1	0.3	0.3

^a Northern squawfish harvested, but no tags recovered.

^b No northern squawfish tagged.

Appendix Table A-3. Exploitation rates (%) of northern squawfish > 250 mm fork length for the site-specific gill-net fishery, 1994-96.

Area or Reservoir	1994	1995	1996
Downstream from Bonneville Dam	^a	0.2	0.0 ^b
Bonneville	5.3	5.9	3.0
The Dalles	0.9	1.1	0.0 ^b
John Day	0.0 ^b	0.0 ^b	0.0 ^b
McNary	0.0 ^b	0.0 ^b	0.0 ^b
Ice Harbor	-- ^{ac}	-- ^c	-- ^{ac}
Lower Monumental	0.0 ^b	0.0 ^b	-- ^a
Little Goose	-- ^a	0.0 ^b	-- ^a
Lower Granite	0.0 ^b	0.0 ^b	-- ^a
Systemwide	1.2	1.9	0.5

^a No fishing effort.

^b Northern squawfish harvested, but no tags recovered.

^c No northern squawfish tagged.

Appendix Table A-4. Total exploitation rates of northern squawfish > 250 mm fork length, 1991-96.

Area or reservoir	1991	1992	1993	1994	1995	1996
Downstream from Bonneville Dam	8.6	11.7	6.0	13.8	16.5	12.7
Bonneville	13.6	6.8	4.3	11.2	9.4	9.1
The Dalles	26.9	7.2	7.0	10.7	16.0	15.5
John Day	8.0	14.2	10.5	5.8	0.0	7.0
McNary	6.5	5.6	16.0	14.0	22.4	18.2
Ice Harbor	4.4	-- ^a	-- ^a	-- ^a	-- ^a	-- ^a
Lower Monumental	7.6	7.7	3.1	0.8	4.5	0.0
Little Goose	6.6	17.9	6.6	9.2	5.7	8.9
Lower Granite	20.0	15.0	12.5	8.7	6.4	11.7
Systemwide	10.7	12.0	8.1	13.2	15.5	12.9

^a No northern squawfish tagged.

Appendix Table A-5. Dates for each sampling period in 1996.

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

Appendix Table A-6. Exploitation of northern squawfish downstream from Bonneville Dam in 1996. T = number of fish tagged. M = number of tagged fish at large. Misc. = tagged fish recaptured outside the program area or fisheries.

Time period	Recaptures					M	Exploitation		
	T	sport	Dam	Net	Misc.		sport	Dam	Net
1		--	--	--	--	--	--		
2	83	--	--	--	--	--	--		
3	334	--	--	--	--	83	--	--	--
4	358	--	--	--	--	417	--	--	--
5	--	--	--			775		--	--
6	--	3	--	--	--	775	0.0039	--	--
7	--	2	--	--	--	772	0.0026		
8		4	--	--	--	770	0.0052	--	--
9		2	--	--	--	766	0.0026	--	--
10	--	2	--	--	--	764	0.0026	--	--
11	--	1	--	--	--	762	0.0013	--	--
12	--	4	--	--	--	761	0.0053		
13		2	--	--	1	757	0.0026	--	--
14	--	9	--	--	--	754	0.0119	--	--
15	--	11	--			745	0.0148	--	--
16	--	11	--			734	0.0150	--	--
17	--	8	--			723	0.0111	--	--
18	--	7	--	--	--	715	0.0098	--	--
19	--	7	--	--	2	708	0.0099	--	--
20	--	3	--			699	0.0043	--	--
21	--	3	--			696	0.0043	--	--
22	--	1	--	--	--	693	0.0014	--	--
23	--	1	--	--	--	692	0.0014	--	--
24	--	3	--	--	--	691	0.0043	--	--
25	--	2	--	--	--	688	0.0029	--	--
26		1	--	--	--	686	0.0015	--	--
27		2	--			685	0.0029		
Total	775	89	0	0	3	--	0.1216	0.0000	0.0000
Adjusted for tag loss							0.1268	0.0000	0.0000

Appendix Table A-7. Exploitation of northern squawfish in Bonneville Reservoir in 1996. T = number of fish tagged. M = number of tagged fish at large. Misc. = tagged fish recaptured outside the program area or fisheries.

Time Period	Recaptures					M	Exploitation		
	T	Sport	Dam	Net	Misc.		Sport	Dam	Net
1	28	--	--	--	--	--	--	--	--
2	187	--	--	--	--	28	--	--	--
3	--	--	--	--	--	215	--	--	--
4	--	--	--	--	--	215	--	--	--
5	--	--	--	2	--	215	--	--	0.0093
6	--	1	--	1	--	213	0.0047	--	0.0047
7	--	--	--	--	--	211	--	--	--
8	--	1	--	--	--	211	0.0047	--	--
9	--	--	--	--	--	210	--	--	--
10	--	1	--	--	--	210	0.0048	--	--
11	--	1	--	1	--	209	0.0048	--	0.0048
12	--	--	--	2	1	207	--	--	0.0097
13	--	2	--	--	--	204	0.0098	--	--
14	--	1	--	--	--	202	0.0050	--	--
15	--	--	--	--	--	201	--	--	--
16	--	3	--	--	--	201	0.0149	--	--
17	--	--	--	--	2	198	--	--	--
18	--	--	--	--	--	196	--	--	--
19	--	--	--	--	--	196	--	--	--
20	--	--	--	--	--	196	--	--	--
21	--	--	--	--	1	196	--	--	--
22	--	2	--	--	--	195	0.0103	--	--
23	--	--	--	--	--	193	--	--	--
24	--	--	--	--	--	193	--	--	--
25	--	--	--	--	--	193	--	--	--
26	--	--	--	--	--	193	--	--	--
27	--	--	--	--	--	193	--	--	--
Total	215	12	0	6	4	--	0.0589	0.0000	0.0284
Adjusted for tag loss						0.0614	0.0000	0.0296	

Appendix Table A-S. Exploitation of northern squawfish in The Dalles Reservoir in 1996. T = number of fish tagged. M = number of tagged fish at large. Misc. = tagged fish recaptured outside the program area or fisheries.

