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

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CONTENTS

II. EVALUATION

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EXECUTIVE SUMMARY

by David L. Ward

We report our results of studies to determine the extent to which northern squawfish predation on juvenile salmonids is a problem in the Columbia River Basin, and to evaluate how effectively fisheries can be used to control northern squawfish populations and reduce juvenile salmonid losses to predation. These studies were initiated as part of a basinwide program to control northern squawfish predation and reduce mortality of juvenile salmonids on their migration to the ocean. Modeling simulations based on work in the John Day Reservoir from 1982 through 1988 indicated that if northern squawfish were exploited at a 10-20% rate, reductions in their numbers and restructuring of their populations could reduce their predation on juvenile salmonids by 50% or more.

We evaluated the success of three test fisheries conducted in 1992 -- a sport reward fishery, a dam angling fishery, and a commercial longline fishery -- to achieve a 20% exploitation rate on northern squawfish. We also gathered information regarding the economic., social, and legal feasibility of sustaining each fishery.

The evaluation team consists of the Oregon Department of Fish and Wildlife Research and Development Section (ODFW), Oregon State University (OSU), and the Computer Sciences Corporation (CSC). ODFW is the lead agency and has subcontracted various tasks and activities to OSU and CSC based on expertise each brings to the evaluation. Objectives of each cooperator are as follows.

1. ODFW (Report G): Continue systemwide, stepwise implementation of the predation index; continue evaluation of test fisheries in the Columbia River Basin as they are implemented; and assist the U.S. Fish and Wildlife Service (USFWS) in developing and evaluating prey protection measures at Columbia and lower Snake River dam bypass systems.

2. OSU (Report H): Continue to evaluate the economic effectiveness of fisheries for northern squawfish; collect, transport, store, and distribute all northern squawfish collected during the 1992 fishing season; continue the development of value-added products; continue to explore new uses for northern squawfish; and continue the evaluation of regulatory and social issues related to the conduct of fisheries for northern squawfish.

3. CSC (Report I): Provide estimates of predation-related juvenile salmonid mortality for Columbia and Snake River projects based on the most recent research data, and revise estimates of salmonid mortality in response to existing and proposed predator control measures and other management actions; develop a user interface for versions of the Columbia River Ecosystem Model (EZ-CREM) to allow researchers and managers to operate the model to investigate the consequences of management

alternatives in the system; and provide estimates of the probable long-term consequences of the present and possible alternative predator control programs on northern squawfish populations and juvenile salmonid mortality.

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

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

1. Density and abundance of northern squawfish 2250 mm fork length were higher downstream from the Bonneville Dam tailrace than in the John Day Reservoir. Northern squawfish consumption of juvenile salmonids was also higher downstream from the Bonneville Dam tailrace, therefore, the predation index was higher downstream from the Bonneville Dam tailrace.

2. Systemwide estimates of exploitation of northern squawfish ranged from 9.8-14.5% (all fisheries combined). Exploitation was 7.6-l 1.2% by the sport reward fishery, 2.2-3.2% by dam angling, and less than 0.1% by longlining.

3. Mean fork length of northern squawfish caught by each fishery was greater than 275 mm. Dam angling was most selective for catching large northern squawfish (392 mm mean fork length).

4. Incidental catch was highest in the longline fishery, and consisted mostly of white sturgeon (*Acipenser transmontanus*).

5. We collected information on northern squawfish population structure, fecundity, age and growth, sex ratio, size at maturity, mortality, and year-class strength. Sampling to collect similar information in future years will help us to evaluate changes in northern squawfish population structure in response to fisheries.

Report H
Economic, Social, and Legal Feasibility of Commercial, Sport, and Bounty Fisheries on Northern Squawfish

1. Commercial fisheries as previously structured are not cost-effective, however, commercial fisheries do offer potential for efficient removal of northern squawfish if allowed to operate on a flexible experimental basis.

2. When adjusted for total administration and oversight costs and for time spent in activities not directly related to removals, the cost per northern squawfish is similar between dam angling and sport reward fisheries. The fisheries are complementary rather than competitive activities.

3. Fish handling plans should be developed that will minimize handling costs to the project as a whole without compromising removal goals. A portion of individual budgets should be dedicated to fish handling and not be counted as removal costs. A permanent quality control system should be implemented, including incentives to comply.

4. The greatest market potential for northern squawfish is in mince, fish meal, and fertilizer. The most cost-effective alternative for utilization is a food/rendering or a food/fertilizer combination.

5. Northern squawfish should be reclassified as a food fish in the state of Washington, and a license should be required for recreational capture of northern squawfish. Active coordination between enforcement and implementation personnel should continue. Public education materials should be developed that present activities of the Predator Control Program in the context of Columbia River issues.

Report I
Columbia River Ecosystem Model (CREM): Modeling Approach for Evaluation of Control of Northern Squawfish Populations Using Fisheries Exploitation

1. Modeling simulations indicated that mortality of juvenile salmonids will decrease in response to current predator control efforts.

2. A preliminary version of EZ-CREM was completed, including a preliminary user's guide.

REPORT G

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

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1992 Annual Report

CONTENTS

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Special thanks go to the project personnel that worked long hours in the field to collect the data presented in this report. Thanks to Kent Anderson for assisting with summaries and collection of data. Thanks also to the following people for assisting with data collection: Tom Adams, Becky Banghart, Christy Cutting, John Donnerberg, Tom Friesen, Karen Hans, Candi Healy, Kim Jackson, Kelly Jenkins, Stephen Morrow, Tom Neill, George Reed, Mike Royle, Vicki Royle, Sarah Schlichting, and Erick Van Dyke.

ABSTRACT

We are reporting progress on predation indexing and fisheries evaluation as part of the northern squawfish (*Ptychocheilus oregonensis*) predator control study in the lower Columbia and Snake rivers for 1992. Our objectives were to (1) continue systemwide, stepwise implementation of the predation index, and (2) continue evaluation of test fisheries in the Columbia River Basin as they are implemented.

We sampled with gillnets and an electrofishing boat to develop an index of northern squawfish abundance downstream from Bonneville Dam tailrace. The abundance index was integrated with a consumption index developed by the U.S. Fish and Wildlife Service (USFWS) to produce a predation index. Results were compared to those from John Day Reservoir. Density and abundance of northern squawfish 2250 mm fork length were higher downstream from Bonneville Dam tailrace than in the John Day Reservoir. Northern

squawfish consumption of juvenile salmonids was also higher downstream from Bonneville Dam tailrace; therefore, the predation index was higher downstream from Bonneville Dam tailrace.

We evaluated the efficiency of three test fisheries (public sport-reward, agency dam-angling, and commercial longlining) by comparing northern squawfish exploitation rates and size composition, and incidental catch of other fish species among fisheries. Systemwide estimates of exploitation in 1992 ranged from 9.8-14.5% (all fisheries combined). Exploitation of northern squawfish was 7.6-l 1.2 % by the sport-reward fishery, 2.2-3.2 % by dam-angling, and less than 0.1% by longlining.

Mean fork length of northern squawfish caught by each fishery was greater than 275 mm. Dam angling was most selective for catching large northern squawfish (mean fork length = 392 mm). Mean fork length of fish caught by the sport-reward fishery (349 mm) was greater than by longlining (323 mm). Incidental catch was highest in the longline fishery, and consisted mostly of white sturgeon (*Acipenser transmontanus*).

We also collected and analyzed data on northern squawfish population structure, fecundity, age and growth, sex ratio, size at maturity, mortality, and year-class strength. These data will be compared to similar data collected after sustained (3-5 years) fisheries.

INTRODUCTION

We began implementation of a predation index, predator control fisheries, and an evaluation plan for lower Columbia River reservoirs in 1990. In 1991 we continued implementation of the predation index and evaluation of fisheries for lower Snake River reservoirs. In 1992 the project expanded further to include the Columbia River downstream from Bonneville Dam (Figure 1). In this report we describe our activities and results in 1992.

The goal of predator control is to reduce inreservoir mortality of juvenile salmonids to predation by northern squawfish (*Ptychocheilus oregonensis*). Our objectives in 1992 were to (1) continue systemwide, stepwise implementation of the predation index, and (2) continue evaluation of test fisheries in the Columbia River Basin as they are implemented. As part of Objective 2, we began a preliminary evaluation of the mechanisms driving the response of predator and prey fish species to sustained northern squawfish fisheries. Results of this preliminary evaluation are presented in Appendix A.

The predation index is the product of a northern squawfish abundance index and a consumption index (Vigg et al. 1990). We collected data on northern squawfish abundance in lower Columbia River reservoirs in 1990, in lower Snake River reservoirs in 1991, and downstream from Bonneville Dam in 1992. The U.S. Fish and Wildlife Service collected data on northern squawfish consumption of juvenile salmonids in the same areas all three years. The envisioned product of the predation index is an assessment of the magnitude of predation in various reservoirs throughout the Columbia River Basin relative to baseline data in John Day Reservoir. This would ideally allow direction of predator control fisheries to places where predation is greatest.

Evaluation is necessary to compare relative efficiencies among predator control fisheries and to determine biological effects of the fisheries. In 1990, 1991, and 1992, fisheries included sport-reward, dam-angling, and longlining. Evaluating efficiency of the fisheries includes comparing northern squawfish exploitation rates and size composition, and comparing catch of incidental species.

Biological evaluation includes comparing northern squawfish population structure, fecundity, sex ratio, size and age at maturity, peak spawning times, age and growth, mortality, and year-class strength before and after sustained (approximately five years) fisheries. Examining mechanisms driving the response of predator and prey fish species to sustained northern squawfish fisheries is also important. Data collected in 1992 represents the final year for collecting baseline data that will be compared in subsequent years to data collected after sustained fisheries.

