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

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VOLUME II - EVALUATION

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VOLUME II. EVALUATION

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EXECUTIVESUMMARY

by David L. Ward

We report our results of studies to determine the extent to which northern squawfish predation on juvenile salmonids is a problem in the Columbia River Basin, and to evaluate how effectively fisheries can be used to control northern squawfish populations and reduce juvenile salmonid losses to predation. These studies were initiated as part of a basinwide program to control northern squawfish predation and reduce mortality of juvenile salmonids on their migration to the ocean. Modeling simulations based on work in the John Day Reservoir from 1982 through 1988 indicated that if northern squawfish larger than 250 mm fork length were exploited at a rate of 10-20%, reductions in their numbers and restructuring of their populations could reduce their predation on juvenile salmonids by 50% or more. We evaluated the success of three test fisheries conducted in 1993 -- a sport-reward fishery, a dam-angling fishery, and a trap-net fishery, to achieve a 10-20% exploitation rate on northern squawfish. We also began evaluating the response of northern squawfish populations to sustained fisheries. In addition, we gathered information regarding the economic, social, and legal feasibility of sustaining each fishery, and report on the structure and function of the fish collection and distribution system.

The evaluation team included the Oregon Department of Fish and Wildlife (ODFW) and Oregon State University (OSU). ODFW was the lead agency and subcontracted various tasks and activities to OSU based on expertise OSU brings to the evaluation. Objectives of each cooperator were as follows.

1. ODFW (Report H): Continue evaluation of test fisheries in the Columbia River Basin as they are implemented; develop approaches to evaluate relative benefits of the fisheries in terms of juvenile salmonid survival; begin evaluation of systemwide response of northern squawfish to sustained fisheries; and monitor movements of radio-tagged northern squawfish away from dams to test assumptions used in developing an index of northern squawfish abundance.

2. OSU (Report I): Oversee the collection, transportation, storage, and distribution of all northern squawfish removed during the 1993 fishing season; conduct baseline monitoring of dam-angling and sport-reward removal fisheries for northern squawfish; and conduct baseline monitoring of social, regulatory, and enforcement issues related to the predator control program.

Highlights of results of our work by report are as follows.

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

1. Systemwide exploitation of northern squawfish was estimated to be 8.5% (all fisheries combined) in 1993. Exploitation was 6.8 % by the sport-reward fishery, 1.3 % by dam angling, and 0.5% by trapnetting. Mean fork length of northern squawfish caught by each fishery was greater than 250 mm. Dam angling was most selective for catching large northern squawfish (406 mm mean fork length). Incidental catch was highest in the trap-net fishery and consisted mostly of cyprinids other than northern squawfish.

2. Modeling results indicated that exploitation of northern squawfish in Snake River reservoirs had little effect on reducing overall predation. However, reducing exploitation in Snake River reservoirs notably increased predation on juvenile salmonids originating upstream from Lower Granite Dam. The goal of reducing overall predation by 50% may be reached by sustaining exploitation at 1991-93 levels. The sport-reward fishery has been two to four times more effective in reducing predation than the dam-angling fishery. However, because of differences in cost and areas fished, the two fisheries are complementary.

3. Proportional stock density, age composition, and sex ratio of northern squawfish populations in the lower Columbia River indicate that the proportion of large individuals has declined in most locations. However, relatively strong recruitment from 1988-90 has increased the proportion of young northern squawfish in most locations.

4. Radio-tagged northern squawfish were rarely found in deep, midchannel areas, supporting our hypothesis that these areas should be excluded when expanding catch indices to abundance indices.

Report I
Economic, Social, and Legal Feasibility of the 1993 Northern Squawfish Removal Fisheries and Fish Distribution System

1. The 1993 handling program was a considerable improvement over previous years; the design of the handling program satisfied all program requirements. An overall atmosphere of cooperation among agencies and fish-handling subcontractors was maintained throughout the season. It is feasible to operate a cost-effective, food-grade collection system in the area between Cascade Locks and The Dalles. At all other areas, the entire catch should be rendered.

2. Results from baseline monitoring of the sport-reward and dam-angling fisheries will be reported when expenditure data become available.

3. Social and regulatory issues associated with the removal fisheries have continued to improve. Enforcement of fishery regulations has been difficult due to large numbers of sport-reward participants, dispersal of registration sites, and difficulties of tracking fish origin. Regulations related to quality of northern **squawfish** continue to be only marginally enforceable.

REPORT H

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

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ABSTRACT

We are reporting progress on evaluation of northern squawfish (*Ptychocheilus oregonensis*) predation and predator control fisheries performance in 1993. Our objectives in 1993 were to (1) evaluate effectiveness of fisheries for northern squawfish by comparing exploitation, size composition and incidental catch among fisheries; (2) develop approaches to compare relative benefits of fisheries in terms of reductions in predation; (3) evaluate changes in relative abundance, consumption, size and age structure, sex ratio, growth, and fecundity of northern squawfish in lower Columbia River reservoirs and Bonneville Dam tailrace; and (4) evaluate movement and distribution of northern squawfish using radiotelemetry.

Systemwide exploitation of northern squawfish in 1993 was 6.8% for sport reward, 1.3% for dam angling, 0.5% for trap nets. Size composition and incidental catch in sport-

reward and dam-angling fisheries was similar to previous years. Incidental catch was very high in the trap net fishery and the majority of northern squawfish harvested were <250 mm fork length.

We developed a spreadsheet to compare reductions in predation among various alternatives for implementation of sport-reward and dam-angling fisheries. Results indicated that exploitation of northern squawfish in Snake River reservoirs had little effect on reducing overall predation. However, reducing exploitation in Snake River reservoirs notably increased predation on juvenile salmonids originating upstream from Lower Granite Dam. The goal of reducing overall predation by 50% may be reached by sustaining exploitation at 1991-93 levels.

We used size-specific reported catch and exploitation of northern squawfish to compare reductions in predation between sport-reward and dam-angling fisheries in 1992 and 1993. Reductions in predation due to the sport-reward fishery ranged from 2.0 to 4.4 times those due to dam angling, depending on the year evaluated and the method used.

We estimated relative abundance and consumption of northern squawfish in Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. Relative abundance in 1993 was similar to or slightly less than in 1990, and relative consumption was considerably lower in 1993 than 1990 in most locations.

Proportional stock density, age composition, and sex ratio of northern squawfish populations in the lower Columbia River indicate that the proportion of large individuals has declined in most locations, particularly in Bonneville Reservoir, and increased in McNary Reservoir. Relatively strong recruitment from 1988-90 has increased the proportion of young northern squawfish in most locations.

Radio-tagged northern squawfish in Bonneville and The Dalles reservoirs were typically found in depths of less than 12 m. More than 80% of the tagged fish moved among different areas (forebay, midreservoir, tailrace, boat-restricted zone) in both reservoirs.

INTRODUCTION

The goal of the predator control program is to reduce in-reservoir mortality of juvenile salmonids to predation by northern squawfish (*Ptychocheilus oregonensis).* From 1990 through 1992, we estimated the relative magnitude of northern squawfish abundance, consumption, and predation in the Columbia River impoundments (1990), Snake River impoundments (1991), and the unimpounded lower Columbia River downstream from Bonneville Dam (1992). Those results established baseline levels of predation and described northern squawfish population characteristics throughout the lower basin before the implementation of sustained predator control fisheries. The 1993 field season represented the third or fourth consecutive year (depending upon area) of predator control fisheries. In this report we describe our activities and findings in 1993, and wherever possible, evaluate any changes from previous years.

Our objectives in 1993 were to (1) evaluate predator control fisheries throughout the lower Columbia River Basin by comparing exploitation, size composition, and incidental catch among fisheries; (2) develop approaches to compare relative benefits of fisheries in terms of losses of juvenile salmonids to predation relative to losses prior to any predator control fisheries; (3) evaluate changes through 1993 in northern squawfish populations, including relative abundance, consumption, size and age structure, sex ratio, growth, and fecundity; and (4) evaluate movement and distribution of radio-tagged northern squawfish outside boat-restricted zones in Bonneville and The Dalles reservoirs to evaluate assumptions associated with abundance indexing and exploitation.

METHODS

Fishery Evaluation

Field Procedures

Three predator control fisheries were conducted in 1993. The sport-reward fishery was implemented by the Washington Department of Wildlife (WDW) from May 3 through September 12 throughout the lower Columbia and Snake rivers. The dam-angling fishery was implemented by Columbia River Inter-Tribal Fish Commission (CRITFC) from May 17 through September 16 at Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose and Lower Granite dams. The trap-net fishery was implemented by Oregon Department of Fish and Wildlife (ODFW), Confederated Tribes of the Warm Springs Reservation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce Tribe from June 1 through August 3 downstream from Bonneville Dam and in Bonneville, The Dalles and John Day reservoirs.

We estimated exploitation of northern squawfish for each fishery based on recovery of fish tagged primarily before implementation of 1993 fisheries. We used electrofishing boats, bottom gill nets and surface gill nets to collect northern squawfish from March 1 to June 17. Sampling effort was randomly allocated in all river kilometers (RKm) from RKm 71 through McNary Reservoir on the lower Columbia River, and in the Snake River from RKm 0 through Lower Granite Reservoir. Fish greater than 225 mm fork length were tagged with a serially numbered spaghetti tag and given a secondary mark (left pelvic fin clip). Tags were recovered from each fishery from May 3 through September 16.

We measured fork lengths of northern squawfish from a subsample of fish harvested in sport-reward and dam-angling fisheries. Fish from each sport-reward check station were sampled at least one weekday per week and one weekend day per month. Fish from each dam were sampled at least one day per week. Fork lengths of fish harvested by the trap-net fishery were collected by ODFW trap-net implementation. Catch composition of each fishery was provided by WDW (sport reward), CRITFC (dam angling), and ODFW Implementation (trap net).

Data Analysis

We used mark and recapture data to compare exploitation rates of northern squawfish among fisheries and reservoirs (Appendix H-2). Exploitation was calculated for one-week periods during predator control fisheries and summed to yield total exploitation for each fishery (Beamesderfer et al. 1987). We adjusted exploitation estimates for tag loss (4.8%) during the season.

We compared mean fork lengths of northern squawfish, length frequency histograms, and incidental catch in 1993 among fisheries. We also compared mean fork lengths of fish harvested by sport-reward and dam-angling fisheries among years (1990-1993).

Relative Benefits of Fisheries

We used a spreadsheet model to compare benefits (reductions in predation by northern squawfish) among various combinations of sport-reward and dam-angling fisheries. Documentation for the "Loss Estimate Spreadsheet" is given in Appendix H-l.

We used age-specific reported catch and age-specific exploitation in 1992 and 1993 to compare reductions in predation due to sport-reward and dam-angling fisheries. For each fishery, we calculated the reduction in predation by each age of northern squawfish as the product of age-specific reported catch or exploitation and age-specific lifetime predation. We summed age-specific reductions to estimate total reduction in predation for each fishery, and determined the ratio of sport-reward to dam-angling reduction.

We used length-at-age analyses from 1990 through 1993 to estimate the age composition of the reported northern squawfish catch for both fisheries. We used Equations 1 through 4 in Appendix H-l to estimate age-specific exploitation for both fisheries. Because calculations using exploitation would give equal weight to each age regardless of age composition, we weighted age-specific exploitation rates by the relative abundance of each age. We used Equation 12 in Appendix H-l to estimate relative age-specific consumption rates for northern squawfish, and then estimated age-specific relative lifetime predation as

$$LC_h = RC_h + (RC_{h+1} \cdot S_{h+1}) + (RC_{h+2} \cdot S_{h+2}) + \cdots + (RC_{h+n} \cdot S_{h+n})$$

where

LC_h = relative lifetime consumption for age h northern squawfish,

RC_h = relative consumption for age h fish, and

S_{h+1} = survival rate of age h fish to age h + 1.

Relative benefits of the fisheries as estimated above depend only upon differences in age (size)-specific catch or exploitation between fisheries. Analysis of observed versus expected recaptures in sport-reward and dam-angling fisheries of northern squawfish tagged inside and outside boat restricted zones indicates that most tagged fish are vulnerable to both fisheries (Appendix Table H-l. 1). Because mixing is relatively complete, only size-related differences in consumption need be considered when evaluating relative benefits of the fisheries.

Biological Evaluation

Field Procedures

To evaluate changes in relative abundance and consumption, we used boat electrofishing, bottom gill nets, and surface gill nets to collect northern squawfish in the Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. Sampling schedules, methods, and gear specifications were as described in previous reports (Vigg et al. 1990; Ward et al. 1991; Parker et al. 1992). Effort in 1993 differed from previous years for two reasons. Abundance indices from 1990 through 1992 were calculated from pooled electrofishing catch and effort data gathered by ODFW and U.S. Fish and Wildlife Service (USFWS). In 1993, John Day Reservoir was the only area sampled by both ODFW and USFWS. As a result, the number of electrofishing runs completed in areas other than John Day Reservoir in 1993 averaged 36% fewer than in 1990. Additionally, high flows in May 1993 prevented sampling in the boat restricted zone (BRZ) of dam tailraces, reducing our total effort in BRZs by approximately 50%. We collected and preserved guts of all northern squawfish ≥250 mm fork length. Details of collection procedures are given in Petersen et al. (1991).

To evaluate changes in population structure, growth, and reproduction, we collected biological data from all northern squawfish collected by electrofishing and gill-net sampling, and from a subsample of northern squawfish caught in the sport-reward and dam-angling fisheries. We measured fork length (mm) and total body weight (g), we determined sex (male, female, undetermined) and maturity (undeveloped or immature, developing, ripe, or spent), and we collected scale samples and gonad samples (ripe females only).

Laboratory Procedures

We examined gut contents of northern squawfish collected by electrofishing to measure relative consumption rates of juvenile salmonids by northern squawfish. Details of laboratory methods are given in Petersen et al. (1991). We pooled ODFW and USFWS data to supplement gut sample size in John Day Reservoir.

We used gravimetric quantification (Bagenal 1968) to estimate fecundity of northern squawfish. Ripe ovaries were preserved in Gilson's solution for a minimum of four weeks. Ovary samples were then prepared for analysis as described by Vigg et al. (1990). Ovary subsamples were weighed and egg counts in the subsamples were extrapolated to total ovarian weight. Only counts of developed eggs, characterized by their relatively large size and yellow or orange color, were used in estimating fecundity and describing fecundity relationships with body weight.

We used scale samples from northern squawfish collected primarily by electrofishing and gill-net sampling for age determinations. We supplemented sample sizes with scales from fish caught in predator control fisheries. For Bonneville Dam tailrace and Columbia River reservoirs, we randomly selected scale samples from 20 individuals from each 25-mm length group. If the initial random sample was not comprised of scales from 10 males and 10 females, we added scales to obtain 10 samples from each sex if possible. Scale collection and aging techniques followed established methods (Jearld 1983).

Data Analysis

We used the reciprocal of the square root of the proportion of zero catches as an index of northern squawfish density (Ward et al. 1992). In 1993, we were unable to calculate a density index for the tailrace BRZs of Bonneville, John Day, and Ice Harbor dams because the proportion of zero catches equaled zero. The next highest density index value we observed throughout all sampling areas in 1993 was 2.309 (Bonneville Dam tailrace non-restricted zone), which was rounded up to the next whole number (3.000) and assigned to the tailrace BRZs of Bonneville, John Day, and Ice Harbor dams. We assumed an index value of 3.000 was representative of high squawfish density in those areas during 1993. We compared density indices between 1990 and 1993 for all sampling areas in the Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. We calculated indices of northern squawtish abundance (Vigg et al. 1990; Ward et al. 1991; Parker et al. 1992), and compared indices between 1990 and 1993 for the lower Columbia River reservoirs and Bonneville Dam tailrace.

The following formula was developed as a consumption index (CI) by the USFWS (Petersen et al. 1991):

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

where

T = water temperature (°C),
MW = mean predator weight (g),
S = mean number of salmonids per predator, and
GW = mean gut weight (g) per predator.

The consumption index is not a rigorous estimate of the number of juvenile salmonids eaten per day by an average northern squawfish. However, it is linearly related to the consumption rate of northern squawfish (Petersen et al. 1991). We compared consumption indices between 1990 and 1993 in spring and summer for sampling areas in lower Columbia River reservoirs and Bonneville Dam tailrace.

We used ODFW electrofishing data to compare mean fork lengths and length frequency histograms (50 mm fork length increments) of northern squawfish between 1990 and 1993 for Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. We also compared sex ratio between 1990 and 1993 by summarizing the proportion of females by 50-mm fork length increments, and by calculating the proportion of females among fish < and ≥ 350 mm fork length.

We determined backcalculated fork lengths at formation of annuli to develop age-at-length keys (Appendix H-3) for northern squawfish from Bonneville Dam tailrace, and the four lower Columbia River reservoirs in 1993. We pooled age-at-length data from 1990-93, applied the pooled keys to the size composition of northern squawtish in standardized electrofishing samples in each area, and compared age composition between 1990 and 1993.

After correcting the observed size distributions for bias associated with size selectivity of electrofishing gear (Beamesderfer and Rieman 1988), we calculated proportional stock density (PSD) for all lower Columbia River locations in all years for which standardized electrofishing catch data was available. We defined PSD for northern squawfish as:

$$PSD = \frac{\text{number of quality-sized fish}}{\text{number of stock-sized fish}} \cdot 100$$

We defined stock-size as ≥ age 4 in Bonneville, The Dalles, and John Day reservoirs, and ≥ age 5 in Bonneville Dam tailrace and McNary Reservoir. We defined quality-size as ≥ age 8 in Bonneville Reservoir, and ≥ age 9 in the remaining areas. We applied the pooled age-at-length keys to the observed size distribution in each year and area.

To evaluate changes in growth rate after implementation of the predator control program, we compared annual growth increments from 1987 to 1990 for northern squawfish of ages 6-l 1 in 1990 samples with growth increments from 1990 to 1993 for like-aged fish in

1993 samples. We limited analysis to fish of at least age 6 because most **6-year-old** fish were "predator-size" (≥ 250mm). We excluded fish older than age 11 because growth increments for older fish were very small, and the accuracy and precision of age determination using scales typically declines for older-age fish. **We** compared growth for two areas — Bonneville Dam **tailrace** and the combined lower Columbia River reservoirs.

We calculated mean fecundity (number of developed eggs per female) and mean relative fecundity (number of developed eggs per gram of body weight) in 1991, 1992, and 1993 (fecundity data were not available for 1990) for two areas — Bonneville Dam **tailrace** and the combined lower Columbia River reservoirs. **We** determined regression parameters for the regression of log,, (fecundity) on log,,, (weight), and tested slopes for equality among years in each area. If slopes were equal, we used analysis of covariance with weight as the covariate to test for differences among years (a significant difference among slopes prohibited our testing for differences in fecundity among years). If fecundity was similar among years, we pooled data from all three years and calculated a single fecundity estimate.

We used age composition (based on pooled age-at-length keys) of **electrofishing** catches in successive catch years to calculate relative year-class strength of northern squawfish cohorts by methods described by El Zarka (1959). We plotted the index of relative year-class strength from 1.975 through 1990 for the Bonneville Dam tailrace, and Bonneville and John Day reservoirs based on catch years 1990-1993.

Radiotelemetry

Field Procedures

The USFWS surgically implanted transmitters (3 **V,** 149-150 MHz) in northern squawfish. Transmitters were digitally encoded with up to 13 codes per frequency. Fish were captured, tagged, and released from April 12, 1993, to May 16, 1993, primarily in the tailraces of John Day and The Dalles dams. Seventy-one northern squawfish (340-515 mm fork length) were tagged in The Dalles Reservoir, and 64 northern squawfish (359-550 mm fork length) were tagged in Bonneville Reservoir. In The Dalles Reservoir, 37 fish were released in John Day Dam **tailrace** BRZ, 28 were released in the **tailrace** outside the BRZ, and six were released at the mouth of the Deschutes River. In Bonneville Reservoir, 45 fish were released in The Dalles Dam **tailrace** BRZ, and 19 were released in the **tailrace** outside the BRZ.

We located tagged fish with a Lotek **SRX1C** 400 receiver, and 3-element and **4-**element Yagi antennas. From May through September, we mobile-tracked fish four days per week from a boat, and one day every two weeks from an airplane. Mobile-tracking by boat was conducted primarily outside the **BRZs,** whereas the USFWS tracked **fish** primarily from fixed stations within the **BRZs.** Flights were used to direct boat tracking efforts by identifying general locations of fish away from dams. Individual signals typically could not be decoded from the air. When fish were located during boat tracking, the receiver decoded the transmitters' signals permitting identification of individual fish. When unique signals were decoded, we recorded location (river kilometer to the nearest 0.16 km), distance to each shore (m), and depth (m).

Mobile tracking was conducted primarily during daylight hours, however, one day-per month from June through September, we tracked selected fish during crepuscular and nighttime hours to assess differences in distance to shore, depth, and general activity with time of day.

Data Analysis

We used radiotelemetry to answer two questions: (1) Do northern squawfish occupy areas that are both within 50 m of shore and less than 12.2 m deep?; and (2) Are fish tagged in tailrace restricted zones equally vulnerable to dam-angling and sport-reward fisheries, and conversely, are fish tagged outside boat restricted zones equally vulnerable to each fishery? The first question addresses our assumption that northern squawfish are primarily distributed in littoral zones within midreservoir areas. It tests whether our standardized sampling approach to index northern squawfish abundance was biased by concentrating our sampling efforts in littoral areas, and excluding deep, midchannel areas when indexing northern squawfish abundance in midreservoirs. Our approach was to determine depth and distance to shore of radio-tagged fish in midreservoir areas. Regarding the second question, our approach was to examine the extent of movement of radio-tagged fish among forebay, midreservoir, tailrace, and BRZ areas in each reservoir.

We summarized depth and distance to the nearest shore by reservoir to evaluate the extent to which squawfish utilize near-shore areas. We calculated mean depth and distance to shore, and calculated frequency distributions for depth (3.05-m intervals) and distance to shore (50-m intervals). We also plotted depth and distance to shore versus time for individual fish that were monitored for up to 16 hours in June, July, and August, and for up to 48 hours in September. These records of individual fish movements were used to illustrate any relationships between depth and location in the channel, and to evaluate any consistent patterns of movement associated with time of day.

To evaluate movement of tagged fish throughout reservoirs, we summarized fish locations (farthest area found from release areas) among reaches that corresponded to sampling areas used to index squawfish abundance and consumption. Reaches in river kilometers (RKm) and corresponding areas in Bonneville Reservoir are RKm 234.9-240.7 (forebay), RKm 240.7-302.5 (midreservoir), RKm 302.5-308.1 (tailrace non-restricted zone), and RKm 308.1-310.2 (tailrace restricted zone). Reaches in The Dalles Reservoir are RKm 308.9-316.2 (forebay), RKm 316.2-341.1 (midreservoir), RKm 341.1-347.9 (tailrace non-restricted zone), and RKm 347.9-348.5 (tailrace restricted zone).

RESULTS

Fishery Evaluation

We tagged and released 1,950 northern squawfish throughout the lower Columbia and Snake rivers. A total of 145 marked northern squawfish were recaptured in the three fisheries — 114 by sport-reward anglers, 23 by dam anglers, and 8 by trap-net fishers. Additionally, three tags were recovered during ODFW electrofishing and gill-net sampling, two were recovered by the National Marine Fisheries Service, and two were recovered by other sport anglers not participating in the sport-reward fishery.

Of the 152 marked fish recovered, 139 (91.4%) were recaptured within the reservoir they were originally tagged and released (Table H-l). Northern squawfish movement past dams differed among reservoirs and areas. Only 68.2% of the recaptured fish originally tagged in Bonneville Reservoir were recaptured in Bonneville Reservoir, whereas 100% of recaptured fish tagged in John Day, McNary, and Little Goose reservoirs were recaptured in the reservoir they were originally released.

Table H-l. Percentage of northern sguawfish tagged in a given reservoir recaptured in each reservoir by removal fisheries. DBD = downstream from Bonneville Dam, BON = Bonneville Reservoir, TDA = The Dalles Reservoir, JDY = John Day Reservoir, MCN = McNary Reservoir, ICH = Ice Harbor Reservoir, LMO = Lower Monumental Reservoir, LGO = Little Goose Reservoir and LGR = Lower Granite Reservoir.

Location marked	Number recaptured	Percent recaptured								
		DBD	BON	TDA	JDY	MCN	ICH	LMO	LGO	LGR
DBD	53	96.2	3.8	--	--	--	--	--	--	--
BON	22	13.6	68.2	18.2	--	--	--	--	--	--
TDA	8	12.5	--	87.5	--	--	--	--	--	--
JDY	13	--	--	--	100.0	--	--	--	--	--
MCN	23	--	--	--	--	100.0	--	--	--	--
ICH	0	--	--	--	--	--	--	--	--	--
LMO	5	--	--	--	--	--	--	80.0	--	20.0
LGO	4	--	--	--	--	--	--	--	100.0	--
LGR	17	--	--	--	--	--	--	--	11.8	88.2

The sport-reward fishery had the highest exploitation of northern squawfish among fisheries in nearly all areas in 1993 (Table H-2). Compared to exploitation rates in 1992, sport-reward exploitation was lower in 1993 than 1992 in all locations except The Dalles, McNary, and Lower Monumental reservoirs. Dam angling exploitation was lower in 1993 relative to 1992 in all areas where tags were recovered both years. No tagged fish were recaptured by dam angling in 1993 in the Bonneville Dam tailrace and The Dalles, Lower Monumental, and Lower Granite reservoirs. The trap-net fishery contributed relatively little to total exploitation below Bonneville Dam and in Bonneville Reservoir. No tagged fish were recovered in trap nets in The Dalles and John Day Reservoir. Reservoir-specific exploitation estimates are conservative because they exclude fish that were recaptured in reservoirs other than where marked, whereas systemwide exploitation estimates include northern squawfish caught in reservoirs other than those in which they were originally tagged. Total exploitation (all fisheries combined) of northern squawfish ≥250 mm during 1993 was 8.5 % , which was lower than in previous years (Table H-3). Reservoir-specific exploitation was lower in 1993 than 1992 in all locations except McNary Reservoir. There are no estimates of exploitation in Ice Harbor Reservoir in 1992 and 1993 because no northern squawfish were tagged.

As was the case in previous years, the sport-reward and dam-angling fisheries harvested a disproportional number of large northern squawfish (Figure H-l). Mean fork length was 335 mm in the sport-reward fishery and 406 mm in the dam-angling fishery. In contrast, the trap-net fishery harvested a wide size range of northern squawfish, with the majority (83.9%) of fish <250 mm. A representative sample of fork lengths was not obtained for small fish, and excluding fish < 250 mm fork length, the mean size of fish harvested in the trap-net fishery was 318 mm (N=493). If small fish had been measured, the mean fork length would be much lower.

Table H-2. Exploitation rates (%) of northern sguawfish ≥250 mm among fisheries in 1993.

Location	Sport reward	Dam angling	Trap net	Total
Downstream from Bonneville Dam	6.1	--	1.0	7.1
Bonneville	2.1	2.2	0.3	4.6
The Dalles	7.0	--	--	7.0
John Day	2.4	8.1	--	10.5
McNary	16.0	0.5	--	16.5
Ice Harbor	--	--	--	--
Lower Monumental	3.1	--	--	3.1
Little Goose	3.3	3.3	--	6.6
Lower Granite	12.6	--	--	12.6
Systemwide	6.8	1.3	0.5	8.5

Table H-3. -Total exploitation rates (all fisheries combined) of northern aquawfish 2250 mm in 1991, 1992 and 1993.

Location	1991	1992	1993
Downstream from Bonneville Dam	8.1	11.8	7.1
Bonneville	15.2	6.8	4.6
The Dalles	10.5	7.2	7.0
John Day	13.3	14.3	10.5
McNary	5.2	5.6	16.5
Ice Harbor	17.5	--	
Lower Monumental	27.0	7.7	3.1
Little Goose	18.4	18.1	6.6
Lower Granite	16.8	14.6	12.6
Systemwide	11.3	12.2	8.5

Mean size of northern squawfish harvested in each reservoir by dam angling in 1993 was generally within the range for previous years (Table H-4). The significance of apparent increases in size in 1993 in McNary, Ice Harbor, and Lower Monumental reservoirs is uncertain because mean fork lengths in 1993 were based on relatively small sample sizes. The size of fish harvested in 1993 by sport-reward anglers declined downstream from Bonneville Dam and in Bonneville Reservoir, but did not change appreciably in other Columbia River reservoirs (Table H-4). The size of fish harvested in 1993 appeared to differ from previous years in Snake River reservoirs, but sampling was limited in the Snake River in 1993.

Incidental catch varied among fisheries (Table H-5). Relative to the total number of fish caught, the sport-reward fishery had the lowest percentage (1.8 %) of incidental catch. Dam-angling incidental catch was also relatively low (5.7%) and consisted mostly of smallmouth bass (*Micropterus dolomieui*) and channel cattish *Ictalurus punctatus*. Incidental catch in the trap-net fishery was 77.0%, and included 2,511 adult and juvenile anadromous salmonids. The proportion of predator-size northern squawfish (≥ 250 mm fork length) relative to total number of squawfish harvested was very low (16.1%) in the trap-net fishery. In contrast, predator-sized fish comprised 93.1% of northern squawfish harvested by sport-reward anglers and 99.0% of northern squawfish harvested by dam anglers.

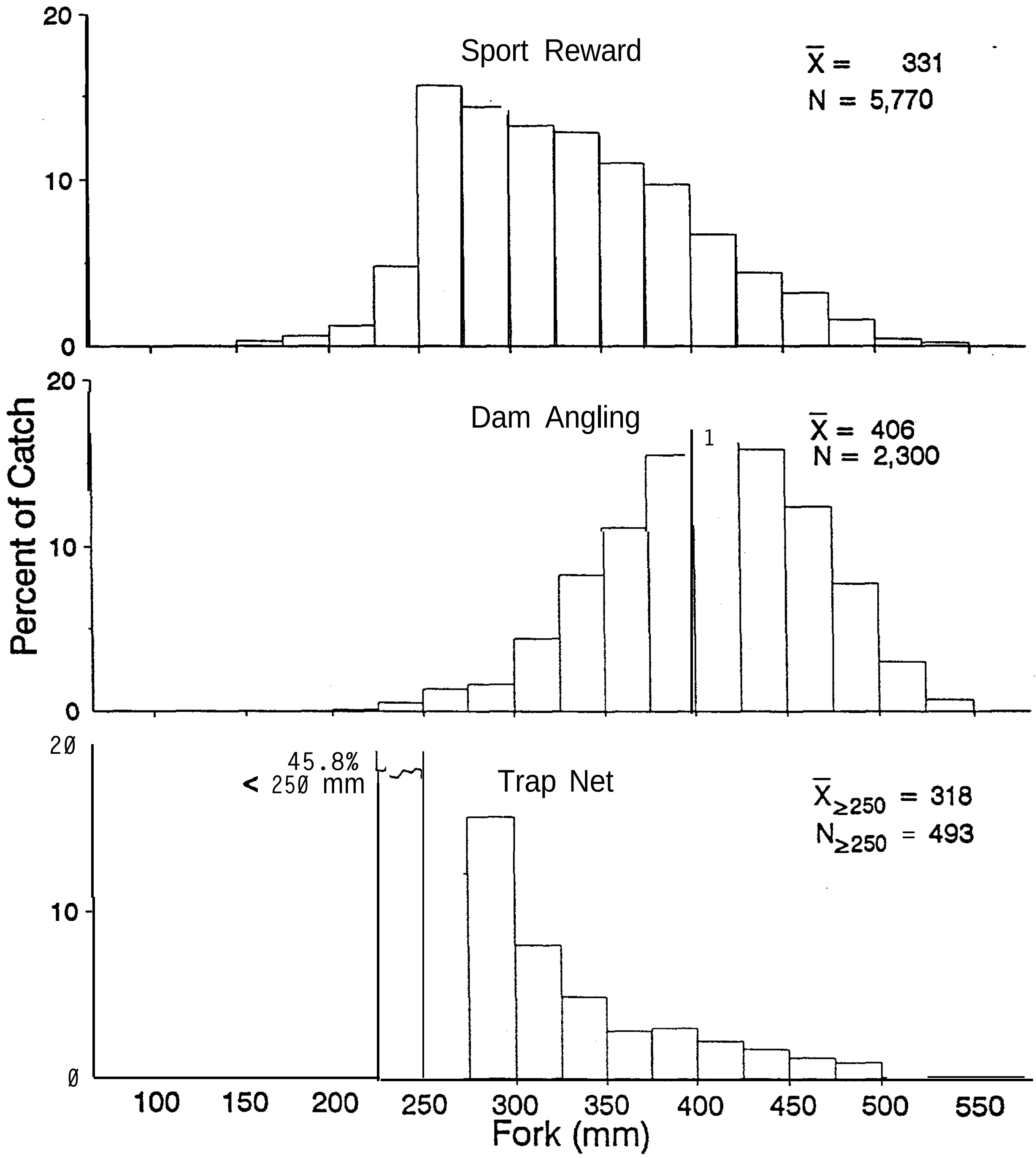

Figure H-1. Size composition and mean fork length of northern squawfish in subsamples of fish harvested system-wide in sport-reward, dam-angling, and trap net fisheries in 1993. N = subsample size.

Table H-4.. Mean fork length (mm) of northern squawfish harvested from 1990 through 1993 in each fishery downstream from Bonneville Dam (DBD), and in each lower Columbia River and lower Snake River reservoir.

	Mean fork length (mm)			
Fishery: location	1990	1991	1992	-1993
Dam angling:				
Bonneville Dam Tailrace	414	417	388	390
Bonneville Reservoir	407	417	416	415
The Dalles Reservoir	421	404	380	420
John Day Reservoir	416	414	417	416
McNary Reservoir	393	393	375	408
Ice Harbor Reservoir	--	375	369	414
Lower Monumental Reservoir	--	325	309	341
Little Goose Reservoir	--	380	346	373
Lower Granite Reservoir	--	--	--	377
Sport reward:				
Downstream from Bonneville Dam	--	332	337	316
Bonneville Reservoir	--	343	347	312
The Dalles Reservoir	--	344	369	369
John Day Reservoir	377	370	367	370
McNary Reservoir	--	354	356	358
Ice Harbor Reservoir	--	357	360	317
Lower Monumental Reservoir	--	338	330	307
Little Goose Reservoir	--	312	347	344
Lower Granite Reservoir	--	343	345	362

Table H-5.. Number of northern sguawfish and incidentally caught fish by species or family in each fishery in 1993.

Species or family	Sport reward	Dam angling	Trap net
Northern sguawfish:			
≥ 250 mm fork length	104,506	17,210	1,684
< 250 mm fork length	7,786	170	8,754
Channel catfish	202	366	74
Smallmouth bass	493	394	45
Walleye'	121	32	13
White sturgeon[a]	11	138	8
American shad' (adult)	28	57	1,500
Salmonidae':			
Chinook (adult)	5	0	36
Chinook (juvenile	0		2
Sockeye (adult)	0	00	319
Coho (adult)	1	0	0
Steelhead (adult)	23	1	657
Steelhead (juvenile)	9	3	71
Unknown (adult)	0	2	26
Unknown (juvenile)	0	0	1,400
Catostomidae[b]	1,105	::	23,724
idae[b]	80		2,650
Other	65	49	4,308
Total (all species)	114,385	18,422	45,298

[a] Walleye = *Stizostedion vitreum vitreum*, white sturgeon = *Acipenser transmontanus*, american shad = Alosa *sapidissima*, salmonids = *Oncorhynchus* spp.

[b] All "non-game" fish caught by dam-angling are classified as "Other."

Relative Benefits of Fisheries

Eventual reductions in predation vary depending on in which reservoirs fisheries are implemented (Table H-6). The number of years required to reach maximum annual benefit also varies. The goal of reducing predation by 50% appears possible if systemwide exploitation is sustained at 1991-93 levels. Eliminating exploitation in Snake River reservoirs will have little effect on overall predation. However, eliminating exploitation in Snake River reservoirs will notably increase predation on juvenile salmonids originating upstream from Lower Granite Dam.