Time period	Recaptures					M	Exploitation		
	T	Sport	Dam	Net	Misc.		Sport	Dam	Net
1	26	--			--	--	--	--	--
2	--	--			--	26	--	--	--
3	--	--	--	--	--	26	--	--	--
4	--	--	--	--	--	26	--	--	--
5	--	--	--	--	--	26	--	--	--
6		--	--	--	--	26	--	--	--
7	46	--	--	--	--	26	--	----	
8	--	1	--	--	--	72	0.0139	--	--
9	--	--	--	--	--	71	--	--	--
10	--	1	--	--	--	71	0.0141	--	--
11	--	1	--	--	--	70	0.0143	--	--
12	--	--			--	69	--	--	--
13	--	--			--	69	--	--	--
14	--	2	--	--	--	69	0.0290	--	--
15	--	1	--	--	--	67	0.0149	--	--
16	--	2	--	--	--	66	0.0303	--	--
17	--	--	--	--	--	64	--	--	--
18	--	--			1	64	--	--	--
19	--	1			--	63	0.0159	--	--
20	--	1	--	--	--	62	0.0161	--	--
21	--	--	--	--	--	61	--	--	--
22	--	--	--	--	--	61	--	--	--
23	--	--	--	--	--	61	--	--	--
24	--	--	--	--	--	61	--	--	--
25	--	--	--	--	--	61	--	--	--
26	--	--	--	--	--	61	--	--	--
27	--	--	--	--	--	61	--	--	--
Total	72	10	0	0	1	--	0.1485	0.0000	0.0000
Adjusted for tag loss							0.1547	0.0000	0.0000

Appendix Table A-9. Exploitation of northern squawfish in John Day Reservoir in 1996. T = number of fish tagged. M = number of tagged fish at large. Misc. = tagged fish recaptured outside the program area or fisheries.

Time period	Recaptures				M	Exploitation	
	T	Sport	Dam	Misc.		sport	Dam
1	23	--			--		--
2	--	--			23	--	--
3	--	--	--	--	23	--	
4	--	--	--	--	23	--	
5	--	--	--	--	23	--	--
6	--	--	--	--	23	--	--
7	3	--	--	1	23		--
8	19	--	--	1	25		
9	19	--	--	1	43	--	--
10	--	--	--	--	61	--	--
11	--	--	--	--	61	--	--
12	--	--	--	1	61	--	
13	--	--	1	--	60	00	0.0167
14	--	--	--	--	59	--	--
15	--	--	--	--	59	--	
16	--	--	--	--	59	--	
17	--	--	--	--	59	--	--
18	--	--	3	--	59	00	0.0508
19	--	--			56	--	--
20	--	--	--	--	56	--	--
21	--	--	--	1	56	--	--
22	--	--	--	--	55	--	--
23	--	--			55		--
24	--	--			55	--	--
25	--	--	--	--	55	--	--
26	--	--	--	--	55	--	--
27	--	--	--	--	55		--
Total	64	0	4	5	--	0.0000	0.0675
Adjusted for tag loss						0.0000	0.0703

Appendix Table A-10. Exploitation of northern squawfish in McNary Reservoir in 1996. T = number of fish tagged. M = number of tagged fish at large. Misc. = tagged fish recaptured outside the program area or fisheries.

Time period	Recaptures				M	Exploitation	
	T	Sport	Dam	Misc.		sport	Dam
1	4	--	--	--	--	--	--
2	--	--	--	--	4	--	--
3	--	--	--	--	4	--	--
4	--	--	--	--	4	--	--
5	104	--	--	--	4	--	--
6	--	1	--	--	108	0.0093	--
7	--	1	--	--	107	0.0093	--
8	--	--	--	--	106	--	--
9	7	1	--	--	106	0.0094	--
10	22	--	--	--	112	--	--
11	18	--	--	--	134	--	--
12	--	--	--	--	152	--	--
13	--	--	--	--	152	--	--
14	--	--	--	--	152	--	--
15	--	1	--	--	152	0.0066	--
16	--	2	--	--	151	0.0132	--
17	--	4	--	--	149	0.0268	--
18	--	6	--	--	145	0.0414	--
19	--	1	--	--	139	0.0072	--
20	--	1	--	--	138	0.0072	--
21	--	--	--	--	137	--	--
22	--	2	--	--	137	0.0146	--
23	--	--	--	--	135	--	--
24	--	1	--	--	135	0.0074	--
25	--	1	--	--	134	0.0075	--
26	--	2	--	--	133	0.0150	--
27	--	--	--	--	131	--	--
Total	155	24	0	0	--	0.1750	0.0000
Adjusted for tag loss						0.1824	0.0000

Appendix Table A-1 1. Exploitation of northern squawfish in Lower Monumental Reservoir in 1996. T = number of fish tagged. M = number of tagged fish at large. Misc. = tagged fish recaptured outside the program area or fisheries.