METHODS

Field Procedures

Predation Index

We used an electrofishing boat, bottom gillnets, and surface gillnets to collect northern squawfish and develop the abundance index portion of the predation index. We sampled the Columbia River downstream from Bonneville Dam tailrace and John Day Reservoir (Figure 1). The Columbia River downstream from Bonneville Dam tailrace was divided into three zones: (1) River Kilometer (RK) 71 to RK 121, (2) RK 122 to RK 177, and (3) RK 178 to RK 224. Each zone was further divided into lower, middle, and upper areas. The John Day Reservoir was divided into forebay, midreservoir, tailrace, and tailrace restricted zone (BRZ) areas. We sampled each area in spring (May-June) and summer (July-August). Gillnetting was conducted by the Oregon Department of Fish and Wildlife (ODFW), whereas electrofishing was conducted by both ODFW and USFWS. Sampling schedules and methods, effort, and gear specifications were described by Vigg et al. (1990). Other than areas sampled, effort was similar to that in 1990.

The USFWS collected data to develop the consumption portion of the predation index by examining gut contents of northern squawfish. Details of their methods are given in Peterson et al. (1991).

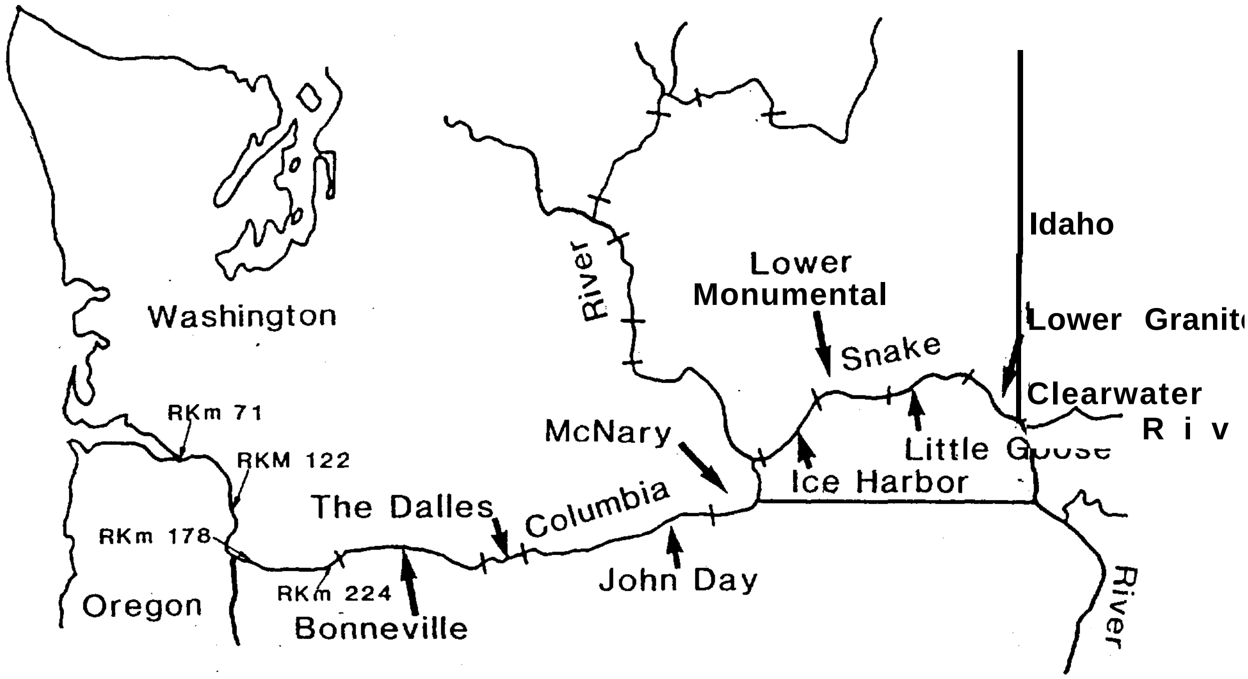

Figure 1. Reservoirs and zones of the lqwer Columbia and Snake rivers sampled from 1990 through 1992.

Fishery Evaluation

We used mark and recapture data to evaluate movements of northern squawfish and to compare exploitation rates of northern squawfish among fisheries. We tagged and released northern squawfish in all lower Columbia and Snake River reservoirs and downstream from Bonneville Dam prior to implementation of the fisheries. Sampling effort was randomly allocated throughout the Columbia River downstream from Bonneville Dam. Size of-the area and time limitations precluded our sampling the entire area upstream from Bonneville Dam; therefore, we randomly sampled the forebay, midreservoir, tailrace and BRZs of each reservoir.

We used electrofishing boats, bottom gillnets and surface gillnets to collect northern squawfish fish from March 2 to May 25. Fish greater than 200 mm fork length were tagged with a serial numbered spaghetti tag and given a secondary mark so we could estimate tag loss. Sampling procedures were similar to those described for the predation index, and tagging procedures were described by Vigg et al. (1990). Tags were recovered from April 21 through September 26 from the sport-reward, dam-angling and commercial longline fisheries, and during ODFW index sampling. Additional tags were recovered from USFWS index sampling and during harvest technology experiments conducted by the University of Washington.

The sport-reward, dam-angling, and commercial longline fisheries were described by Vigg et al. (1990). The sport-reward fishery was conducted from May 25 through September 27 throughout the lower Columbia and Snake rivers. Dam angling was conducted from April 20 through September 3 at Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams. The commercial longline fishery was conducted from May 18 through August 14 downstream from Bonneville Dam (Figure 1).

We collected biological data from a subsample of northern squawfish caught in each fishery. Each sport-reward check station was sampled at least one weekday per week and one weekend day per month. Each dam was sampled at least one day per week. Catches from each of four longline boats were sampled weekly. We measured fork length (mm) and total body weight (g); we determined sex and maturity (undeveloped or immature, developing, ripe, or spent); and we collected scale samples and gonad samples (ripe females only) from northern squawfish. We removed and weighed gonads from both male and female northern squawfish to determine weekly gonosomatic index (GSI).

We also collected baseline. biological data on northern squawfish populations while index sampling. Data collected were the same as described for predator control fisheries.

Laboratory Procedures

We used gravimetric quantification (Bagenal 1968) of developed and undeveloped eggs to estimate fecundity of northern squawfish in the John Day Reservoir and downstream from Bonneville Dam. Ripe ovaries were placed in Gilson's solution and allowed to fix for a minimum of four weeks. Ovary samples were then prepared for analysis as described by Vigg et al. (1990). Ovary subsamples were weighed and egg counts in the subsamples were extrapolated to total ovarian weight. To assure accurate egg production estimates, we enumerated both developed and undeveloped eggs. Only counts of developed eggs, characterized by their relatively large size and yellow or orange color, were used in calculating fecundity estimates and describing fecundity relationships with length and weight. To determine accuracy of fecundity estimates, we counted the total number of developed and undeveloped eggs in five ovary samples and compared the number to extrapolated estimates.

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

Data Analysis

Predation Index

We used the square root of the percent of zero catches of ODFW and USFWS electrofishing runs (SQRT % 0) as an index of density of northern squawfish (Ward et al. 1992). Differences in the density index were compared among the zones downstream from Bonneville Dam, and among areas of John Day Reservoir. Although sampling was stratified by season, density for each zone or area included data from both spring and summer. An index of northern squawfish abundance was calculated as the product of density and surface area. Main-channel, midreservoir areas deeper than about 40 ft were excluded when estimating surface areas because Nigro et al. (1985) showed that northern squawfish rarely are found in these areas.

The consumption index was developed by USFWS (Petersen et al. 1991). The consumption index is not a rigorous estimate of the number of juvenile salmonids eaten per day by an average northern squawfish; however, it is linearly related to the consumption rate of northern squawfish (Petersen et al. 1991). Consumption data was summarized for spring and summer.

We computed the predation index as the product of the abundance and consumption indices. We compared predation indices among the zones downstream from Bonneville Dam tailrace and the areas in John Day Reservoir for spring and summer.

Fishery Evaluation

Relative Efficiency

We used mark and recapture data to compare exploitation rates of northern squawfish among fisheries. We evaluated movements of recaptured northern squawfish to determine the extent of mixing among marked and unmarked fish so -we could define areas containing discrete populations. Exploitation was calculated for each one-week period and summed to. yield total exploitation for each fishery (Beamesderfer et al. 1987). We adjusted exploitation estimates to reflect tag loss during the season (4.8 %).

Logistical problems precluded our marking fish throughout each reservoir upstream from Bonneville Dam, increasing the potential for bias in our exploitation estimates. Therefore we estimated sport-reward and dam-angling exploitation for each reservoir in two ways to establish a range. The first scenario assumed full mixing of tagged and untagged fish and random allocation of fishing effort throughout each reservoir. This gave us a maximum exploitation estimate. The second scenario assumed no mixing of fish outside the areas they were tagged and that fishing occurred only in the same areas fish were tagged. Because we sampled the entire forebay and tailrace of each reservoir, but only a relatively small proportion of each midreservoir, we adjusted the number of tagged fish in midreservoir by dividing the number of fish actually tagged by the proportion of midreservoir area sampled. We used the adjusted number of tags when calculating exploitation, giving us a minimum estimate.

We compared mean fork lengths and length frequency histograms for northern squawfish among fisheries and ODFW indexing in John Day Reservoir and downstream from Bonneville Dam to evaluate fishery selectivity for large individuals. We also plotted monthly mean fork lengths of northern squawfish collected by angling at each dam and by the sport-reward fishery in each reservoir and downstream from Bonneville Dam to determine if size declined over time within the season..

We compared incidental catch among fisheries to determine selectivity of each fishery for northern squawfish. We compared total number of fish caught and the percentage of northern squawfish captured in each fishery. We also compared the various species that made up the incidental catch for each fishery.

Baseline Biological Data

We tabulated the ratio of female to male northern squawfish less than and greater than 350-mm fork length from each fishery and index sampling to compare sex ratio of the catch among fisheries. For each fishery we also plotted the percentage of the catch composed of females each month. We estimated size at maturity for male and female northern squawfish by plotting the percentage of fish in each 25-mm fork length increment that were mature for all fisheries combined. We also calculated the GSI of male and female northern squawfish for all fisheries combined. We plotted GSI by week from May through September to determine reproductive peaks. GSI was calculated as

$$(GW/BW) \cdot 100$$

where

GW = gonad weight (g), and
BW = total body weight (g).