The sport-reward fishery has had more effect on reducing predation than dam angling (Table H-7). Estimates of sport-reward benefits in 1992 were highest when using reported catch. However, sport-reward catch may include fish caught outside program boundaries. This is reflected by differences in ratios between reported catch and exploitation rate.

Biological Evaluation

Density (Table H-8) and relative abundance (Figure H-2) of northern squawfish ≥250 mm in John Day Reservoir were nearly identical between 1993 and 1990. The percent change from 1990 to 1993 in abundance indices for other areas ranged from -36.1% in Bonneville Reservoir to + 16.7% in Bonneville Dam tailrace.

Northern squawfish consumption indices in 1993 were lower in most sampling areas than in 1990, particularly in summer (Table H-9), which translated into lower indices of predation in 1993 (Figure H-3). The percent change from 1990 to 1993 in predation indices during spring was -37.6% for Bonneville Dam tailrace, -75.4% for Bonneville Reservoir, -35.0% for The Dalles Reservoir, +14.9% for John Day Reservoir, and -90.5% for McNary Reservoir. The change in predation indices during summer was -42.3% for Bonneville Dam tailrace, -82.3% for Bonneville Reservoir, -96.2% for The Dalles Reservoir, -54.5% for John Day Reservoir, and -49.2% for McNary Reservoir. Combining spring and summer predation indices, predation in 1993 was 40-50% lower than in 1990 in Bonneville Dam tailrace, and John Day and McNary reservoirs, and an order of magnitude lower in Bonneville and The Dalles reservoirs.

Table H-6.- Comparison of predicted annual losses of juvenile salmonids (expressed as percent of loss prior to exploitation of northern sguawfish) to northern sguawfish predation among various alternatives for distribution of fishing effort. Exploitation rates in each reservoir beyond 1993 were assumed to equal the mean 1991-93 rate (from Table H-3). Reservoirs are: 1-Downstream from Bonneville Dam, 2-Bonneville, 3-The Dalles, 4-John Day, 5-McNary, 6-Ice Harbor, 7-Lower Monumental, 8-Little Goose, and 9-Lower Granite.

	Reservoirs fished		Overall predation		Predation on fish originating upstream from Lower Granite Dam	
Fisheries alternative	Sport reward	Dam angling	% of pre-exploitation	Year reached	% of pre-exploitation	Year reached
1	1-9	1-8	50	2004	45	2001
2	1-5,8,9	1-4,7,8	52	2000	50	1999
3	1-5	1-5	55	1998	84	2004
4	1-5	1-4	55	1999	84	2004
5	1-4	1-4	61	2002	84	2004
6	1-4	1,4	63	2002	84	2004
7	1,2,4	1,4	65	2004	84	2004
8	1,2	1,4	67	2004	84	2004
9	1,4	1,4	71	2002	84	2004
10	1,8,9	1,7,8	76	2003	51	1998
11	1	1	80			
12	8,9	7,8	96	2004 2003	84 69	2003 2003

Table H-7. Ratio of sport-reward fishery to dam-angling fishery for reported catch, estimated exploitation rate, and reduction in losses of juvenile salmonids to northern sguawfish predation.

			Reduction in predation	
Year	Reported catch	Exploitation rate	Based on age-specific reported catch	Based on age-specific exploitation
1992	6.7-1.0	3.5-1.0	4.4-1.0	2.0-1.0
1993	6.1-1.0	5.1-1.0	3.1-1.0	3.1-1.0

Table H-8.- Indices of northern sguawfish density in 1990 and 1993 for sampling zones within Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. (N) = number of electrofishing runs. BRZ = boat restricted zone.

Location, zone	Density index (N) 1990	1993
Bonneville Dam tailrace		
Dam tailrace		
Tailrace	1.732 (27)	2.309 (16)
Tailrace BRZ	3.464 (12)	3.000 (9)
Bonneville Reservoir		
Forebay	4.847 (47)	1.414 (32)
Mid-reservoir	1.961 (50)	1.414 (28)
Tailrace	1.609 (37)	1.387 (25)
Tailrace BRZ	3.250 (13)	1.225 (6)
The Dalles Reservoir		
Forebay	[illegible] (62)	1.434 (37)
Mid-reservoir	[illegible] (34)	1.233 (38)
Tailrace	2.812 (45)	1.271 (21)
Tailrace BRZ	3.317 (11)	3.000 (5)
John Day Reservoir		
Forebay	1.183 (56)	1.254 (44)
Mid-reservoir	1.116 (61)	1.078 (43)
Tailrace	1.275 (39)	1.217 (37)
Tailrace BRZ	1.789 (16)	1.732 (9)
McNary Reservoir		
Forebay	[illegible] (64)	1.032 (33)
Mid-reservoir	[illegible] (60)	1.036 (29)
Tailrace	[illegible] (38)	1.195 (30)
Tailrace BRZ	[illegible] (14)	3.000 (5)
Upper-reservoir	1.279 (54)	1.128 (42)

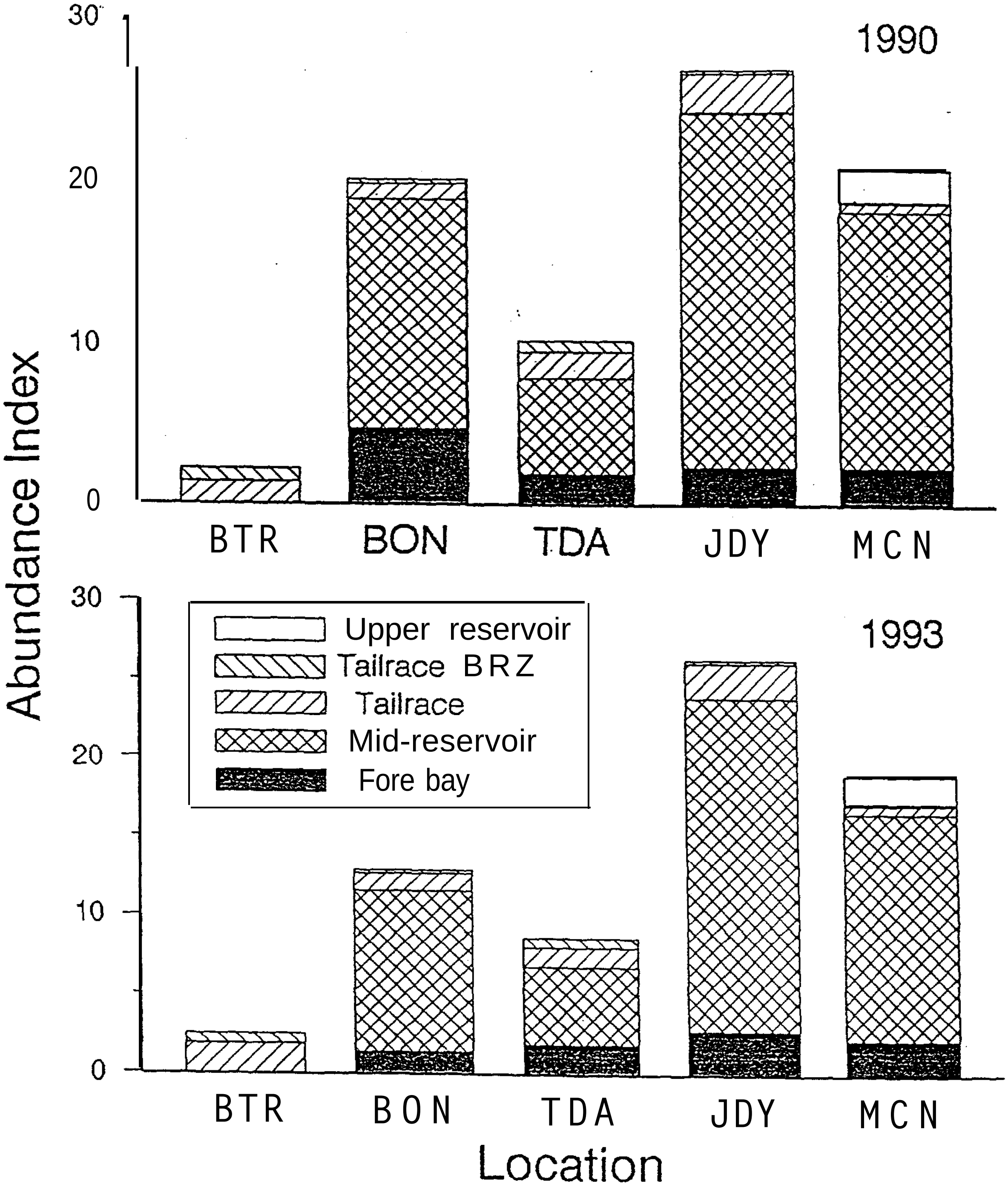

Figure H-2. Index of northern squawfish abundance in 1990 and 1993 in Bonneville Dam tailrace (BTR), and Bonneville (BON), The Dalles (TDA), John Day (JDY), and McNary (MCN) reservoirs,

Table H-9. - Indices of northern squawfish consumption of juvenile salmonids in 1990 and 1993 in sampling zones within Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs. BRZ = boat restricted zone. N = the number of northern eguawfieh digestive tracts examined.

	Consumption index (N)			
	1990		1993	
Location, zone	Spring	Summer	Spring	Summer
Bonneville Dam tailrace				
Dam tailrace				
Tailrace	1.2 (61)	0.5 (45)	0.8 (74)	1.2 (81)
Tailrace BRZ	2.7 (86)	5.5 (109)	1.1 (64)	1.0 (61)
Bonneville Reservoir				
Forebay	0.6 (153)	1.8 (139)	0.7 (20)	0.5 (95)
Mid-reservoir	0.0 (39)	0.0 (42)	0.0 (14)	0.0 (31)
Tailrace	0.3 (7)	0.0 (4)	0.0 (18)	0.0 (14)
Tailrace BRZ	2.3 (41)	0.8 (61)	--	1.0 (23)
The Dallee Reservoir				
Forebay	0.8 (38)	1.0 (50)	0.1 (19)	0.0 (28)
Mid-reservoir	0.0 (15)	0.1 (46)	0.4 0.0 (12)	0.0 (13)
Tailrace	0.7 (27)	0.0	(8)	0.0 (9)
Tailrace BRZ	0.9 (50)	6.4 (50)	0.0 (1)	0.5 (117)
John Day Reservoir		)		
Forebay	1.5 (38)	2.4 (16)	0.0 1.5 (11)	0.6 (40)
Mid-reservoir	0.0 (6)	0.9 (7	(2)	0.6 (10)
Tailrace	1.5 (17)	2.6 (25)	2.0 (15)	0.0 (8)
Tailrace BRZ	2.5 (60)	11.7 (50)	--	0.6 (119)
McNary Reservoir				
Forebay	1.3 (24)	2.4 (9)	0.0 (1)	8.6 (3)
			(1)	0.0 (1)
Tailracervoir	0.1 - (9)	0.8 (13)	0.0 (2)	0.0 (21)
Tailrace BRZ	2.4 (14)	0.9 (79)	--	0.0 (27)
Upper-reservoir	1.5 (33)	1.5 (36)	0.2 (15)	0.0 (1)

Size composition of northern squawfish in standardized electrofishing samples was quite different between 1990 and 1993 (Figure H-4, H-5, and H-6). Mean fork length in 1993 was lower than 1990 in all locations except McNary Reservoir. Mean fork length decreased by more than 50 mm in the Bonneville Dam tailrace and The Dalles reservoir, and by nearly 100 mm in Bonneville Reservoir, primarily due to an increase in the proportion of northern squawfish <250mm. Mean fork length in John Day Reservoir was only 16 mm lower in 1993 than 1990.

Northern squawfish <250 mm were primarily of undetermined sex, whereas fish > 400 mm were nearly all females (Figure H-4 through H-6). Sex ratio differed in most locations between 1990 and 1993 (Table H-10). The percent of female northern squawfish in electrofishing catches declined in 1993 in Bonneville Dam tailrace and Bonneville Reservoir, primarily due to a decline in the percent of females among fish *c* 350 mm fork length. In contrast, the percent of females was similar or increased in The Dalles, John Day, and McNary reservoirs. The < 350 mm fork length category excludes most small (<200 mm) fish because their gonads were typically immature and we could not determine their sex (Figures H-4 through H-6).

Proportional stock density (PSD) differed among years and locations (Table H-11). Proportional stock density was lower in 1993 than 1990 in all areas except McNary Reservoir. The proportion of large fish fluctuated widely from 1990 to 1993 in the Bonneville Dam tailrace and Bonneville Reservoir, whereas the range of PSD estimates was narrower in John Day Reservoir. Differences in PSD between 1990 and 1993 were consistent with differences in mean fork length (Figures H-4, H-5, and H-6), even though PSD estimates excluded fish <250mm fork length.

Age composition of northern squawfish differed between years and among locations (Figures H-7, H-8, and H-9). The proportion of fish younger than age 5 was considerably higher in 1993 than 1990 in the Bonneville Dam tailrace, and Bonneville and The Dalles reservoirs, and to a lesser extent in John Day Reservoir, whereas the proportion of young fish was similar between years in McNary Reservoir.

Growth of northern squawfish from ages 6-11 has not increased since the implementation of predator control fisheries (Figure H-10 and H-11). Annual growth increments from 1990 to 1993 were generally similar to (Bonneville Dam tailrace) or less than (Columbia River reservoirs) increments for like-aged fish from 1987 to 1990.

The pattern of variation in year-class strength of northern squawfish was similar in Bonneville Dam tailrace, and Bonneville and John Day reservoirs (Figure H-12). The magnitude of variation was smaller in John Day Reservoir than in Bonneville Dam tailrace and Bonneville Reservoir. In general, year-class strength declined from 1980 to 1987, and increased in the years since 1987.

Fecundity of northern squawfish has not changed appreciably from 1991 through 1993 (Table H-12). Slopes for the regression of $\log_{10}$(fecundity) on $\log_{10}$(body weight) were similar among years ($P=0.09$) for northern squawfish in the Bonneville Dam tailrace. Analysis of covariance revealed no difference ($P=0.26$) in fecundity (adjusted for any differences in weight) among years. The estimate (pooled among years) of fecundity for fish in Bonneville Dam tailrace was 30,396. Slopes for the regression of $\log_{10}$(fecundity) on log&body weight) for the Columbia River reservoirs were different ($P=0.05$), therefore, we could not use analysis of covariance to test for differences among years and could not pool data from 1991-1993. Mean fecundity was very similar in 1991, 1992, and 1993.

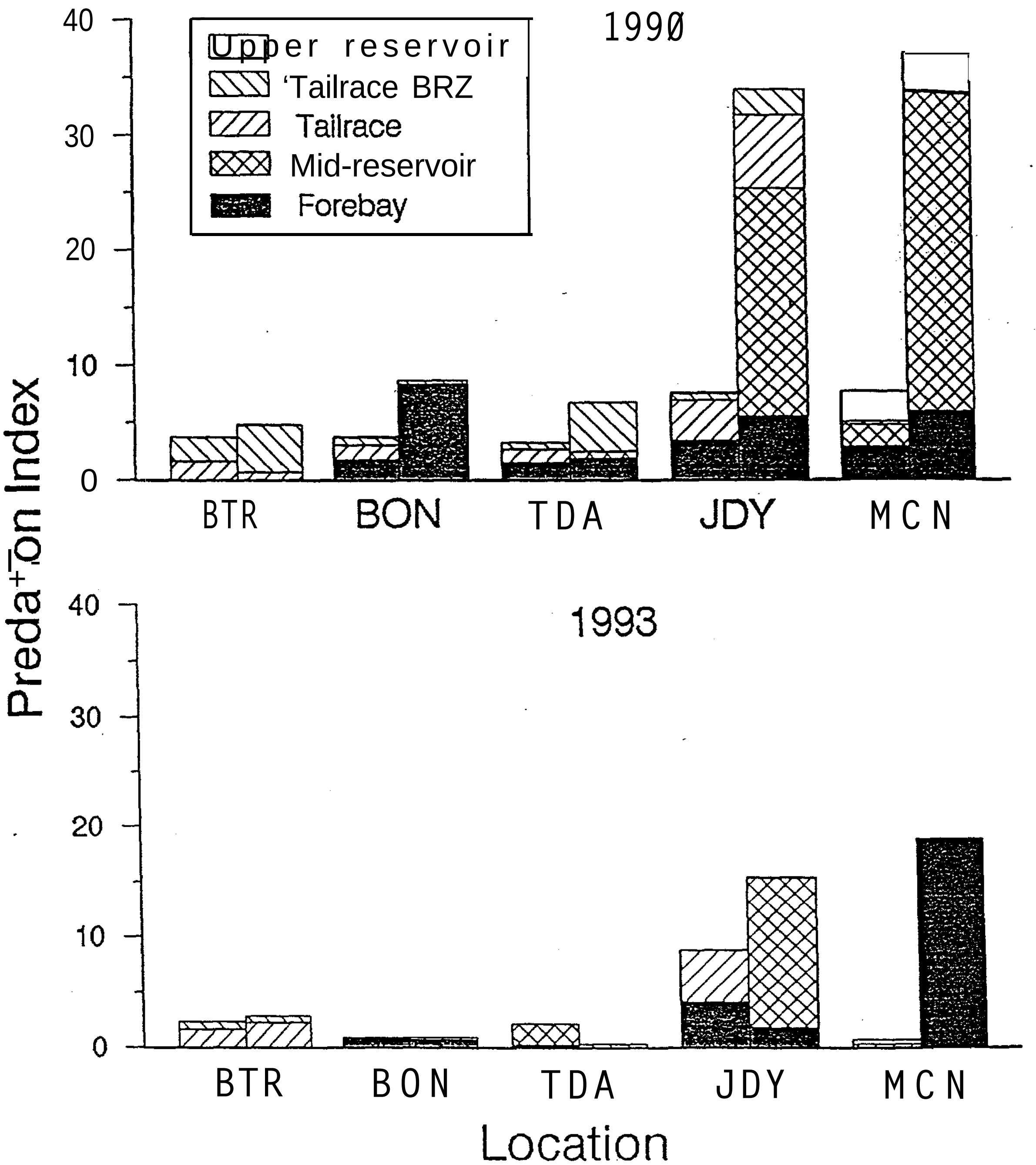

Figure H-3. Index of northern squawfish predation in 1990 and 1993 in Bonneville Dam tailrace (BTR), and Bonneville (BON), The Oalles (TDA), John Day (JOY), and McNary (MCN) reservoirs. The bar on the left represents spring and the bar on the right represents summer.

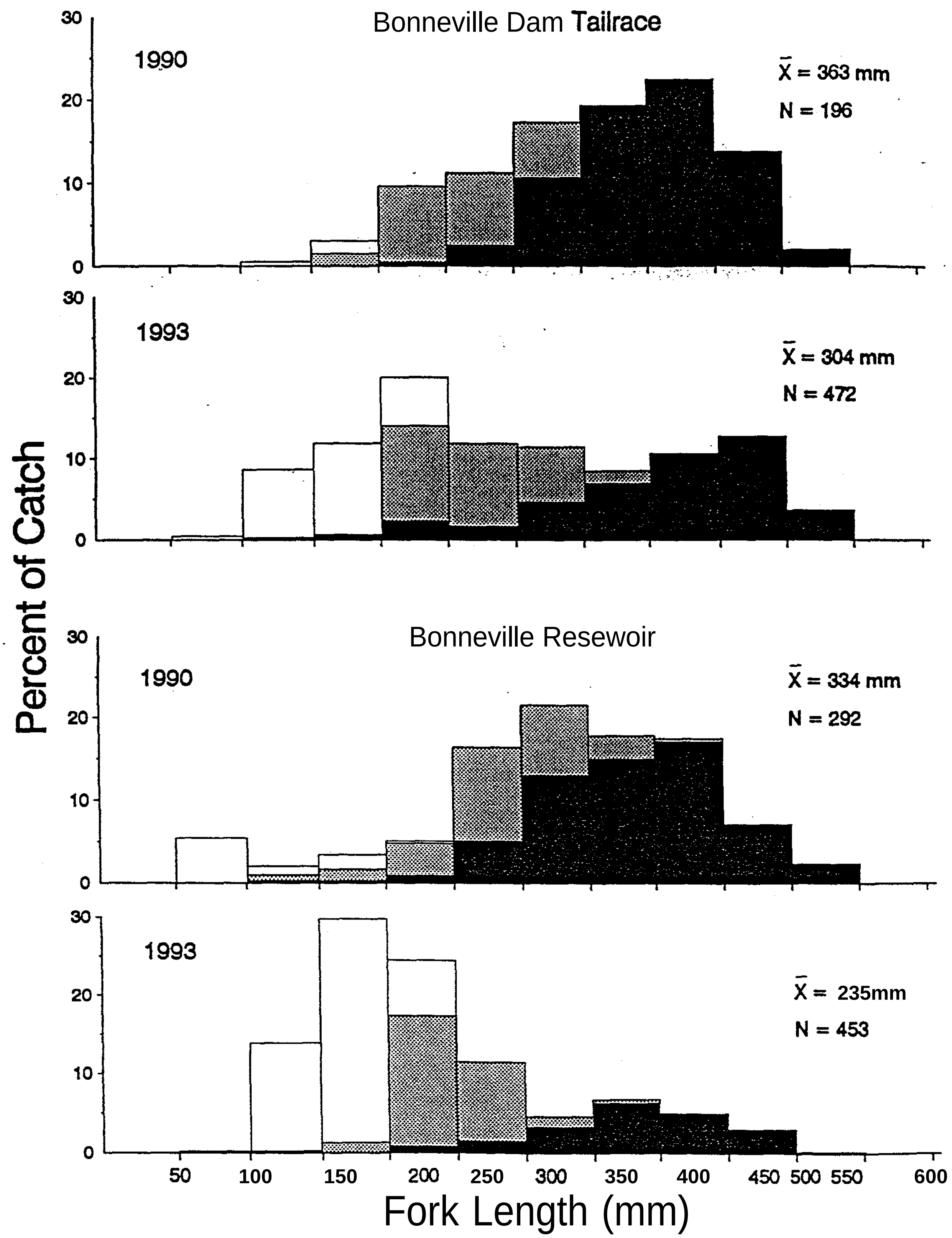

Figure H-4. Size and sex composition of northern squawfish in electrofishing samples from Bonneville Dam tailrace and Bonneville Reservoir in 1990 and 1993. Unshaded portion of bars is undetermined sex, stippled portion is males, and darkened portion is females.

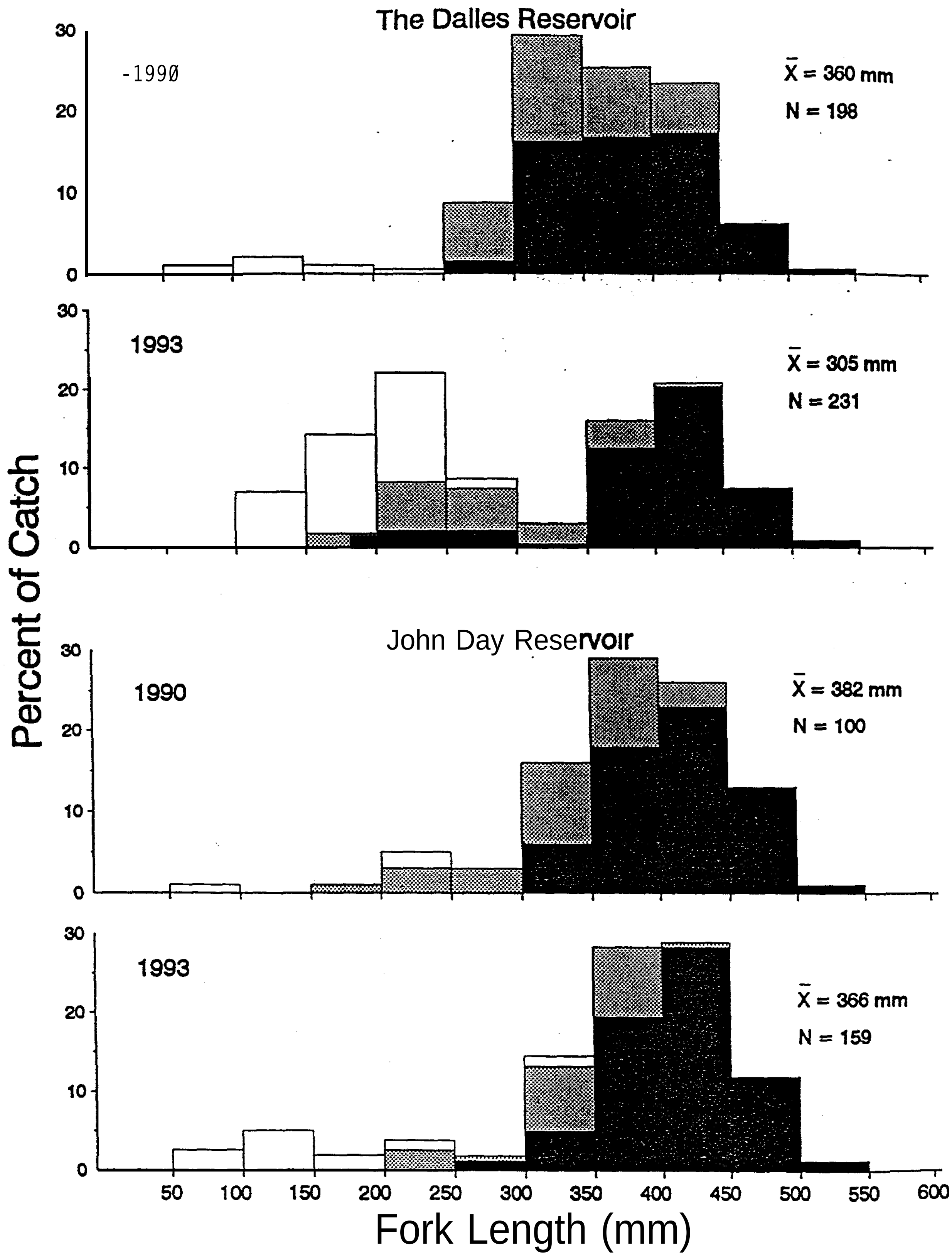

Figure H-5. Size and sex composition of northern squawfish in electrofishing samples from The Dalles and John Day reservoirs in 1990 and 1993. Unshaded portion of bars is undetermined sex, stippled portion is males, and darkened portion is females.

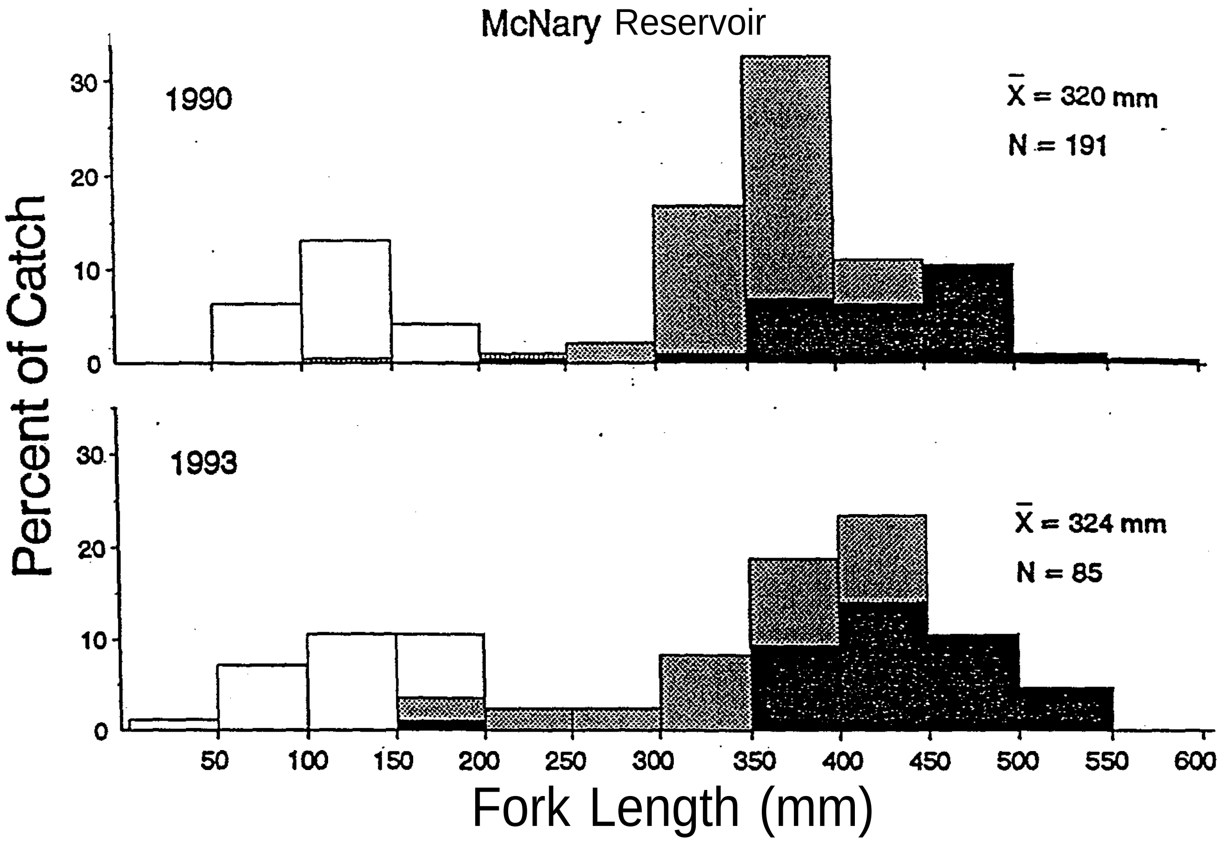

Figure H-6. Size and sex composition of northern squawfish in electrofishing samples from McNary Reservoir in 1990 and 1993. Unshaded portion of bars is undetermined sex, stippled portion is males, and darkened portion is females.

Table H-10. Percent of female northern sguawfish in electrofishing samples from Bonneville Dam tailrace and lower Columbia River reservoirs in 1990 and 1993.

	Percent females					
	<350 mm		≥350 mm		All sizes	
Location	1990	1993	1990	1993	1990	1993
Bonneville Dam tailrace	33.8	23.6	99.1	95.3	72.9	58.5
Bonneville Reservoir	43.6	15.8	93.1	97.1	68.2	40.8
The Dalles Reservoir	44.3	23.4	73.7	91.3	62.5	70.2
John Day Reservoir	27.3	38.5	78.6	85.1	66.3	76.4
McNary Reservoir	7.9	7.7	44.9	66.0	35.2	54.0

Table H-11. Proportional stock density (PSD) of northern sguawfish in electrofishing samples from Bonneville Dam tailrace and lower Columbia River reservoirs from 1990 to 1993.

Location	1990	1991	1992	1993
Bonneville Dam tailrace	30	42	28	22
Bonneville Reservoir	29	49	38	10
The Dalles Reservoir	28	--	--	18
John Day Reservoir	51	49	48	41
McNary Reservoir	41	--	--	59

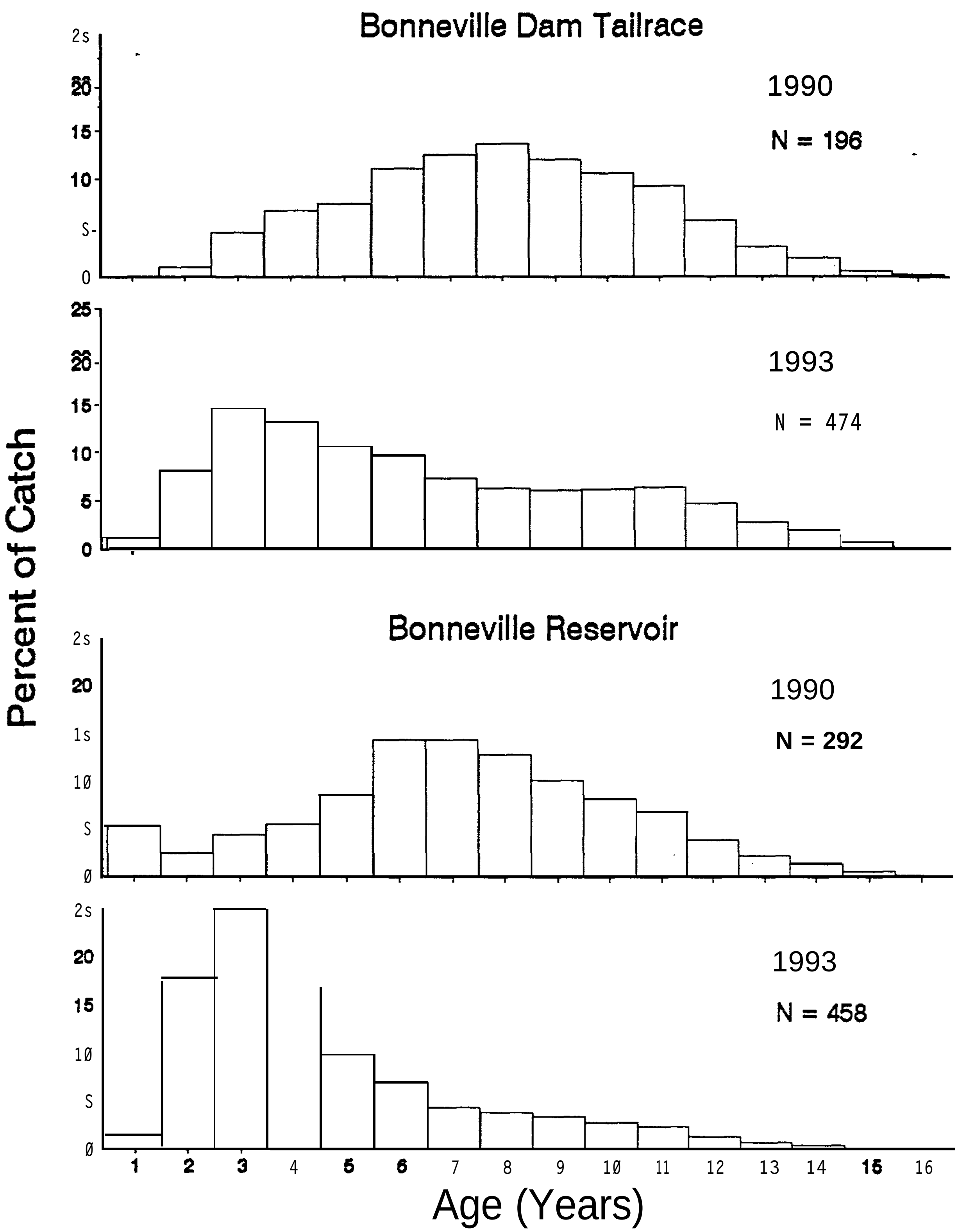

Figure H-7. Age composition in Bonneville Dam tailrace and Bonneville Reservoir in 1990 and 1993.