Time period	Recaptures				M	Exploitation	
	T	sport	Dam	Misc.		sport	Dam
1		--	--	--	--	--	--
2		--	--		--	--	--
3		--	--		--	--	--
4	--	--	--	--		--	--
5	--	--	--	--	--	--	--
6		--	--	--	--	--	--
7			--	--	--	--	--
8	--		--	--	--	--	--
9	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--
11	50	--	--	--	--	--	--
12	--	--	--	--	50	--	--
13	--	--	--	--	50	--	--
14	--		--		50	--	--
15	--	--	--		50	--	--
16	--	--	--	--	50	--	--
17	--	--	--	--	50	--	--
18		--	--	--	50	--	--
19	--	--	--	--	50	--	--
20	--	--	--		50	--	--
21	--	--	--	--	50	--	--
22		--	--	--	50	--	--
23		--	--	--	50	--	--
24		--	--		50	--	--
25			--	--	50	--	--
26		--	--		50	--	--
27		--	--	--	50	--	--
Total	50	0	0	0	--	0.0000	0.0000
Adjusted for tag loss						0.0000	0.0000

Appendix Table A-12. Exploitation of northern squawfish in Little Goose Reservoir in 1996. T = number of fish tagged. M = number of tagged fish at large. Misc. = tagged fish recaptured outside the program area or fisheries.

Time period	Recaptures				M	Exploitation	
	T	Sport	Dam	Misc.		sport	Dam
1	--	--	--	--	--		--
2	--	--	--	--	--		--
3	--	--	--	--	--		--
4	--	--	--	--	--	--	--
5	--	--	--	--	--	--	
6	--	--	--	--	--	--	
7	--	--	--	--	--	--	--
8	--	--	--	--	--		--
9	--	--	--	--	--		--
10	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--
13	24	--	--	--	--		--
14	--	--	--	--	24	--	--
15	--	--	--	--	24		--
16	--	--	--	--	24		--
17	--	--	--	--	24		--
18	--	1	--	--	24	0.0417	--
19	--	--	--	--	23	--	--
20	--	--	--	--	23	--	--
21	--	--	--	--	23	--	--
22	--	1	--	--	23	0.0435	--
23	--	--	--	--	22	--	--
24	--	--	--	--	22	--	--
25	--	--	--	--	22	--	--
26	--	--	--	--	22	--	--
27	--	--	--	--	22	--	--
Total	24	2	0	0	--	0.0851	0.0000
Adjusted for tag loss						0.0887	0.0000

Appendix Table A-13. Exploitation of northern squawfish in Lower Granite Reservoir in 1996. T = number of fish tagged. M = number of tagged fish at large. Misc. = tagged fish recaptured outside the program area or fisheries.

Time period	Recaptures				M	Exploitation	
	T	Sport	Dam	Misc.		sport	Dam
1	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--
6	75	1	--	--	--	0.0133	--
7	--	--	--	--	74	--	--
8	--	--	--	--	74	--	--
9	--	--	--	--	74	--	--
10	--	--	--	--	74	--	--
11	--	1	--	--	74	0.0135	--
12	--	--	--	--	73	--	--
13	--	1	--	--	73	0.0137	--
14	--	1	--	--	72	0.0139	--
15	--	--	--	--	71	--	--
16	--	2	--	--	71	0.0282	--
17	--	1	--	--	69	0.0145	--
18	--	--	--	--	68	--	--
19	--	--	--	--	68	--	--
20	--	--	--	--	68	--	--
21	--	--	--	--	68	--	--
22	--	--	--	--	68	--	--
23	--	--	--	--	68	--	--
24	--	1	--	--	68	0.0147	--
25	--	--	--	--	67	--	--
26	--	--	--	--	67	--	--
27	--	--	--	--	67	--	--
Total	75	8	0	0	--	0.1118	0.0000
Adjusted for tag loss						0.1165	0.0000

Appendix Table A-14. Exploitation of northern squawfish systemwide in 1996. T = number of fish tagged. M = number of tagged fish at large. Misc. = tagged fish recaptured outside the program area or fisheries.

Time period	Recaptures					M	Exploitation		
	T	Sport	Dam	Net	Misc.		Sport	Dam	Net
1	81	--	--	--	--	--	--		
2	270	--	--	--	--	81	--		
3	334	--	--	--		351	--		
4	358	--	--	--		685	--	--	--
5	104	--		2	--	1043		--	0.0019
6	75	6		1	--	1145	0.0052	--	0.0009
7	49	3	--		1	1213	0.0025		
8	19	6	--	--	1	1258	0.0048		
9	26	4	--	--	--	1270	0.003 1	--	--
10	22	4	--	--	--	1292	0.003 1	--	--
11	68	4	--	1	--	1310	0.003 1	--	0.0008
12	--	5	--	2	--	1373	0.0036	--	0.0015
13	24	6	1			1366	0.0044	0.0007	--
14	--	13	--	--	--	1383	0.0094	--	--
15	--	13	--	--	--	1370	0.0095		
16	--	20	--	--	1	1357	0.0147		
17	--	14	--		1	1336	0.0105	--	--
18	--	15	3		--	1321	0.0114	0.0023	--
19	--	9	--		2	1303	0.0069	--	--
20	--	5	--	--	--	1292	0.0039	--	--
21	--	5	--		--	1287	0.0039		
22	--	6	--		--	1282	0.0047		
23	--	1	--		--	1276	0.0008	--	--
24	--	5	--	--	--	1275	0.0039	--	--
25	--	3	--	--	--	1270	0.0024	--	--
26	--	3	--	--	--	1267	0.0024	--	--
27	--	2	--		--	1264	0.0016		
Total	1430	152	4	6	6	--	0.1156	0.0030	0.0050
Adjusted for tag loss							0.1205	0.003 1	0.0052

APPENDIX B

Density, Abundance, Consumption, and Predation Indices for Sampling Locations in the Lower
Columbia and Snake Rivers, 1990-96

Appendix Table B-1. Indices of northern squawfish density from 1990-96 for sampling areas in the lower Columbia and Snake rivers. RKm = river kilometer, BRZ = boat restricted zone.