We estimated average fecundity and average relative fecundity of northern squawfish for John Day Reservoir and the Columbia River downstream from Bonneville Dam. Relative fecundity was defined as the number of developed eggs per gram of total body weight. We used least squares regression analysis (SAS Institute, Inc. 1987) to examine the relationship between log,, (fecundity) and log,, (fork length) and log,, (body weight) for John Day Reservoir and downstream from Bonneville Dam.

We determined backcalculated fork lengths at formation of annuli for northern squawfish in John Day Reservoir and downstream from Bonneville Dam tailrace to develop age-at-length keys. We summarized fork lengths of northern squawfish collected while index sampling and used the age-at-length keys to estimate age composition in each area. We also plotted length at age of northern squawfish for John Day Reservoir and downstream from Bonneville Dam tailrace. We used linear regression (SAS Institute, Inc. 1987) to examine the relationship between log,, (fork length) and log,, (body weight) for each of these areas.. We further examined growth of northern squawfish by fitting the von Bertalanffy growth model (Ricker 1975) to estimated mean length at age.

We used age frequencies from indexing data (electrofishing and gillnetting combined) to generate catch curves (Ricker 1975). We plotted log, (% catch) against age to establish catch curves for John Day Reservoir and downstream from Bonneville Dam tailrace. Total instantaneous mortalities and annual mortality rates were estimated by linear regression (SAS Institute, Inc. 1987) of the descending limb of the catch curves (Ricker 1975).

We evaluated year-class strength of northern squawfish in John Day Reservoir by methods described by El Zarka (1959). We plotted the index of year-class strength from 1975 through 1989 using aging data from 1990, 1991, and 1992 to determine the relative success of each cohort.

RESULTS

Predation Index

Density of northern squawfish 2250 mm was higher downstream from Bonneville Dam tailrace than in John Day Reservoir (Table 1); however, because of its large size, abundance was higher in the John Day Reservoir than in any of the zones downstream from the Bonneville Dam tailrace (Figure 2). Density and abundance were similar among the three zones, but increased slightly with distance from Bonneville Dam tailrace.

Northern squawfish consumption indices differed among the zones downstream from Bonneville Dam tailrace and among areas in John Day Reservoir (Table 2). Because of differences in abundance and consumption, relative predation on juvenile salmonids by northern squawfish differed among areas and time of year (Figure 3). Predation was highest in the Columbia River between RK 178 and RK 224, especially in summer. Predation in each zone downstream from Bonneville Dam was higher than in John Day Reservoir. We found no evidence of predation in the midreservoir or tailrace of John Day Reservoir.

Table 1. Index of northern squawfish density (1 divided by the square root of the percentage of electrofishing runs in which no northern squawfish were caught) in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir. **BRZ** = boat restricted zone.

Location, zone	Number of electrofishing runs	Index
Downstream from Bonneville Dam tailrace		
RK 71 to RK 121	204	1.597
RK 122 to RK 177	202	1.458
RK 178 to RK 224	203	1.390
John Day Reservoir		
Forebay	68	1.243
Midreservoir	62	1.174
Tailrace	47	1.045
Tailrace BRZ	17	2.380

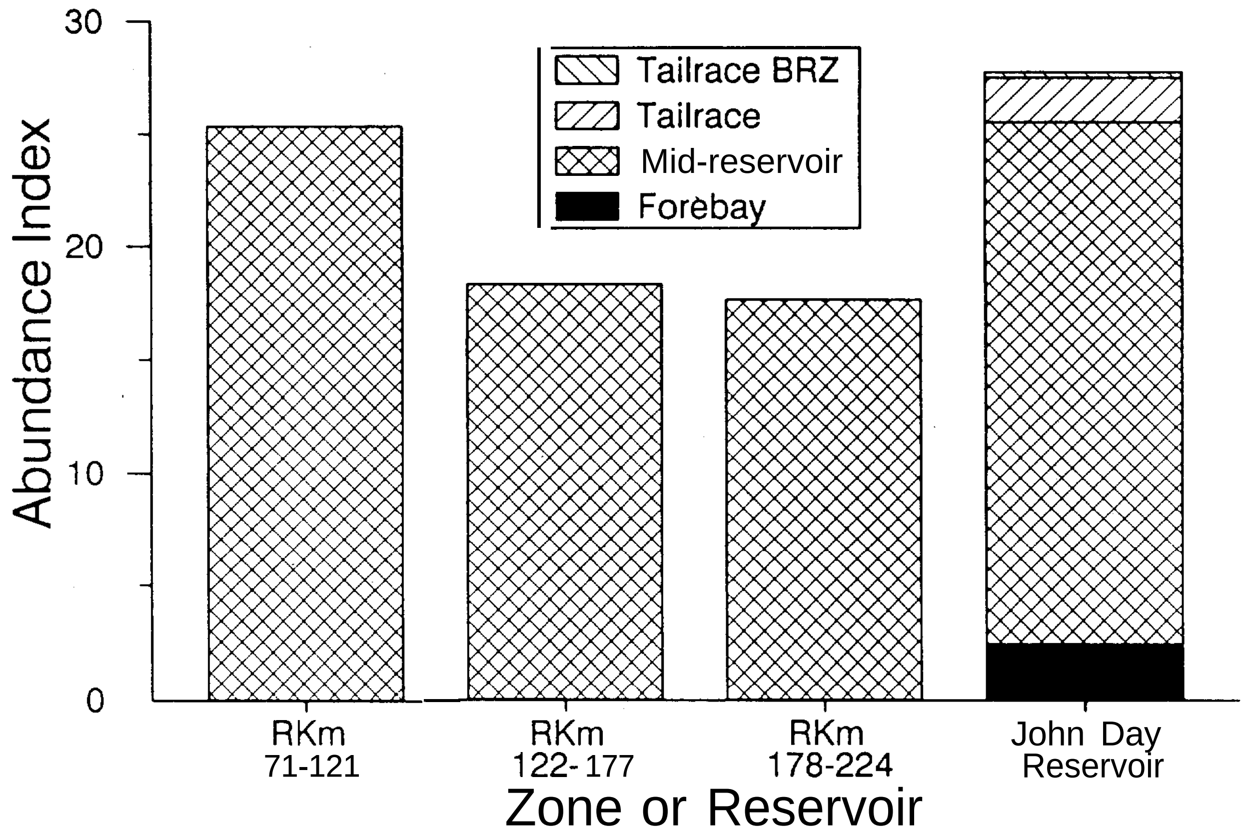

Figure 2. Index of northern squawfish abundance in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

Table 2. Index of northern squawfish consumption of juvenile salmonids in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir (summarized from Petersen et al. 1992). BRZ = boat restricted zone. N equals the number of northern digestive tracts examined.

Location, zone	Spring N	Spring Index	Summer N	Summer Index
Downstream from Bonneville Dam tailrace				
RK 71 to RK 121	102	0.522	117	0.305
RK 122 to RK 177	189	1.033	136	1.334
RK 178 to RK 224	126	1.122	59	1.886
John Day Reservoir				
Forebay	38	1.868	27	0.745
Midreservoir	8	0	13	0
Tailrace	9	0	1	0
Tailrace BRZ	35	9.336	67	4.550

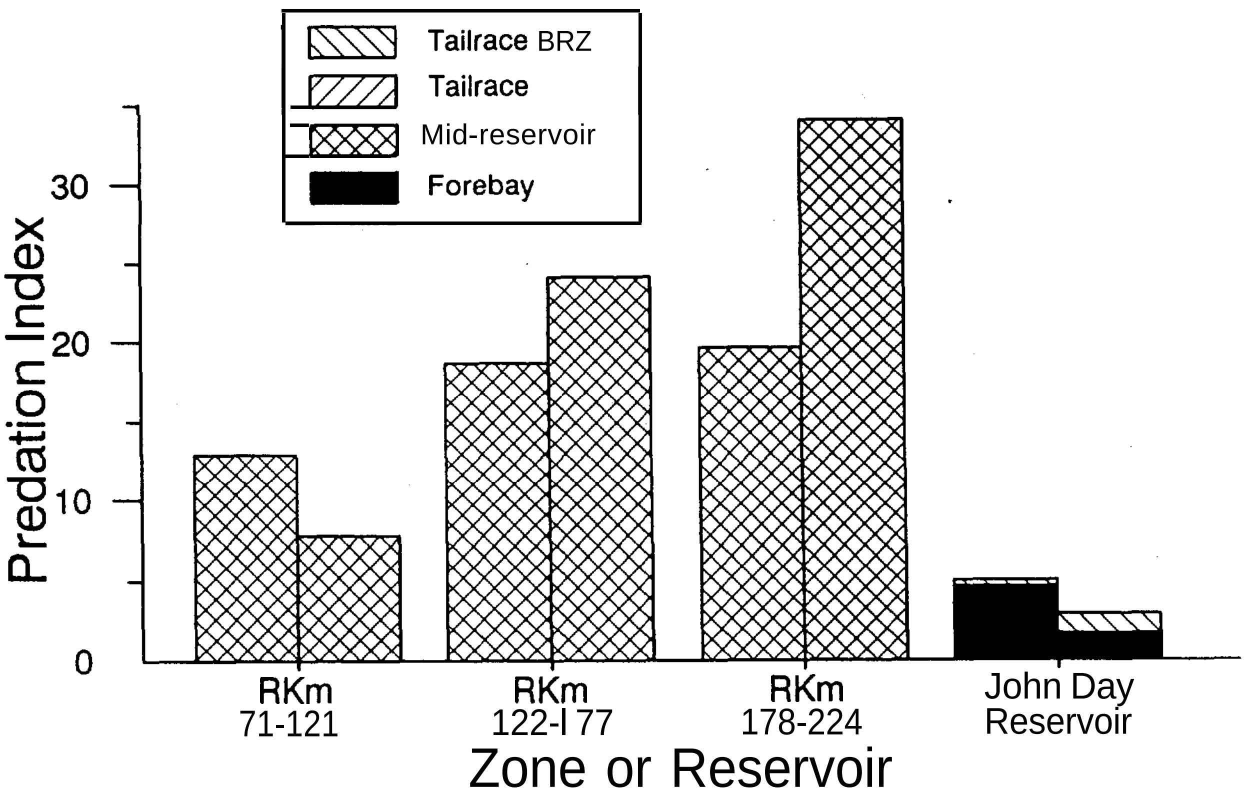

Figure 3. Index of northern squawfish predation on juvenile salmonids in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir. The first bar represents spring predation, the second bar represents summer predation.