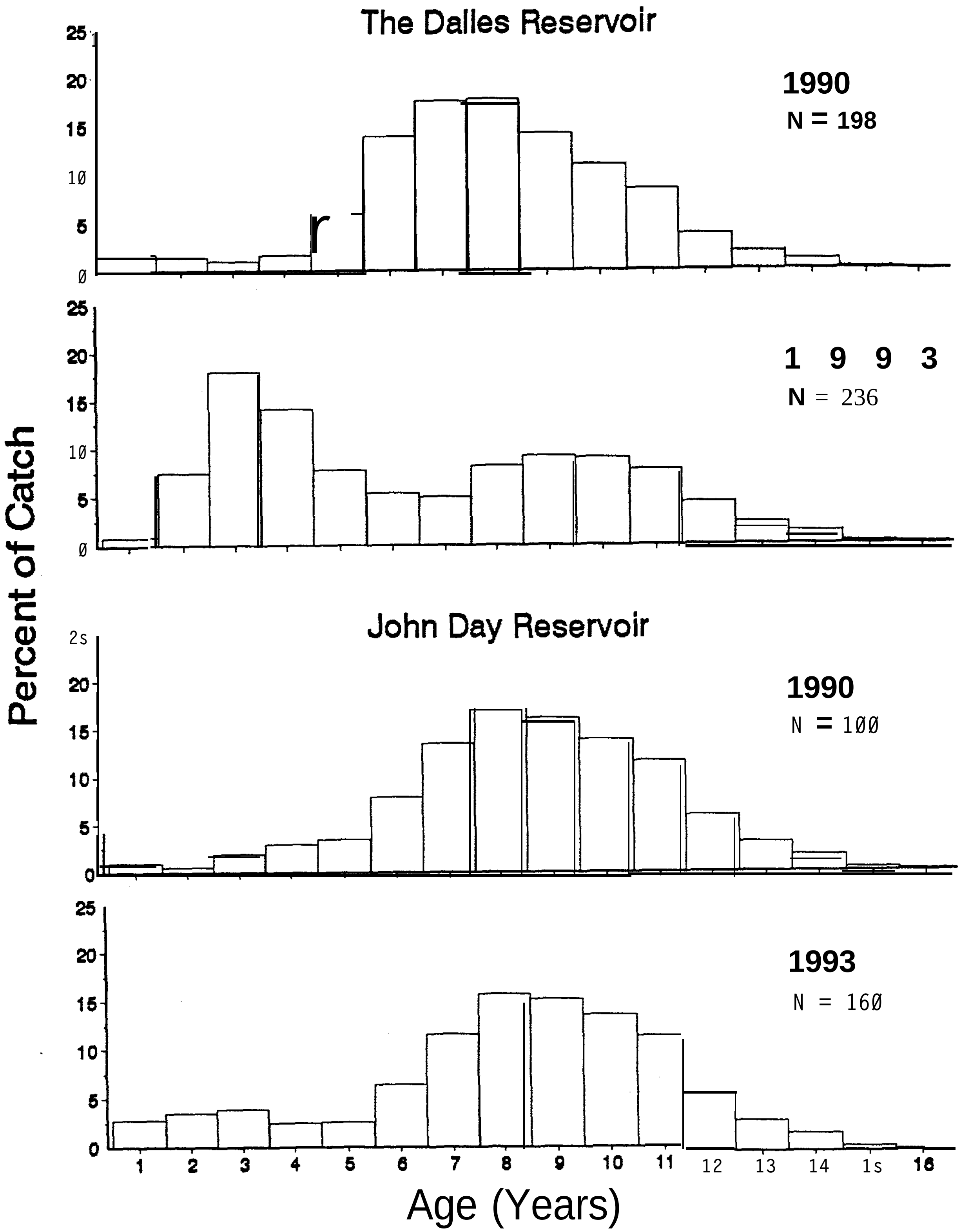

Figure H-8. Age composition in The Dalles and John Day reservoirs in 1990 and 1993.

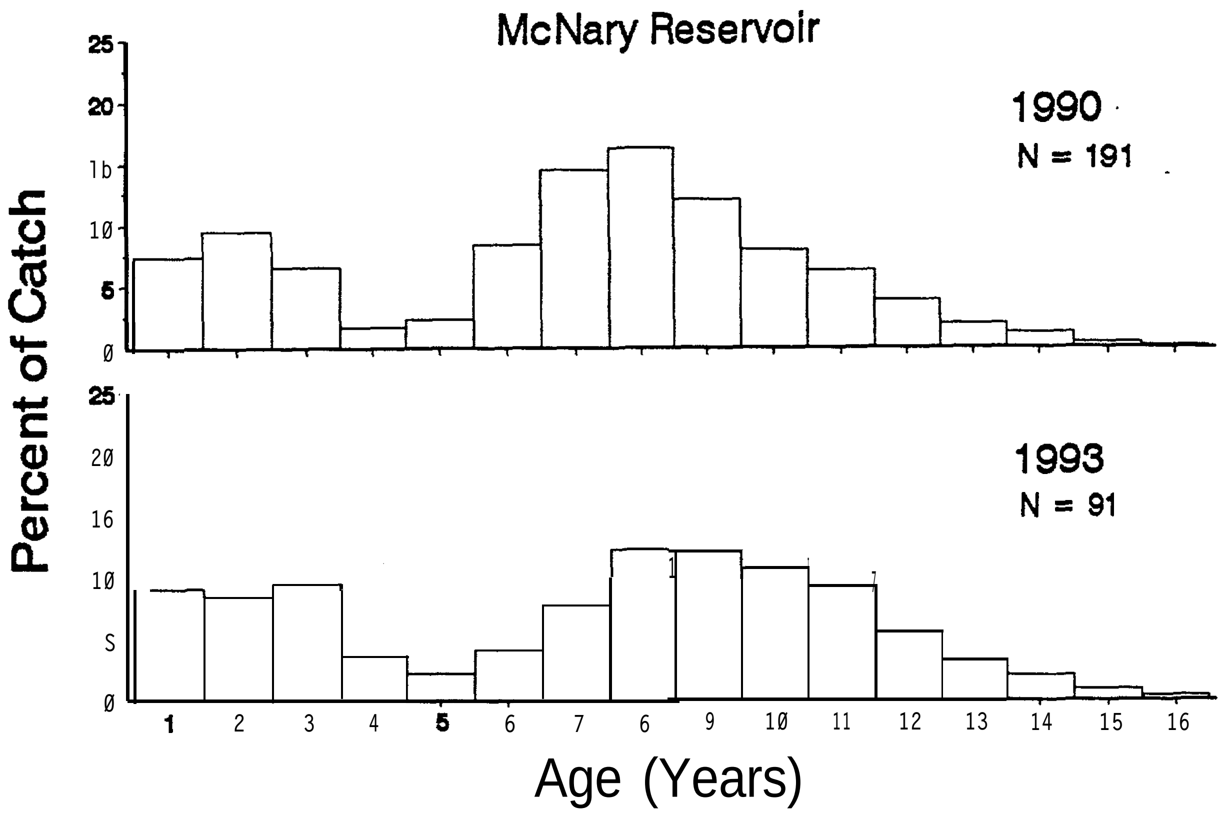

Figure H-9. Age composition in McNary Reservoir in 199Ø and 1993.

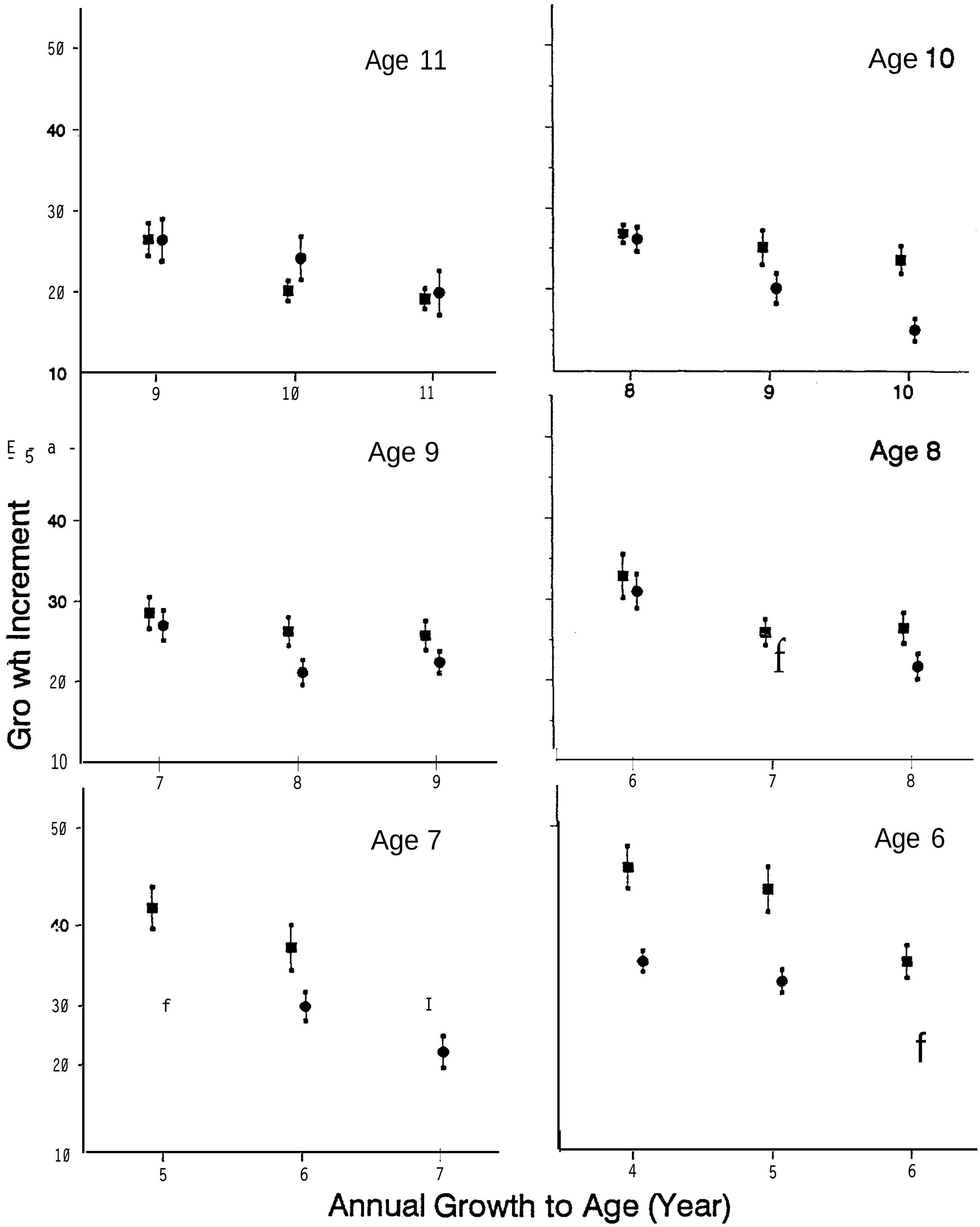

Figure H-10. Mean annual growth increments (mm) from 1987 to 1990 (closed squares) versus 1990 to 1993 (closed circles) for northern squawfish aged 6-11 in Bonneville Dam tailrace. Bars are standard errors. An asterisk indicates a significant difference ($P \leq 0.05$) between pairs.

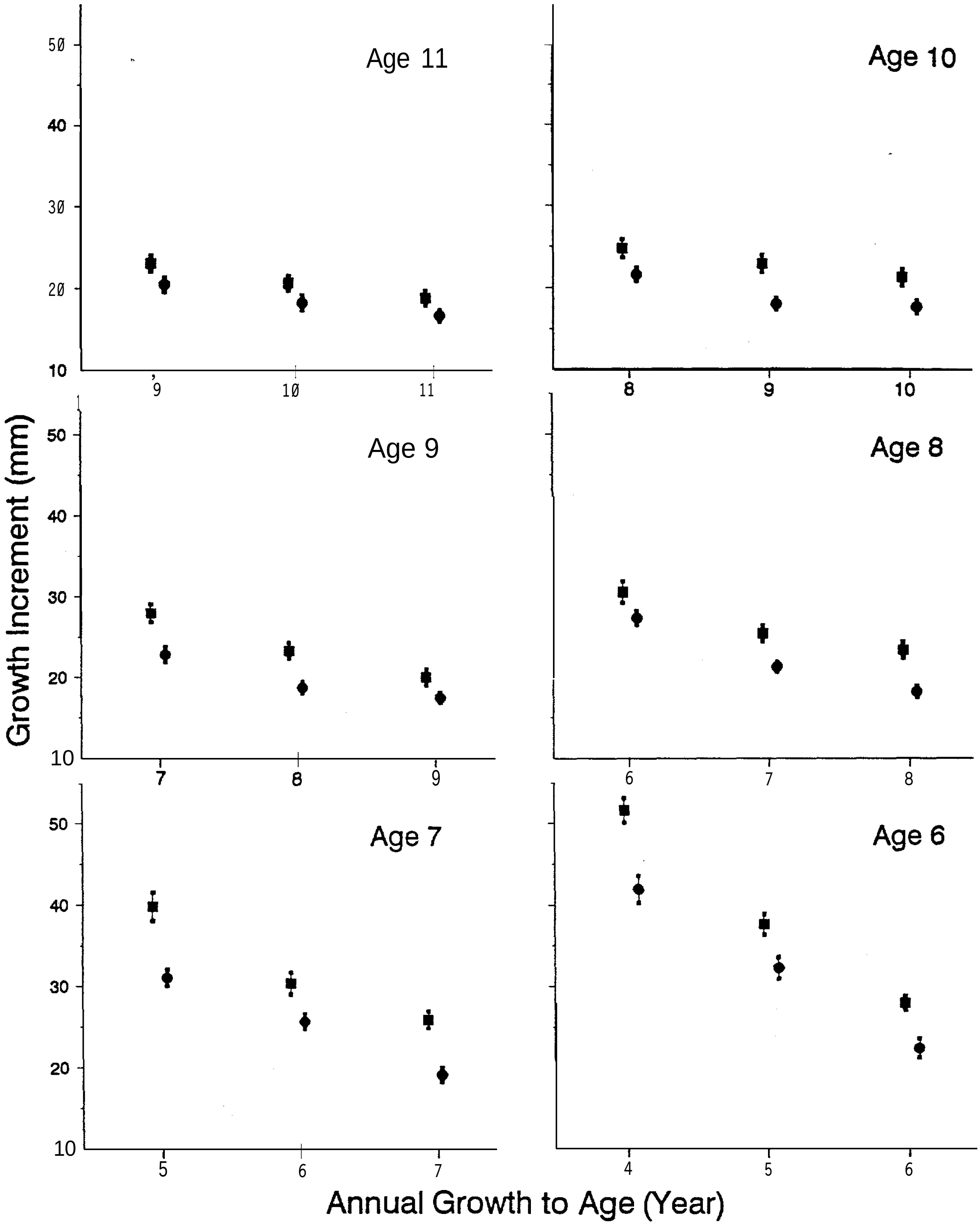

Figure H-11. Mean annual growth increments (mm) from 1987 to 199Ø (closed squares) versus 199Ø to 1993 (closed circles) for northern squawfish aged 6-11 in Columbia River reservoirs. Bars are standard errors. An asterisk indicates a significant difference ($P \leq 0.05$) between pairs.

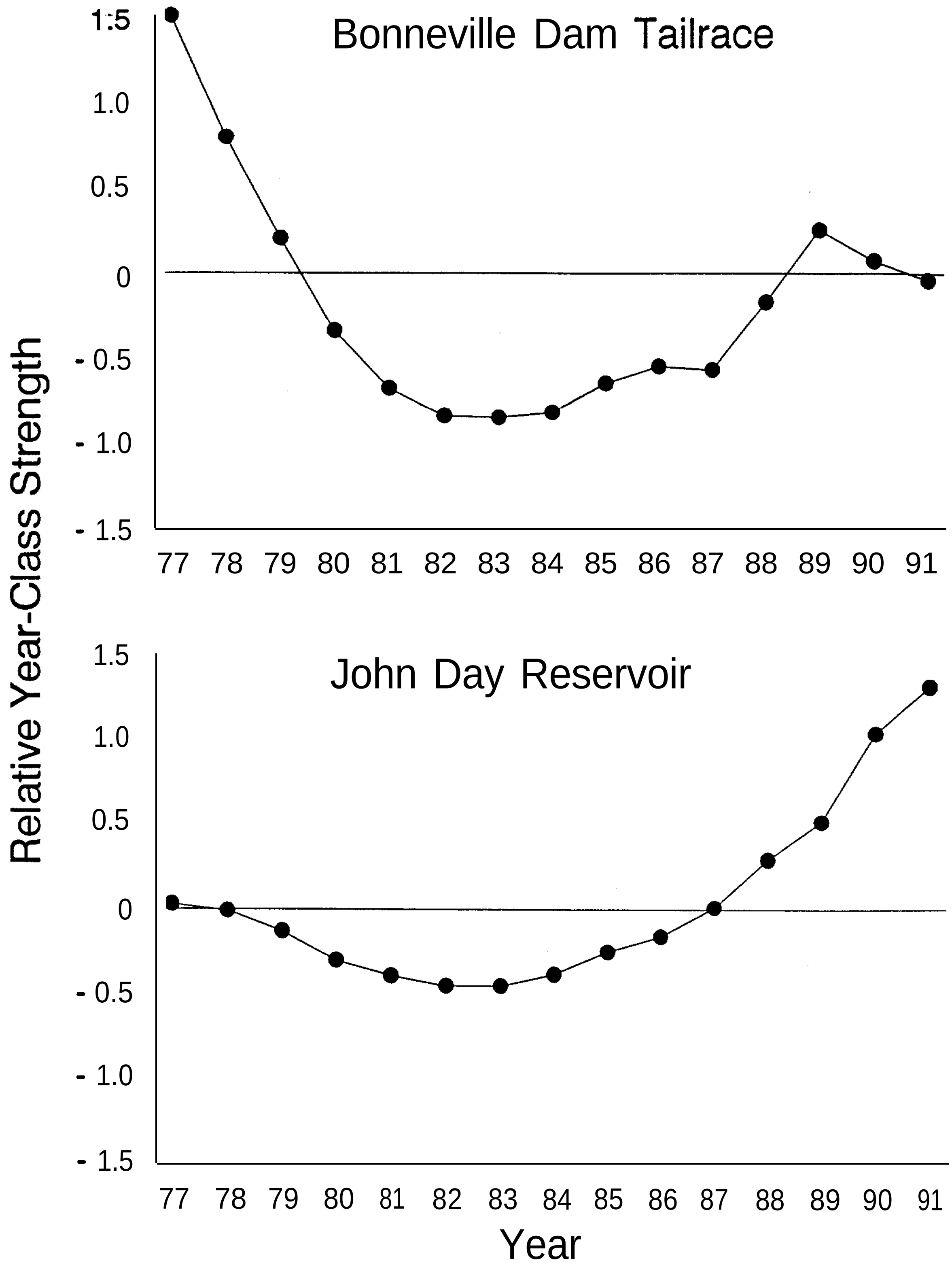

Figure H-12. Index of relative year-class strength of northern squawfish in Bonneville Dam tailrace and John Day Reservoir.

Table H-12.. Mean fecundity (number of developed eggs per female), mean relative fecundity (number of developed eggs per gram of body weight), and slope, intercept, and coefficient of determination (R^2) for the linear regression of $\log_{10}$(fecundity) on $\log_{10}$(body weight) for northern squawfish in Bonneville Dam tailrace and the combined lower Columbia River reservoirs.

Location, parameter	1991	1992	1993	Pooled 1991-1993
Bonneville Dam tailrace				
Mean fecundity	34,807	33,136	23,235	30,396
Mean relative fecundity	36.58	38.44	33.18	35.59
Slope	1.09	0.86	0.62	0.95
Intercept	1.27	1.96	2.57	1.65
R^2	0.60	0.59	0.25	0.50
Columbia River reservoirs				
Mean fecundity	30,376	29,805	29,418	--
Mean relative fecundity	31.74	32.19	30.59	--
Slope	0.57	0.67	0.49	--
Intercept	2.74	2.47	2.99	--
R^2	0.22	0.37	0.17	--

Radiotelemetry

The USFWS and ODFW crews combined located 70 (98.6% of total) of the northern squawfish released in The Dalles Reservoir at least once, and 61 (95.3 %) of the fish released in Bonneville Reservoir. Excluding USFWS in and near the BRZs, ODFW crews located 51 (71.8 %) fish released in The Dalles Reservoir at least once, and 49 (76.6%) fish released in Bonneville Reservoir at least once.

Mean depth of fish located in the midreservoir of Bonneville Reservoir was 3.4 m, and all fish were located at depths less than 12.2 m (Table H-13). Mean depth of fish located in midreservoir of The Dalles Reservoir was 7.4 m, and 83.5% of the observations were at depths of less than 40 m. Although fish were mainly found at relatively shallow depths in midreservoirs, they were frequently found in areas greater than 50 m from either the Washington or Oregon shore (Table H-13). Mean distance to shore was 75.2 m in Bonneville Reservoir and 182.2 m in The Dalles Reservoir. However, nearly all fish that occupied areas distant from shore were along shorelines of islands.

There was no consistent relationship between depth, distance to shore, and time of day based upon records of individual fish movements (Figures H-13 through H-16). Four fish were tracked June 17-18 at Miller Island in The Dalles Reservoir (Figure H-13), four fish were tracked July 15-16 in the same area (Figure H-14), three fish were tracked August 23-24 in The Dalles Reservoir forebay (Figure H-15), and five fish were tracked September 21-24 between The Dalles Dam forebay and Miller Island (Figure H-16). Behavior among fish was highly variable, with some exhibiting little movement (e.g., Figure H-15; frequency

149900, code 57), and others exhibiting extensive movement (e.g., Figure H-16; frequency 149860, code 65). There were no consistent patterns of movement associated with day, night, or crepuscular hours.

Table H-13. Number of observations of radio-tagged northern sguawfish at various intervals of depth and distance to shore in the midreservoirs of Bonneville and The Dalles reservoirs.

	Number of observations (%)	
Interval	Bonneville Reservoir	The Dalles Reservoir
Depth (m)		
<3.0	15 (46.9)	40 (21.3)
3.0- 6.1	13 (40.6)	70 (37.2)
6.1- 9.1	4 (12.5)	38 (20.2)
9.1-12.2	0 (0)	9 (4.8)
>12.2	0 (0)	31 (16.5)
Distance to shore (m)		
<50	7 (26.9)	68 (39.8)
50-100	15 (57.7)	17 (9.9)
100-150	2 (7.7)	14 (8.2)
150-200	(7.7)	10 (5.8)
200-250	0 (0)	7 (4.1)
250-300	0 (0)	11 (6.4)
>300	0 (0)	44 (25.7)

The vast majority of fish were found outside their release area at some time in both The Dalles and Bonneville reservoirs (Table H-14). Only 15 (11.4 %) of 13 1 fish apparently remained within their area of release. Of fish released in the tailrace BRZ in The Dalles Reservoir, four moved as far as forebay, 13 moved to the midreservoir, and 17 were found in the tailrace outside the restricted zone. Of the 29 fish released in the non-restricted portion of the tailrace in The Dalles Reservoir, 13 fish moved downstream and 14 fish moved upstream. One fish crossed The Dalles Dam into Bonneville Reservoir, and two fish moved past John Day Dam into John Day Reservoir. Fish released at the mouth of the Deschutes River were subsequently found in the tailrace restricted zone. Two-way movement between the tailrace and midreservoir of The Dalles Reservoir was particularly common, with most fish using the mouth of the Deschutes River or Miller Island in the mid-reservoir. Most fish occupying the Deschutes River remained near the river mouth, but three fish were found 24-64 km upriver. Exchange was extremely common between the non-restricted and restricted portions of the tailrace, where many fish were logged alternately in both areas throughout the summer.

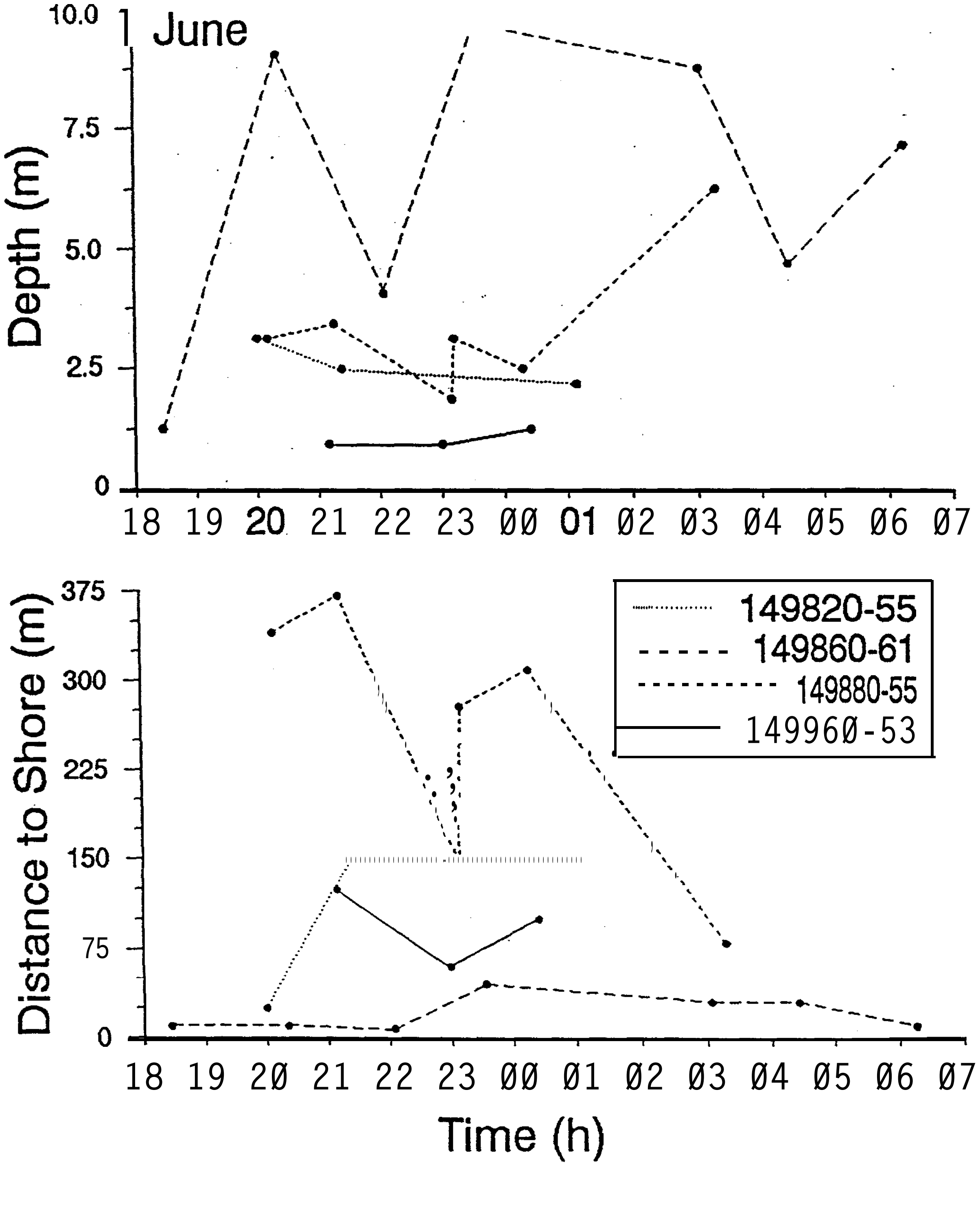

Figure H-13. Depth (m) and distance to shore (m) versus time (h) for 4 fish tracked from 2230 on 17 June to 1300 on 18 June around Miller Island (RKm 328.2-334.7) in The Dalles Reservoir. The 6-digit frequency and 2-digit code for each fish is provided in the key.

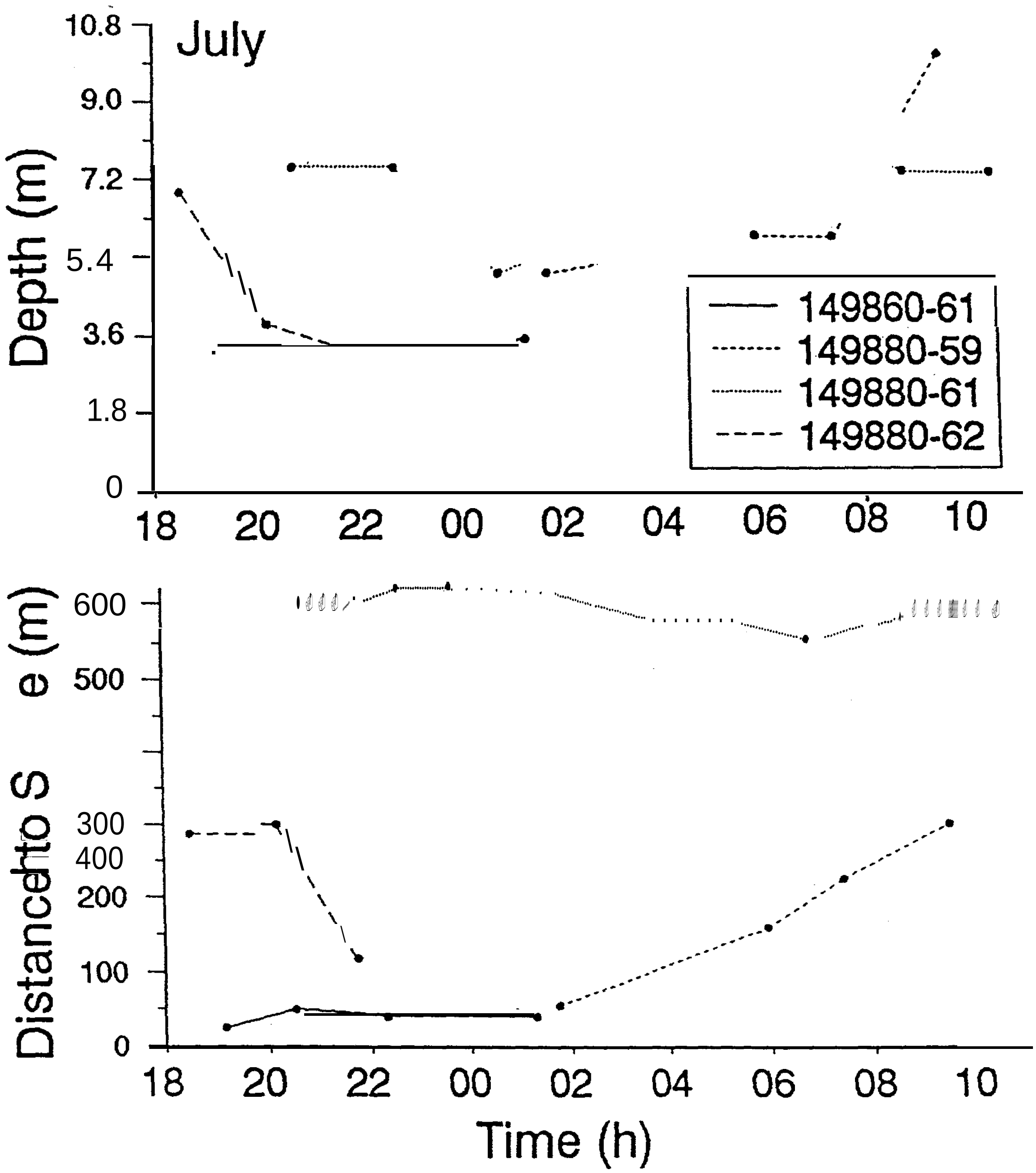

Figure H-14. Depth (m) and distance to shore (m) versus time (h) for 4 fish tracked from 1800 on 15 July to 1000 on 16 July around Miller Island (RKm 328.2-333.1) in The Dalles Reservoir. The 6-digit frequency and Z-digit code for each fish is provided in the key.

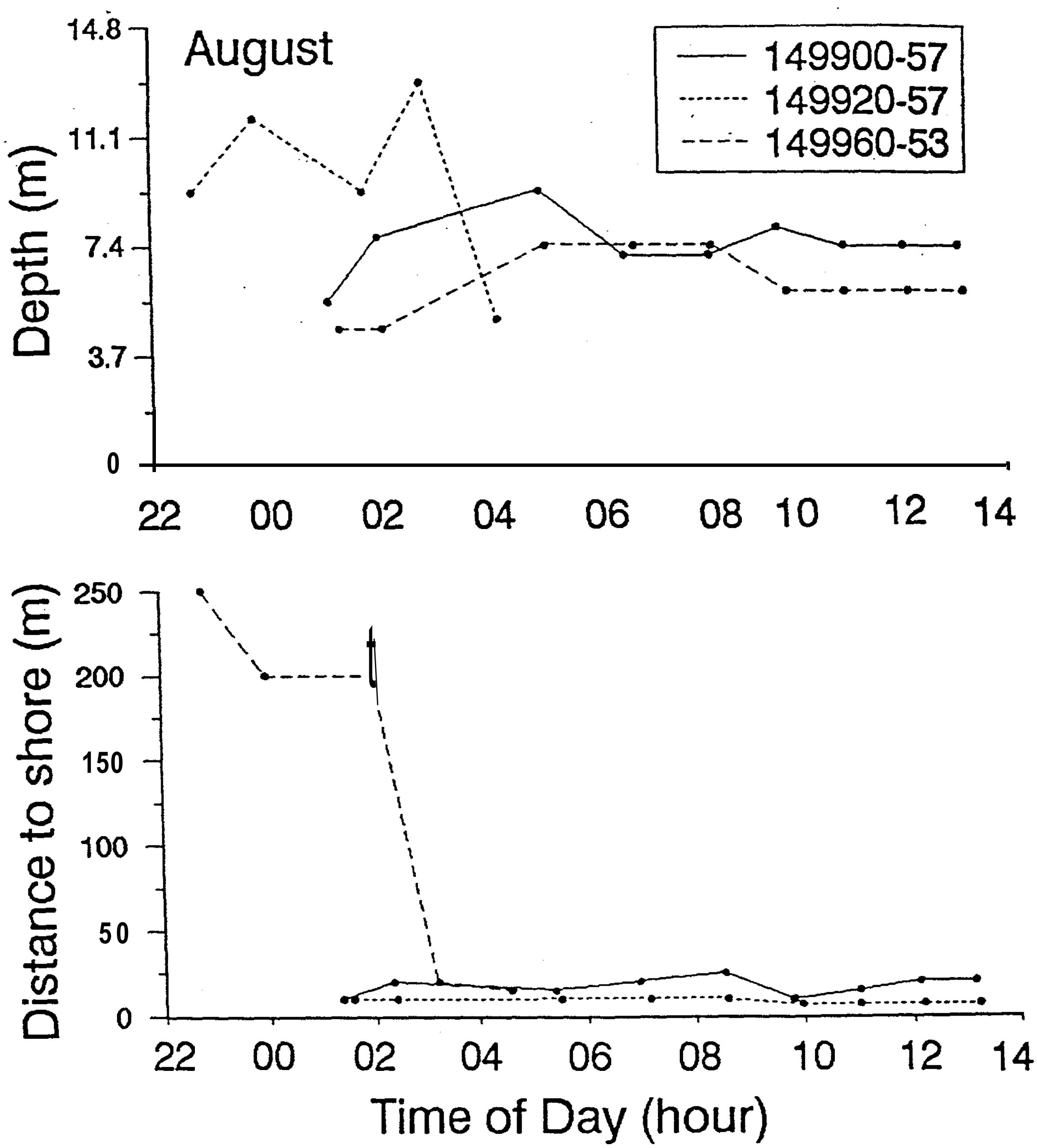

Figure H-15. Depth (m) and distance to shore (m) versus time (h) for 3 fish tracked between 2200, 23 August and 1300, 24 August in the forebay (RKm 310.5-317.0) of The Dalles Reservoir. The 6-digit frequency and 2-digit code for each fish is provided in the key.