Location, area	Density Index (number of electrofishing runs)						
	1990	1991	1992	1993	1994	1995	1996
Below							
Bonneville Dam							
RKm 71-121	--	--	1.3(68)	--	1.0(36)	0.9(45)	0.8(43)
RKm 122-177	--	--	1.6(65)	--	1.8(33)	1.4(36)	1.5(35)
RKm 178-224	--	--	2.4(64)	--	1.7(43)	1.1(40)	1.3(40)
Tailrace	5.8(26)	6.9(27)	3.4(37)	9.6(16)	2.9(27)	2.3(16)	2.8(24)
Tailrace BRZ	13.7(13)	19.0(13)	12.9(23)	14.5(9)	18.9(8)	4.3(8)	5.8(7)
Bonneville Reservoir							
Forebay	5.7(47)	--	--	2.2(35)	2.4(97)	2.4(79)	1.3(80)
Mid-reservoir	2.1(52)	--	--	1.2(28)	0.7(84)	1.0(45)	0.7(57)
Tailrace	0.5(37)	--	--	1.1(25)	0.6(60)	1.1(80)	0.8(69)
Tailrace BRZ	5.5(15)	--	--	1.5(6)	6.8(8)	--	--
The Dalles Reservoir							
Forebay	1.1(62)	--	--	1.2(31)	0.6(92)	0.6(62)	0.4(59)
Tailrace	2.8(45)	--	--	0.7(21)	0.7(40)	1.6(27)	3.7(28)
Tailrace BRZ	21.5(11)	--	--	10.8(5)	5.5(8)	3.5(8)	1.0(3)
John Day Reservoir							
Forebay	0.7(56)	0.7(61)	1.3(68)	0.6(44)	0.7(91)	0.3(75)	0.3(54)
Mid-reservoir	0.3(61)	0.2(58)	0.3(62)	0.2(43)	0.1(43)	0.1(94)	0.1(52)
Tailrace	0.8(39)	0.8(44)	0.1(47)	0.5(37)	0.3(60)	0.3(80)	0.5(72)
Tailrace BRZ	14.7(16)	17.9(15)	9.2(17)	13.3(9)	2.4(14)	--	--
Lower Monumental Res.							
Tailrace	--	1.5(40)	--	--	0.3(39)	0.1(38)	0.2(24)
Tailrace BRZ	--	16.3(16)	--	--	1.2(5)	3.9(8)	1.0(8)
Little Goose Reservoir							
Tailrace	--	1.6(40)	--	--	0.4(31)	0.1(32)	0.3(33)
Tailrace BRZ	--	28.3(17)	--	--	6.4(8)	10.3(8)	1.0(4)
Lower Granite Reservoir							
Upper reservoir	--	1.9(55)	--	--	0.5(85)	0.2(89)	0.3(89)

Appendix Table B-2. Indices of northern squawfish abundance from 1990-96 for sampling areas in the lower Columbia and Snake rivers. RKm = river kilometer, BRZ = boat restricted zone.

Location, area	Abundance Index						
	1990	1991	1992	1993	1994	1995	1996
Below							
Bonneville Dam							
RKm 71-121	--	--	26.8	--	15.4	14.5	12.2
RKm 122-177	--	--	19.7	--	26.2	17.4	18.7
RKm 178-224	--	--	17.9	--	22.1	14.2	16.4
Tailrace	4.5	5.4	2.7	7.6	2.3	1.8	2.2
Tailrace BRZ	3.0	4.1	2.8	3.1	4.1	1.0	1.3
Bonneville Reservoir							
Forebay	5.5	--	--	2.1	2.3	2.3	1.3
Mid-reservoir	15.2	--	--	8.5	5.0	7.4	4.9
Tailrace	0.4	--	--	0.8	0.5	0.8	0.7
Tailrace BRZ	0.9	--	--	0.2	1.1	--	--
The Dalles Reservoir							
Forebay	1.4	--	--	1.6	0.7	0.5	0.6
Tailrace	2.7	--	--	0.7	0.6	1.5	3.6
Tailrace BRZ	4.4	--	--	2.2	1.1	0.7	0.7
John Day Reservoir							
Forebay	1.4	1.3	2.5	1.2	1.4	0.5	0.6
Mid-reservoir	5.2	4.7	6.6	3.2	2.3	1.0	1.1
Tailrace	1.4	1.4	0.2	0.9	0.5	0.6	1.0
Tailrace BRZ	1.6	1.9	1.0	1.4	0.3	--	--
Lower Monumental Res.							
Tailrace	--	1.3	--	--	0.3	0.1	0.1
Tailrace BRZ	--	0.8	--	--	0.1	0.2	0.1
Little Goose Reservoir							
Tailrace	--	0.7	--	--	0.2	<0.1	0.1
Tailrace BRZ	--	1.7	--	--	0.4	0.6	0.1
Lower Granite Reservoir							
Upper reservoir	--	1.6	--	--	0.5	0.2	0.2

Appendix Table B-3. Indices of northern squawfish consumption of juvenile salmonids from 1990-96 during spring in the lower Columbia and Snake rivers. RKm = river kilometer, BRZ = boat restricted zone.