Fishery Evaluation

Relative Efficiency

We tagged and released 4,171 northern squawfish throughout the lower Columbia and Snake rivers (Table 3). A total of 552 marked northern squawfish were recaptured in the three fisheries; 442 by sport-reward anglers, 108 by dam-anglers, and two by longliners. An additional 63 tags were recovered during ODFW (20) and USFWS (43) index sampling. The University of Washington recaptured another nine tags. Of the 624 marked fish recaptured, 59 (9.5%) had migrated past a dam. Except for Ice Harbor Reservoir, the percentage of tagged fish recaptured by all fisheries varied among reservoirs from approximately 8% to 20% (Table 3).

Northern squawfish movement differed among reservoirs and areas (Table 3). Except for Bonneville and McNary reservoirs, we found that 90-100% of recaptured fish remained in the reservoir they were originally tagged. Only 59% of the recaptured fish originally tagged in Bonneville Reservoir were recaptured in Bonneville Reservoir. Because results precluded easy definition of discrete populations, we estimated exploitation for each reservoir and for the Columbia River downstream from Bonneville Dam. We also pooled data to estimate exploitation for the entire study area.

Table 3. Percentage of tagged northern squawfish that were recaptured in each reservoir. DB = downstream from Bonneville Dam, Bon = Bonneville Reservoir, Dal = The Dalles Reservoir, JD = John Day Reservoir, McN = McNary Reservoir, Ice = Ice Harbor Reservoir, LoMo = Lower Monumental Reservoir, Goo = Little Goose Reservoir and Gran = Lower Granite Reservoir.

Location marked	Number marked	Location Recaptured									
		DB	Bon	Dal	JD	McN	Ice	LoMo	Goo	Gran	Total
DB	2135	10.6	0.2	0.1	0	0	0	0	0	0	10.9
Bon	565	3.5	8.3	1.8	0.5	0	0	O	0	0	14.1
Dal	194	0	0	7.7	0	0	0	O	0	0	7.7
JD	259	0	0	0.4	18.9	0	0	0	0	0	19.3
McN	112	O	O	0	0	6.3	1.8	0	0	0	8.1
Ice	7	O	O	0	0	0	0	0	0	0	0
LoMo	226	0	0	0	O	0.4	0	8.4	0	0	8.8
Goo	545	0	O	0	O	0	0	1.8	18.0	0	19.8
Gran	128	0	O	0		0	0	0	0	12.5	12.5

Exploitation of northern squawfish differed among fisheries and reservoirs (Table 4). These estimates are conservative because they exclude fish that were recaptured in reservoirs other than where marked. The sport-reward fishery had the highest exploitation of northern squawfish > 250 mm in nearly all reservoirs and downstream from Bonneville Dam. The longline fishery contributed little to exploitation and dam angling exploitation was intermediate. Low numbers of tagged fish present in Ice Harbor Reservoir resulted in no subsequent recaptures, and an exploitation estimate of zero.

Dam angling was the most selective fishery for large northern squawfish (Figure 4). The mean fork length of northern squawfish caught by the longline fishery was lower than either the dam-angling or sport-reward fisheries. The greatest size range of northern squawfish was collected during index sampling. The fisheries harvested a disproportional number of large individuals compared to their relative abundance in ODFW index sampling.

Table 4. Minimum and maximum estimated exploitation rates of northern squawfish 2250 mm. Randomly allocated tagging effort downstream from Bonneville Dam resulted in only one exploitation estimate for each fishery. All exploitation estimates are adjusted for tag loss (4.8%).

	Sport-Reward		Dam-Angling		Longline		Total	
Location	Min	Max	Min	Max	Min	Max	Min	Max
Downstream from Bonneville Dam	11.5		0.2		0.1		11.8	
Bonneville	2.3	5.8	1.5	4.0	--	--	3.8	9.8
The Dalles	4.8	7.7	0.7	1.2	--	--	5.5	8.9
John Day	2.7	4.2	8.4	13.4	--	--	11.1	17.6
McNary	4.0	7.2	--	--	--	--	4.0	7.2
Ice Harbor	--	--	--	--	--	--	--	--
Lower Monumental	1.0	2.5	3.2	8.7	--	--	4.2	11.2
Little Goose	9.9	14.1	5.1	7.1	--	--	15.0	21.2
Lower Granite	11.2	18.1	--	--	--	--	11.2	18.1
Systemwide	7.6	11.2	2.2	3.2			9.8	14.5

Northern squawfish exceeding 250-mm fork length comprised the majority of the catch in all fisheries (Table 5). Indexing samples were generally smaller and only 50 % of the ODFW indexing catch downstream from Bonneville Dam exceeded 250 mm. Monthly mean fork lengths of fish harvested by dam-angling and sport-reward anglers fluctuated throughout 1992. Monthly mean fork lengths of sport-reward catches were variable among reservoirs (Figure 5). Generally, the mean size of the dam-angling catch declined from May to September by 30-75 mm except at The Dalles and Lower Monumental dams, where mean size stayed relatively stable (Figure 6).

Incidental catch of species other than northern squawfish varied among fisheries. The sport-reward fishery had the lowest percentage of incidental catch (Table 6). Dam angling incidental catch was also relatively low, and consisted mostly of channel catfish (*Ictalurus punctatus*). The commercial longline fishery had the highest percentage of incidental catch, composed mostly of white sturgeon..

Baseline Biological Data

Female northern squawfish captured by each of the fisheries generally outnumbered males almost 3 to 1 (Table 7). The sex ratio of northern squawfish less than 350-mm fork length captured by the sport-reward and dam-angling fisheries was 1 to 1. Almost all fish greater than 350 mm were females. The percentage of northern squawfish females remained relatively stable from May through September in each of the fisheries (Figure 7). The ODFW index sampling catch consisted of a lower percentage of females than the catch in each of the removal fisheries.

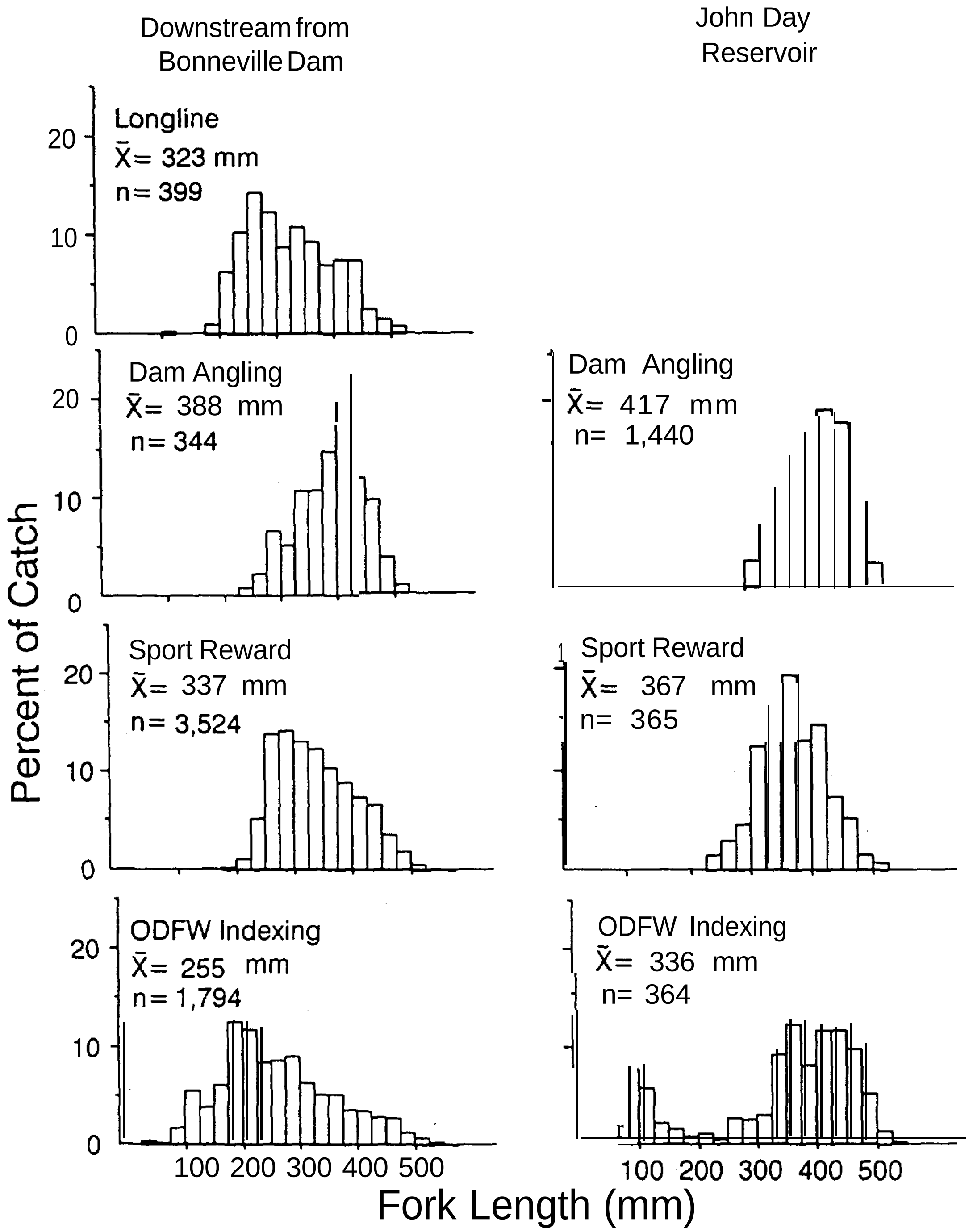

Figure 4. Size composition of the northern squawfish catch in the Columbia River downstream from Bonneville Dam and in John Day Reservoir in each fishery and in ODFW indexing samples.

Table 5. Percentage of northern squawfish exceeding various fork lengths in each fishery and in ODFW indexing samples in the Columbia River downstream from Bonneville Dam and in John Day Reservoir.