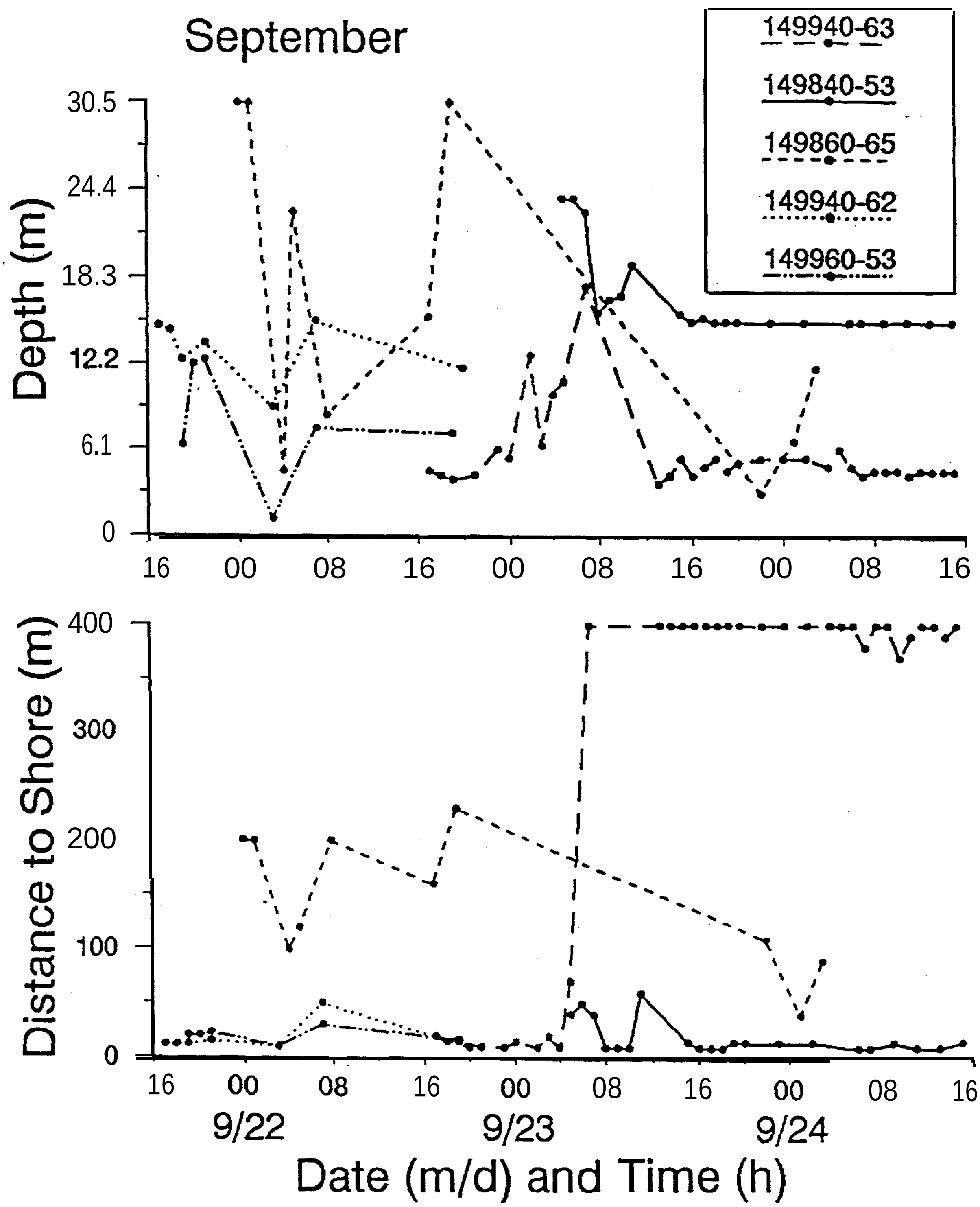

Figure H-16. Depth (m) and distance to shore (m) versus time (h) for 5 fish tracked between 1600, 21 September and 1600, 24 September in The Dalles deservoir (RKm 310.5-329.8). The 6-digit frequency and 2-digit code for each fish is provided in the key.

Table H-14, Number and percent (in parentheses) of fish located in various areas of Bonneville (BON), The Dalles (TDA), and John Day (JDY) reservoirs relative to the release site. Numbers in bold-face indicate the number of fish that were never located outside their release site. Reservoir areas are forebay (FOR), midreservoir (MID), non-restricted tailrace (TRN), and restricted zone of tailrace (BRZ). For each release area, the total represents the number of radio-tagged fish that were located at least once.

Farthest distance travelled	Number of fish by release area (percent)				
	BON TRN	BON BRZ	TDA MID	TDA TRN	TDA BRZ
BON FOR	--	1 (2.3)	--	--	
MID	1 (5.6)	5 (11.6)	--	--	--
TRN	1 (5.6)	15 (34.9)	--	--	--
BRZ	12 (66.7)	9 (20.9)	--	1 (3.5)	--
TDA FOR	1 (5.6)	1 (2.3)	--	3 (10.3)	4 (10.8)
MID	--	1 (2.3)	--	9 (31.0)	13 (35.1)
TRN	1 (5.6)	--	--	2 (6.9)	17 (46.0)
BRZ	2 (11.1)	11 (25.6)	4 (100)	12 (41.4)	3 (8.1)
JDY FOR		--	--	1 (3.5)	--
MID		--	--	1 (3.5)	
Total	18 (100)	43 (100)	4 (100)	29 (100)	37 (100)

Fish released in the non-restricted tailrace in Bonneville Reservoir generally moved upriver. Most (66.7%) moved only as far as the restricted zone, but four fish passed The Dalles Dam into The Dalles Reservoir. While most fish released in the tailrace BRZ moved downstream, 13 moved upstream into The Dalles Reservoir. Eleven of those fish were found as far upstream as the tailrace BRZ in The Dalles Reservoir, and many of those lingered in the midreservoir around the Deschutes River or Miller Island. As an indication of how far northern squawfish can move in a four-month period, six of the 17 fish that moved from Bonneville Reservoir upstream to The Dalles Reservoir later returned to Bonneville Reservoir.

DISCUSSION

Exploitation declined in most locations in 1993 relative to 1992. Since exploitation rates in 1991 and 1992 were already at the lower end of the 10-20% target range, every effort should be made to increase harvest of northern squawfish in 1994.

Our analyses indicate that a reduction in the scope of fisheries may not result in a significant increase in predation. Eliminating sport-reward exploitation in Ice Harbor and Lower Monumental reservoirs, and eliminating dam-angling exploitation in Ice Harbor and

McNary reservoirs resulted in an eventual predation increase of only 2% overall, and only 5% on juvenile salmonids originating upstream from Lower Granite Dam. It is obvious that management alternatives will affect individual stocks of juvenile salmonids differently. Eliminating fisheries from Columbia River reservoirs resulted in a decrease in overall benefits of 25%, but benefits to fish originating upstream from Lower Granite Dam were unchanged.

Although results varied among years and methods, benefits of the sport-reward fishery have been greater than that of dam angling. However, the greater cost of the sport-reward fishery, and differences in the areas fished by the two fisheries, result in fisheries being complementary and make both fisheries important components of a program designed to remove 10-20% of northern squawfish ≥275 mm annually.

Relative abundance of northern squawfish was similar between 1990 and 1993, but relative consumption was lower in 1993, particularly in summer. While a decline in predation was anticipated based on predator control efforts to date, lower consumption estimates in 1993 may also be attributable to annual variation in temperature, flow regime, and differences in the timing of sampling to estimate relative consumption of juvenile salmonids by northern squawfish. Predation in John Day Reservoir differed each year from 1990 through 1993, with predation in 1993 intermediate between the low levels seen in 1992 and the higher levels seen in 1990 and 1991. The "indices" of relative abundance, consumption, and predation were intended to detect order-of-magnitude differences among locations or years, and any decrease in sample sizes might further compromise the precision of the indices. Since ODFW is now the only agency collecting abundance and consumption data in all locations throughout the lower Columbia Basin, we will refine our sampling schedule in 1994 such that sample sizes for electrofishing effort and northern squawfish gut samples are comparable to those in 1990-92.

Northern squawfish population structure, as characterized by mean fork length, size composition, PSD, and sex ratio has changed to varying degrees, depending upon location, from 1990 to 1993. Changes in mean fork length and the proportion of small (< 250 mm) fish reflected changes throughout the entire population, whereas changes in PSD and sex ratio reflected changes primarily among predator-sized fish. The proportion of small individuals increased markedly in the Bonneville Dam tailrace, and Bonneville and The Dalles reservoirs. Consequently, declines in mean fork length were greatest in those three areas. The increase in the proportion of small fish in all locations suggests that 1988-1990 were good recruitment years for northern squawfish throughout the lower Columbia River, and these fish will be recruited into lower end of the "predator size range" (≥250 mm) in 1994.

The change in sex ratio from 1990 to 1993 differed among locations, with the greatest decline (14 %) in Bonneville Reservoir and the greatest increase (19%) in McNary Reservoir. These changes were generally consistent with changes in PSD, which declined by 19% in Bonneville Reservoir and increased by 18% in McNary Reservoir. Declines in the proportion of large, predominantly female northern squawfish are consistent with variation in year-class strength for reservoirs downstream from McNary Dam. In contrast, the recruitment history in McNary Reservoir is apparently quite different.

The current structure of northern squawfish populations in the lower Columbia River probably reflects variation in recruitment and the effects of three or four years of exploitation. Low levels of exploitation may be contributing to the changes outlined above, but since they would be occurring anyway, it is difficult to separate the effects of squawfish harvest from age-structured population dynamics. Most populations in the lower Columbia River have shifted toward fewer old and many more young individuals. Both dam-angling and sport-reward fisheries are selective for large (> 350 mm) northern squawfish, and catch rates and harvest may decline over the next 2-3 years, except perhaps in McNary Reservoir. Meanwhile, it will take several years for the strong 1988-1990 cohorts to grow into the size range that fisheries exploit most heavily. The challenge will be to maintain effort and interest in the fisheries through a few lean years until the strong cohorts are fully recruited.

We believe that our estimates of year-class strength of northern squawfish in lower Columbia River reservoirs were not greatly affected by different rates of size-specific exploitation in different years because exploitation rates have been relatively low and similar among years. However, estimates of year-class strength based on size and age composition may be biased in the future as northern squawfish fisheries are sustained. Although we are not currently aware of alternative methods to reconstruct the recruitment histories of northern squawfish populations throughout the lower Columbia Basin, we propose to investigate alternatives during 1994.

We found no evidence of compensation among northern squawfish, either in growth or fecundity. Compensation may be unlikely after only 3-4 years of relatively low exploitation rates.

Movement of radio-tagged northern squawfish supported our approach to estimate relative abundance. While we often found fish long distances from either shore, fish typically occurred in depths of less than 12.2 m. Tagged fish therefore occupied areas that we defined as potential squawfish habitat for purposes of expanding density indices to relative abundance We also found that most fish tagged and released in tailrace BRZs subsequently moved outside BRZs and would therefore be vulnerable to fisheries occurring outside BRZs. Similarly, most fish tagged outside BRZs subsequently moved into BRZs for at least some time and would be vulnerable to dam angling. This indicates that fisheries are for the most part harvesting northern squawfish from a single population rather than two subpopulations composed of large, highly predaceous fish in BRZs, and smaller, less predaceous fish outside BRZs. The implication is that fish harvested by sport anglers are no less important than fish harvested by dam angling because sport-caught fish have a reasonably high probability of residing in BRZs at some time.

Movement of radio-tagged fish past dams was consistent with tag recovery data in 1993 (Table H-3) and 1992 (Parker et al. 1992), which showed that interreservoir movement was far more prevalent at Bonneville and The Dalles dams than at other projects.

Interreservoir movement could confound attempts to characterize population structure in the Bonneville Dam tailrace, and Bonneville and The Dalles reservoirs, particularly if the degree of mixing differs among years. Mixing among the three areas may have also contributed to similar trends in population structure that were summarized in this report.

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APPENDIX H-l

Documentation for Spreadsheet Used to Compare Relative Losses of Juvenile Salmonids Among Various Management Alternatives

Introduction

Our objective is to estimate losses of juvenile salmonids to predation by northern squawfish relative to losses that occurred prior to implementation of northern squawfish removal fisheries. The user enters any combination of exploitation estimates among reservoirs and years for sport-reward and dam-angling fisheries in the "Loss Estimate Spreadsheet" (Appendix Figure H-l. 1). The effects of exploitation on predation are presented as "Losses as a percent of pre-exploitation." Steps involved in estimating losses are (1) exploitation in year j is estimated for each age of northern squawfish, (2) the effect of exploitation and natural mortality in year j on the age distribution of northern squawfish in year j+l is calculated, (3) an index of losses of juvenile salmonids in year j+ 1 is calculated as the product of abundance and consumption rate for each age, and (4) the loss index for year j + 1 is presented as the percent of the loss index prior to northern squawfish removals. Calculations through Step 3 are made for each reservoir (the Columbia River downstream from Bonneville Dam is treated as a reservoir); results are summed to yield a "systemwide" estimate for Step 4.

Northern squawfish population structure prior to removals is expressed in an equilibrium or mean state. Although this equilibrium state rarely, if ever, actually occurs in a given year, it is a good representation of the average population status over a number of years. By presenting population structure in this manner, variations in factors such as year-class strength are eliminated, and changes in northern squawfish population structure (and therefore predation) are related directly to removals. This, in effect, allows us to estimate what the effects of removals would be if we were somehow able to hold all variables except exploitation constant.

Because of differences in diet, consumption (Vigg et al. 1991), and vulnerability to fisheries among sizes of northern squawfish, information is summarized for each age. Northern squawfish less than 250-mm fork length were not considered because few juvenile salmonids are consumed by these fish. Northern squawfish do not reach 250-mm fork length until age 5 in most reservoirs (Rieman and Beamesderfer 1990; Parker et al., in review). Therefore, we evaluate predation only by fish ≥ age 5.

Exploitation

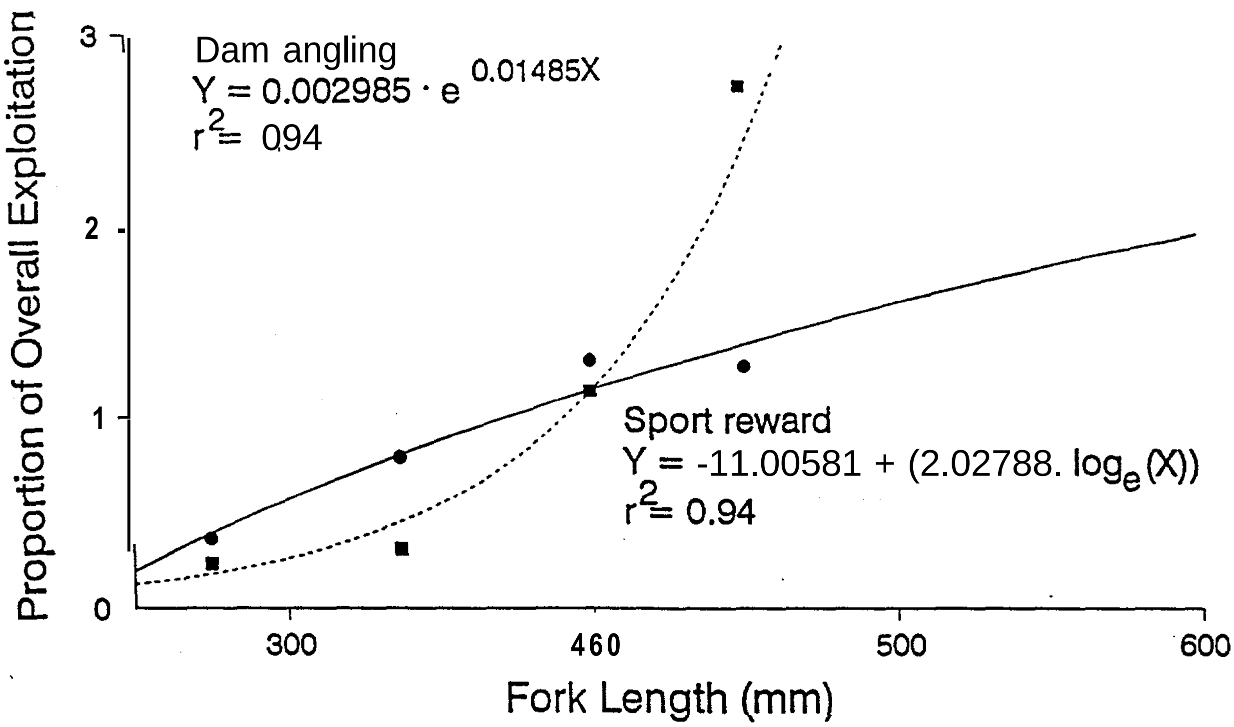
Exploitation estimates in future years are entered by the user in the "Loss Estimate Spreadsheet" (Appendix Figure H-l. 1). Only sport-reward and dam-angling fisheries are presently included, however, the spreadsheet can be modified if other fisheries are found to be effective, Exploitation estimates entered by the user are used to estimate age-specific exploitation rates. From 1990 through 1993, overall exploitation increased with northern squawfish size, however, the relationship between exploitation and size differed between the sport-reward and dam-angling fisheries (Appendix Figure H-l .2).

Relative benefits of the sport-reward and dam-angling fisheries are based on the assumption that all fish in a reservoir are available to both fisheries. For this to be true, fish tagged outside of boat restricted zones must be available to dam anglers, and fish tagged within boat restricted zones must be available to sport-reward anglers. Information from 1992 and 1993 indicated that an assumption of complete mixing is much more realistic than an assumption of no mixing (Appendix Table H-l. 1).

LOSS ESTIMATE SPREADSHEET

Reservoir	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Below Bonneville																	
sport	0.000	0.079	0.108	0.058													
Dam	0.000	0.002	0.001	0.009													
Bonneville																	
sport	0.000	0.134	0.099	0.020													
Dam	0.012	0.018	0.029	0.024													
The Dalles																	
Sport	0.000	0.061	0.051	0.067													
Dam	0.013	0.044	0.031	0.000													
John Oey																	
sport	0.045	0.043	0.034	0.023													
Dam	0.042	0.090	0.079	0.078													
McNary																	
sport	0.000	0.033	0.097	0.153													
Dam	0.014	0.019	0.004	0.005													
Ice Harbor																	
Sport	0.000	0.039	0.245	0.000													
Dam	0.000	0.136	0.018	0.000													
Lower Monumental																	
Sport	0.000	0.100	0.052	0.030													
Dam	0.000	0.170	0.083	0.000													
Little Goose																	
Sport	0.000	0.050	0.123	0.032													
Dam	0.000	0.134	0.064	0.032													
Lower Granite																	
Sport	0,000	0.168	0.171	0.120													
Oam	0.000	0.000	0.000	0.000													
losses (% of pre-exploitation)	100	W	88	80	79	83	87	91	94	96	98	99	100	100	100	100	100

Appendix Figure H-l. 1. Loss Estimate Spreadsheet used to enter exploitation estimates.



Appendix Figure H-1.2. Relationship between exploitation rate and northern squawfish fork length for sport-reward and dam-angling fisheries.

Appendix Table H-1.1. Expected catch of tagged northern squawfish in the sport-reward and dam-angling fisheries assuming no mixing and complete mixing of fish tagged within and outside boat restricted zones (BRZs), and observed catch. Numbers in parentheses indicate expected catch after adjueting for differences in size-related vulnerability between fish tagged within and outside BRZs. Sport-reward effort is limited to areas outside BRZs, whereas dam angling is limited to BRZs.

	Sport reward		Dam angling	
Year, catch distribution	Tagged in BRZ	Tagged outside BRZ	Tagged in BRZ	Tagged outside BRZ
1992				
Expected (no mixing)	110	239	103	0
Expected (complete mixing)	114 (124)	235 (225)	34 (37)	69 (66)
Observed	134	215	86	17
1993				
Expected (no mixing)	10	100	24	0
Expected (complete mixing)	10 (11)	100 (99)	2 (2)	22 (22)
Observed	13	97	5	19

For the sport-reward fishery, the preliminary exploitation rate on each age northern squawfish in a given year is computed as:

$PE_{s,h,i,j} = E_{s,i,j} \cdot$ (-11.00581 + (2.02788 . log&J) $\cdot (RP_{h,0} / RP_{h,j})$ (1)

where

$PE_{s,h,i,j}$ = preliminary sport-reward exploitation rate on age h fish in reservoir i in year j,

$E_{s,i,j}$. = overall sport-reward exploitation rate in reservoir i in year j,

$L_{h,i}$ = mean fork length of age h fish in reservoir i,

$RP_{h,0}$ = proportion of reservoir population aged h in 1990, and

$RP_{h,j}$ = proportion of reservoir population aged h in year j.

Although Equation 1 addresses the relationship between exploitation and northern squawfish size, the sum of the age-specific exploitation rates may not equal the overall exploitation rate. Age-specific exploitation rates are therefore corrected as:

$$E_{s,h,i,j} = PE_{s,h,i,j} \cdot (E_{s,i,j} / \sum_h PE_{s,h,i,j}) \qquad (2)$$

where

$E_{s,h,i,j}$ = sport-reward exploitation rate on age h fish in reservoir i in year j,

$PE_{s,h,i,j}$ = preliminary sport-reward exploitation rate on age h fish in reservoir i in year j, and

$E_{s,i,j}$ = overall sport-reward exploitation rate in reservoir i in year j.

For the dam angling fishery, the preliminary exploitation rate on each age in a given year is computed as:

$$PE_{d,h,i,j} = E_{d,i,j} \cdot e^{(0.01485 \cdot L_{h,i})} \cdot (RP_{h,0} / RP_{h,j}) \qquad (3)$$

where

$PE_{d,h,i,j}$ = preliminary dam-angling exploitation rate on age h fish in reservoir i in year j,

$E_{d,i,j}$ = overall dam-angling exploitation rate in reservoir i in year j,

$L_{h,i}$ = mean fork length of age h fish in reservoir i,

$RP_{h,0}$ = proportion of reservoir population in size group h in 1990, and

$RP_{h,j}$ = proportion of reservoir population in size group h in year j.

Age-specific dam-angling exploitation rates are also corrected as:

$$E_{d,h,i,j} = PE_{d,h,i,j} \cdot (E_{d,i,j} / \sum_h PE_{d,h,i,j}) \qquad (4)$$

where

$E_{d,h,i,j}$ = dam-angling exploitation rate on age h fish in reservoir i in year j,

$PE_{d,h,i,j}$ = preliminary dam-angling exploitation rate on age h fish in reservoir i in year j, and

$E_{d,i,j}$ = overall dam-angling exploitation rate in reservoir i in year j.

Total exploitation for each age is calculated as the sum of sport-reward and dam-angling exploitation rates:

$$E_{h,i,j} = E_{s,h,i,j} + E_{d,h,i,j} \quad (5)$$

where

$E_{h,i,j}$ = total exploitation rate on age h fish in reservoir i in year j,

$E_{s,h,i,j}$ = sport-reward exploitation rate on age h fish in reservoir i in year j, and

$E_{d,h,i,j}$ = dam-angling exploitation rate on age h fish in reservoir i in year j.

The maximum exploitation rate for any age is 1.0. If calculations result in exploitation exceeding 1.0, the result is changed to 1.0. If realistic exploitation estimates are entered, this will occur rarely, and only for the oldest ages. This may result in overall exploitation being less than the rate originally entered. However, if populations have been restructured so that total harvest of large fish is possible, overall exploitation rates will probably be lower than if more large fish were available. This is because small fish are less vulnerable to exploitation than larger fish (Appendix Figure H-l .2).

Size and Age Structure

An index of abundance of northern squawfish ≥ 250 mm fork length in each reservoir prior to removals was estimated from boat electrofishing data (Ward et al., in review). Data was collected from Columbia River reservoirs in 1990, Snake River reservoirs and John Day Reservoir in 1991, and the Columbia River downstream from Bonneville Dam and John Day Reservoir in 1992. Abundance was indexed for each reservoir forebay, midreservoir, tailrace, tailrace restricted zone (BRZ), and upper reservoir where applicable. Indices from these areas were summed to yield a reservoir-wide index. To simplify comparisons, the mean 1990-92 index of abundance for John Day Reservoir was assumed to equal 100,000 fish (Appendix Table H-1.2). It is important to note that the index should not be used to estimate actual numbers of fish; its proper use is as an indicator of relative differences among reservoirs.

Size and age structure of northern squawfish populations were estimated from boat electrofishing data collected while sampling to estimate relative abundance. Catches were used to generate length-frequency histograms for each reservoir, and scale analyses were used to estimate mean length at age of northern squawfish in each reservoir. Unadjusted age frequencies were then estimated by multiplying the number of fish in each 25-mm length interval by the proportion of fish of each age in a subsample from that length interval.

Appendix Table H-1.2. Indices of abundance and estimates of natural mortality for northern squawfish prior to implementation of removal fisheries.

Reservoir	Year(s) indexed	Abundance index for year sampled	Abundance index at equilibrium	Recruitment to age 5	Natural mortality (%)
Downstream from Bonneville Dam	1992	235,745	176,290	60,351	34
Bonneville	1990	74,707	73,163	18,889	25
The Dalles	1990	37,893	38,408	9,235	23
John Day	1990-92	100,000	99,284	16,620	14
McNary	1990	77,397	75,213	14,917	18
Ice Harbor	1991	23,233	22,494	6,632	29
Lower Monumental	1991	16,857	16,414	7,882	48
Little Goose	1991	24,973	24,683	5,935	23
Lower Granite	1991	23,812	23,178	7,270	31

Because different sizes of northern squawfish are differentially vulnerable to capture even when samples from different gears are pooled (Beamesderfer and Rieman 1988), the following formula was used to index the relative vulnerability of northern squawfish:

$$Y = 0.0112 \cdot e^{-(408.1 - L)^2 / 12261.8} \qquad (6)$$

where

Y = index of vulnerability to capture, and

L = fork length of northern squawfish.

Age composition for each reservoir was adjusted by dividing the unadjusted proportion of fish at each age by the index of vulnerability for the mean length at that age.

We used the adjusted age composition to estimate an equilibrium or average age composition for each reservoir prior to removals. For each reservoir, we used linear regression on a catch curve constructed from adjusted age frequencies (Ricker 1975) to estimate (1) annual mortality rate, and (2) mean recruitment of fish to age 5 (Appendix Table H-1.2). Because data was collected prior to or coinciding with full implementation of fisheries in each reservoir, we assumed all estimated mortality to be natural. We calculated the equilibrium abundance index for each age northern squawfish in a reservoir as

$$AI_{h,i} = AI_{5,i} \cdot ((1 - M_i) \cdot (h - 5)) \qquad (7)$$

where

$AI_{h,i}$ = equilibrium abundance index of age h fish in reservoir i,

$AI_{5,i}$ = abundance index (mean recruitment) of age 5 fish in reservoir i (from Appendix Table H-1.2), and

M_i = annual natural mortality rate in reservoir i prior to exploitation (from Appendix Table H-l .2).

Age structure of northern squawfish populations after removals change as a function of exploitation and natural mortality:

$$AI_{h,i,j} = AI_{h-1,i,j-1} \cdot (1 - ((M_i \cdot (1 - E_{h-1,i,j-1})) + E_{h-1,i,j-1})) \quad (8)$$

where

$AI_{h,i\,j}$ = abundance index of age h fish in reservoir i in year j,

$AI_{h-1,i,j-1}$ = abundance index of age h-l fish in reservoir i in year j-l (in the first year of exploitation this equals $AI_{h,i}$),

M_i = annual natural mortality rate in reservoir i prior to exploitation, and

$E_{h-1,i,j-1}$ = exploitation rate of h-l fish in reservoir i in year j-l.

This assumes that natural mortality occurs after fishing ends and that the forces of natural mortality remain constant (Picker 1975). The recruitment of fish to age 5 remains constant at the equilibrium level.

Consumption

An index of consumption of juvenile salmonids by northern squawfish in each reservoir prior to removals was estimated by examining digestive tracts of northern squawfish collected by electrofishing (Petersen et al. 1990; Ward et al., in review). Sampling was concurrent with that for indexing northern squawfish abundance and size structure. A consumption index was calculated for each reservoir area in both spring and summer:

$$CI_{l,m} = 0.0209 \cdot T^{1.60} \cdot MW^{0.27} \cdot (S \cdot GW^{-0.61}) \quad (9)$$

where

$CI_{l,m}$ = consumption index for area 1 in season m, T = water temperature (°C),

MW = mean weight (g) of northern squawfish in sample,

S = mean number of juvenile salmonids per northern squawfish in sample, and

GW = mean total gut weight (g) of northern squawfish in sample.

Although sampling for consumption was timed to coincide with peak densities of juvenile salmonids, predicting highest passage densities was difficult. We therefore used linear regression to evaluate the relationship between salmonid densities and northern squawfish consumption indices for each area and season. To approximate the number of fish in tailraces and upper reservoirs, we summed estimates of passage at the nearest upstream dam or collection facility and releases directly into the area from hatcheries, and subtracted estimates of fish removed at collection facilities and later transported downstream. We used similar information adjusted for rate of juvenile salmonid migration to approximate number of fish in midreservoirs. We used estimates of passage at the nearest downstream dam to approximate the number of fish in forebays. Salmonid density was approximated as mean daily passage for days sampled divided by surface hectares.

We found no significant relationship between consumption indices and juvenile salmonid density except in tailrace areas (both non-BRZs and BRZs) in summer. The functional response of northern squawfish consumption to salmonid density has been described by exponential or sigmoid models (Petersen and DeAngelis 1992), however, the linear model we used explained much of the variability in consumption indices among tailraces in summer (non-BRZ r^2 = 0.77; BRZ r^2 = 0.60). Relationships in the spring, and in non-tailrace areas in summer was poor (r^2 = 0.01 - 0.26), and would not fit any functional response model well. We therefore used observed consumption indices in subsequent analyses except that indices in tailrace non-BRZs in summer were calculated as

$$CI_{1,s} = -0.40 + (0.075 \cdot D_{1,s}) \qquad (10a)$$

and indices in tailrace BRZs in summer were calculated as

$$CI_{1,s} = 1.55 + (0.015 \cdot D_{1,s}) \qquad (10b)$$

where

$CI_{1,s}$ = consumption index in area 1 (tailrace non-BRZ or tailrace BRZ) in summer, and

$D_{1,s}$ = density of juvenile salmonids (mean daily passage during days sampled divided by surface hectares) in area 1 in summer.

Consumption indices were converted to consumption rates (juvenile salmonids per northern squawfish per day) by the formula from Petersen et al. (1990):

$$Log_{10}(MC_{l,m}) = -0.41 + (1.17 \cdot Log_{10}(CI_{l,m})) \qquad (11a)$$

or,

$$Log_{10}(MC_{l,m}) = -0.41 + (1.17 \cdot Log_{10}(CI_{l,s})) \qquad (11b)$$

where

$MC_{l,m}$ = consumption rate for mean size (age) northern squawfish in sample from area 1 in season m,

$CI_{l,m}$ = consumption index for area 1 in season m, and

$CI_{l,s}$ = consumption index for area 1 (tailrace non-BRZ or BRZ) in summer.

Size of northern squawfish used in estimates of consumption is important because consumption rates generally increase with northern squawfish length (Vigg et al. 1991). Consumption rates were therefore adjusted to reflect differences in mean size of northern squawfish in samples. The relationship between consumption rate and northern squawfish fork length was based on consumption rates observed in John Day Reservoir (U.S. Fish and Wildlife Service, unpublished data):

$$RC_{h,l,m} = 0.0016149 \cdot (e^{(F_{h,l} \cdot 0.0130939)}) \qquad (12)$$

where

$RC_{h,l,m}$ = relative consumption rate for age h fish in area 1 and season m, and

$F_{h,l}$ = mean fork length of age h fish in area 1.

After the mean age of northern squawfish used in developing a consumption index (and therefore calculating $MC_{l,m}$) for each area was determined, a consumption rate for each age calculated as

$$CR_{h,l,m} = MC_{l,m} \cdot (RC_{h,l,m} / MRC_{l,m}) \qquad (13)$$

where

$CR_{h,l,m}$ = consumption rate for age h fish in area 1 and season m,

$MC_{l,m}$ = consumption rate for mean age fish in sample from area 1 in season m,

$RC_{h,l,m}$ = relative consumption rate for age h fish in area 1 and season m, and

$MRC_{l,m}$ = relative consumption rate for mean age fish in sample from area 1 in season m.

The relative abundance of each age of northern squawfish in each reservoir area Was then used to develop a reservoirwide consumption rate for each age for each season:

$$CR_{h,i,m} = \sum_{l} (CR_{h,l,m} \cdot RP_{h,l}) \qquad (14)$$

where

$CR_{h,i,m}$ = consumption rate for age h fish in reservoir i in season m,

$CR_{h,l,m}$ = consumption rate for age h fish in area 1 and season m, and

RP_h = proportion of reservoir population of age h fish in area 1.

Loss Estimates

Estimates of the relative loss of juvenile salmonids to northern squawfish predation in each reservoir are calculated as the product of northern squawfish abundance and consumption rates. Seasonal predation by each age of northern squawfish is calculated and summed to yield annual predation by each age:

$$L_{h,i,j} = \sum_{m} (AI_{h,i,j} \cdot CR_{h,i,m} \cdot D_m) \qquad (15)$$

where

$L_{h,i,j}$ = loss of juvenile salmonids to age h northern squawfish in reservoir i in year j,

$AI_{h,i,j}$ = abundance index of age h fish in reservoir i in year j,

$CR_{h,i,m}$ = consumption rate of age h fish in reservoir i in season m, and

D_m = number of days in season m.

Total annual predation in each reservoir is calculated as the sum of the seasonal losses:

$$RL_{i,j} = \sum_{h} L_{h,i,j} \qquad (16)$$

where

$RL_{i,j}$ = total loss of juvenile salmonids to northern squawfish in reservoir i in year j, and

$L_{h,i,j}$ = loss of juvenile salmonids to northern squawfish of age h in reservoir i in year j.

Predation is summed for all reservoirs then divided by the predation estimate for 1990 **to** yield "Losses as a percent of pre-exploitation" (Appendix Figure H-l. 1):

$$TL_j = (\sum_i RL_{i,j}) / (\sum_i RL_{i,0})) \cdot 100 \qquad (17)$$

where

TL_j = total loss of juvenile salmonids to northern squawfish in year j expressed as a percentage of losses prior to exploitation,
$RL_{i,j}$ = total loss of juvenile salmonids to northern squawfish in reservoir i in year j, and

$RL_{i,0}$ = total loss of juvenile salmonids to northern squawfish in reservoir i in 1990.

Appendix H-l References

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APPENDIX H-2

Exploitation by Reservoir and Fishery in 1993

Appendix Table H-2.1. Exploitation of northern squawfish downstream from Bonneville Dam.

		Recaptures					Exploitation		
P	T	Sport	Dam	Net	Misc.	M	Sport	Dam	Net
1	783	--	--	--		---	--	--	
2	--	5	--	--		783	0.0064		--
3		1	--	--		778	0.0013		
4			--	--		777	- -	--	
5	--	2	--	--	--	777	0.0026	--	--
6	--	3	--	--	1	775	0.0039	--	--
7	--	3	--	1	--	771	0.0039	--	0.0013
8	--	7	--	--	--	767	0.0091	--	--
9	--	5	--	--	1	760	0.0066	--	--
10	--	6	--	2	--	754	0.0080	--	0.0027
11	--	2	- -	1	1	746	0.0027	--	0.0013
12	--	- -	- -	2		742	- -	--	0.0027
13		2	- -	1	1	740	0.0027	--	0.0014
14		1	--	- -	1	737	0.0014	--	--
15	--	2	--	--	- -	735	0.0027	--	--
16	--	1	--	--	1	733	0.0014	--	--
17	--	2	--	--	- -	732	0.0027	--	--
18	--	1	--	--	- -	730	0.0014	--	--
19	--	- -	--	--		729	- -	--	--
20	--	1	--	--	--	729	0.0014		--
21		- -	--	--	--	728	- -		--
22	--	--	--	--		728	- -	--	--
Total	783	44	0	7	4	---	0.0580	0.0000	0.0093
Adjusted for tag loss							0.0608	0.0000	0.0098

Appendix Table H-2.2. Exploitation of northern squawfish in Bonneville Reservoir.

		Recaptures					Exploitation		
P	T	Sport	Dam	Net	Misc.	M	Sport	Dam	Net
1	333	--	--	--	--	---	--	--	--
2	18	--	--	--	--	333	--	--	--
3	--	--	--	--	--	351	--	--	--
4	--	1	--	--	--	351	0.0028	--	--
5	--	1			1	350	0.0029	--	--
6	--	--	--		1	348	--	--	--
7	--	--	2	--	--	347	--	0.0058	--
8	--	4	--	--	2	345	0.0116	--	--
9	a -	--	2	--	1	339	--	0.0059	--
10	--	1	1	--	1	336	0.0030	0.0030	--
11	--		--		1	333	--		--
12	--		2	1		332	--	0.0060	0.0030
13	--		--	--	--	329	--		--
14	--	--	--	--	--	329	--	--	--
15	--	--	--	--	--	329	--	--	--
16	--	--	--	--	--	329	--	--	--
17	--		--	--		329	--	--	--
18	--	--	--	--	--	329	--	--	--
19	--	--	--	--	--	329	--	--	--
20	--	--	--	--	1	329	--	--	--
21	--	--	--	--	--	328	--	--	--
22	--	--	--	--	--	328	--	--	--
Total	351	7	7	1	8		0.0203	0.0207	0.0030
Adjusted for tag loss							0.0212	0.0217	0.0032

Appendix Table H-2.3. Exploitation of northern squawfish in The Dalles Reservoir.