Location, area	Consumption Index (number of digestive tracts examined)						
	1990	1991	1992	1993	1994	1995	1996
Below							
Bonneville Dam							
RKm 71-121	--	--	0.5(102)	--	0.5(14)	0.5(25)	0.4(23)
RKm 122-177	--	--	1.0(189)	--	1.1(34)	0.2(28)	0.1(43)
RKm 178-224	--	--	1.1(126)	--	1.5(42)	0.7(25)	0.4(33)
Tailrace	1.2(61)	--	0.5(22)	0.8(75)	3.2(57)	0.8(25)	0.4(29)
Tailrace BRZ	2.7(86)	--	1.0(77)	1.1(63)	0.6(95)	1.7(17)	0.6(8)
Bonneville Reservoir							
Forebay	0.6(153)	--	--	0.7(20)	0.2(116)	0.3(88)	0.0(59)
Mid-reservoir	0.0(39)	--	--	0.0(14)	0.2(34)	0.0(26)	0.1(17)
Tailrace	0.3(7)	--	--	0.0(18)	0.0(19)	0.2(22)	0.0(35)
Tailrace BRZ	2.3(41)	--	--	--	--	--	--
The Dalles Reservoir							
Forebay	0.8(38)	--	--	0.1(19)	0.1(22)	0.0(22)	0.0(15)
Tailrace	0.7(27)	--	--	0.0(8)	--	--	--
Tailrace BRZ	0.9(50)	--	--	0.0(1)	--	--	--
John Day Reservoir							
Forebay	1.5(38)	1.9(23)	1.9(38)	1.5(11)	1.0(11)	1.7(7)	0.7(4)
Mid-reservoir	0.0(6)	0.5(6)	0.0(8)	0.0(2)	0.0(3)	0.0(1)	0.0(3)
Tailrace	1.5(17)	0.9(23)	0.0(9)	2.0(24)	0.3(13)	0.8(13)	0.5(14)
Tailrace BRZ	2.5(60)	1.5(55)	0.9(35)	--	0.7(8)	--	--
Lower Monumental Res.							
Tailrace	--	0.6(58)	--	--	0.7(9)	0.0(2)	0.0(2)
Tailrace BRZ	--	0.7(12.7)	--	--	--	1.3(7)	0.0(1)
Little Goose Reservoir							
Tailrace	--	0.7(68)	--	--	1.9(12)	1.4(2)	0.7(7)
Tailrace BRZ	--	1.2(126)	--	--	1.5(25)	1.6(63)	--
Lower Granite Reservoir							
Upper-reservoir	--	0.3(127)	--	--	0.6(41)	1.2(16)	0.2(23)

Appendix Table B-4. Indices of northern squawfish consumption of juvenile salmonids from 1990-96 during summer in the lower Columbia River. Rkm = river kilometer, BRZ = boat restricted zone.

Location, area	Consumption Index (number of digestive tracts examined)						
	1990	1991	1992	1993	1994	1995	1996
Below							
Bonneville Dam							
Rkm 71-121	--	--	0.3(117)	-	1.8(22)	1.5(14)	0.0(9)
Rkm 122-177	--	--	1.3(136)	-	1.5(32)	0.4(22)	0.0(9)
Rkm 178-224	--	--	1.9(59)	--	0.4(32)	1.2(20)	0.0(20)
Tailrace	0.5(45)	--	2.1(43)	1.2(81)	0.4(24)	0.9(11)	0.6(38)
Tailrace BRZ	5.5(109)	--	7.8(147)	1.0(131)	2.1(56)	1.3(16)	3.1(33)
Bonneville Reservoir							
Forebay	1.8(139)	--	--	0.5(95)	0.3(111)	0.0(96)	0.3(44)
Mid-reservoir	0.0(42)	--	--	0.0(31)	0.0(24)	0.0(19)	0.0(21)
Tailrace	0.0(4)	--	--	0.0(14)	0.0(15)	0.8(67)	0.0(23)
Tailrace BRZ	0.8(61)	--	--	1.0(23)	3.2(54)	--	--
The Dalles Reservoir							
Forebay	1.0(61)	--	--	0.0(28)	0.0(27)	0.0(15)	0.0(8)
Tailrace	0.0(46)	--	--	0.0(9)	0.8(27)	0.0(41)	0.7(92)
Tailrace BRZ	6.4(50)	--	--	0.5(117)	1.2(43)	2.2(28)	5.4(3)
John Day Reservoir							
Forebay	2.4(16)	3.1(17)	0.7(27)	0.6(40)	1.2(57)	2.0(13)	0.4(13)
Mid-reservoir	0.9(7)	0.0(3)	0.0(13)	0.6(10)	0.6(5)	0.0(4)	0.0(0)
Tailrace	2.6(25)	0.0(19)	0.0(1)	0.0(11)	0.0(4)	0.6(13)	0.3(19)
Tailrace BRZ	11.7(50)	2.8(77)	4.6(67)	0.6(119)	1.9(31)	-	--

Appendix Table B-5. Indices of northern squawfish predation of juvenile salmonids from 1990-96 during spring in the lower Columbia and Snake rivers. **RKm** = river kilometer, **BRZ** = boat restricted zone.