Location, fishery	Percentage greater than 200 mm	250 mm	300 mm	350 mm	400 mm
Downstream from Bonneville Dam					
Sport-Reward	99.6	92.7	63.9	39.0	20.0
Dam-Angling	100.0	99.1	90.1	73.8	46.8
Longline	98.5	81.0	55.6	36.1	19.5
ODFW Indexing	69.5	49.2	31.4	20.0	11.3
John Day Reservoir					
Sport-Reward	100.0	98.1	90.7	60.5	28.3
Dam-Angling	100.0	99.9	99.3	89.2	63.8
ODFW Indexing	80.2	78.3	73.4	59.9	39.6

Table 6. Northern squawfish and incidental catch for each fishery.

Species	Sport Reward	Dam Angling	Longline
Northern squawfish	200,796	27,868	2,158
Smallmouth bass'	693	294	1
Channel catfish	141	1,081	37
Walleye'	231	8	0
Sturgeon	17	217	3,660
Peamouth'	588	0	48
Salmonids	73	24	7
Other	606	82	124

[a] Smallmouth bass = *Hicropterus dolomieui,* walleye = *Stizostedion vitreum vitreum,* peamouth = *Mylocheilus caurinus*.

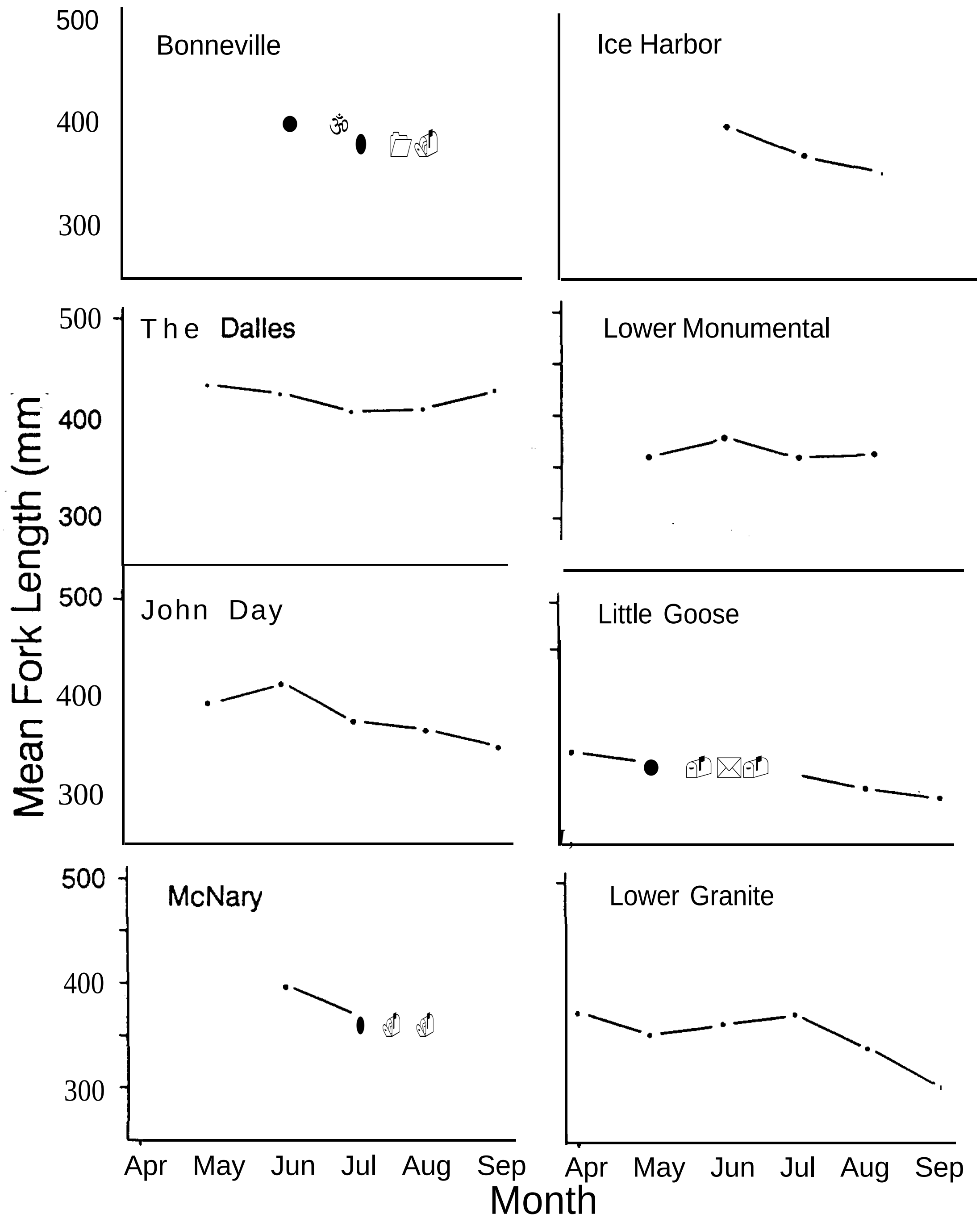

Figure 5. Monthly mean fork length of northern squawfish sampled from the dam angling catch at lower Columbia and Snake River dams.

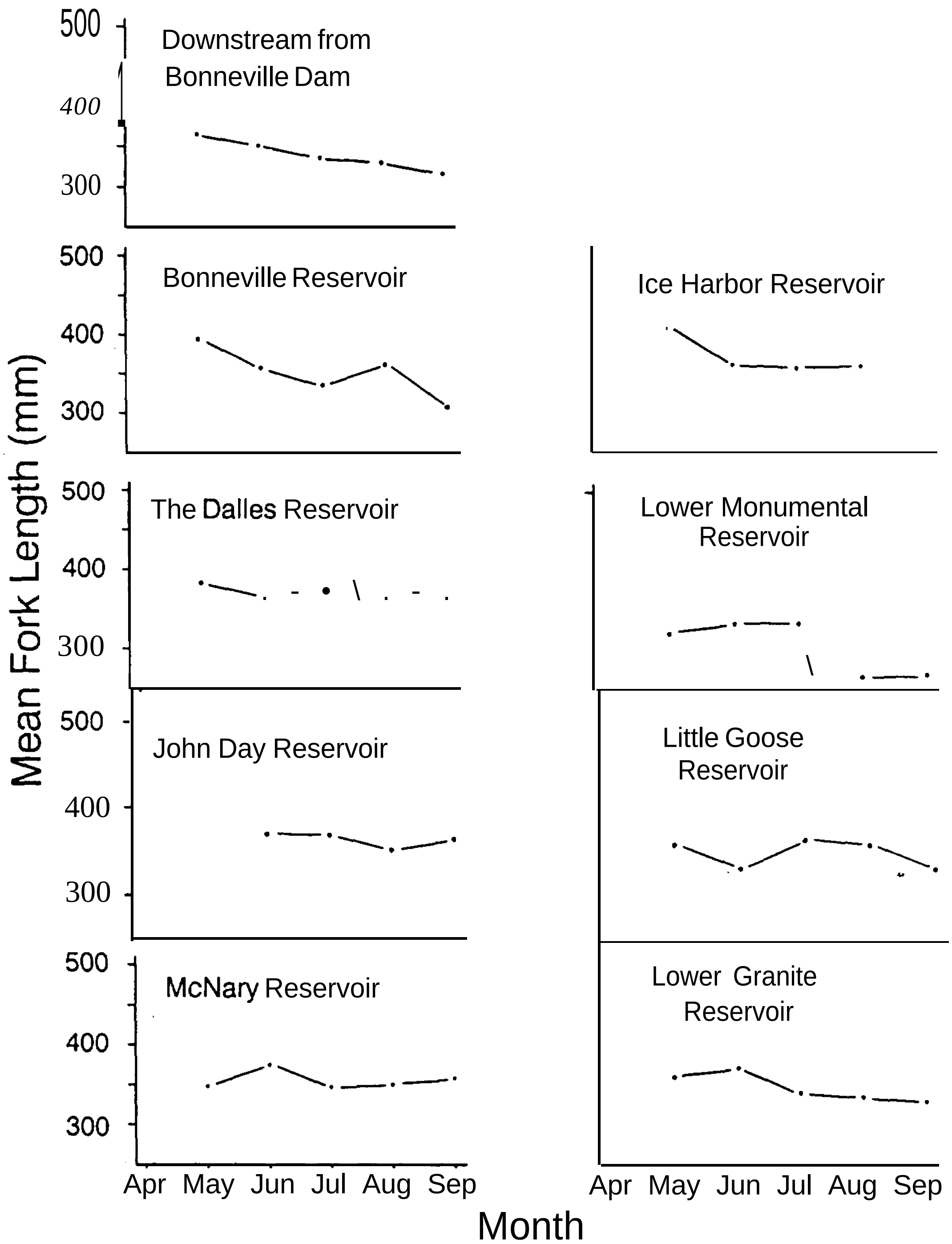

Figure 6. Monthly mean fork length of northern squawfish sampled from the sport-reward fishery in the lower Columbia and Snake rivers.