P	T	Recaptures				M	Exploitation		
		Sport	Dam	Net	Misc.		Sport	Dam	Net
1	92		--	--	--	---	--	--	
2			--	--	--	92		--	--
3	18		--	a -	--	92	--	--	--
4	--		--	--	2	110	--	--	--
5	--	--	--	--	--	108		--	--
6	--	1	--	--	--	108	0.0093	--	
7	--	1	--	--	--	107	0.0093	--	
8	--	2	--	--	--	106	0.0189	--	--
9	--	1	--	--	--	104	0.0096	--	--
10	--		--	--	--	103	--	--	--
11	--	--	--	--	--	103	--	--	
12	--	--	--	--	1	103		--	--
13	--	--	--	--	--	102	--	--	
14	--	2	--	--	--	102	0.0196	--	--
15	--		--	--	--	100	--	--	--
16	--	--	--	--	--	100	--	--	--
17	--	--	--	--	--	100	--	--	
18	--	--	--	--	--	100	--	--	
19	--	--	--	--	--	100	--	--	
20	--	--	--	--	--	100		--	--
21	--	--	--	--	--	100	--	--	--
22			--	--	--	100		--	--
Total	110	7	0	0	3		0.0667	0.0000	0.0000
Adjusted for tag loss							0.0669	0.0000	0.0000

Appendix Table H-2.4. Exploitation of northern squawfish in John Day Reservoir.

P	T	Recaptures				M	Exploitation		
		Sport	Dam	Net	Misc.		Sport	Dam	Net
1	66	--	--	--	--	---	--	--	--
2	--	--	--	--	--	66	--	--	--
3	--	--	--	--	--	66	--	--	--
4	--	--	--	--	--	66	--	--	--
5			--	--	--	66	--	--	--
6	53	1	--	--	--	66	0.0152	--	--
7	8	--	--	--	--	118	--	--	--
8	9	--	--	--	--	126	--	--	--
9	--	--	--	--	--	135	--	--	--
10	--		2	--	--	135	--	0.0148	--
11	26	1	4	--	--	133	0.0075	0.0301	--
12	--		2	--	--	154	--	0.0130	--
13	--	--	--	--	--	152	--	--	--
14	--	--	2	--	--	152	--	0.0132	--
15	--	--	1	--	--	150	--	0.0067	--
16	--	--	--	--	--	149	--	--	--
17	--		--	--	--	149	--	--	--
18	--		--	--	--	149	--	--	--
19	--		--	--	--	149	--	--	--
20	--	--	--	--	--	149	--	--	--
21	--	--	--	--	--	149	--	--	--
22	--	--	--	--	--	149	--	--	--
Total	162	2	11	0	0	---	0.0227	0.0777	0.0000
Adjusted for tag loss							0.0238	0.0814	0.0000

Appendix Table H-2.5. Exploitation of northern squawfish in McNary Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	50	--	--	--	---	--	--
2	--	--	--	--	50	--	--
3	--	--	--	--	50	--	--
4	--	--	--	--	50	--	--
5	3	--	--	--	50		--
6		--		--	53	--	--
7	157	3	--	--	53	0.0566	--
8	--	1	--	--	207	0.0048	--
9	--	1		--	206	0.0049	--
10	--	4	--	--	205	0.0195	
11	--	1	1	--	201	0.0050	0.0050
12	--	1	--	--	199	0.0050	--
13	--	2	--	--	198	0.0101	--
14		3			196	0.0153	--
15	--	1	--	--	193	0.0052	
16	--	2	--	--	192	0.0104	--
17	--	--	--	--	190	--	--
18	--	1	--	--	190	0.0053	--
19	--	1	--	--	189	0.0053	--
20		1	--	--	188	0.0053	
21		--	--	--	la7	--	--
22	--		--	--	187	--	
Total	210	22	1	0	---	0.1527	0.0005
Adjusted for tag loss						0.1600	0.0052

Appendix Table H-2.6. Exploitation of northern squawfish in Lower Monumental Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	97	--	--	--		--	--
2	--	--	--	--	97	--	--
3		--		--	97	--	--
4	21	--	--		97		--
5	17	--	--		118		--
6	--	1	--	--	135	0.0074	--
7	--	--	--	--	134	--	--
8	2	1	--	--	134	0.0075	--
9		1	--	--	135	0.0074	--
10		--	--	--	134		--
11		--		1	134	--	--
12	--	--		--	133	--	--
13	--	--	--	--	133	--	--
14	--	--	--	--	133	--	--
15	--	--	--	--	133	--	--
16	--	--	--	--	133	--	--
17	--	--	--	--	133	--	--
18			--	--	133	--	--
19		1		--	133	0.0075	--
20	--	--		--	132		--
21	--	--	--	--	132	--	--
22	--	--	--	--	132	--	--
Total	137	4	0	1	---	0.0298	0.0000
Adjusted for tag loss						0.0312	0.0000

Appendix Table H-2.7. Exploitation of northern equawfish in Little Goose Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	4	--	--	--	---	--	--
2	1	--	--	--	4	--	--
3	3	--	--	--	5	--	
4	37	--		--	8	--	--
5				--	45		--
6	--	--	--	--	45		--
7	--	--	--	--	45	--	--
8	20	--	--	--	45	--	--
9	--	--	--	--	65		
10	--		--		65	--	
11	--			--	65	--	
12	--		1	--	65	--	0.0154
13	--	1	--	--	64	0.0156	--
14	--	--	--	--	63	--	--
15	--	--	--	--	63	--	
16	--	1	--	--	63	0.0159	
17	--		1		62	--	0.0161
18	--		--	--	61	--	--
19	--	--	--	--	61	--	--
20	--	--	--	--	61	--	--
21	--	--	--	--	61	--	--
22	--	--	--	--	61	--	
Total	65	2	2	0		0.0315	0.0315
Adjusted for tag loss						0.0330	0.0330

Appendix Table H-2.8. Exploitation of northern squawfish in Lower Granite Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	45	--	--	--	---	--	--
2	87	--	--	--	45	--	--
3	--	3	--	--	132	0.0227	--
4	--	--	--	--	129	--	--
5	--	3	--	--	129	0.0233	--
7	--	3	--	--	126	0.0238	--
8 --	--	2 1	-- --	-- --	123 121	0.0163 0.0083	-- --
9	--	--	--	--	120	--	--
10	--	--	--	--	120	--	--
11							
12 --	--	-- 2	-- --	-- 1	120 119	0.0168 --	-- --
13	--	--	--	1	117	--	--
14	--	1	--	--	116	0.0086	--
15	--	--	--	--	115	--	--
16	--	--	--	--	115	--	--
17	--	--	--	--	115	--	--
18	--	--	--	--	115	--	--
19	--	--	--	--	115	--	--
20	--	--	--	--	115	--	--
21	--	--	--	--	115	--	--
22	--	--	--	--	115	--	--
Total	132	15	0	2	---	0.1197	0.0000
Adjusted for tag loss						0.1255	0.0000

Appendix Table H-2.9. Exploitation of northern squawfish systemwide.

P	T	Recaptures Sport	Dam	Net	Misc.	M	Exploitation Sport	Dam	Net
1	1,470	--	--	--	--	--	--	--	--
2	106	5	--	--	--	1,470	0.0034	--	--
3	21	4	--	--	--	1,571	0.0025	--	--
4	58	1	--	--	2	1,588	0.0006	--	--
5	20	6	--	--	1	1,643	0.0037	--	--
6	53	11	--	--	--	1,565	0.0066	--	--
7	165	9	2	1	--	1,698	0.0053	0.0012	0.0006
8	31	18	--	--	--	1,851	0.0097	--	--
9	--	9	2	--	1	1,864	'0.0048	0.0011	--
10	--	12	3	2	--	1,852	0.0065	0.0016	0.0011
11	26	8	5	1	--	1,835	0.0044	0.0027	0.0005
12	--	4	5	3	--	1,847	0.0022	0.0027	0.0016
13	--	5	1	1	1	1,835	0.0027	0.0005	0.0005
14	--	7	2	--	1	1,828	0.0038	0.0011	--
15	--	3	1	--	--	1,818	0.0017	0.0006	--
16	--	4	--	--	1	1,814	0.0022	--	--
17	--	2	1	--	--	1,810	0.0011	0.0006	--
18	--	2	--	--	--	1,807	0.0011	--	--
19	--	2	--	--	--	1,805	0.0011	--	--
20	--	2	1	--	--	1,803	0.0011	0.0006	--
21	--	--	--	--	--	1,800	--	--	--
22	--	--	--	--	--	1,800	--	--	--
Total	1,950	114	23	8	7	--	0.0646	0.0126	0.0044
Adjusted for tag loss							0.0677	0.0132	0.0045

APPENDIX H-3

Backcalculated Lengths and Age-at-Length Keys for 1593

Appendix Table H-3.1. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from Bonneville Dam tailrace, 1993.

Year Class	Age														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1992	96														
1991	44	132													
1990	41	125	183												
1989	32	113	164	207											
1988	33	126	178	214	245										
1987	33	146	199	235	268	296									
1986	33	141	202	244	279	309	335								
1985	35	148	194	237	271	305	328	354							
1984	33	145	208	253	298	335	363	385	408						
1983	35	157	217	265	304	336	366	394	415	434					
1982	35	147	209	250	291	324	355	384	412	435	458				
1981	37	157	220	268	312	346	373	400	428	452	471	497			
1980	35	152	215	262	301	329	352	377	402	422	444	462	477		
1979	35	136	181	224	263	302	334	367	391	415	438	455	475	497	
1978	37	154	191	231	280	312	336	354	373	392	420	443	464	490	520
N	256	244	212	179	159	128	100	65	55	35	26	16	7	3	1
Mean	39	136	194	237	277	316	349	382	412	436	459	482	479	494	520
SD	16	24	27	32	33	31	31	29	29	26	24	29	21	7	--
Increment	39	97	58	43	40	39	33	33	30	24	23	23	--	--	--

Appendix Table H-3.2. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from Bonneville Reservoir, 1993.

Year Class	Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1992	68															
1991	33	111														
1990	32	107	169													
1989	32	123	184	230												
1988	33	127	193	238	271											
1987	30	134	183	223	262	293										
1986	29	137	204	248	280	306	329									
1985	32	137	199	250	287	314	335	354								
1984	30	138	206	251	285	314	339	359	375							
1983	33	138	203	253	293	324	350	373	394	414						
1982	31	127	198	254	295	329	356	379	399	416	435					
1981	31	145	208	264	312	345	373	403	426	447	467	485				
1980	31	144	206	261	299	337	364	388	416	437	459	480	501			
1979	28	142	205	268	325	356	387	410	430	453	475	492	511	526		
1978	39	115	168	222	235	281	325	364	392	420	442	460	475	492	512	
1977	39	90	154	191	232	255	298	320	341	357	392	417	441	458	472	505
N	293	289	259	209	157	139	126	101	78	63	41	25	13	5	2	1
Mean	32	126	190	244	286	318	346	373	399	425	451	481	497	506	492	505
SD	8	25	27	28	27	30	32	33	33	35	31	25	27	31	28	--
Increment	32	94	64	54	42	32	28	27	26	26	26	30	16	9	--	--

Appendix Table H-3.3. Mean backcalculated fork lengths (mm) at the end of each year of life for northern sguawfish from The Dalles Reservoir, 1993.

Year Class	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1992	--															
1991	46	121														
1990	41	120	182													
1989	41	123	180	226												
1988	41	136	192	233	267											
1987	41	152	211	259	290	314										
1986	41	151	222	266	295	318	338									
1985	42	144	210	261	295	322	342	361								
1984	41	133	203	256	293	323	345	364	384							
1983	40	144	217	268	301	331	356	376	393	413						
1982	44	134	210	263	302	331	358	381	402	422	441					
1981	42	132	202	253	291	321	344	367	387	407	425	446				
1980	43	143	212	260	301	335	362	388	408	428	448	464	484			
1979	42	169	226	270	309	343	373	396	415	433	452	467	479	494		
1978	39	163	215	265	300	329	358	377	401	425	446	458	474	488	504	
1977	45	161	198	239	279	306	341	367	396	313	434	453	469	483	490	511
N	277	277	262	214	167	145	127	102	85	61	46	36	27	12	8	2
Mean	42	135	199	251	292	324	349	373	395	420	441	458	480	489	500	511
SD	6	24	30	29	23	21	25	26	26	25	27	28	30	34	24	35
Increment	42	93	64	52	41	32	25	24	22	25	21	17	22	9	11	11

Appendix Table H-3.4. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from John Day Reservoir, 1993.

Year Class	Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1992	86															
1991	66	97														
1990	63	136	187													
1989	65	164	218	258												
1988	68	144	209	256	279											
1987	68	166	233	269	297	320										
1986	66	171	226	266	296	320	341									
1985	69	167	232	274	304	328	347	364								
1984	69	173	237	278	313	340	360	379	399							
1983	68	184	244	285	313	340	361	382	398	415						
1982	67	154	223	279	317	349	370	393	410	423	438					
1981	67	189	252	290	322	349	376	403	424	446	467	486				
1980	67	170	228	268	304	331	354	381	400	421	440	455	471			
1979	66	202	244	278	306	330	347	361	375	399	429	453	465	479		
1978	70	156	206	249	283	314	335	358	381	405	428	446	465	477	494	
1977	68	122	175	224	247	275	295	322	348	365	390	420	444	465	478	525
N	167	160	156	148	139	133	118	93	70	49	29	22	16	9	9	1
Mean	68	166	228	271	303	330	352	376	399	418	440	459	466	476	492	525
SD	7	32	33	29	29	29	30	28	28	27	24	25	19	18	22	--
Increment	68	98	62	43	32	27	22	24	23	19	22	19	7	10	16	33

Appendix Table H-3.5. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from McNary Reservoir, 1993.

Year Class	Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1992	68															
1991	62	120														
1990	63	123	175													
1989	59	133	172	203												
1988	61	134	197	236	263											
1987	60	139	199	243	274	298										
1986	61	142	196	240	273	300	320									
1985	61	153	213	259	294	318	338	357								
1984	60	157	218	258	291	317	339	357	376							
1983	62	161	226	269	309	338	362	383	401	420						
1982	65	163	232	276	308	333	357	377	396	412	428					
1981	65	179	235	281	320	349	370	390	412	433	449	468				
1980	67	175	223	262	295	327	353	382	405	432	450	467	486			
1979	59	147	205	240	285	320	344	363	377	403	416	436	447	459		
1978	59	133	199	243	284	323	352	379	400	419	442	456	477	494	508	
1977	60	153	201	236	260	293	323	351	366	384	410	425	440	453	467	486
N	187	182	168	163	156	140	123	98	74	49	33	18	11	6	4	1
Mean	62	148	209	253	288	318	343	369	392	419	436	460	472	475	498	486
SD	6	27	27	28	26	26	27	28	28	29	32	24	29	30	34	--
Increment	62	86	61	44	35	30	25	26	23	27	17	24	12	3	23	--

REPORT I

Economic, Social, and Legal Feasibility of the 1993 Northern Squawfish Removal Fisheries and Fish Distribution System

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1993 Annual Report

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ABSTRACT

We report on our research conducted from April 1, 1993, through September 30, 1993, to analyze the economic, social and legal feasibility of northern squawfish (*Ptychocheilus oregonensis*) removal fisheries. We also report on the structure and function of the fish collection and distribution system.

Northern squawfish were provided to this project from two removal fisheries — a sport-reward fishery and a dam-angling fishery. We performed baseline monitoring of the two removal fisheries and assessed cost-effectiveness of removals. We evaluated the removal fisheries for social, regulatory, and enforcement issues related to their conduct.

We developed and administered an extensive collection, transportation, storage and delivery system for northern squawfish landed by the sport-reward and dam-angling fisheries. We provided northern squawfish for both food and non-food uses.

We analyzed the angler participation segment of the sport-reward fishery through responses to a survey administered to all anglers returning northern squawfish to check stations. We surveyed creel clerks for further information on angler response and fishery

operations. We assessed several social issues related to the operation of the sport-reward fishery through surveys of fishery participants, fishery staffs, and enforcement personnel.

We make several specific recommendations concerning fish collection and distribution in subsequent fishing seasons.

INTRODUCTION

The 1993 season concluded our research of the feasibility of alternative fisheries for northern squawfish (*Ptychocheilus oregonensis).* The research was first begun in February 1989. This report summarizes our research activities and results during the first half of the performance period from April 1, 1993, until September 30, 1993. The 1993 project has three objectives related to the evaluation of the feasibility of northern squawfish removal fisheries. These three objectives are listed below.

1. Oversee the collection, transportation, storage, and distribution of all northern squawfish removed during the 1993 fishing season.

2. Conduct baseline monitoring of dam-angling and sport-reward removal fisheries for northern squawfish.

3. Conduct baseline monitoring of social, regulatory, and enforcement issues related to the predator control program.

This report presents results of research activities conducted through September 30 under the three project objectives. Discussions are presented in four subject areas — fishery operations, distribution of catch, catch utilization, and social and regulatory issues.

METHODS

Fishery Operations

Northern squawfish were harvested by two types of fisheries in 1993 — sport reward and dam angling. The number of harvest sites in the sport-reward and dam-angling fisheries continued as in 1992, but the mix of harvest locations changed. Harvest sites included eight mainstem dams and sport-reward locations ranging from Longview, Washington, east to Clarkston, Washington.

Staggered opening times in the two fisheries meant that northern squawfish were provided to the Oregon State University (OSU) project during different time periods. The dam-angling fishery was conducted between May 17 and September 19. As in the 1992 season, opening times varied for different dams. The sport-reward fishery operated between May 3 and September 12.

Operations of the two northern squawfish removal fisheries were monitored by this project for logistics of operations, characteristics of sport anglers, and the effectiveness of fish collection and distribution systems. Catch and effort per site, agency expenditures, and conflicts will be evaluated in the second half of the performance period. Because funding interest in the economic and social components of the fishery has waned, the 1993 monitoring level was reduced to a much lower level than in 1992.

Five sources of data provided monitoring of the sport-reward fishery — reward voucher questionnaires, registration forms, catch weight, a survey of creel clerks, and agency expenditures.

Consistent with the lower level of monitoring, the survey instrument used to collect data from the sport-reward fishery was revised to include fewer questions. The 1993 angler survey included questions on amount of time spent fishing, reason for the fishing trip, fishing methods, reasons for participation in the northern squawfish program, distance traveled to fish, frequency of recreational fishing throughout the year, age, and home state. Questions on angler expenditures, accommodations, information sources, and education were eliminated. Responses in the previous two years were similar enough to indicate that no new information would be generated by their continuance.

The survey was administered to every participant in the sport-reward fishery returning to a check station. The design of the survey instrument was coordinated with the Washington Department of Wildlife (WDW) and the Pacific States Marine Fisheries Commission (PSMFC). The 1993 sport-reward fishery survey form is presented in Appendix Figure I-l. 1. As in 1992, the payment voucher certifying number of northern squawfish caught was incorporated into the survey form to ensure a high level of survey response. Receipt of payment for landed squawfish was dependent on the completion of the survey. The list of 1993 sport-reward fishery check stations and their numerical codes is presented in Appendix Table I-l. 1.

Survey data were entered throughout the 1993 fishing season; 9,357 survey forms were coded and processed. A total of 10,251 survey forms were returned, but 894 of these forms (8.7%) were returned after the data entry position was terminated and so were not entered. The distribution of both analyzed and not analyzed survey forms is presented in Appendix Table I-1.2. The percent of each check station's total surveys not analyzed ranged from a low of 2.4% for The Dalles to a high of 19.9% for Columbia Park. These percentages are consistent with the distribution of analyzed surveys across sites.

The cost-effectiveness of sport-reward fishery operations in terms of total expenditures and average expenditures per fish removed is awaiting data to be provided by cooperators in the Washington Department of Fisheries and Wildlife. Cost-effectiveness summaries appear in Appendix Tables I- 1.3 and I- 1.4.

Dam-angling fishing operations were monitored using two sources of data — catch data and agency expenditures. Further assessments of dam-angling fishery operations were made through a survey of dam supervisors and enforcement personnel. The major questions of interest to the feasibility project concerning the dam-angling removal method are the effectiveness per unit cost and the interactions with other project components, dam operations, and the general public. Effectiveness is measured in terms of northern squawfish removals per dollar spent to plan, operate and manage the fishery. Data elements required for the feasibility analysis are catch, effort, incidental catch, gear, bait, time spent fishing, labor costs, and equipment costs. These data were provided by CRITFC, which oversaw dam-angling operations. The results are presented in Appendix I-2.

Distribution of Catch

The 1993 harvest of northern squawfish was approximately 142,500 lb. This quantity was harvested by the two removal fisheries. The northern squawfish were used in minced-food production and rendered for fish meal and oil. Of the total, Stoller Fisheries Inc. received approximately 99,000 lb of frozen, food-grade northern squawfish for the production of minced fish and fishmeal/oil. The remaining 43,500 lb was rendered for conversion to fish meal and fish oil.

Seventy-eight percent of the 1993 northern squawfish catch that was handled in food-grade collection areas was food-grade quality. Oversight and quality control of the handling program increased in effectiveness in 1993 because food-grade handling was limited to three locations, as opposed to five locations in 1992. Two of the locations, Tri-River Smelt in Kelso and the Cascade Locks facility, were operated by subcontractors who worked with the program in 1992. Desert Cold Storage in Pasco, Washington, was a new participant in 1993. All three handlers have performed very well during their involvement with the program.

Good handling practices by both sport-reward creel clerks and the dam anglers allowed for the collection of a high proportion of food-grade northern squawfish. Coolers containing fish, with very few exceptions, were properly labeled, iced and drained when received by the processors. The good field handling practices made the job of grading individual fish easier. Stoller Fisheries trucks picked up the frozen squawfish promptly when minimum quantities were accumulated, eliminating the need for temporary cold storage.

The 1993 northern squawfish collection, handling and distribution program was designed to accomplish four tasks associated with our first project objective. Objective 1 is to oversee the collection, transportation, storage, and distribution of all northern squawfish collected during the 1993 fishing season. Tasks associated with Objective 1 are listed below:

1. Set up a network for receiving, handling and shipping of northern squawfish operated principally by the private sector.

2. Design and develop a program to facilitate the transfer of virtually all handling responsibilities to the private sector in 1994.

3. Develop a quality control plan with the goal of 75% food-grade collection. Include a plan for the complete transfer of fish handling responsibilities and handling equipment to participating agencies that operate in remote, relatively unproductive areas (e.g., Snake River dams, Lyons Ferry).

4. Establish a mechanism for northern squawfish purchase by private sector users.

The collection, handling and distribution system was designed and implemented with several key components. Equipment to facilitate the handling and distribution of northern squawfish was distributed to participating agencies and subcontractors for their maintenance and use. The equipment included chest freezers, commercial fishing totes and coolers purchased by the OSU project between 1990 and 1992. Distribution of the equipment to the various projects handling northern squawfish was done to simplify its oversight, maintenance and protection.

Two companies, Tri-River Smelt in Kelso, Washington, and Desert Cold Storage in Pasco, Washington, were contracted to receive and process food-grade northern squawfish. The food-grade fish were harvested by the sport-reward and dam-angling fisheries. The fish were packaged and frozen at the two facilities.

A fish processing facility in Cascade Locks, Oregon, served as the headquarters for the handling program and processed about 60% of harvested squawfish in 1993. The facility was rented fully equipped with an ice machine, freezer, cooler, fork lift, and other processing equipment. Three fish-handling technicians were hired to staff the facility. Storage spaces were rented in Portland, Oregon, and Dallesport, Washington, to serve as pickup locations for squawfish harvested in these areas.

Three businesses were subcontracted in eastern Washington to provide disposal services. Dayton Cut and Wrap, Finch's Market, and Height's Meat market transferred northern squawfish for rendering. The disposal service arrangement was established to accommodate fishing areas logistically unsuited for the collection of food-grade northern squawfish.

A 30,000-lb truck was rented to provide the principal transportation needs for the lower river collection area. This area extended from Longview to The Dalles. The truck was equipped with a lift gate for delivering totes of ice and picking up northern squawfish.

A quality control program was implemented at sport-reward check stations and dam fishing sites in areas with food-grade fish handling services. The program resulted in the collection of food-grade northern squawfish representing 78% of the total catch weight in these areas. As in 1992, packaged food-grade northern squawfish were made available to Stoller Fisheries in Spirit Lake, Iowa. The frozen northern squawfish were delivered by Stoller Fisheries trucks to their Iowa plant for processing into minced-fish products.

A summary of northern squawfish collection and distribution by area follows.

Longview: Tri-River Smelt in Kelso, Washington, provided food-grade fish handling services for the Cathlamet, Rainier, and Kalama sport-reward sites. The facility, located at 804 Westside Highway in Kelso was well suited for the purpose of boxing and freezing squawfish, but was not able to provide ice. Ice was provided by the Cascade Locks facility, delivered weekly by an OSU employee. One employee hired by Tri-River Smelt processed fish and cleaned coolers daily. At the end of each sport-reward check station shift, creel clerks delivered coolers containing iced squawfish to the walk-in cooler in the facility. The Tri-River Smelt facility also served as the WDW sport-reward field office.

Portland: A storage space was rented from Brattain Ideal lease, 13101 N.E. Whitaker Way, Portland, Oregon. Northern squawfish from the M. James Gleason and Camas sport-reward check stations were delivered daily to this facility by WDW creel clerks. Coolers containing the iced northern squawfish were picked up daily by an OSU employee dispatched from the Cascade Locks facility. As needed, OSU employees delivered clean coolers and insulated totes containing ice to sport-reward check stations for use by WDW. Northern squawfish collected from the storage site were processed at the Cascade Locks facility.

Cascade Locks: The Cascade Locks facility was located at 100 Herman Creek Dr., Cascade Locks, Oregon. It processed squawfish received from several fishery locations. The sport-reward fishery locations served by the Cascade Locks facility included M. James Gleason, Camas, The Fishery, Hamilton Island, Cascade Locks, Bingen Marina, The Dalles, and LePage Park. Dam-angling fishing sites served by the facility included Bonneville Dam, The Dalles Dam, and John Day Dam.

As was mentioned earlier, sport-reward fish from M. James Gleason and Camas were delivered by WDW to the Portland storage location and later picked up by OSU employees for transport to Cascade Locks. OSU employees also transported ice, coolers and northern squawfish to and from Bonneville and The Dalles dams. Northern squawfish from The Fishery, Hamilton Island and Cascade Locks Marina were delivered directly to the Cascade Locks facility by WDW technicians. Squawfish from Bingen Marina, The Dalles, and Lepage Park were delivered to the Dallesport field office by WDW and then picked up daily by OSU technicians and transported to Cascade Locks. Squawfish caught by dam anglers on John Day Dam were bagged and frozen in chest freezers on site and picked up as needed by osu.

The Cascade Locks facility provided all equipment necessary for the fish handling needs of the program. The equipment included a fork lift, a -5°F freezer, cooler, conveyer line, steam cleaner and a standard-height loading dock. This facility also served as the office for the handling and distribution program office.

Northern squawfish received at the facility were sorted into food grade and industrial grade. Food-grade northern squawfish were boxed, frozen and stored in the freezer. Industrial-grade northern squawfish were dropped into a tote and picked up weekly by Darling Delaware, a renderer from Portland, Oregon. Boxes of frozen northern squawfish were picked up by Stoller Fisheries from Cascade Locks and Pasco when a total of 45,000 lb was accumulated.

The Dalles: A storage space at HWY 197 and Tidyman Rd., Dallesport, Washington, was rented from Gilmore Fish. This facility served as a drop-off location for Bingen, The Dalles, and LePage Park sport-reward sites. An OSU technician picked up full coolers daily for transport to Cascade Locks and delivered ice and clean coolers as needed. WDW also rented office space at this location.

Tri-Cities: Desert Cold Storage at Pasco Airport, Building E, Pasco, Washington, was subcontracted to supply food-grade handling services. This facility served as a receiving area for fish from the Umatilla, Columbia Point, Vemita, and Hood Park sport-reward sites and also from McNary Dam. Desert Cold Storage subcontracted for both ice supplies and rendering services, and also rented office space to WDW.

WDW creel clerks delivered full coolers daily to Desert Cold Storage. McNary Dam anglers delivered their daily catch to the Umatilla sport-reward site and exchanged filled coolers for clean coolers and ice. WDW technicians then delivered these coolers from the Umatilla check station to Desert Cold Storage in Pasco.

Lyons Ferry: Northern squawfish landed at the Lyons Ferry sport-reward check station were bagged and frozen in a chest freezer located at the Lyons Ferry Marina. WDW technicians delivered the frozen bags weekly to Dayton Cut and Wrap, 406 Main St., Dayton, Washington. The northern squawfish were ultimately rendered.

Pullman: Northern squawfish landed at the Boyer Park sport-reward check station were delivered daily by WDW technicians to Finch's Market, 850 S. Grand, Pullman, Washington. The fish were picked up occasionally from Finch's Market by a Spokane rendering company.

Clarkston: Northern squawfish landed at the Greenbelt Park check station were delivered daily by WDW to Height's Meat Market, 2454 Appleside - 15th S., Clarkston, Washington. Squawfish from the Snake River dam-angling fishery were also periodically delivered to this location by CRITFC. The fish delivered by CRITFC had been previously bagged and frozen in chest freezers on the dams, and were ultimately rendered.

Social and Regulatory Issues

The 1993 assessment of social and regulatory issues associated with the conduct of the sport-reward and dam-angling fisheries for northern squawfish is based on information from the operation of the two fisheries. Information on conflicts occurring either on the water or on shore during the 1993 season was collected through surveys of sport anglers, creel clerks, dam anglers, and enforcement personnel.

The creel clerks' perspective on fishery operations and suggestions for improvement were assessed through a written survey. The survey was distributed to creel clerks at the end of the season and asked to assess the program in terms of the number of angler complaints they heard about boat ramps, fishing, registration, operating hours, data forms, fish check-in, data collection, staffing and equipment. Creel clerks were also asked to identify any areas of needed change in the operations of the sport-reward fishery. The 1993 creel clerk survey form is presented in Appendix Figure I-l .2.

Information summarizing social and coordination issues in the dam-angling fishery was acquired from CRITFC personnel. Enforcement issues related to both the dam-angling fishery and the sport-reward fishery were identified through interviews with enforcement personnel from all geographic areas of the predator control program. Enforcement personnel were also asked for their recommendations for change in operations of either the sport-reward or dam-angling fishery.

RESULTS

Fishery Operations

Sport-Reward Fishery

The sport-reward fishery began on May 3 and encompassed 18 check stations along the Columbia and Snake rivers, two fewer than in 1992. We again used a combined voucher-survey form to collect information from participating anglers. Information collected included fishing time and methods, distance traveled, fishing experience, reasons for participating in the program, and various demographic variables. The 1993 survey-voucher form is included in Appendix Figure I-l. 1. Sport-reward fishery check stations and station codes are listed in Appendix Table I-l. 1.

The sport-reward fishery involved agency expenditures for creel clerk wages, reward payments, uniforms, vehicles, fuel, oil, and miscellaneous equipment. Data on costs in the sport-reward fishery were provided to this project by the Washington Department of Fish and Wildlife. Sport-reward fishery expenditures are summarized by registration check station in Appendix Tables I-l .3 and I-l .4. Expenditure data represents only station-specific expenditures and includes no apportionment of administrative costs. The most cost-effective check stations were those that caught the most fish for the expenditures allocated. Costs per fish removed ranged from a low of $6.87 at Covert's Landing to a high of $66.19 at Umatilla. The five most cost-effective check stations were, in order of least-cost per fish removed, Covert's Landing, Greenbelt Park, LePage Park, Vemita Bridge, and Hamilton Island. The five least cost-effective check stations were, in descending order from the least cost-effective, Umatilla, Boyer Park, Rainier, Kalama, and Lyon's Ferry.

A total of $1,425,273 was spent in the 1993 sport-reward fishery to remove 104,616 fish. On average over all sites, $13.62 was spent per northern squawfish removed from the rivers.

Analysis of angler survey data reveals several areas in which angler participation varied among check stations. A summary of characteristics by site is presented in the "Discussion" section. Residence of anglers varied according to the location of the check station (Appendix Figure I-l .3). Not surprisingly, anglers tended to use check stations closest to their homes. Oregon residents dominated at Gleason (4), The Fishery (6), Cascade Locks (8), The Dalles (10), LePage Park (1 1), and Umatilla (12). Washington residents dominated at Cathlamet (1), Camas (5), Hamilton Island (7), Columbia Park (13), Vernita (14), Hood Park (15), Lyons Ferry (16), and Boyer Park (17). Idaho residents dominated at Greenbelt (18).

Anglers varied in age from 14 to over 60, with the largest proportion of anglers in the 30-50 age bracket (Appendix Figure I-1.4). Greenbelt (18) was the exception, with anglers in the 41-50 and > 60 age groups dominating.

At all check stations, the majority of participants fished frequently, with most making over 25 trips per year (Appendix Figure I-l .5). This pattern of angler experience is similar to 1992. With the exception of Cathlamet (1), the majority of anglers at all check stations had participated in the sport-reward fishery in 1992 (Appendix Figure I- 1.6). However, some sites attracted large numbers of new participants, notably Cathlamet (1), Rainier (2), Kalama (3), Umatilla (12), Vemita (14), and Lyons Ferry (16).

Sites are distinguished by the distances anglers traveled to fish at them. Sites at Cathlamet, Rainier, Kalama, Gleason, Camas, Hamilton Island, Cascade Locks, Bingen, The Dalles, Umatilla, and Greenbelt attracted a majority of anglers from distances of less than 20 miles. At LePage Park, The Fishery, Columbia Park, Vemita, Hood Park, Lyons Ferry, and Boyer Park, the majority of anglers traveled greater distances to fish. Anglers fishing out of LePage Park and Lyons Ferry typically traveled distances of over 100 miles.

For the majority of participating anglers, fishing for northern squawfish was the primary reason for the fishing trip (Appendix Figure I-l .8). Exceptions are at The Dalles (10), Umatilla (12), and. Lyons Ferry (16) check stations, where the majority of anglers said they would have taken the trip even without the northern squawfish fishery.

The number of anglers represented on a single survey form varied very little across check stations. Most people filled out surveys as single anglers (Appendix Figure I-1.9). Similarly, the average number of hours fished also varied little, ranging from 4.5 hours to 7 hours per day (Appendix Figure I-l. 10). The number of northern squawfish caught per trip did vary across check stations. The lowest average catches were at Camas (5) and Umatilla (12). The highest at Vemita (14) and Hood Park (15) (Appendix Figure I-1.11). Very high maximum catch levels were reported at Gleason (4), The Fishery (6), Bingen (9), Vemita (14), and Hood Park (15). Average catch per hour did not vary much by check station, ranging from a low of .69 at Rainier (2) to a high of 2.34 at Hood Park (15; Appendix Figure I-1.12).

At most check stations, the primary fishing target was northern squawfish. The exception was at Lyons Ferry (16), where other target species were the primary objective for the majority of anglers (Appendix Figure I-l. 13).

Anglers were asked about their motivations for participating in the northern squawfish fishery. One survey question asked anglers to assess the importance of four different factors in their decision to participate — receiving a payment for squawfish, access to a recreational opportunity, covering expenses for other target species, and participating in a salmon enhancement activity. Results are presented in Appendix Figures I-l. 14 to I-l. 17. Receiving. a payment for squawfish was very important to the majority of anglers at all check stations, but Camas (5), Umatilla (12), and Lyons Ferry (16) were similar in having a larger proportion of anglers to whom payment was only somewhat important than did other check stations (Appendix Figure I- 1.14).

Having access to a recreational fishing opportunity was very important to a majority of anglers fishing out of Kalama (3), Gleason (4), Camas (5), Bingen (9), The Dalles (10) and Boyer Park (17), but less important at others. The recreational fishing opportunity element of fishing for northern squawfish was least important to anglers fishing at Vemita (14) and Greenbelt (18; Appendix Figure I-l. 15). Vemita (14) and Greenbelt (18) are also the two check stations where the majority of anglers named payment for northern squawfish as a very important factor in their participation. The majority of anglers said the opportunity to cover fishing expenses was either very or somewhat important at all check stations except Cathlamet (1). For other check stations, between 20-40% of anglers said covering fishing expenses was not important (Appendix Figure I-l. 16). The opportunity to participate in a salmon enhancement activity was very important to the majority of anglers at all check stations, repeating patterns of 1992 (Appendix Figure I-l. 17).