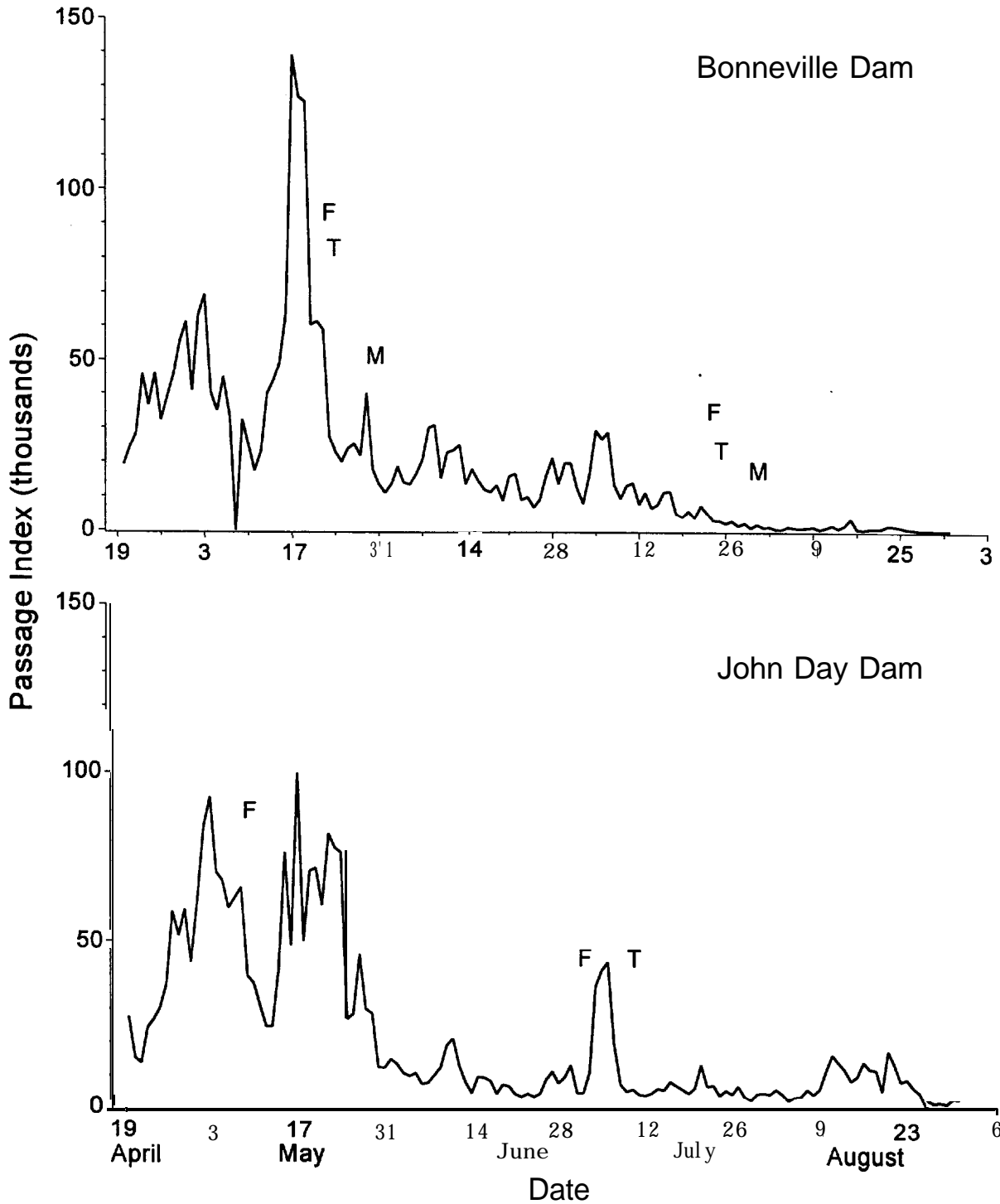
Location, area	Predation Index						
	1990	1991	1992	1993	1994	1995	1996
Below							
Bonneville Dam							
RKm 71-121	--	--	10.1	--	8.0	7.3	4.9
RKm 122-177	--	--	20.5	--	25.5	3.5	1.9
RKm 178-224	--	--	33.4	--	33.2	9.9	6.6
Tailrace	5.5	--	1.4	6.1	7.4	1.4	0.9
Tailrace BRZ	8.0	--	2.8	3.5	2.5	1.7	0.8
Bonneville Reservoir							
Forebay	3.3	--	--	1.5	0.3	0.7	0.0
Mid-reservoir	0.0	--	--	0.0	1.0	0.0	0.5
Tailrace	0.1	--	--	0.0	0.0	0.2	0.0
Tailrace BRZ	2.0	--	--	--	--	1.5	--
The Dalles Reservoir							
Forebay	1.1	--	--	0.2	0.1	0.0	0.0
Tailrace	1.9	--	--	0.0	--	--	--
Tailrace BRZ	3.9	--	--	0.0	--	--	--
John Day Reservoir							
Forebay	2.1	2.4	4.7	1.9	1.3	0.9	0.4
Mid-reservoir	0.0	2.4	0.0	0.0	0.0	0.0	0.0
Tailrace	1.9	1.3	1.9	1.7	0.2	0.5	0.3
Tailrace BRZ	3.9	2.9	0.9	--	0.2	--	--
Lower Monumental Res.							
Tailrace	--	0.8	--	--	0.2	0.0	0.0
Tailrace BRZ	--	0.6	--	--	--	0.3	0.0
Little Goose Reservoir							
Tailrace	--	0.5	--	--	0.4	<0.1	0.1
Tailrace BRZ	--	2.0	--	--	0.6	1.0	--
Lower Granite Reservoir							
Upper-reservoir	--	0.5	--	--	0.3	0.2	0.1

Appendix Table B-6. Indices of northern squawfish predation of juvenile salmonids from 1990-96 during summer in the lower Columbia River. **RKm** = river kilometer, **BRZ** = boat restricted zone.