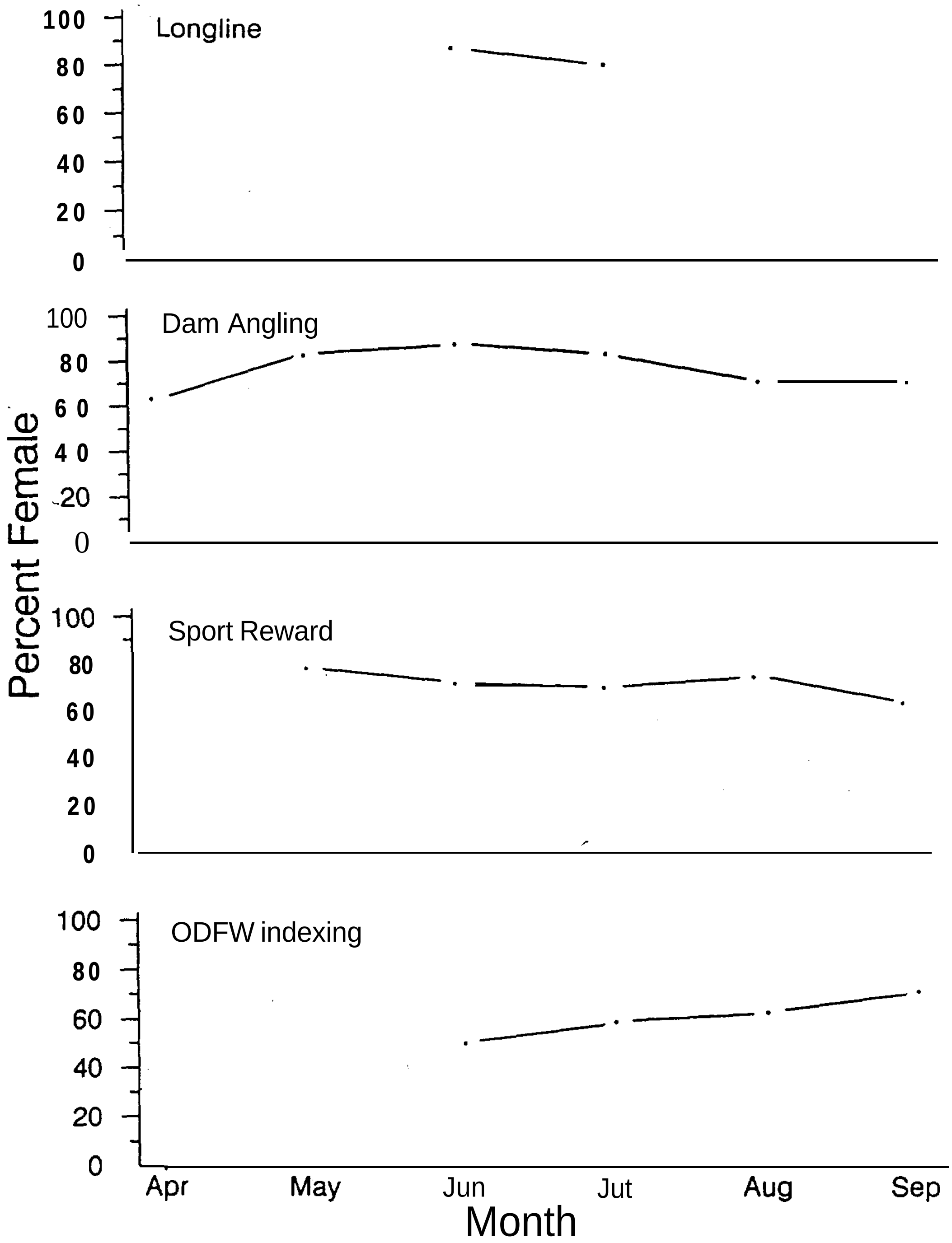

Figure 7. Percent of the northern squawfish catch composed of females in each fishery and ODFW index sampling by month, all areas combined.

Table 7. Sex ratio of northern squawfish catch by fishery.

Fishery	Female to male ratio		
	<350 mm	>350 mm	Total
Sport reward	1:1	9:1	3:1
Dam angling	1:1	12:1	4:1
Longline	3:1	22:1	6:1
ODFW indexing	1:2	9:1	1:1
Total	1:1	10:1	3:1

A few northern squawfish matured as small as 150-199 mm, however, the proportion of fish showing strong signs of reproductive maturity dramatically increased when fish reached 250-274 mm. (Figure 8). Using ages estimated from backcalculated length at age keys, it appears that some northern squawfish mature as early as age 3, but most were not sexually mature until age 5. The percentage of male northern squawfish mature at 200-224 mm was greater than that of similar sized females.

The gonosomatic index (GSI) of northern squawfish indicated that peak spawning activity occurred in late May and then gradually declined (Figure 9). Low GSI values representing post-spawning condition were observed by early to mid-August. Female GSI values were generally twice that of males throughout the season. Male and female GSI indices showed concomitant peaks in gonadal development.

Total egg counts from five northern squawfish ovaries indicated that the subsample method estimated total fecundity within 5% to 10%. Because fecundity was not consistently over- or underestimated, no correction factor was applied to extrapolated fecundity estimates. We estimated mean fecundity for 412 female northern squawfish collected from the Columbia River downstream from Bonneville Dam and in John Day Reservoir to be 26,948 developed eggs (Table 8). Estimates ranged from 5,117 eggs (fork length = 286 mm) to 91,967 eggs (fork length = 530 mm). The mean fork length of fish used in fecundity estimates was 389 mm (range = 242 to 540 mm). Mean relative fecundity was 35.5 developed eggs per gram of body weight. Variability in fecundity was higher downstream from Bonneville Dam than in John Day Reservoir. The number of developed eggs was positively, but not highly, correlated (r2 = 0.31 to 0.40) with fork length and body weight (Figures 10 and 11).

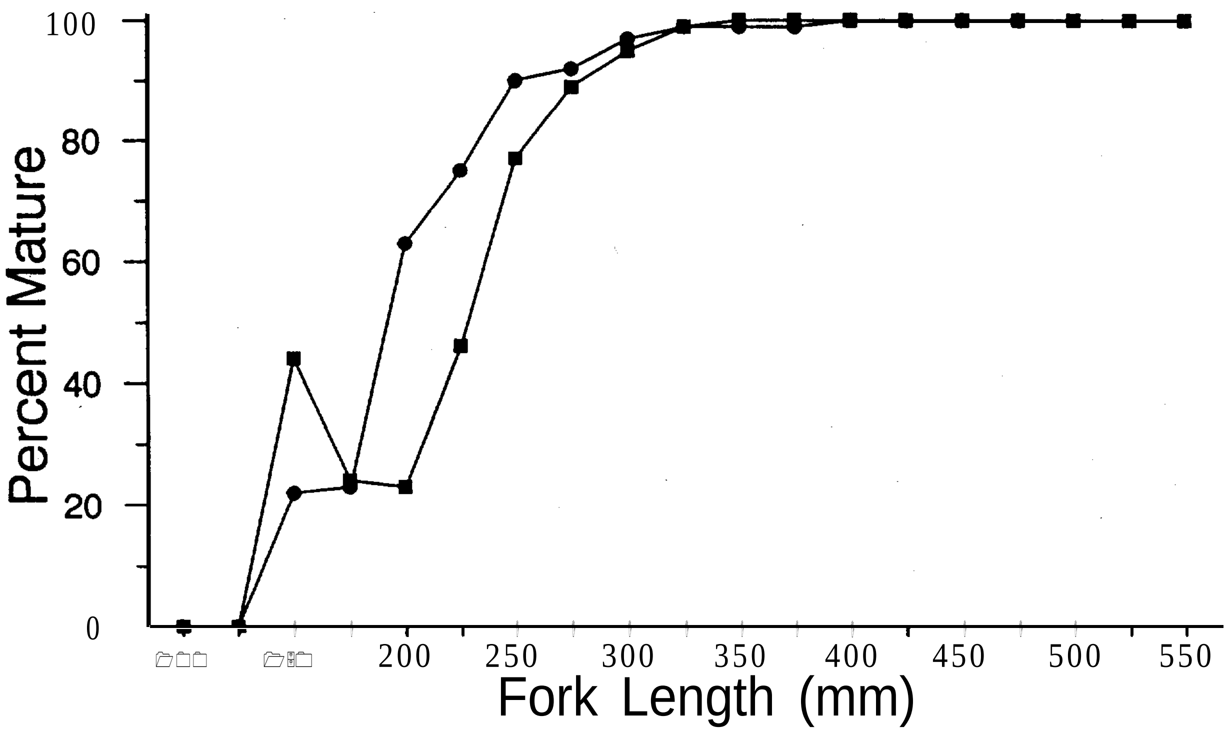

Figure 8. Percent catch found to be mature by 25-mm size classes for male (circles) and female (squares) northern squawfish sampled from all fisheries.

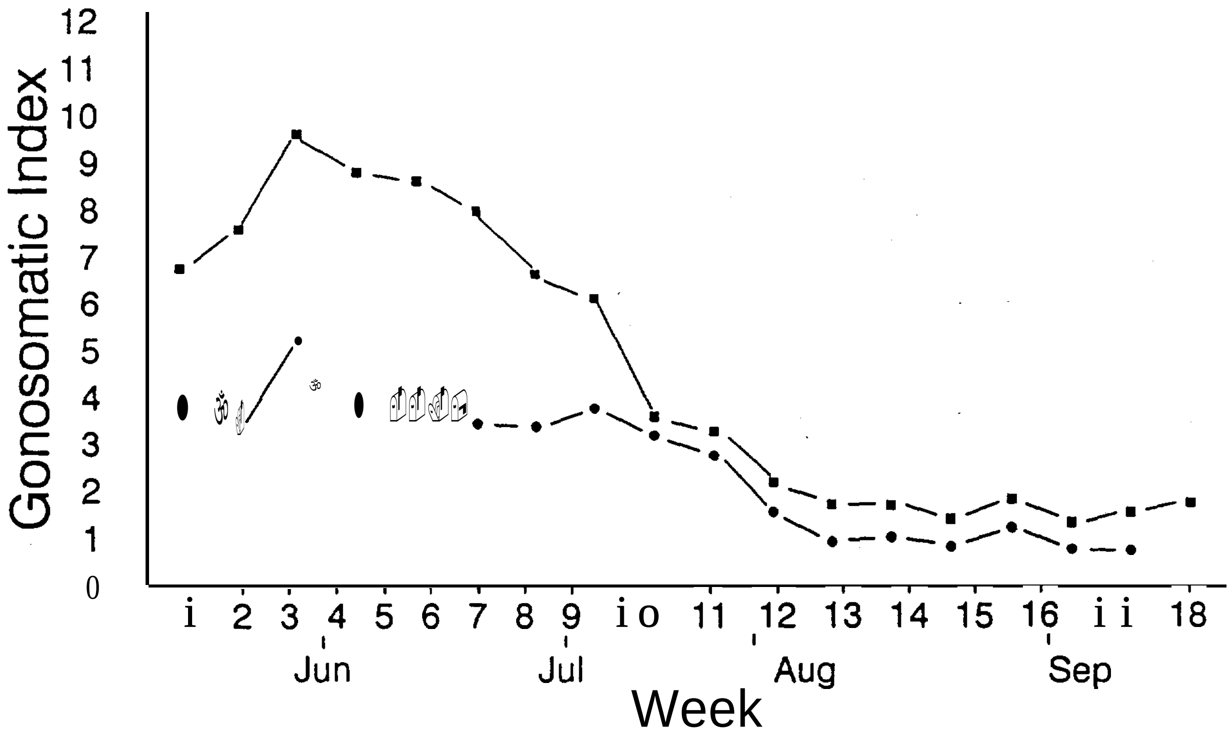

Figure 9. Weekly mean gonosomatic index (GSI) of male (circles) and female (squares) northern squawfish sampled from all fisheries.