Fishing methods used by anglers varied by check station (Appendix Table I-1.5). Anglers fishing at Kalama (3), Camas (5), Hamilton Island (7), Cascade Locks (8), Bingen (9), The Dalles (10), LePage Park (11), Umatilla (12), Lyons Ferry (16), and Greenbelt (18) had a stronger preference for fishing from shore. In contrast, more anglers fishing at Rainier (2), Gleason (4), The Fishery (6), Columbia Park (13), Vemita (14), and Hood Park (15) fished from boats. Other methods, for example the type of boat fishing and the type of angling, varied as well.

Bait and tackle used by anglers also varied by check station (Appendix Table I-1.6). Overall, worms were the most commonly used bait. Hook and line with a single hook was the most commonly used tackle at most check stations.

The results of the sport-reward creel clerk survey indicated that check station operation has improved in several areas since 1992. The majority of creel clerks evaluated the adequacy of station operating hours, the registration process, data forms, the data collection process, staffing, and station security as "good" (Appendix Table I-1.7). These results are indicative of improvement in data forms, staffing, station security and the registration process, which had received several "fair" or "poor" ratings in 1992. Equipment at check stations continues to be evaluated as less than adequate; only 47% of creel clerks evaluated the equipment as "good," while 42 % judged it to be "fair," and 11% thought it was "poor."

Registration time at check stations, an area of frequent angler complaint in 1992, was the source of few complaints in 1993 according to 90% of responding creel clerks. The paperwork required at registration was still the source of some complaint. Fish quality requirements, which dictated fish handling practices by anglers, was still the most common source of complaint; 28% of the creel clerks reporting said they had received some complaints in this area. Also a fairly common source of complaint were the activities of other water users, resulting in complaints about speeding boats, jet skiers, and water skiers (Appendix Table I- 1.8).

According to the creel clerks, anglers were pleased, as in previous years, with the opportunity to earn money fishing and to participate in salmon enhancement activities. Several anglers also noted the benefit of the northern squawfish fishery as a fishing opportunity for children.

Dam-Angling Fishery

The 1993 dam-angling fishery was conducted by seven fishing crews fishing Columbia and Snake River dams — Lower Granite and Little Goose, Ice Harbor and Lower Monumental, McNary, John Day, Bonneville and The Dalles. In addition to crews assigned to these dams, fishing was also conducted by a mobile crew and a volunteer crew. Management and oversight of the dam-angling fishery was provided by the Columbia River Inter-Tribal Fish Commission (CRITFC), which subcontracted operations on some dams to tribal fishing crews. The focus of interest for the feasibility project in this fishery are fishing effectiveness (CPUE); incidental catch; and costs for gear, bait, labor and equipment.

Data on total agency expenditures and expenditure per fish removed by fishing crew in the dam-angling fishery were provided by CRITFC. Expenditures include subcontractor costs plus costs incurred by CRITFC specific to each dam's operation, plus costs incurred by CRITFC common to all operations (e.g., data handling, coordination, reporting).

Total agency (CRITFC) expenditures and expenditure per fish removed by fishing operation in the dam-angling fishery are presented in Appendix Table I-2.1. Expenditures include all expenditures dedicated to the operation and oversight of seven fishing crews — crews located at Bonneville and The Dalles, John Day, McNary, Ice Harbor and Lower Monumental, Little Goose and Lower Granite, the mobile crew and a volunteer angling group. Most angling crews were supervised through subcontractors. Most crews were associated with dams, but some were not. Catch figures in Appendix Table I-2.1 represent each operation's catch and may therefore not exactly correspond to catches reported for each dam.

Total expenditure figures reported for each fishing crew in Appendix Table I-2.1 include costs of project administration common to all operations. Administrative costs associated with the dam-angling fishery not directly allocable to a particular operation were distributed among the crews on a proportional basis. Proportions of common administrative costs assigned to each crew ranged from .09 for the volunteer angling crew to .22 to the mobile crew. Examples of common administrative costs apportioned among fishing crews include centrally procured supplies, data handling, coordination, and reporting. Crews that were supervised directly by CRITFC and crews that required extra oversight attention accounted for a higher proportion of total administrative costs.

The costs of handling fish are included in total costs. These costs were subtracted from total costs in 1992, but since fish handling responsibilities were shared by the removal fishery projects in 1993, handling costs are included as a part of each fishery operation.

A total of $638,480 was spent in the 1993 dam-angling fishery to remove 16,949 fish. On average over all dam operations, $38 was spent per northern squawfish removed from the rivers. Expenditures per fish removed by dam operation ranged from a low of $20 per fish for the McNary operation to a high of $134 per fish for the Little Goose and Lower Granite operation. Because most operating costs are fixed, cost per fish depends on the size of the catch for the paid crews; the larger the catch, the larger the number of fish among which to distribute the fixed costs, and the smaller the average cost per fish. Therefore, McNary Dam, with its high levels of catch, represents the lowest expenditures per fish removed, followed by the mobile crew operation at $29 per fish removed. The volunteer crew, although accounting for small total numbers caught, accounted for expenditures of $26 per fish removed. The relatively low expenditure per fish removed by the volunteer crew is possible because crew time is not reimbursed and costs are limited to those required for administration and oversight.

Comparisons of expenditures per fish removed between fisheries should appropriately be done on the basis of total project expenditures related to implementation of each fishery. Costs for monitoring, enforcement, avoidance of negative impacts, and quality control should be included in the assessment of total costs so that comparable calculations are made. These costs have not been accounted for by all fisheries to date.

Distribution of Catch

Fish Collection and Distribution

The 1993 collection and distribution system operated smoothly and efficiently. The experience in 1992 allowed us to ensure that mechanisms were in place from the season's beginning to anticipate and resolve problems. One measure of the system's success is that the pre-season goal of collecting 75% food-grade squawfish was exceeded because mechanisms were in place to handle any problems.

Of the total 142,500 lb caught in 1993, 126,300 lb, or 89%, was handled by the system set up to provide food-grade fish. Out of the food-grade handling system, 99,000 lb was food-grade, 78 % . Out of the same handling system, 27,300 lb was industrial-grade. Industrial-grade fish results from several factors. Biological sampling requires cutting open the fish, making them unsuited for food processing. Northern squawfish are sometimes in poor condition when anglers bring them in to the check station. Poor handling on site at the check station also can contribute to degraded quality. Finally, some fish, although > 11 inches, may be too small to process, and for that reason are graded for industrial use.

Overall, fish handling by the packaging subcontractors, WDW and CRITFC was excellent. However, lower than expected catch rates and smaller squawfish from the sport-reward fishery resulted in a relatively low yield in 1993. All food-grade northern squawfish were picked up by Stoller Fisheries and processed in Spirit Lake, Iowa. Stoller Fisheries indicated that the quality of the fish received was very high. All industrial-grade squawfish were processed by regional rendering facilities.

Collection and Distribution by Area

Longview: Tri-River Smelt in Kelso, Washington, provided excellent service at a suitable facility. The same company provided office space for WDW in 1992 and 1993. Only 7,839 lb were handled at this facility in 1993. The low volume combined with fixed costs of operation resulted in very high handling costs ($2.14/lb). We are looking into the possibility of Tri-River Smelt supplying rendering services for a greatly reduced cost in the future.

Portland: A small warehouse space was rented from Brattain Ideal Lease, a truck rental business. The warehouse space served as a transfer station for northern squawfish caught in the Portland area sport-reward fishery. Conflicts between OSU and Brattain Ideal lease concerning use of the space resulted in an assessment that the space was not compatible with the program. In future, northern squawfish caught in the Portland area should probably be rendered.

Cascade Locks: The Cascade Locks facility is owned by Bomstein Seafood in Seattle. This facility served the handling program very well in 1993. This building was equipped to meet all handling and packaging needs. Most of the equipment used in the sport-reward fishery, dam fishery, and the collection and distribution system is currently stored in this space. Provided this facility is available in 1994, it should again be rented for handling purposes.

Once it became apparent that 1993 catch would not be at large as in 1992, OSU began laying off handling staff at the Cascade Locks facility. The season started with three employees. One employee was laid off in mid-July. A second employee converted to half-time in early August. The 1993 season provided insight on labor requirements for operating this facility.

The Cascade Locks facility handled 86,512 lb of squawfish and packaged 68,200 lb of food-grade fish at a direct cost of $0.53/lb. Considering the modest harvest in 1993, the unit cost of processing food-grade fish at this facility was reasonable.

The Dalles: Gilmore fish in Dallesport, Washington, provided a building to serve as a fish transfer station and WDW field office. Because the facility has functioned as a fish-buying station, it has water, a loading dock, and other attributes that served the collection and distribution program well. The facility should be considered for the 1994 program.

Tri-Cities: Desert Cold Storage provided food-grade handling services to the collection and distribution program. Office space for WDW was also provided. In previous years it was difficult to find qualified subcontractors in the Tri-Cities area. The service provided by Desert Cold Storage was of high quality. The facility handled a total of 31,964 lb of northern squawfish in 1993. Of this total, 24,600 lb of food-grade fish were packaged at a cost of $0.57/lb. The facility should be subcontracted in 1994 for office space and to serve in some fish handling capacity.

Lyons Ferry: Dayton Cut and Wrap provided adequate rendering services for this low volume area. The facility should be subcontracted in 1994 if the Lyons Ferry sport-reward site is retained.

Pullman: Finch's Market provided adequate rendering services for northern squawfish returned to the Boyer Park sport-reward check station. The facility should be considered for subcontracting in 1994.

Clarkston: Height's Meat Market provided various services to the collection and distribution program. In both 1992 and 1993, a cooler cleaning station was provided for the use of creel clerks at the Greenbelt Park sport-reward check station. Rendering services were also provided in the same time period. Rendering services for northern squawfish harvested in the Snake River dam-angling fishery were provided in 1993. Height's rendered 13,130 lb of northern squawfish in 1993. Height's rendering services are charged at $0.31 per lb, a low unit cost for a medium volume area.

Collection and Distribution Volume and Cost

Fish handling costs are summarized in Appendix I-3. All costs associated with handling operations in each area are included in the summary. Cost items include personnel, rental (building and equipment), supplies (packaging and ice), and transportation (vehicle rental). Administration and other fixed costs were not included when handling costs by area were calculated because they do not directly influence the efficiency of individual operations. These cost, however, are itemized and included in the total budget summary for 1993. Appendix Table I-3.1 summarizes the yield, costs by handling area, and total handling program costs for the first half of the 1993 performance period.

The 1993 collection and distribution program handled 142,480 lb of squawfish at a total cost of $113,925. Average direct handling costs were $0.80 per lb. Of the total direct costs, about $24,000 ($0.17 per lb) was spent for logistical arrangements associated with the program's large geographic scope. The program covers 26 collection sites over a 350-mile wide area. In absence of the costs associated with geographic scope, direct fish handling costs are reduced to $89,925, $0.63 per lb.

Height's Meat Market in Clarkston provided the handling and distribution program the least expensive rendering services ($0.31/lb) for a medium volume area (13,135 lb). A programwide rendering system probably could not have operated for less than $0.40 - $0.45/lb. Rendering for the squawfish program is expensive because of the labor and space rental associated with a demand for daily services for 4.5 months. Rendering costs increase with volume because labor and equipment requirements also increase. Higher volumes require more frequent pickups. Large volumes of northern squawfish require additional labor for fish handling. In addition, large volumes of fish must be chilled in the field and remain chilled until pickup to prevent spoilage. Per-ton rendering costs at $30-$50/ton do not decrease as volume increases. Finally, the odor of rotting fish would surely cause public concern and a poor perception of the handling program.

Provided reimbursement for northern squawfish in the range of $. 11 to $. 15 is possible, food-grade handling becomes cost-effective as the volume handled at one location increases. For example, a food-grade operation at Cascade Locks can be operated as inexpensively as a rendering program in the same area (about $0.45/lb after sale of fish at $0.15/lb), provided the volume handled is large. With some streamlining, a cost-effective food-grade program may be possible for the Tri-Cities area as well.

Catch Utilization

Minced Food Product

Stoller Fisheries again processed northern squawfish into a minced food product in 1993. A total of 103,010 lb of northern squawfish were received by this firm. The quality of fish received by Stoller Fisheries was very high. Fish was freshly frozen and well-packaged. Of the total received by Stoller Fisheries, 96.3% of the fish were large enough - over 13 inches long - and of high enough quality to be processed as deboned product. The mince was processed by itself and not mixed with other species. Yield rates for deboned mince were 32.43%. The remaining 3,820 lb (3.7%) were processed into fish meal.

The exvessel value of food-grade northern squawfish collected in 1993 ranged between $6,600 to $12,000 depending on assumed exvessel price ($. 11 - $. 15) and recovery yields (9-15%). Recovery yields vary with size of fish. Sale of northern squawfish within this price range represents a substantial potential cost-recovery for the handling and distribution program.

In 1991 and 1992, research on the food qualities of northern squawfish and its suitability for processing was supported by this project. A Masters of Science thesis on this subject was completed in 1993 (Lin 1993). Findings are consistent with Stoller Fisheries evaluations of northern squawfish characteristics. Production of deboned minced fish was found to be an effective method of utilizing northern squawfish. Textural qualities of minced flesh were found to be robust to lack of washing or washing, as well as to different temperature settings. Cryoprotectants were found to be effective for maintaining texture during frozen storage. Minced flesh maintained good qualities with respect to oxidation (Lin 1993).

Northern squawfish flesh was also tested for its suitability for surimi. Surimi yield from whole fish ranged between 15.5-21.6%. Freshness of flesh was positively associated with surimi quality and negatively associated with frozen storage life. Experimental results indicated that it was feasible to produce surimi from northern squawfish stored on ice for up to nine days (Lin 1993).

Renderers

The 43,500 lb of industrial-grade northern squawfish delivered to renderers was combined with other protein sources and eventually processed into animal feed.

Social and Regulatory Issues

Sport-Reward Fishery

Continuing conflict with other on-water users is evident in the sport-reward fishery. “Some” to “many” angler complaints about crowding from other anglers were received by 21% of creel clerks in 1993. A percentage of creel clerks also reported “some” to “many” complaints about speeding boats (24%), jet skiers (28%), water skiers (22%), and litter on banks (19%). Very few complaints were heard about commercial fishermen or gear damage in 1993, an improvement over 1992 (Appendix Table I-1.7). Other complaints made by anglers to creel clerks often enough to take note include questions about fish quality requirements, the need for registration paperwork, and check-in times.

Creel clerks were asked to make note of the most frequent complaints heard from anglers about the sport-reward fishery. A recurring complaint from anglers concerns the lack of payment for fish < 11 inches. Many making this complaint suggest a small reward for undersized fish. It is notable, however, that unlike previous years, no complaints about the size of the reward payment were registered. In fact, some complaints about the reward payment being too large were noted. Other complaints center on the requirement to fish in the mainstem rather than tributaries and the need to register every day. Still others complained that the entire program was a waste of public money.

Creel clerks were also asked to record frequently heard compliments about the sport-reward fishery. The most frequent compliment was about the income opportunities associated with the program. Anglers like participating in salmon enhancement activities, and also liked the ability to pre-register.

Creel clerks were asked for their evaluation of several aspects of sport-reward check station operations — operating hours, registration process, check-in process, data forms, data collection, staffing, equipment, and station security. Results of this evaluation are summarized in Appendix Table I-l .6.

Operating hours were evaluated to be "good" by 79% of reporting creel clerks and "fair" by 21%. Most creel clerks responding to the survey made suggestions for improvement. One suggestion was to vary the opening hours by check station, scheduling the longest opening hours at the most productive check stations. Another suggestion was to arrange opening hours to enable only one shift per site. A related suggestion was to allow self-registration in the morning and extend the check station hours into the evening.

The registration process received exactly the same evaluation as did operating hours — 79% "good" and 21% "fair." One suggestion for improvement made by several creel clerks was to allow anglers to register only once. Others suggested that registration boxes be placed at boat ramps, that registration paperwork be streamlined, and that anglers be allowed to register the previous day.

The check-in process received very high ratings by creel clerks, with 97% rating it "good." The only suggestion for change was a single suggestion to take complete biological data on fish under 10 inches and continue to use the current protocol on fish > 11 inches.

Data forms were also rated highly, with 92% of the responding creel clerks evaluating them as "good." Suggestions for improvement included eliminating the overlapping data on the OSU survey form, placing the last name first, and requiring registration proof for fishing in waters closed to trout or steelhead.

The data collection process was evaluated as "good" by 89% of responding creel clerks and "fair" by 11%. Creel clerk suggestions included improving the scale cards and envelopes, to use the same protocol for all fish, and to decrease the number of early-season scale samples required.

Staffing received a “good” rating by 82% of responding creel clerks, and was rated only “fair” by 18%. Several comments suggested that check stations were overstaffed. One suggestion was that a single employee is enough for check stations that process fewer than 500 fish per day.

Equipment received the worst rating of all check station elements evaluated. Only 47% of responding creel clerks gave the equipment a good rating; 42% rated it “fair,” and 11% rated it “poor." The major complaint was about the scales used at check stations. The scales were characterized as old and inaccurate. Additional comments were made about dull knives and the need to have battery operated lights instead of Coleman lanterns.

Although 89% of responding creel clerks thought station security was good, several concerns were also expressed. Major concerns were that remote stations needed phone or radio communication and that stations should either have two creel clerks on duty in the evening or be closed after dark.

The existence of the sport-reward and dam-angling fisheries for northern squawfish has increased the burden on limited enforcement resources. The survey of enforcement personnel identified several regulatory issues related to the sport-reward fishery. These issues fall into the categories of enforceability of program boundaries, “allowable fish," fishing without licenses, closed fishing areas, and coordination of enforcement considerations with project planning.

Enforceability ofprogram boundaries: There is a mismatch between Oregon state law that allows the take of northern squawfish from any area and the predator control program boundaries, which restrict the area from which northern squawfish can be taken for reimbursement. A similar problem in Washington state was resolved with the reclassification of northern squawfish as game fish, which can be restricted in area of catch. Taking fish from beyond the specified boundaries of the program represents fraud when those fish are presented for reimbursement under the predator control program, but is not a violation of fish and wildlife code. It is difficult for enforcement entities to justify devoting limited enforcement resources to this issue while other code violations are demanding their attention. Anglers turning in fish caught outside the program area has been a source of complaint to enforcement from other anglers. Enforcement personnel suspect that fishing outside the program area remains a common practice, with estimates of up to 10% ‘of total catch coming from outside program boundaries.

Allowable fish": In addition to the cases mentioned above of landed fish that are illegal by area of catch, a few incidents of fish caught with illegal gear were reported. Some fish with obvious gill-net marks were accepted by check stations. Other fish in poor condition were accepted.

Fishing without licenses: A few cases were reported of anglers with revoked Washington fishing licenses attempting to purchase Oregon fishing licenses to fish for northern squawfish. This problem is not specific to the predator control program and is not thought to be widespread.

Closed fishing areas: The reclassification of northern squawfish as game fish in Washington state has allowed the state to impose closed areas and gear restrictions for management purposes. These changes have eased the enforcement burden somewhat. Problems persist in areas that are closed to other sport fishing, but open to northern squawfish fishing. A specific example involves two reaches along the Columbia River, one below Priest Rapids Dam and the other below McNary Dam, that are closed to spring fishing to protect nesting waterfowl, but are not closed to northern squawfish fishing.

Coordination of enforcement efforts with program planning: Enforcement personnel mentioned the continuing need to improve the coordination between predator control program operations and enforcement needs. Program design and rules have enforcement implications that are often not considered by program planners. As a consequence, enforcement burdens are sometimes higher than necessary and compliance is sometimes not as high as it could be. The general assessment was that coordination is improving, but further improvements are needed.

Dam-Angling Fishery

The assessment of dam-angling operations by both CRITFC and enforcement personnel indicate a continued improvement in dam-angling interactions with other program participants and with the public.

The volunteer angling program, in which members of the public participate in dam angling, was reported by CRITPC to be producing intangible benefits of cooperation between tribal members and non-tribal recreational anglers, between the predator control program and members of the public, and between fishery management organizations and the public. Additional benefits are realized through interactions between visitors to dams and members of dam-angling fishing crews.

Relationships between dam angling crews and Army Corps of Engineers personnel are generally good, and are continuing to improve in areas that were problematic in the past.

Enforcement personnel report very few social or regulatory problems with the dam-angling fishery. There do continue to be complaints form the public concerning dam anglers fishing in the boat restricted zones around dams. Although dam anglers are not in violation while fishing in these areas, the public is generally not aware of this exception to general angler regulations.

DISCUSSION

Fishery Operation

Sport-Reward Fishery

The sport-reward fishery was far less cost-effective in 1993 than in 1992. Average cost per fish removed increased by almost $4 per fish, a 29% increase. The primary reason for the decrease in cost-effectiveness was a large decline in the number of fish removed. Compared to 1992, total catch in the sport-reward fishery declined by 79,670 fish, a decrease of 43%. Total per-site expenditures declined 20% compared to 1992, but the larger proportional decrease in catch overwhelmed the potential cost savings. Continuation of sport-reward fishery operations that are based on fixed per-site costs will continue the fishery's per-fish cost vulnerability to variations in catch.

Anglers are satisfied with the reward payment in 1993, although some still request payment for northern squawfish < 11 inches. Large numbers of anglers still see the recreation opportunity provided by northern squawfish fishing and the contribution to salmon enhancement as important motivations for their participation. An increased reward level is not necessary for continued participation of repeat anglers.

The continued use by anglers of check stations nearest their homes indicates the importance of continuing to locate check stations near large population centers and at sites that have involved the most anglers in the past. Angler response to check station hours combined with the expense of operating extended or double shifts at check stations indicates that cost savings could be realized through a combination of shorter hours with more flexible anglers registration systems. The predominant age group attracted to a given check station may serve as a guide for custom-tailoring station hours.

Most anglers in the sport-reward fishery continue to be repeat from earlier seasons. However, new participants are being attracted at new check stations. For continued project operations, it will be important to decide whether to encourage more effort by repeat, experienced anglers or whether to locate check stations to attract new anglers.

Angler motivations remain consistent with earlier seasons. Payment for northern squawfish is important, as is having a recreational opportunity. Even more important to most anglers is the opportunity to participate in salmon enhancement activities. Unlike previous years, creel clerks registered few if any complaints about the size of the reward payment. There is no evidence to suggest that an increase in the reward payment is warranted. However, the program may want to consider a reduced reward payment for northern squawfish < 11 inches, suggested by many anglers.

Processing of anglers at check stations has clearly improved with time. However, complaints about poor equipment are still being received from creel clerks.

The patterns of participation and operation continue to vary by site. Site characteristics were summarized from the angler voucher survey data to characterize "typical" patterns at each site. These summaries are listed below. "Typical" characteristics are determined by the modal, or most frequent, response for each variable and are expressed as the typical angler at each site. These characteristics may be used to plan for future program planning and site configuration.

Cathlamet: Washington angler, 30-50 years old, new participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent over five hours fishing in the trip, and caught about five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

Rainier: Washington or Oregon angler, 51-60 years old, new participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent almost six hours fishing for northern squawfish, and caught about four fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with a single hook-and-line.

Kalama: Washington angler, 41-50 years old, takes over 25 fishing trips per year, could be either a new or repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than five hours fishing for northern squawfish, and caught about four fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

Gleason: Oregon angler, 3 l-40 years old, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about six hours fishing for northern squawfish, and caught about eight fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with a single hook-and-line.

Camas: Washington angler, 21-40 years old or > 60, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent between five and six hours fishing for northern squawfish, and caught about five fish.

Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

The Fishery: Oregon angler, 31-50 years old, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 40 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about seven hours fishing for northern squawfish, and caught about 12 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with a single hook-and-line.

Hamilton Island: Washington angler, any age, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than five hours fishing for northern squawfish, and caught about eight fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

Cascade *Locks:* Oregon angler, 21-50 years old, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent over six hours fishing for northern squawfish, and caught about five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing *expenses.* Preferred bottom angling from shore, and used worms with a single hook-and-line.

Bingen: Washington angler, any age, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than six hours fishing for northern squawfish, and caught about 10 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

The Dalles: Oregon angler, 41-60 years old, takes over 25 fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for species other than northern squawfish. Spent about five hours fishing for northern squawfish, and caught about five fish.

Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

LePage Park: Oregon angler, any age, takes a varying number of fishing trips per year, repeat participant in the northern squawfish fishery in 1993. Traveled more than 100 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about six hours fishing for northern squawfish, and caught about eight fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred shore fishing or boat trolling, and used worms with a single hook-and-line.

Umatilla: Oregon angler, any age, takes over 25 fishing trips per year, could be either a new or repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was either to fish for northern squawfish or to fish for other species. Spent about five hours fishing for northern squawfish, and caught about five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred shore fishing or boat trolling, and used worms with spinners.

Columbia Park: Washington angler, any age, takes over 25 fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled up to 40 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than six hours fishing for northern squawfish, and caught about 10 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with a single hook-and-line.

Vemita: Washington angler, any age, takes over 25 fishing trips per year, either a new or repeat participant in the northern squawfish fishery in 1993. Traveled between 41-60 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about seven hours fishing for northern squawfish, and caught about 18 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred bottom angling from an anchored boat, and used worms with spinners.

Hood Park: Washington angler, 31-50 years old, takes over 25 fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled varying distances to fish, and the primary reason for the trip was to fish for northern squawfish. Spent about six hours fishing for northern squawfish, and caught about 18 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from a drifting boat, and used worms with a single hook-and-line.

Lyons Ferry: Washington angler, any age, takes a *varying* number of fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled over 100 miles to fish, and the primary reason for the trip was to fish for a combination of northern squawfish and other species. Spent less than six hours fishing for northern squawfish, and caught less than five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, recreational opportunity, payment for northern squawfish, and covering fishing expenses. Preferred bottom angling from shore, and used worms with a single hook-and-line.

Boyer Park: Washington angler, 41-50 years old, takes over 25 fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled between 81-100 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent more than five hours fishing for northern squawfish, and caught about five fish. Factors motivating participation in the sport-reward fishery were, in order of priority, participation in salmon enhancement, payment for northern squawfish, recreational opportunity, and covering fishing expenses. Preferred boat trolling with worms.

Greenbelt: Idaho angler, 31-40 years old or over 60, takes over 25 fishing trips per year, a repeat participant in the northern squawfish fishery in 1993. Traveled less than 20 miles to fish, and the primary reason for the trip was to fish for northern squawfish. Spent less than five hours fishing for northern squawfish, and caught less than 10 fish. Factors motivating participation in the sport-reward fishery were, in order of priority, payment for northern squawfish, participation in salmon enhancement, recreational opportunity, and covering fishing expenses. Preferred bottom angling from shore, and used cutfish with a single hook-and-line.

Data to evaluate cost-effectiveness of sport-reward site operations have not been provided to this project.

Dam-Angling Fishery

Operations of the 1993 dam-angling fishery proceeded smoothly for the most part. The cost effectiveness of dam angling *operations* varied considerably across fishing sites. Costs to remove northern squawfish through dam angling varied from a low of $20 per fish at McNary Dam to a high of $134 per fish at Little Goose and Lower Granite dams. Because the cost of maintaining crews on dams is fixed for a fishing season, the per-fish cost of removal is obviously very sensitive to volumes caught. In 1993, high volumes corresponded to low per-fish costs and vice versa. The volunteer angler program is a method to reduce operating costs to administrative costs through the elimination of labor costs. An increase in the size of the volunteer effort would result in lower per-fish removal costs by averaging fixed administrative costs over a larger effort.

The dam-angling fishery caught fewer fish at higher cost per fish in 1993 than in 1992. Average cost per fish removed increased from $28 to $38, a large increase even after adjustment for a change in accounting procedures between the two years. The increase in expenditures per fish removed is attributable to lower volumes of fish handled.

Harvest Collection and Distribution

Aside from a smaller than expected harvest, the 1993 squawfish handling program was a considerable improvement over previous years. This success can be attributed principally to conscientious fish handling by sport-reward creel clerks and CRITFC dam anglers. An overall atmosphere of cooperation among WDW, CRITFC, ODFW, and OSU was maintained throughout the season. The performance of fish-handling subcontractors was also excellent.

The design of the handling program satisfied all program requirements. The program provided the necessary services for the agencies and subcontractors operating the removal fisheries. The food-grade handling facilities packaged, froze and shipped to Stoller Fisheries 78% of the volume they handled. The exceptional care taken by all parties handling fish demonstrated that a food-grade quality control program is possible. Costs of rendering compared to costs of food-grade handling show that cost-effective food-grade processing is possible when medium to large volumes of fish are sold at prices ranging between $. 11 and $.15 per pound.

The 1993 harvest was collected, processed and distributed to various end uses for an average of $0.80/lb. Of the $.80 per lb, $0.17/lb represented unavoidable logistical costs associated with the geographic scope of the program. At an estimated $0.15/lb exvessel price for the packaged squawfish, the overall direct handling cost of operating the 1993 food-grade/rendering system ($0.63/lb) was not cost-effective. However, based on information and experience gained in 1993, we conclude that it is feasible to operate a cost-effective food-grade collection system in the area between Cascade Locks and The Dalles, the most concentrated removal area. Limiting food-grade collection to the Cascade Locks-The Dalles area would reduce direct handling costs to about $0.40 - $0.50/lb (net sale at $0.15/lb).

A programwide rendering handling system probably cannot be operated at for less than $0.40 - $0.50/lb for several reasons. Rendering is inexpensive only for areas of low volume because small amounts of labor and handling equipment are required. Per unit costs rise as volumes increase due to the need for additional equipment, labor, more frequent pickups and higher rendering fees. Because of the high volumes processed, rendering in the Cascade Locks area would require most of the equipment, ice, and some of the labor necessary for food-grade handling. An additional consideration is that rendering costs in western Oregon and Washington are twice as high as those in eastern Oregon and Washington. The reason for this price discrepancy is unknown.

Large volumes of fish require some level of attention to prevent spoilage while awaiting rendering pickup. The potential for public complaint or failing Department of Agriculture inspections would make a cut-rate rendering program risky. A rendering system would not provide the services provided by the 1993 food-grade handling system — cooler steam cleaning, cooler repair, full cooler pickups, and ice deliveries in some areas. Without a food-grade handling system in place, costs of these services would be passed on to the agencies responsible for the two fisheries, WDW and CRITFC.

Collection and Distribution Recommendations

A least-cost squawfish handling system that accommodates the overall removal program should be implemented in 1994. This system should not only be cost-conscious, but also represent an awareness of overall logistics, public perception of the program, public nuisance and health issues. The handling program could include limited food-grade collection in areas where this can be accomplished cost-effectively ($0.40 - $0.50/lb) compared to rendering. The following recommendations are for a system that satisfies all of the objectives listed above.

1. Operate a food-grade collection system that receives squawfish from all harvest locations between The Fishery and Lepage Park sport-reward check stations. Do not include John Day Dam in this system. This area handled 53% of the total catch in 1993. The Cascade Locks facility used in 1993 should be rented again for 1994.

2. Render the entire catch at all other areas, with the possible exception of the Tri-Cities area.

3. At rendering-only locations, WDW and CRITFC technicians should be responsible for overall cleaning and sanitation of all equipment at their work sites. Employee time should be budgeted to help with rendering pickups from field office locations, probably once or twice a week. Involvement of WDW and CRITFC personnel in fish handling activities will reduce overall labor costs to the program.

4. Maintain the quality-control requirements for anglers in the sport-reward fishery.

5. Sell food-grade squawfish to Stoller Fisheries or other interested processors.

6. Consolidate sport-reward field stations where possible to reduce logistical costs.

7. Evaluate the possibility of renting dam-angling field offices in areas that accommodate both the dam angling crews and fish handling logistics.

Social and Regulatory Issues

Social and regulatory issues associated with the removal fisheries for northern squawfish have continued to improve.

The most prominent issues continue to be related to the large numbers of anglers participating in the sport-reward fishery. Large number of anglers (over 40,000 registered in 1992) mean more conflicts for space at boat ramps, congestion at check stations, congestion on the water, and conflicts with other river users such as commercial fishermen and jet skiers. Enforcement of fishery regulations of both the northern squawfish fisheries and other fisheries becomes increasingly difficult as numbers of anglers increase.

Enforcement efforts have been made difficult by the dispersal of registration sites, the large number of anglers possessing northern squawfish, and the difficulties of tracking fish origin. The establishment of clear regulations, consistent between Oregon and Washington, related to the legality of party fishing and fishing license numbers on registration forms are minimum conditions for reasonable oversight by enforcement personnel.

Enforcement personnel had the following recommendations for changes in the sport-reward and dam-angling fisheries. Oregon should reclassify northern squawfish as a game fish to ensure that regulations affecting its capture arc consistent with other sport fish and with Washington. Regulations managing northern squawfish should be coordinated with other existing fish and wildlife management efforts. More pre-season coordination should exist between the sport-reward fishery and enforcement personnel.

Because of the difficulties caused by limits on the source of origin of qualifying fish, enforcement personnel recommended that the sport-reward fishery remove its restrictions on origin of fish and accept all fish delivered. Alternatively, if the fishery needs to continue to restrict source of origin, the program should hire its own criminal investigator to pursue possible sources of fraud rather than rely on existing law enforcement personnel. A half-time officer might be sufficient to this task. It was noted that most violations occur early in the season when tributary squawfish are easier to catch in warmer water. An alternative approach to hiring a criminal investigator would be for WDFW squawfish biologists to assume some enforcement responsibilities as field observers. This function is now performed by ODFW biologists during big game seasons.

Enforcement personnel made two additional recommendations about sport-reward fishery operations. The first is to reconsider the self-registration procedure, which allows anglers to falsify actual registration time and provides them the opportunity to fish at greater distances from the registration site. The second recommendation is to carefully consider the effect of incentive programs such as tags and drawings. These programs encourage anglers to report violations, but also encourage more fraud.

Regulations related to quality of northern squawfish continue to be only marginally enforceable. Without placing the burden of quality evaluation solely on the creel clerk, it is difficult to see how angler contributions to fish quality can increase over current levels. On-site handling of northern squawfish once anglers have delivered the fish still has some unmet potential for improvement.

REFERENCES

Lin, D. 1993. Characteristics of northern squawfish (Ptychocheilus oregonensis) and feasibility for utilization as human food. Unpublished M.S. Thesis. Oregon state University, Department of Food Science and Technology, Corvallis.

APPENDIX I-l

Sport-Reward Fishery Information

Appendix Figure I-l. 1. Sport-reward fishery survey form, 1993.

Both voucher and questionnaire must be completed before payment will be made. An incomplete voucher or questionnaire will be returned to sender for completion. This will delay processing and payment.

PLEASE CIRCLE OR FILL IN THE APPROPRIATE ANSWER

1. Number of anglers reporting catch on this form: ___ anglers

2. Number of hours each angler reporting on this form spent fishing: a npgr l e r

3. Primary reason for this fishing trip **(circle only one):**
   1. Squawfish
   2. Other fish
   3. Combination of squawfish/other

4. Would you have taken this fishing trip if there were no squawfish reward fishery?
   1. Yes
   2. No
   3. Don't know

5. Fishing methods used this trip **(Circle any that apply):**
   1. Boat, anchored
   2. Boat, drifting
   3. Boat, trolling
   4. Fished from shore
   5. Angling, surface
   6. Angling, bottom
   7. Other (specify) ______________

6. Bait or tackle used this trip (Circle **any that apply):**
   1. worms
   2. Cut fish bait
   3. Spinners
   4. spoons
   5. Flatfish
   6. Surface plugs
   7. Hook and line with 1 hook
   8. Hook and line with >1 hook
   9. Other (specify) ______________

7. Did you fish in the squawfish reward fishery last year?
   1. Yes
   2. No

8. How important are the following factors in your participation in the squawfiih reward fishery? (Circle **the number that applies: 1=very important; 2= somewhat important; 3=not important)**
   - A. Payment for squawfish 1 2 3
   - B. Recreationalopportunity 1 2 3
   - C. Covering expenses for other target species 1 2 3
   - D. Participating in salmon enhancement program 1 2 3

9. Miles traveled (one way) to this location:
   1. ≤20
   2. 21-40
   3. 41-60
   4. 61-80
   5. 81-100
   6. >100

10. Number of fishing trips (for any species) you usually take per year:
    1. 0
    2. 1-5
    3. 6-10
    4. 11-15
    5. 16-20
    6. 21-25
    7. >25

11. Your age:
    1. ≤20
    2. 21-30
    3. 31-40
    4. 41-50
    6. 51-60
    7. >60

12. Home state:
    1. Oregon
    2. Washington
    3. Idaho
    4. Other (specify) ______________

SPORT REWARD VOUCHER

LAST NAME | FIRST NAME | MI

STREET

CITY | STATE | ZIP

MO DAY YR | DOCUMENT # | SOCIAL SECURITY # ___ – ___ – ___

NUMBER OF QUALIFYING SQUAWFISH | SITE

NUMBER OF QUALIFYING SQUAWFISH: (print)

VOUCHER #:

CREEL CLERK SIGNATURE

ANGLER SIGNATURE (Signed in presence of Creel Clerk)

I have followed all programrules. All northern squawfii exchanged for this voucher of payment were legally obtained.