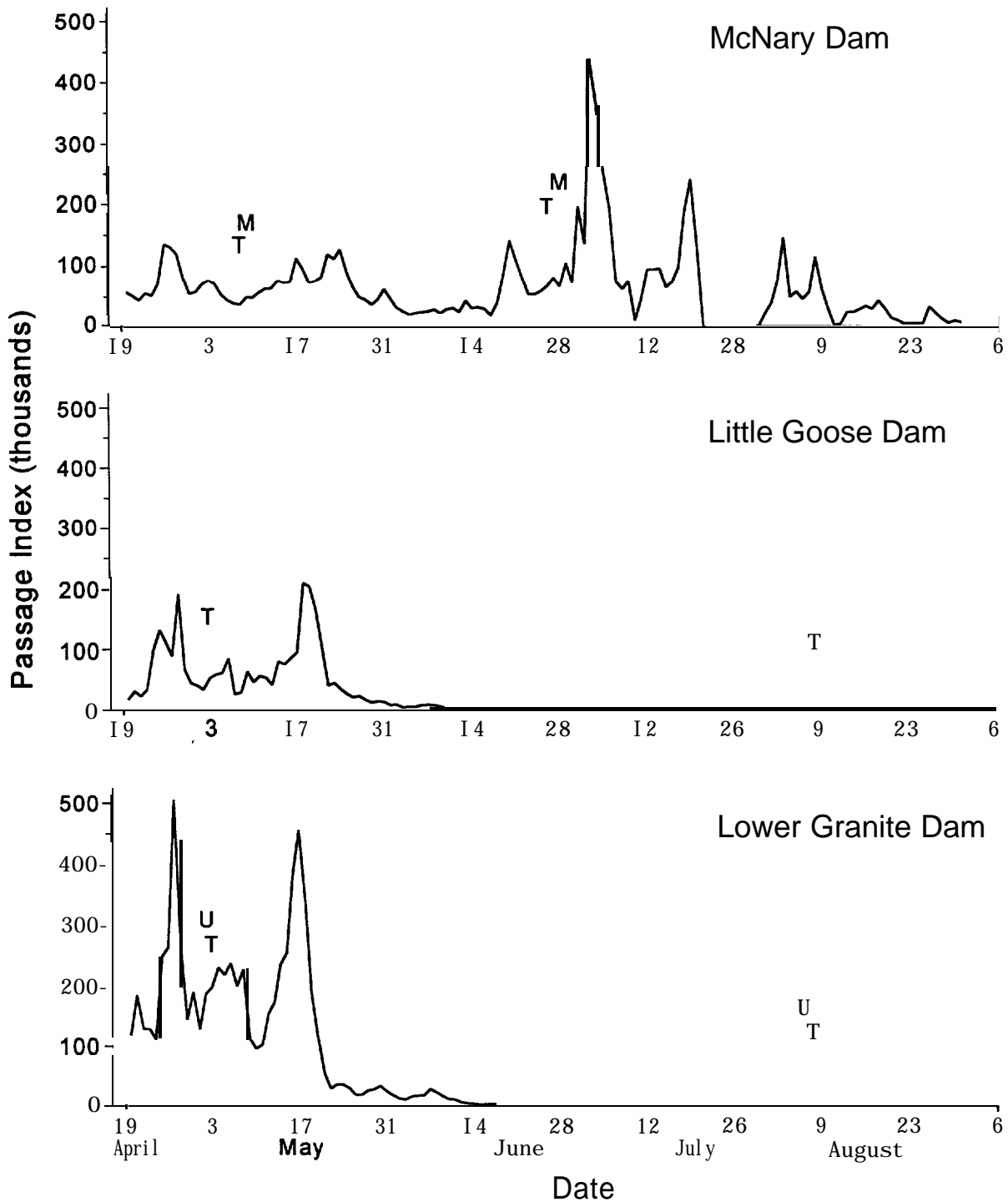
Location, area	Predation Index						
	1990	1991	1992	1993	1994	1995	1996
Below							
Bonneville Dam							
RKm 71-121	--	--	6.0	--	27.3	14.5	0.0
RKm 122-177	--	--	26.6	--	34.8	7.0	0.0
RKm 178-224	--	--	37.8	--	9.5	17.0	0.0
Tailrace	2.3	--	5.7	9.1	1.0	1.6	1.3
Tailrace BRZ	16.4	--	21.8	3.2	1.3	1.2	4.0
Bonneville Reservoir							
Forebay	9.9	--	--	1.1	0.6	0.0	0.4
Mid-reservoir	0.0	--	--	0.0	0.0	0.0	0.0
Tailrace	0.0	--	--	0.0	0.0	0.6	0.0
Tailrace BRZ	0.7	--	--	0.2	3.5	--	--
The Dalles Reservoir							
Forebay	1.4	--	--	0.0	0.0	0.0	0.0
Tailrace	0.0	--	--	0.0	0.5	0.0	2.5
Tailrace BRZ	27.8	--	--	1.1	1.4	1.5	3.8
John Day Reservoir							
Forebay	3.4	4.0	1.7	0.8	1.6	1.0	0.2
Mid-reservoir	4.7	--	0.0	2.0	1.4	0.0	0.0
Tailrace	3.8	--	0.0	0.0	0.0	0.4	0.2
Tailrace BRZ	18.6	5.4	4.6	0.9	0.5	--	--

APPENDIX C

Timing of 1996 Consumption Index Sampling in Relation to Juvenile Salmonid Passage Indices
at Lower Columbia and Snake River Dams



Appendix Table C-1. Timing of consumption index sampling with respect to juvenile salmonid passage indices at Bonneville and John Day dams in 1996. Sample times for forebay (F), tailrace (T), and areas downstream from Bonneville Dam tailrace (M) are shown.



Appendix Table C-2. Timing of consumption index sampling with respect to juvenile salmonid passage indices at McNary, Little Goose, and Lower Granite dams in 1996. Sample times for tailraces (T), mid-reservoir areas of McNary Reservoir (M), and upper Lower Granite Reservoir (U) are shown.