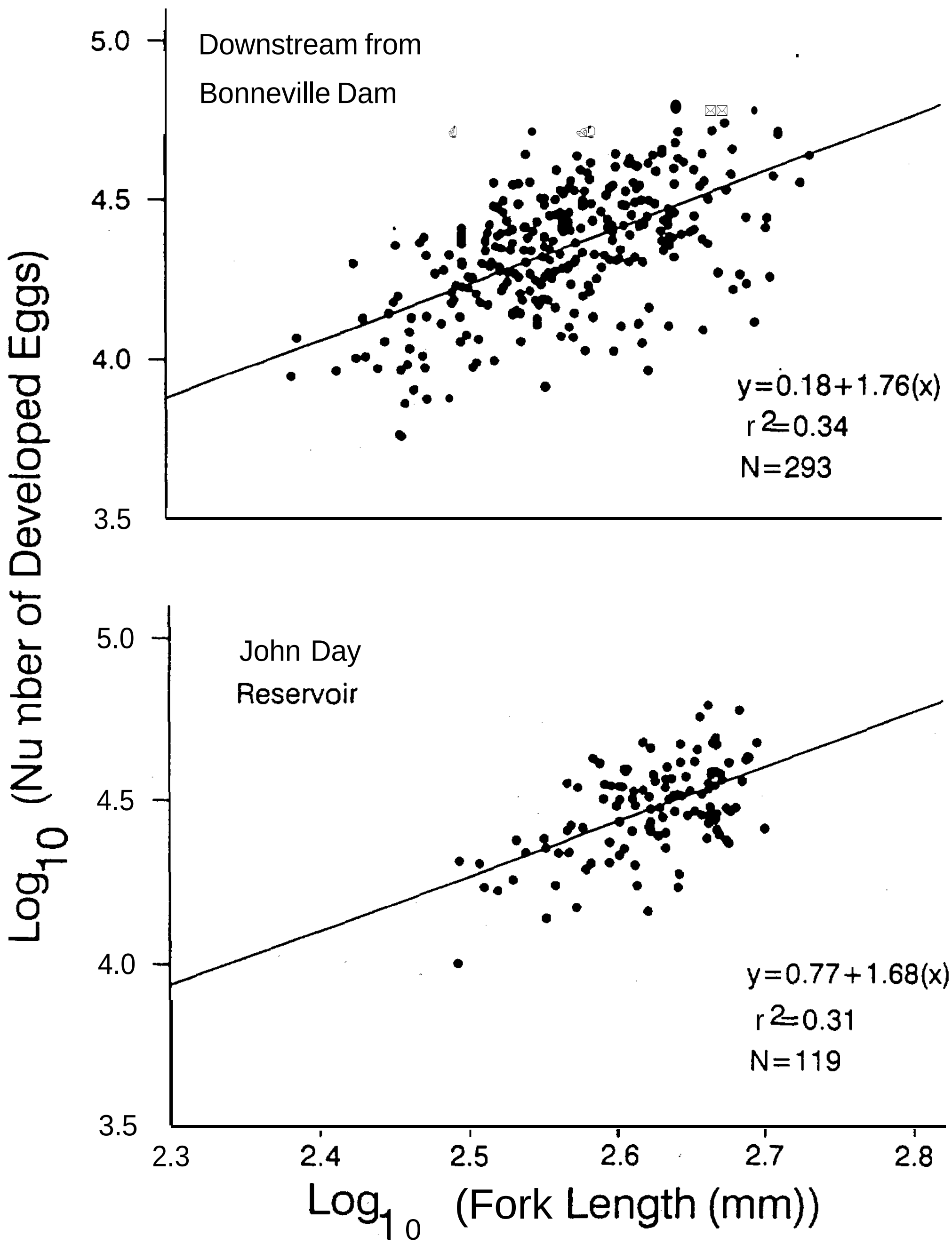

Figure 10. Relationship of fecundity to fork length for female northern squawfish in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

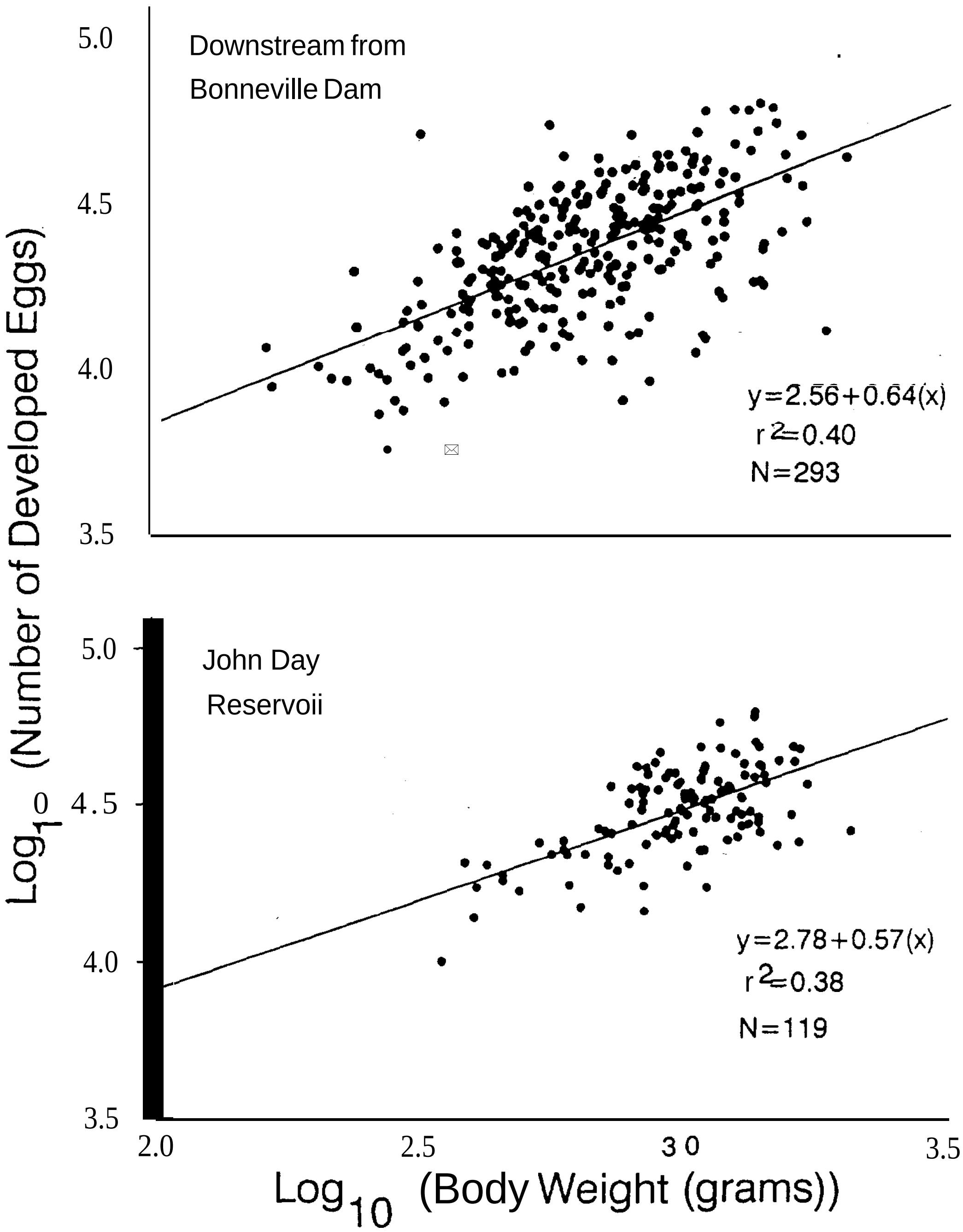

Figure 11. Relationship of fecundity to weight for female northern squawfish in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

Table 8. Mean fecundity estimates for female northern squawfish sampled from all fisheries. N = sample size.

Location	N	Developed eggs	Undeveloped eggs
Downstream from			
Bonneville Dam	293	25,097	10,831
John Day Reservoir	119	31,504	15,291

The maximum age of northern squawfish in our samples was 16 years old; age composition varied widely between locations. Many more younger fish were captured downstream from Bonneville Dam tailrace than in John Day Reservoir (Figure 12). Mean backcalculated fork lengths at age were similar between locations (Figure 13). Von Bertalanffy growth parameters were variable, but also similar between locations (see. Appendix D). Relationships between weight and fork length were also similar between locations (Figure 14).

Northern squawfish appeared fully vulnerable to our indexing gear (electrofishing, bottom gillnets, and surface gillnets combined) by age 4 downstream from Bonneville Dam tailrace and age 9 in John Day Reservoir (Figure 15). The annual mortality rate was higher in John Day Reservoir.

Cyclical variations were observed in northern squawfish year-class strength in John Day Reservoir (Figure 16). Very weak year classes occurred in 1979 and 1987. Stronger year-classes occurred in 1976 and 1984.

DISCUSSION

Results from index sampling indicate that predation on juvenile salmonids by northern squawfish occurs throughout the Columbia River downstream from Bonneville Dam tailrace, and exceeds predation in John Day Reservoir. In fact, northern squawfish predation downstream from Bonneville Dam exceeds that in any lower Columbia or Snake River impoundment (Ward et al. 1992).