Keep record of voucher #. To receive payment voucher mast be postmarked no later than 10/15/93.

---------------------------------- fold here ----------------------------------

Place
Stamp
Here

SQUAWFISH SPORT-REWARD PROGRAM
POBOX683
‘OREGON CITY, OR 97045

Appendix Table I-l. 1. Sport fishery check station codes, 19%.

Check Station	Code
Cathlamet	1
Rainier	2
Kalama	3
Gleason	4
Camas/Washougal	5
Covert's Landing	6
Hamilton Island	7
Cascade Locks	8
Bingen Marina	9
The Dalles	10
LePage Park	11
Umatilla	12
Columbia Park	13
Vernita Bridge	14
Hood Park	15
Lyons Ferry State Park	16
Boyer Park	17
Greenbelt	18

Appendix Table I-1.2. Number of angler surveys per check station, 1993.

Check Station	Analyzed		Not Analyzed		
	N	(%) Total	N	(%) Total	% Station Total
Cathlamet	430	4.6	32	3.6	6.9
Rainier	242	2.6	33	3.7	12.0
Kalama	231	2.5	45	5.0	16.3
Gleason	795	8.5	71	7.9	8.2
Camas	902	9.6	112	12.5	11.0
The Fishery	1052	11.2	89	10.0	7.8
Hamilton Island	1066	11.4	47	5.3	4.2
Cascade Locks	282	3.0	19	2.1	6.3
Bingen	546	5.8	51	5.7	8.5
The Dalles	577	6.2	14	1.6	2.4
LePage Park	728	7.8	72	8.1	9.0
Umatilla	214	2.3	25	2.8	10.5
Columbia Park	277	3.0	69	7.7	19.9
Vemita	447	4.8	39	4.4	8.0
Hood Park	215	2.3	24	2.7	10.0
Lyons Ferry	191	2.0	35	3.9	15.5
Boyer Park	149	1.6	11	1.2	6.9
Greenbelt	1011	10.8	106	11.9	9.5

Appendix Figure I-1.2. Sport-reward fishery creel clerk survey form, 1993.

Creel Clerk Questionnaire
1993 Sport-Reward Fishery

We would like your help in evaluating the operation and conduct of the sport-reward fishery this summer. Your answers will be confidential. Information from this survey will be reported in summary form only. Individual respondents will not be identified.

1. Please tell us how many complaints in the **following** categories you heard from anglers.

	Many	**Some**	**Few**	None	NA
<u>Boat **Ramps**</u>					
overcrowding on boat ramps	___	___	___	___	___
size of boat ramps	___	___	___	___	___
time waiting to launch	___	___	___	___	___
other (specify)					
______________________	___	___	___	___	___
______________________					
<u>Fishing</u>					
crowding with other anglers	___	___		___	___
crowding with commercial fishermen	___	___	___	___	___
gear damage from crowding with anglers	___	___		___	___
gear damage from crowding with comm. fishr.	___	___		___	___
boats passing too fast	___	___	___	___	___
jet skiers	___	___	___	___	___
water skiers	___	___	___	___	___
litter in water	___	___	___	___	___
litter on banks	___	___	___	___	___
other (specify)					
______________________	___	___		___	___
______________________	___	___	___	___	___
<u>Registration and Check-In</u>					
registration processing time	___	___	___	___	___
registration processing paperwork	___	___	___	___	___
problems with other anglers	___	___	___	___	___
check-in time	___	___	___	___	___
check-in paperwork	___	___	___	___	___
fish quality requirements	___	___	___	___	___
other (specify)					
______________________	___	___	___	___	___
______________________	___	___	___	___	___

2. We would like your evaluation of several parts of the sport-reward fishery operation, and any recommendations you have for change.

a. operating hours: good___ fair___ poor___

recommendations: ____

____

b. registration process: good ___ fair ___ poor ___ .

recommendations: ____

____

c. fish check-in process: good ___ fair ___ poor ___

recommendations: ____

____

d. data forms: good ___ fair ___ poor ___

recommendations: ____

____

e. data collection process: good ___ fair ___ poor ___

recommendations: ____

____

f. staffing: good ___ fair ___ poor ___

recommendations: ____

____

g. equipment: good ___ fair ___ poor ___

recommendations: ____

____

h. <u>interaction with public</u>: good ___ fair ___ poor ___

recommendations: ____

____

i. <u>station security</u>: good ___ fair ___ poor ___

recommendations: ____

____

j. <u>other recommendations:</u> ____

____

____

____

3. Did you or your crew hear any complaints about the sport-reward fishery from townspeople near your site? YES___ NO ___
If yes, please specify:

____

____

____

4. Did you or your crew hear <u>compliments</u> about the operation of the sport-reward fishery? YES ___ NO ___ If yes, please specify:

____

____

____

____

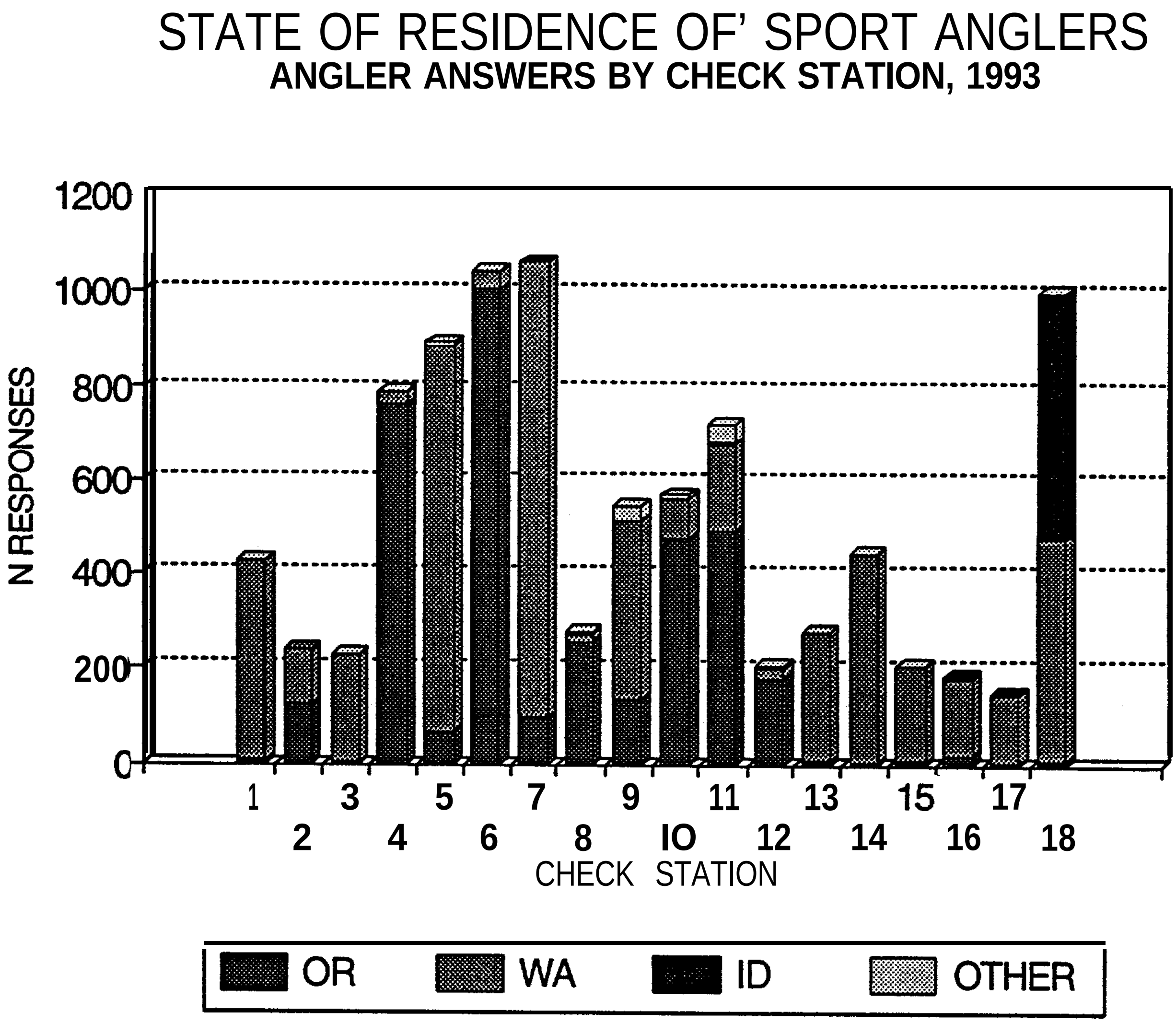
THANK YOU FOR YOUR HELP.

Appendix Table I-l .3. Agency total expenditures and expenditure per fish removed for the sport-reward fishery by check station, station-specific expenditures only.

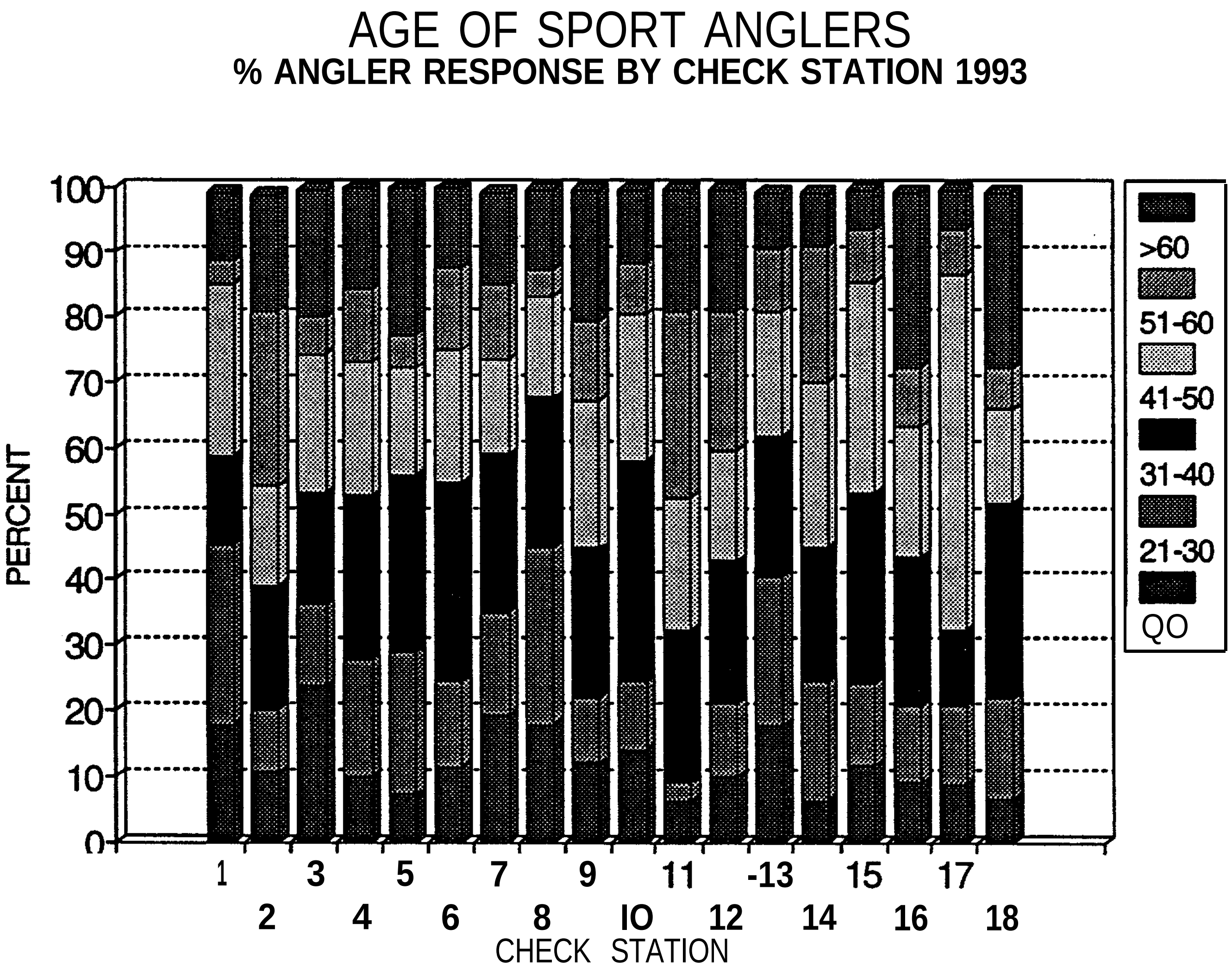
Check Station	Total Expenditure (including payment per fish)	Total Catch	Expenditure Per Fish Removed
Cathlamet	$60,278	3,960	$15.22
Rainier	73,398	1,561	47.02
Kalama	74,237	1,605	46.25
M. James Gleason	105,776	9,719	10.88
Camas/Washougal	90,460	5,920	15.28
Covert s Landing	112,057	16,308	6.87
Hamilton Island	92,055	9,126	10.09
Cascade Locks	58,070	1,881	30.87
Bingen Marina	79,335	6,408	12.38
Dalles	72,332	4,338	16.67
LePage Park	95,772	10,643	9.00
Umatilla	66,194	1,000	66.19
Columbia Park	80,209	5,192	15.51
Vemita Bridge	90,857	9,765	9.30
Hood Park	62,086	4,119	15.07
Lyons Ferry State Park	62,362	1,466	45.54
Boyer Park	63,887	1,296	49.30
Greenbelt	85,917	10,309	8.33
TOTAL	$1,425,273	104,616	$13.62

Appendix Table I-1.6. Agency expenditure per fish removed for the sport-reward fishery by check station, station-specific expenditures only.

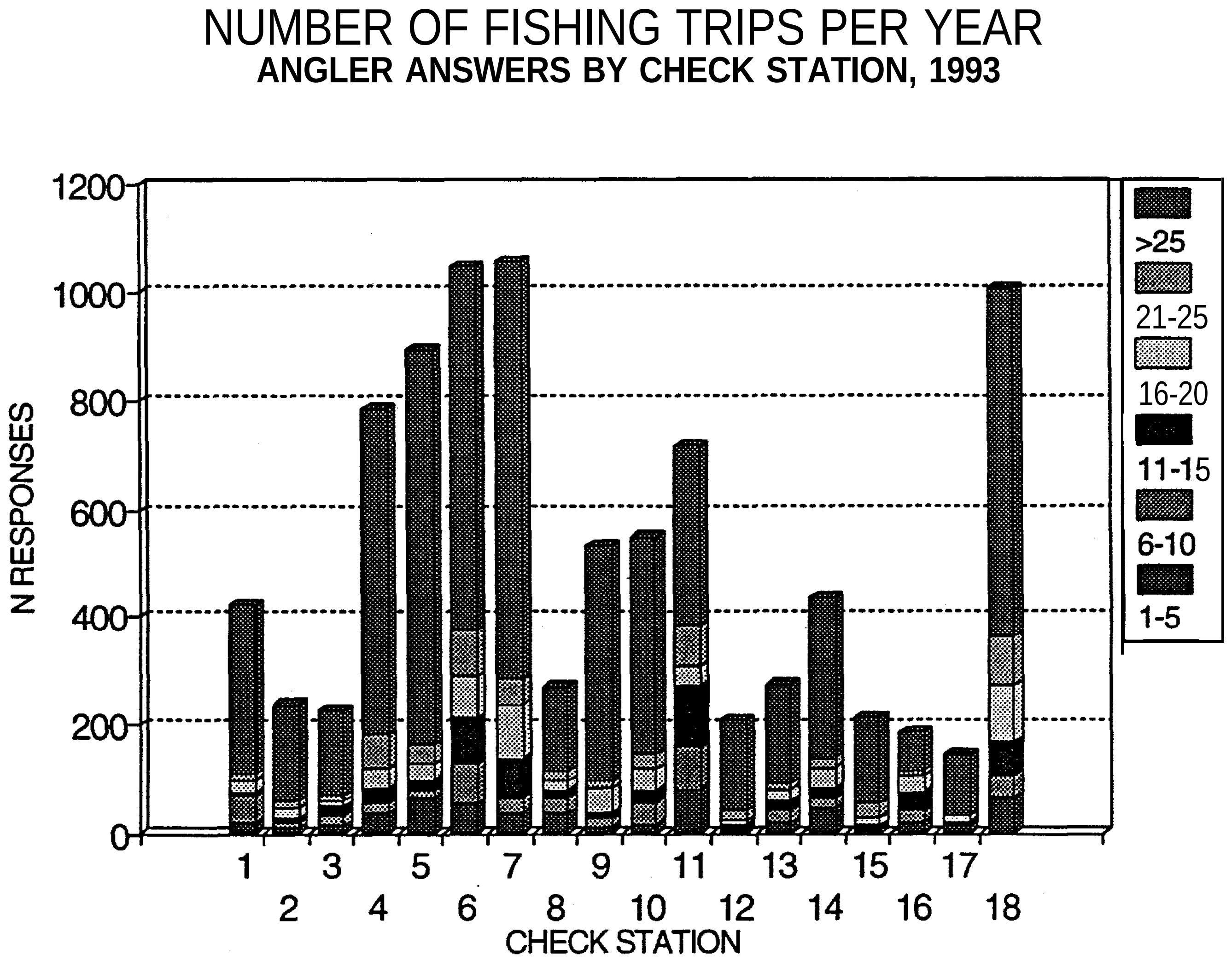
Check Station	Expenditure Per Fish Removed (excluding administrative expenditures)
Cathlamet	$15.22
Rainier	47.02
Kalama	46.25
M. James Gleason	10.88
Camas/Washougal	15.28
Covert s Landing	6.87
Hamilton Island	10.09
Cascade Locks	30.87
Bingen Marina	12.38
Dalles	16.67
LePage Park	9.00
Umatilla	66.19
Columbia Park	15.51
Vernita Bridge	9.30
Hood Park	15.07
Lyons Ferry State Park	45.54
Boyer Park	49.30
Greenbelt	8.33
TOTAL	$13.62



Appendix Figure I-l. 3. State of residence of sport anglers, 1993.



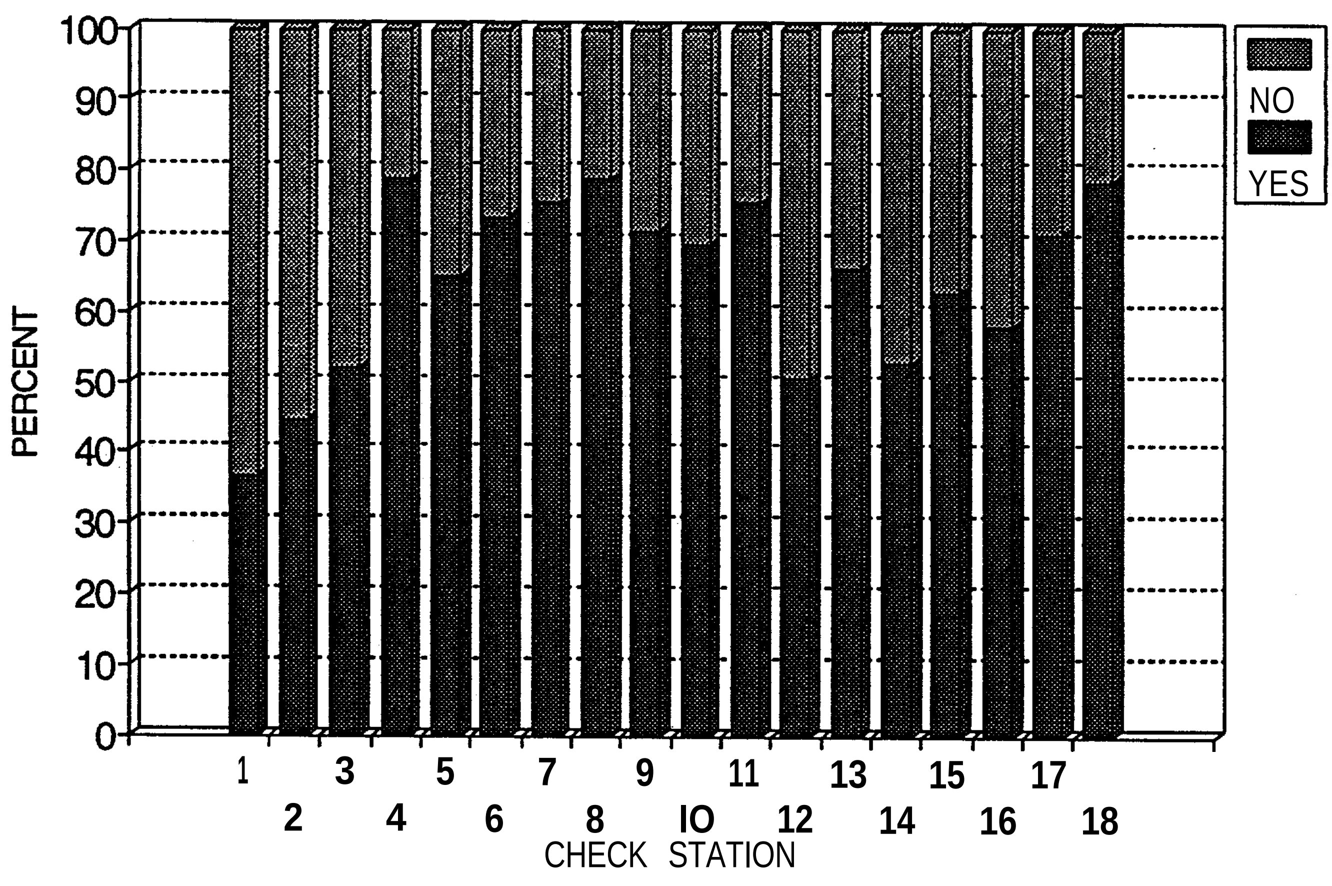
Appendix Figure I-1.4. Age of sport anglers, 1993.



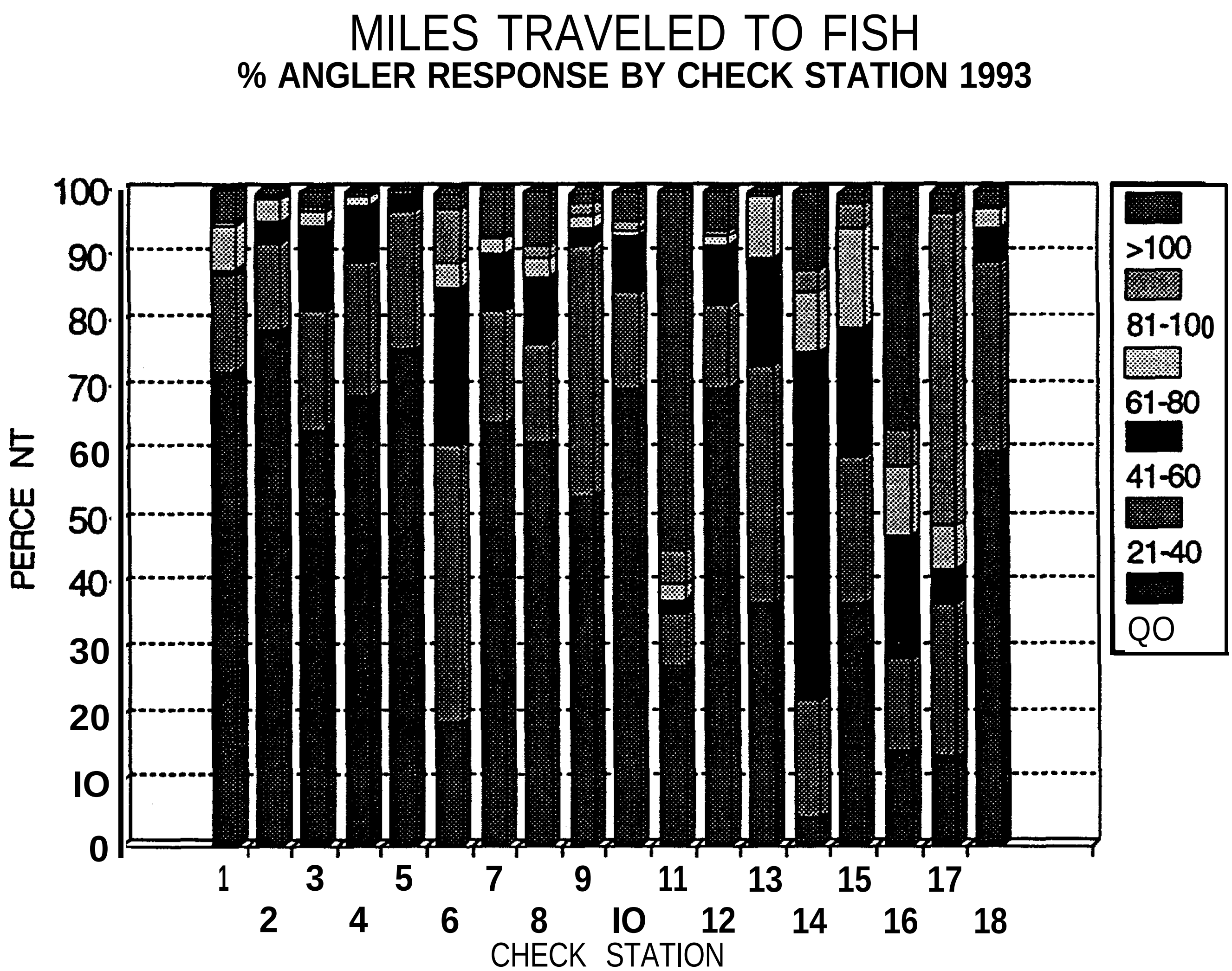
Appendix Figure I-1.5. Number of sport-fishing trips made by anglers per year, 1993.

PERCENT ANGLERS REPEATING FROM 1992

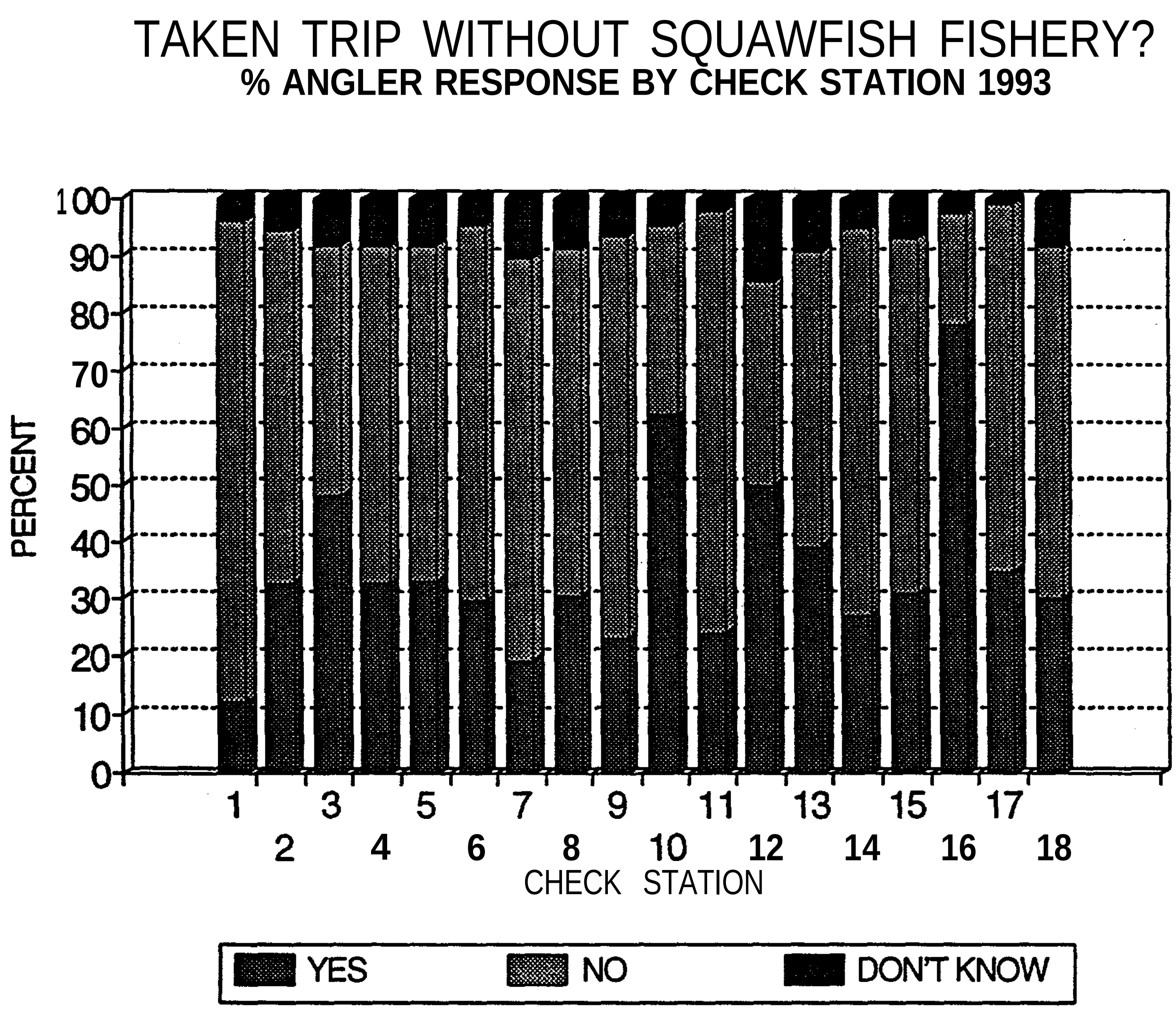
CHECK STATIONS 1-18, 1993



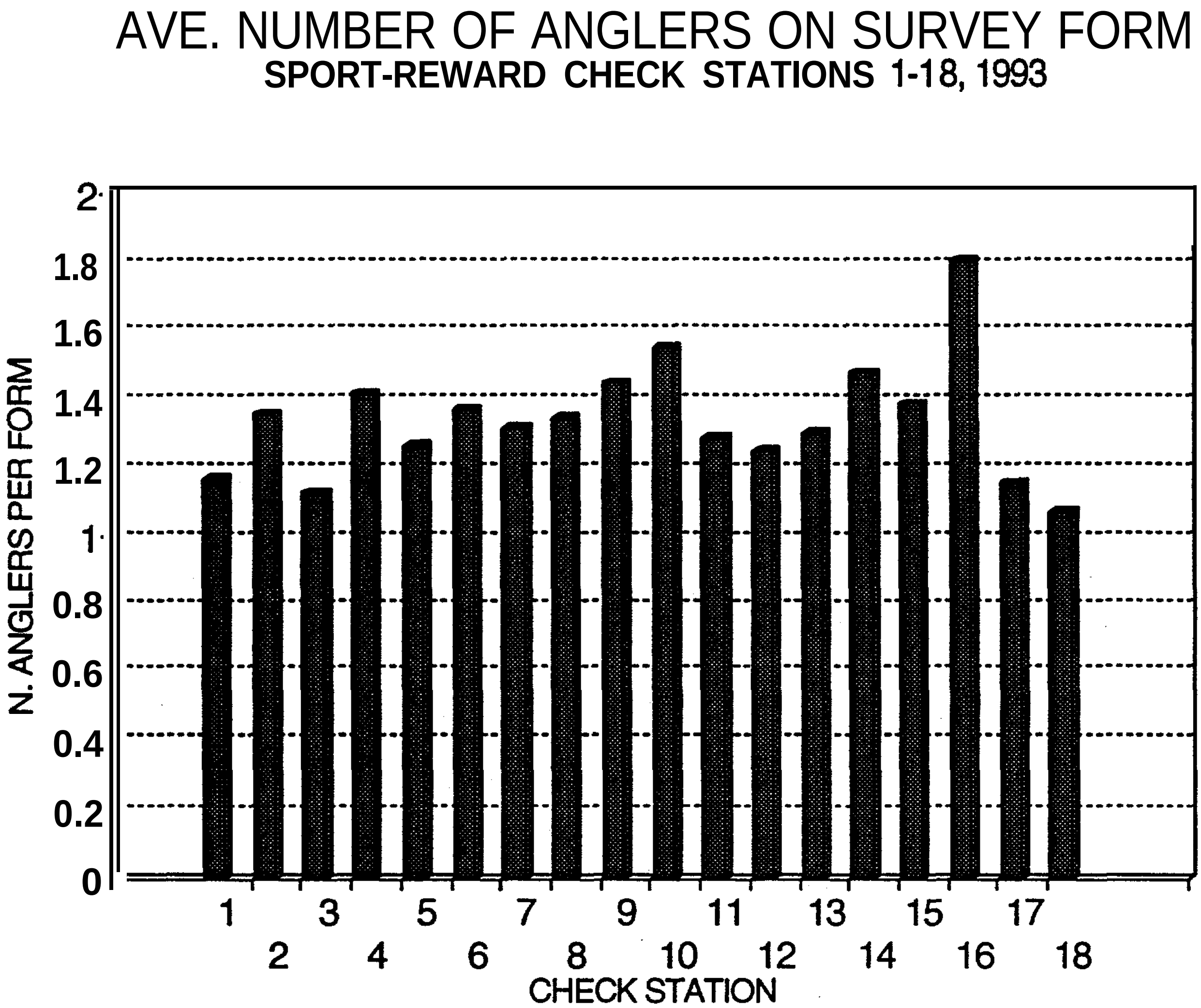
Appendix Figure 1-1.6. Percent anglers repeating from 1992.