APPENDIX D

Digestive Tract Contents and Comparison of Fish Diets of Northern Squawfish,
Smallmouth Bass, and Walleye in 1996

We examined digestive tract contents of 665 northern squawfish, 870 smallmouth bass, and 112 walleye collected during standardized electrofishing in **1996 (Appendix Table D-1)**. The systemwide frequency of occurrence (%FO) of salmonids in digestive tracts was 6.9% in northern squawfish and 0.8% in smallmouth bass, or approximately 50% lower than in 1994-95 (Zimmerman et al. in press). The %FO of salmonids in walleye was 5.2%. The %FO of salmonids in northern squawfish was highest in Bonneville Dam tailrace during both spring (18.9%) and summer (19.7%). Frequency of occurrence of salmonids in smallmouth bass from all Snake River locations during spring was 3.2%. During summer, the %FO of salmonids in smallmouth bass was greatest below Bonneville Dam tailrace (2.7%) and in John Day Reservoir (1.7%). Systemwide %FO of salmonids in walleye was higher during spring (8.0%) than summer (1.6%).

The composition of prey fishes (by family) found in northern squawfish and smallmouth bass in 1996 was generally similar to 1994-95 (Zimmerman et al. in press). Salmonids comprised the majority (43-83%) of prey fish consumed by northern squawfish, whereas sculpins (*Cottus* spp.) comprised the majority (62-86%) consumed by smallmouth bass (**Appendix Table D-2**). The proportion of salmonids found in both northern squawfish and smallmouth bass was greatest in the Snake River. Smallmouth bass utilized prey other than salmonids and sculpins to a far greater extent than northern squawfish, with cyprinids making up the largest proportion of other prey taxa in all three reaches. The proportion of salmonids declined and the proportion of sculpins increased in the diets of northern squawfish and smallmouth bass in 1996. The most common prey fishes utilized by walleye were cyprinids and sandrollers *Percopsis transmontana*. Salmonids comprised a greater proportion of the diets of walleye than of smallmouth bass. No salmonids were found in walleye stomachs downstream from Bonneville Dam; this is probably attributable to a small sample size. Total number of prey fish per predator (all areas combined) was highest (0.59) for walleye, followed by 0.23 prey fish per smallmouth bass and 0.18 prey fish per northern squawfish. Number of prey consumed per predator in 1996 was 33-46% lower than 1994-95 for smallmouth bass and northern squawfish.

Appendix Table D-1. Number of northern squawfish, smallmouth bass, and walleye digestive tracts examined (N) from the lower Columbia and Snake rivers in 1996 that contained food, fish, and juvenile salmonids (Sal).

Period: or area	Northern squawfish				Smallmouth bass				Walleye				Reservoir	
	N	Food	Fish	Sal	N	Food	Fish	Sal	N	Food	Fish	Sal		
Spring:														
Below Bonneville														
Dam tailrace			99	43	18	8	39	19	6	0	2	2	2	0
Bonneville Dam														
tailrace			37	15	10	7	6	5	4	0	8	5	4	0
Bonneville			111	41	10	1	174	120	36	0	10	1	1	0
The Dalles			15	7	0	0	100	81	27	0	4	3	3	2
John Day			21	9	2	3	111	84	16	0	26	10	8	2
Lower Mon.			3	2	2	0	6	5	4	0	0	--	--	--
Little Goose			7	6	4	4	35	30	13	1	0	--	--	--
Lower Granite			23	16	4	3	83	54	10	3	0	--	--	--
Summer:														
Below Bonneville														
Dam tailrace			38	7	2	0	13	8	6	1	1	1	1	0
Bonneville Dam														
tailrace			71	26	19	14	7	4	3	0	5	3	2	0
Bonneville			88	27	3	0	56	35	12	0	5	4	4	0
The Dalles			103	20	7	4	55	40	11	0	20	8	7	0
John Day			32	15	2	2	115	89	21	2	31	21	21	1
Lower Mon.			9	2	1	0	24	18	4	0	0	--	--	--
Little Goose			6	1	0	0	20	13	2	0	0	--	--	--
Lower Granite			3	2	0	0	26	18	7	0	0	--	--	--

Appendix Table D-2. Sample size and percentage of salmonids, cottids, and other fish families in northern squawfish, smallmouth bass, and walleye digestive tracts containing identifiable fish in three reaches of the lower Columbia and Snake rivers in 1996. Reaches are downstream from Bonneville Dam (DBD), lower Columbia River reservoirs (COL), and lower Snake River reservoirs (SNK).

Sample size, DBD	Northern squawfish			Smallmouth bass			Walleye family		
	COL	SNK	DBD	COL	SNK	DBD	COL	SNK	
Digestive tracts	246	370	50	65	611	194	16	96	0
Total fish	64	37	16	21	134	41	9	57	--
Identifiable fish	57	30	12	16	85	35	5	38	--
% Salmonidae	63.2	43.3	83.3	6.2	3.5	11.4	0	13.2	--
% Cottidae	26.3	56.7	16.7	62.5	85.9	48.6	20.0	42.1	--
% Other taxa	10.5	0	0	31.3	10.6	40.0	80.0	44.7	--
% Cyprinidae	1.8	--	--	12.5	3.5	20.0	40.0	23.7	--
% Catostomidae	3.5	--	--	6.2	0	2.9	0	2.6	--
% Ictaluridae	0	--	--	0	1.2	17.1	0	0	--
% Percopsidae	5.3	--	--	6.2	3.5	0	40.0	3.5	--
% Gasterosteidae	0	--	--	0	0	0	0	0	--
% Centrarchidae	0	--	--	0	1.2	0	0	0	--
% Percidae	0	--	--	6.2	1.2	0	0	0	--

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