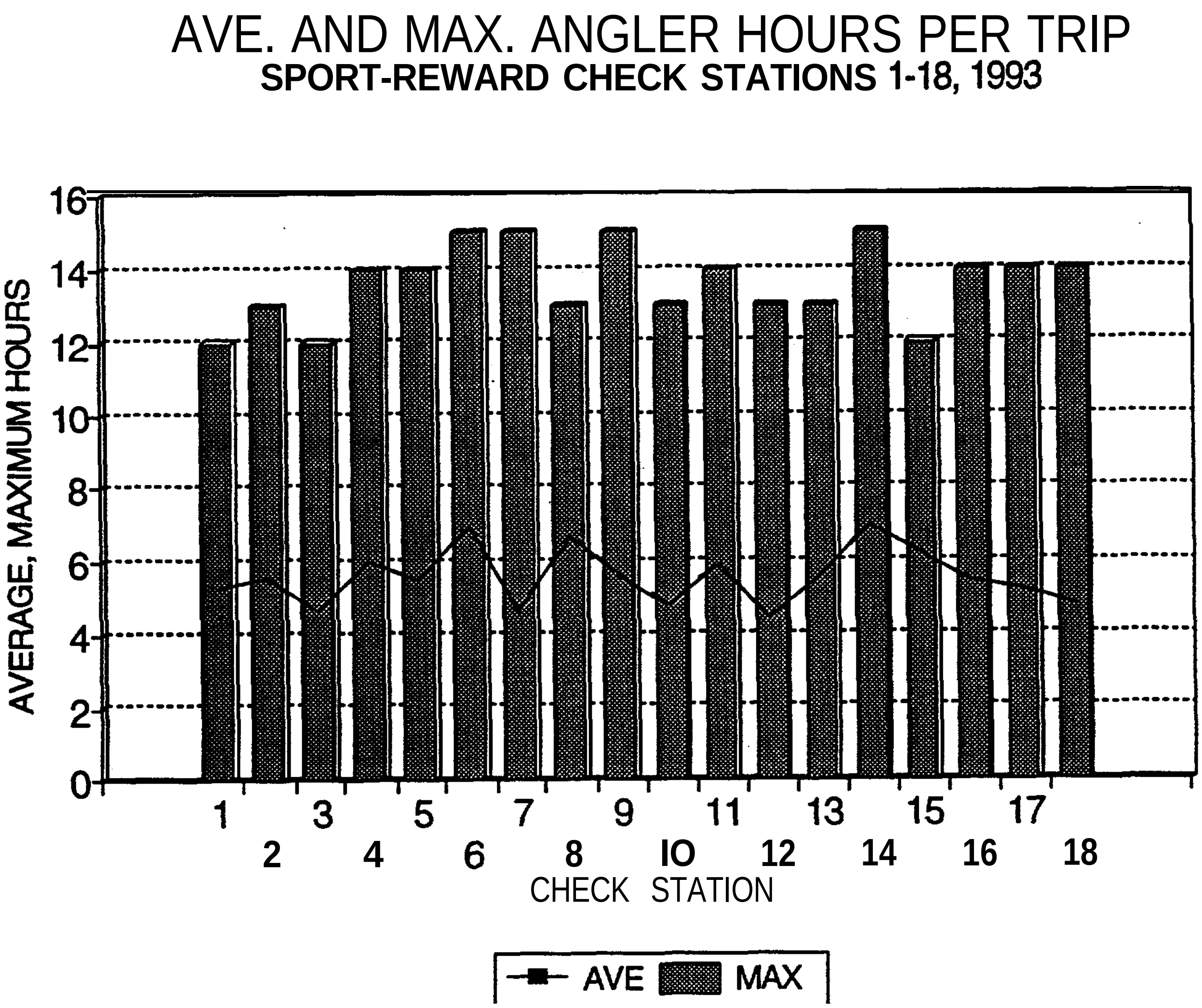
Appendix Figure I-l .7. Miles traveled to fish, 1993.



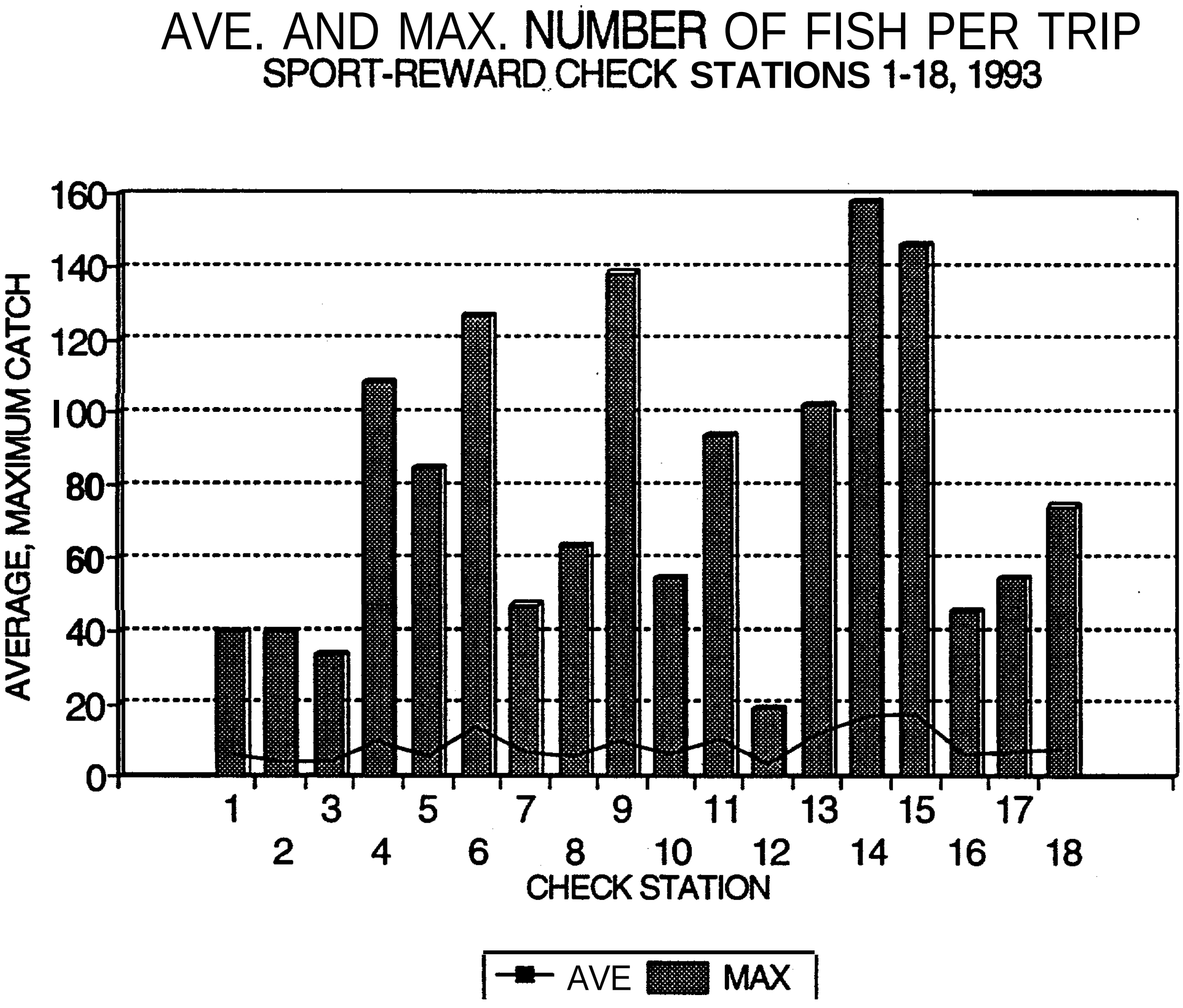
Appendix Figure I-l .8. Taken trip without the squawfish fishery?



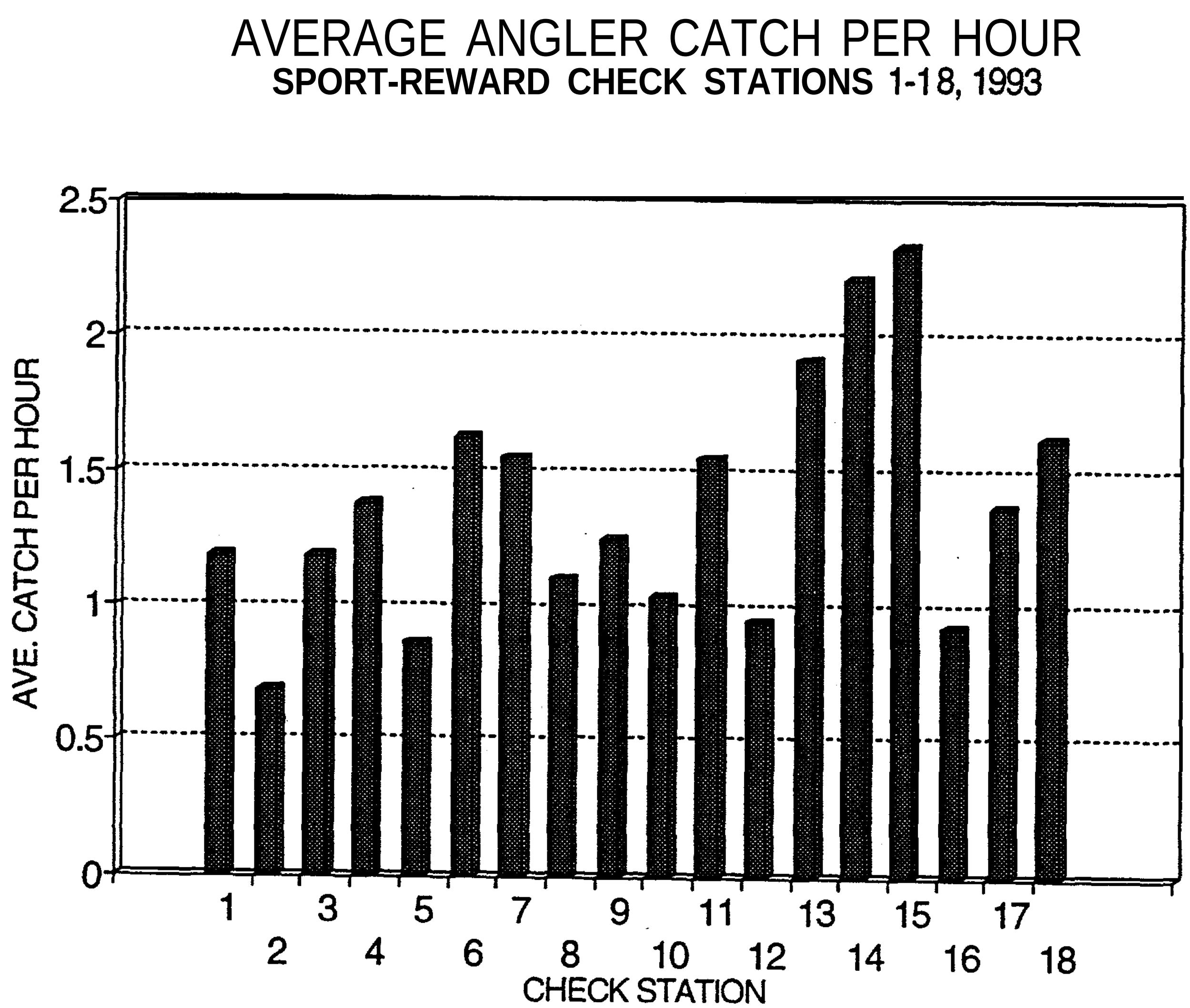
Appendix Figure I- 1.9. Average number of sport anglers on survey form, 1993.



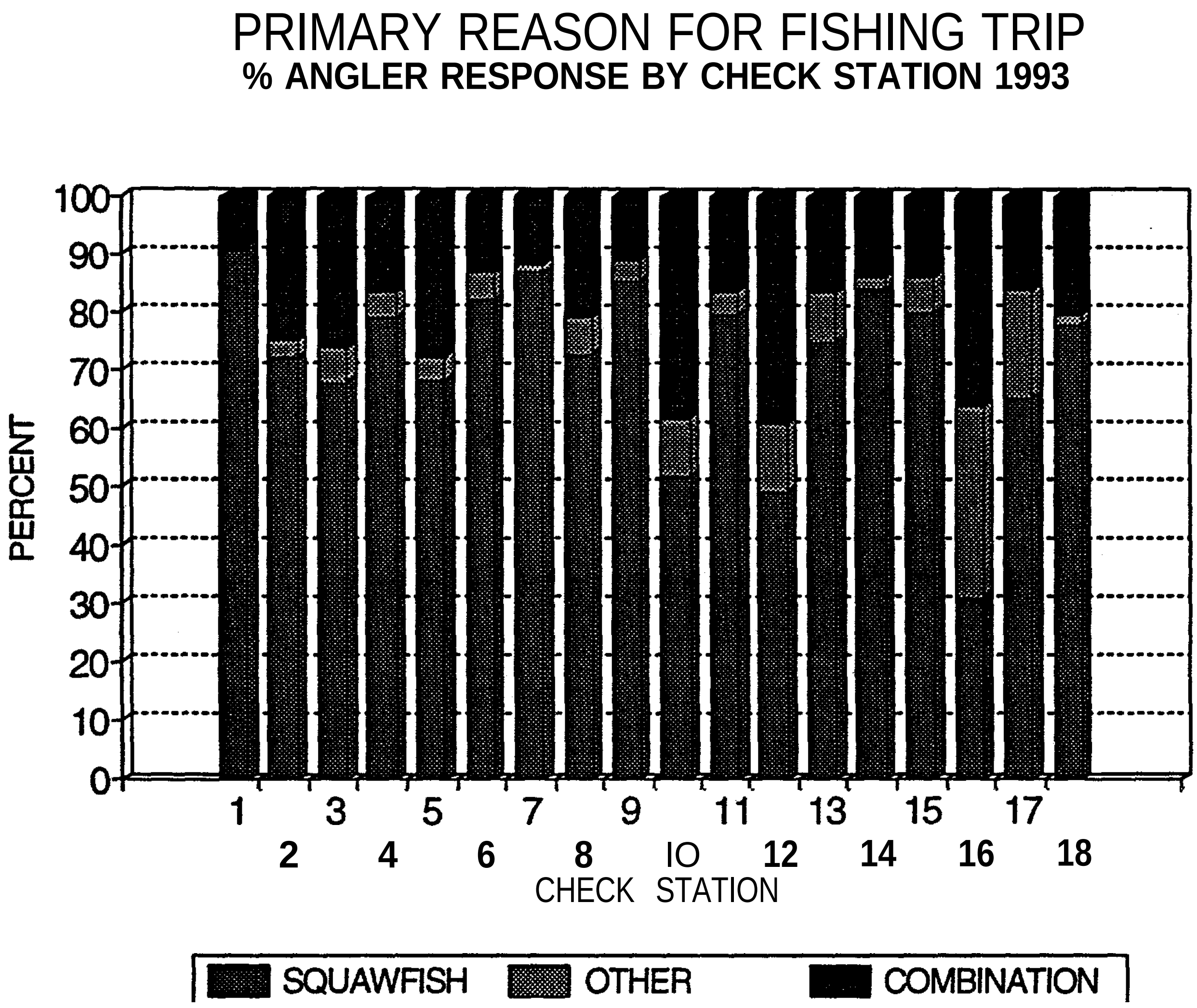
Appendix Figure I-l. 10. Average and maximum angler hours per trip, 1993.



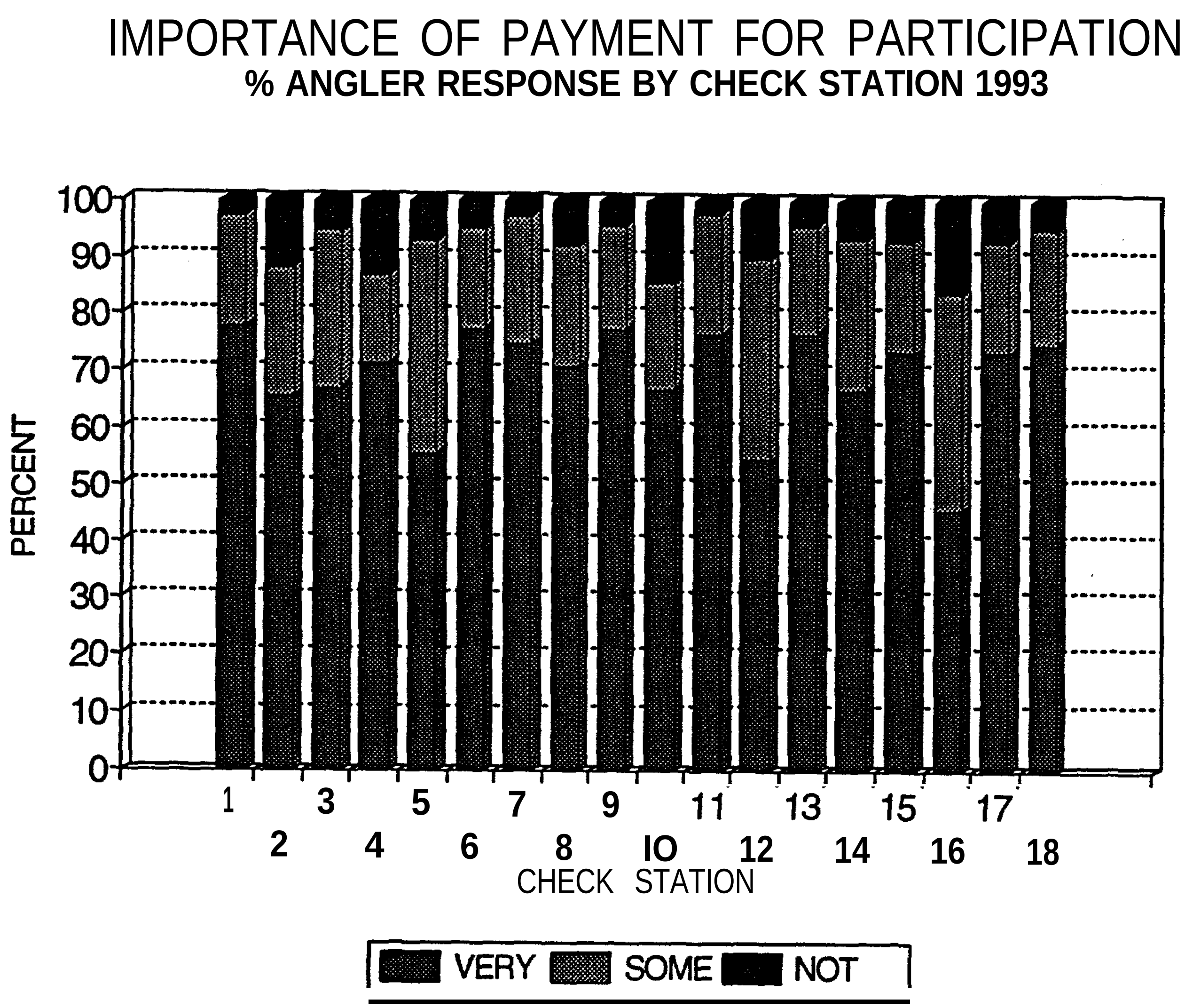
Appendix Figure I-l. 11. Average and maximum number of fish per trip, 1993.



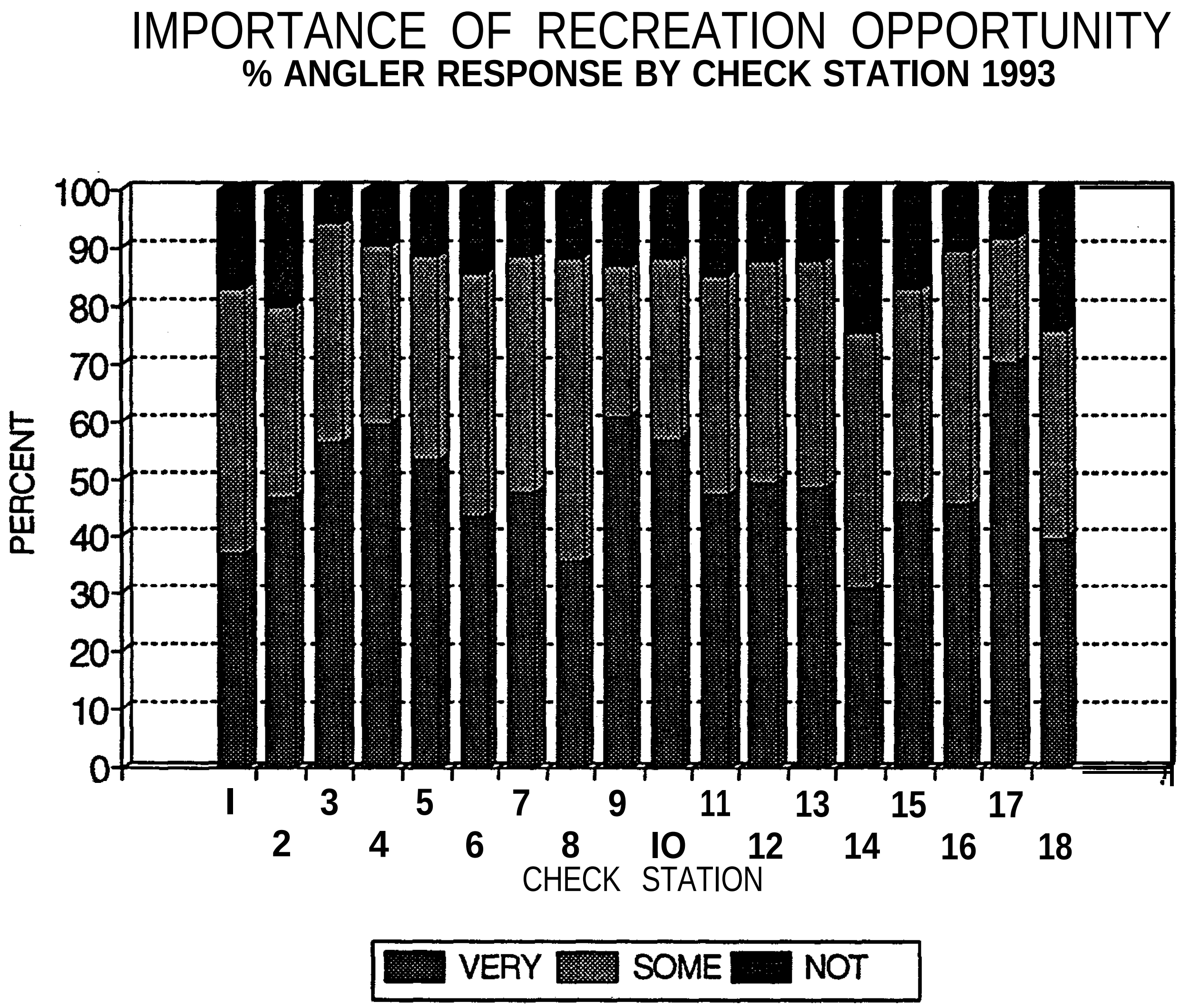
Appendix Figure I-l. 12. Average angler catch per hour, 1993.



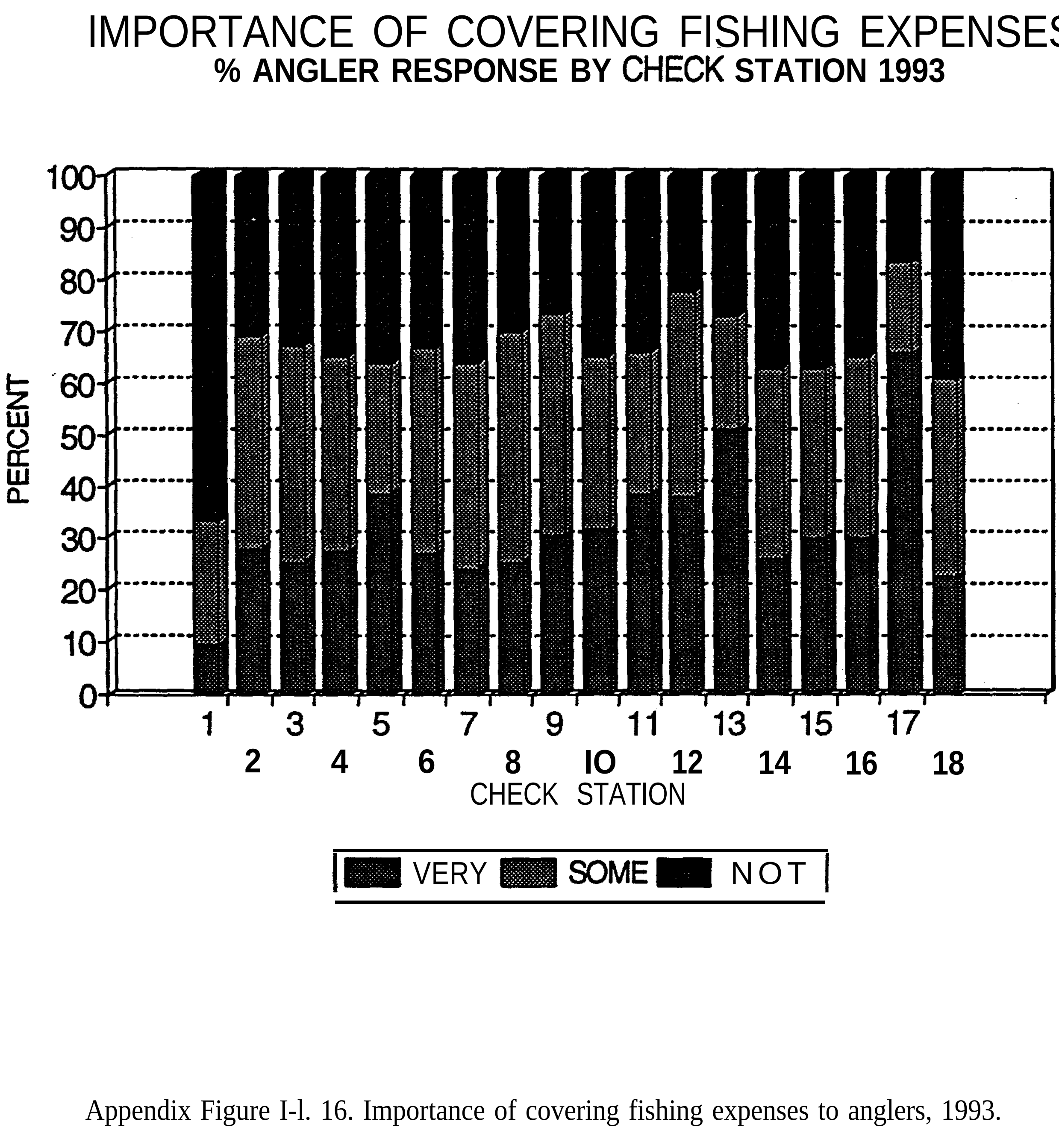
Appendix Figure I-l. 13. Primary reason for fishing trip, 1993.



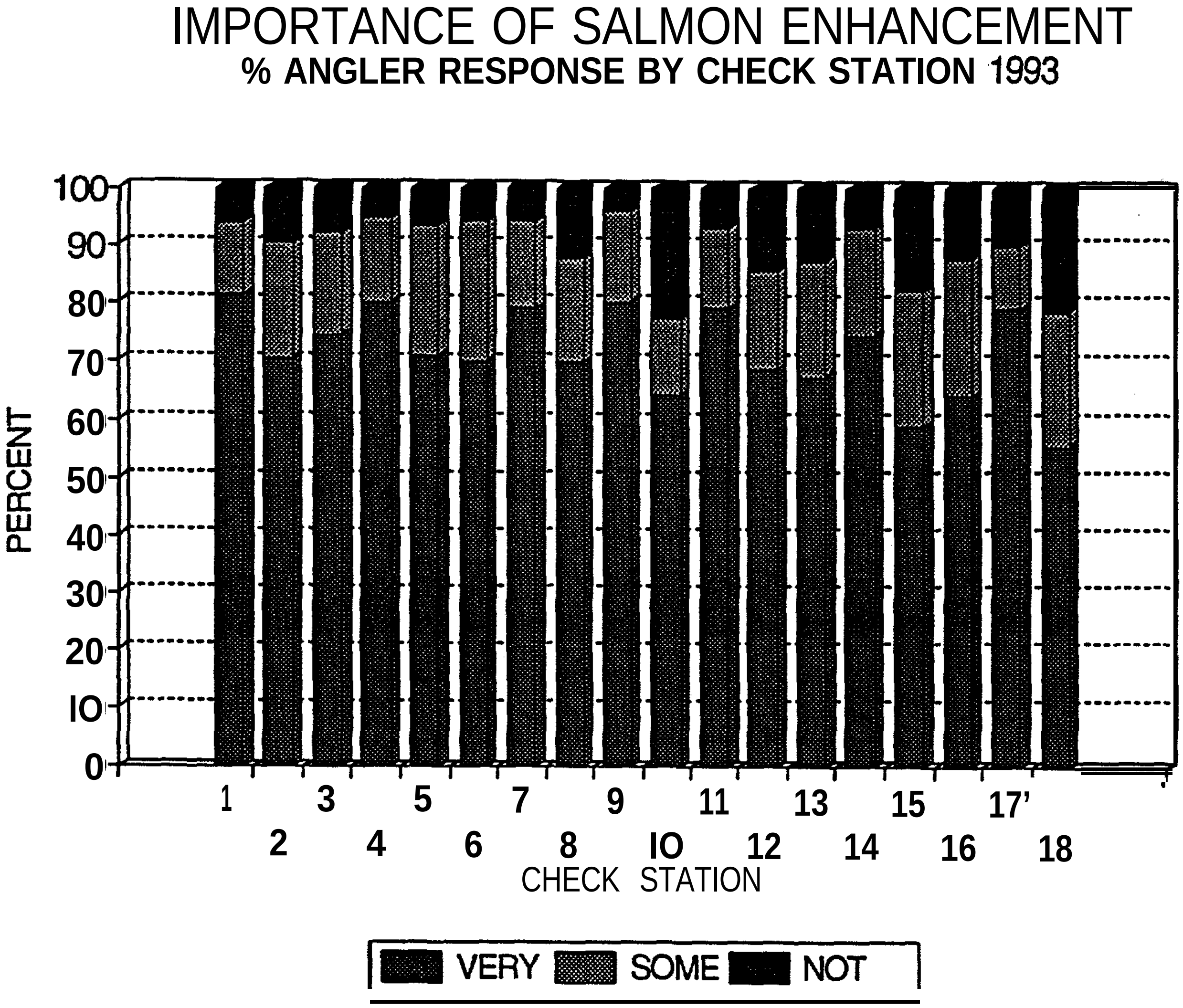
Appendix Figure I-l. 14. Importance of payment for participation, 1993.



Appendix Figure I-l. 15. Importance of the recreation opportunity to anglers, 1993.



Appendix Figure I-l. 16. Importance of covering fishing expenses to anglers, 1993.



Appendix Figure I-l. 17. Importance of salmon enhancement to anglers, 1993.

Appendix Table I-1.5. Distribution of fishing methods by check station, 1993.

Station	Boat Anchored	Boat Drifting	Boat Trolling	Shore	Angling Surface	Angling Bottom	Other
1	71	12	7	153	11	176	1
2	88	6	5	59	7	77	0
3	55	18	5	80	9	62	1
4	254	40	121	125	18	225	13
5	161	55	67	341	34	237	6
6	384	82	108	182	52	238	7
7	90	25	24	759	32	133	2
8	33	10	5	132	11	90	0
9	66	24	20	276	38	122	0
10	56	32	95	239	21	133	1
11	28	41	261	315	12	71	0
12	27	7	31	103	18	29	0
13	90	56	22	58	1	50	1
14	139	96	46	87	12	68	0
15	40	78	32	31	5	29	0
16	35	16	30	58	14	37	1
17	11	19	53	39	6	21	0
18	149	56	12	**528**	22	241	2

Appendix Table I-1.6. Distribution of bait and tackle used by check station, 1993.

Station	Worms	Cut-fish	Spin-ners	Spoon	Flat-fish	Surface plugs	H&L 1 hook	H&L >1 hook	Other
1	160	26	8	10	1	8	164	28	23
2	104	24	4	2	4	8	50	28	18
3	100	17	14	11	5	9	40	11	24
4	214	70	57	31	32	34	225	41	86
5	324	87	43	14	10	48	201	58	116
6	324	163	70	32	32	85	209	42	88
7	332	96	26	20	7	42	253	22	267
8	101	56	21	5	2	4	74	7	10
9	256	19	49	22	12	12	126	9	40
10	258	6	70	10	24	46	110	7	45
11	165	4	31	32	29	57	197	38	176
12	71	8	34	40	6	5	28	6	15
13	108	18	34	1	5	4	53	6	47
14	167	41	56	27	13	23	55	12	51
15	91	9	35	6	7	9	38	4	15
16	58	19	18	4	5	14	33	14	25
17	34	9	8	1	10	5	13	4	63
18	224	236	29	14	7	14	327	23	127

Appendix Table I-1.7. Creel clerk evaluation of the 1993 sport-reward program (N=38).

Program Component	Good N (%)	Fair N (%)	Poor N (%)	NA N (%)
Operating Hours	30 (79)	8 (21)	0 (0)	0 (0)
Registration Process	30 (79)	8 (21)	0 (0)	0 (0)
Check-in Process	37 (97)	1 (3)	0 (0)	0 (0)
Data Forms	35 (92)	3 (8)	0 (0)	0 (0)
Data Collection	34 (89)	4 (11)	0 (0)	0 (0)
Staffing	31 (82)	7 (18)	0 (0)	0 (0)
Equipment	18 (47)	16 (42)	4 (11)	0 (0)
Station Security	34 (89)	4 (11)	0 (0)	0 (0)

Appendix Table I-1.8. Frequency of angler complaints about various aspects of the 1993 sport-reward fishery, as reported by creel clerks **(N =38).**

Type of Complaint	Many N	Many (%)	Some N	Some (%)	Few N	Few (%)	None N	None (%)	NA N	NA (%)
Boat Ramps										
overcrowding	4	(11)	3	(8)	10	(27)	20	(54)	0	(0)
size	0	(0)	6	(15)	8	(20)	24	(60)	2	(5)
wait time to launch	2	(6)	4	(11)	9	(26)	20	(57)	0	(0)
Fishing										
angler crowding	1	(3)	7	(18)	14	(36)	16	(41)	1	(3)
corn. fish. crowding	4	(1)	0	(0)	4	(11)	22	(59)	7	(19)
gear damage/anglers	0	(0)	1	(3)	10	(26)	26	(68)	1	(3)
gear damage/commer.	0	(0)	1	(3)	2	(5)	28	(76)	6	(16)
speeding boats	5	(13)	4	(11)	14	(37)	15	(39)	0	(0)
jet skiers	5	(13)	6	(15)	9	(23)	18	(46)	1	(3)
water skiers	4	(11)	4	(11)	8	(21)	21	(55)	1	(3)
litter in water	1	(3)	4	(11)	10	(26)	23	(61)	0	(0)
litter on banks	1	(3)	6	(16)	6	(16)	25	(66)	0	(0)
Registration/Check-In										
regis. time	0	(0)	4	(10)	9	(23)	26	(67)	0	(0)
regis. paperwork	1	(3)	8	(22)	12	(32)	16	(43)	0	(0)
other anglers	0	(0)	4	(10)	9	(23)	26	(67)	0	(0)
check-in time	3	(8)	5	(13)	12	(32)	17	(45)	1	(3)
check-in paperwork	1	(3)	6	(16)	15	(39)	15	(39)	1	(3)
fish quality require.	2	(6)	8	(22)	16	(44)	10	(28)	0	(0)

APPENDIX I-2

Dam-Angling Fishery Expenditures

Appendix Table I-2.1. Agency total expenditures and expenditure per fish removed for the 1993 dam-angling fishery, by fishing crew.

Fishing Operation	Total Expenditure (components explained in text)	Total Catch	Expenditure Per Fish Removed
Bonneville + The Dalles	$188,659	5,879	$32.00
John Day	106,309	1,743	61.00”
McNary	95,381	4,685	20.00
Ice Harbor + Lower Monumental	33,946	325	104.00
Little Goose + Lower Granite	115,654	861	134.00[b]
Mobile Crew	84,375	2,906	29.00
Volunteers	14,157	550	26.00
Total	$638,480	16,949	$38.00

[a] Number is net of 261 fish reportedly caught before July 11. If the 261 fish are added to the total catch, $/NSF declines to $53.
[b] Total costs and $/NSF are high due to cost of boat angling at dams.

APPENDIX I-3

Collection and Distribution of Northern Squawfish

Appendix Table I-3.1. Collection and distribution budget summary, 1993.

Area	Total Lb	Lb Fd-grd.	% Fd-grd.	Total cost	cost /lb.
Longview	7,839	6,200	79	$16,800	$2.14
Portland	17,170	--	--	**$13,000**[3]	$0.76
c. Locks	45,897	**68,200**[2]	79	$46,000	$0.53
T. Dalles	23.445	--	--	**$14,200**[3]	$0.61
	86,512[1]				
Tri-Cities^	31,964	24,600	77	$18,325	$0.57
L. Ferry”	1,607	--	--	**$1,000(est)**	$0.62
Pullman”	1,423	--	--	$400	$0.28
Clarkston	13.135	--	--	$4,200	$0.31
Subtotal	142,480	99,000	78	$113,925	$0.80

Other Costs (applying to all areas)	Administration	$30,500
	Travel	$12,300
	Op. and Maint.	$11,700
	Ind. Costs @ 15%	$25.200
Total Costs Through Nov. 1993		**$193,625**[4]

[1] Squawfish from the Portland, C. Locks, and The Dalles areas were processed in C. Locks. This figure is the total for these areas.
[2] Volume of food-grade squawfish processed in Cascade Locks.
[3] These cost reflect rent, personnel, and transportation only because squawfish were not processed at these locations.
[4] This total includes all FY 1993 salaries associated with the handling program.
^ Rendering only locations.