Sampling to collect baseline information on predation before fisheries for northern squawfish were implemented is now complete. Sampling in 1993 will represent the first year of monitoring after removal fisheries have been sustained. We will sample to evaluate northern squawfish size structure and consumption in the same areas we sampled in 1990 (Bonneville Dam tailrace, and Bonneville, The Dalles, John Day, and McNary reservoirs). If fisheries are successful in removing large northern squawfish, we expect populations to eventually consist of a higher percentage of smaller fish. If consumption of juvenile salmonids by smaller fish does not increase, the program will have succeeded in reducing predation.

It appears that the various fisheries combined exploited 10-15 % of the northern squawfish population in the lower Columbia and Snake rivers. Sport-reward exploitation estimates depend largely upon the accuracy and willingness of sport anglers to return tags and divulge accurate catch location information. Sport-reward exploitation in some reservoirs appears to be low considering the relatively large number of northern squawfish removed. It is possible that sport anglers captured fish outside designated fishing locations and returned fish to lower Columbia and Snake River registration areas. Dam angling appears to have effectively exploited northern squawfish in reservoirs where sport-reward exploitation was low. Longlining does not appear to be an efficient method of large-scale northern squawfish removal.

In past years, we primarily marked and released fish collected by dam anglers. Although we were able to mark and release a considerable number of fish this way, estimates of exploitation in the early part of the fishery season were limited because relatively few fish were caught, marked, and released until the season was well under way. Additionally, marking fish at dams may have biased our estimates of exploitation for each fishery. To improve our exploitation estimates in 1992, we marked and released fish in all reservoir areas prior to the start of fisheries. This "pre-season" tagging appears to be a much better way to obtain accurate exploitation data. In 1993 we will again tag fish prior to the start of removal fisheries and we will attempt to increase precision by sampling throughout the lower Columbia and Snake rivers.

It appears that fish are smaller and younger downstream from Bonneville Dam than in John Day Reservoir. We also found differences in the size of northern squawfish removed among fisheries. Although all three fisheries captured large, predaceous-sized fish, dam-angling harvests had the largest mean fork length. Monthly mean fork lengths of northern squawfish harvested by the sport-reward fishery were variable and we observed no obvious decrease in fork length. However, monthly mean fork lengths of northern squawfish captured by dam angling declined in nearly all reservoirs. We will continue to monitor monthly fork length trends in 1993 to evaluate inseason effects of harvest on northern squawfish populations.

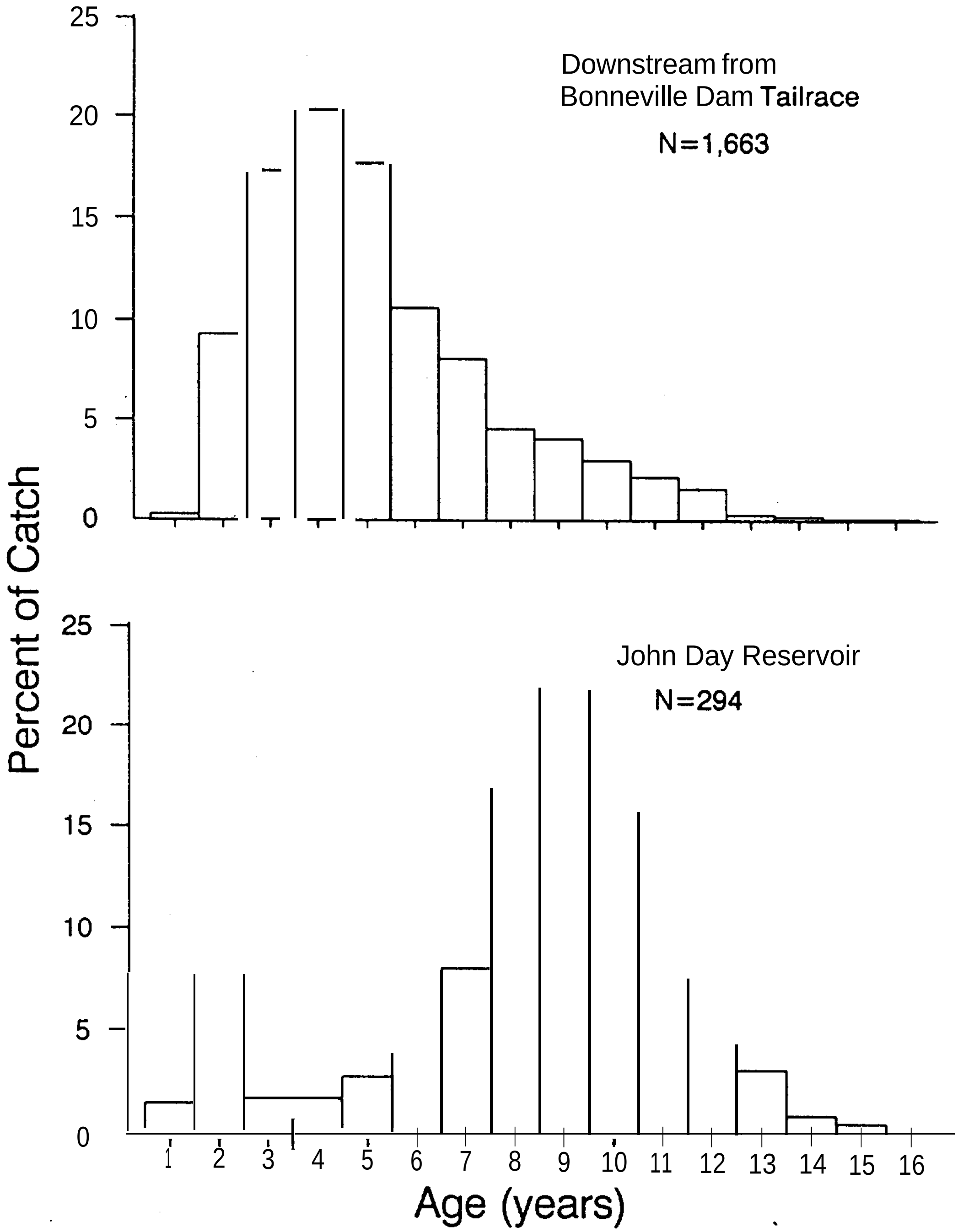

Figure 12. Age composition of northern squawfish in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

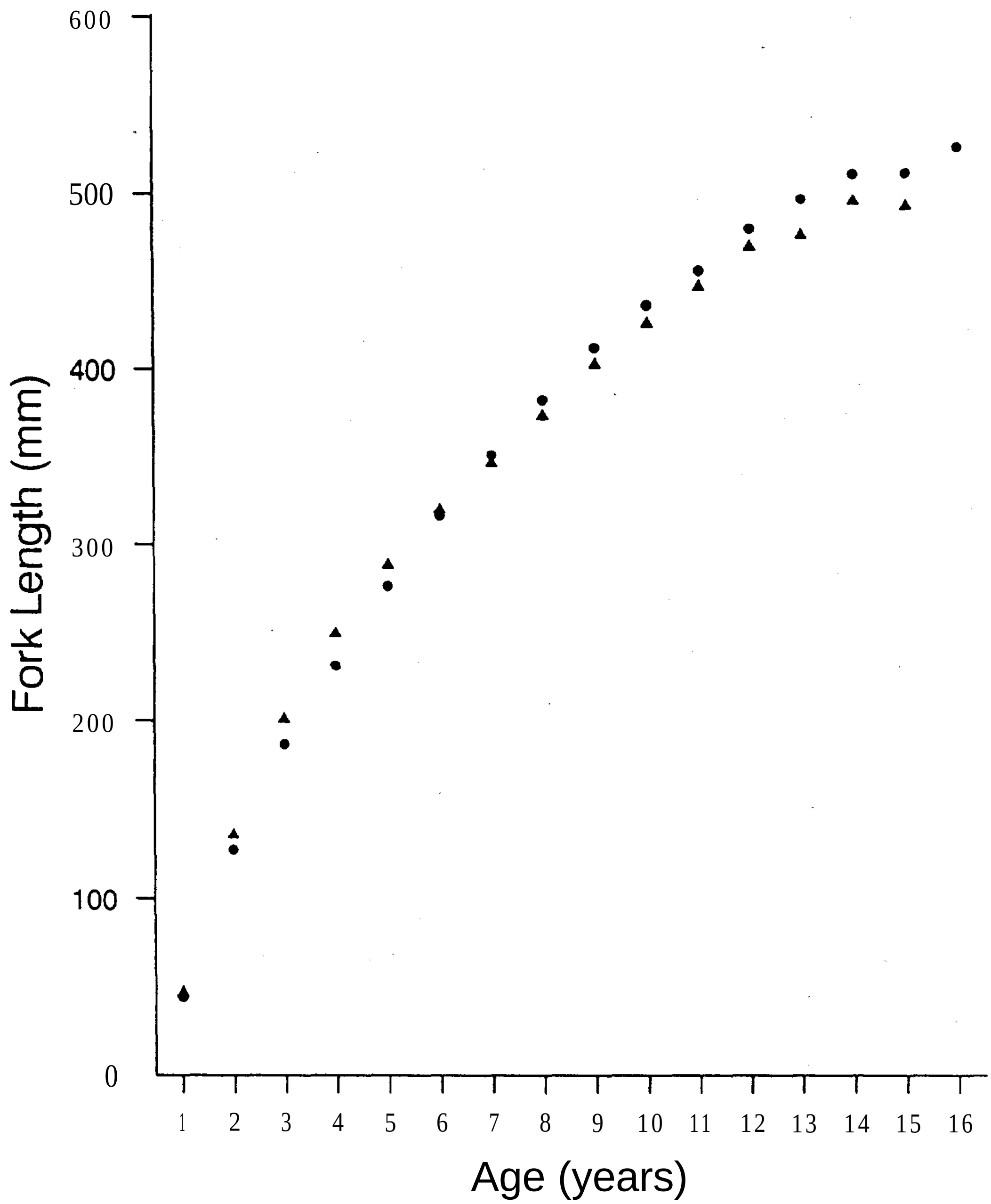

Figure 13. Backcalculated fork lengths at age for northern squawfish in the Columbia River downstream from Bonneville Dam tailrace (circles) and in John Day Reservoir (triangles).

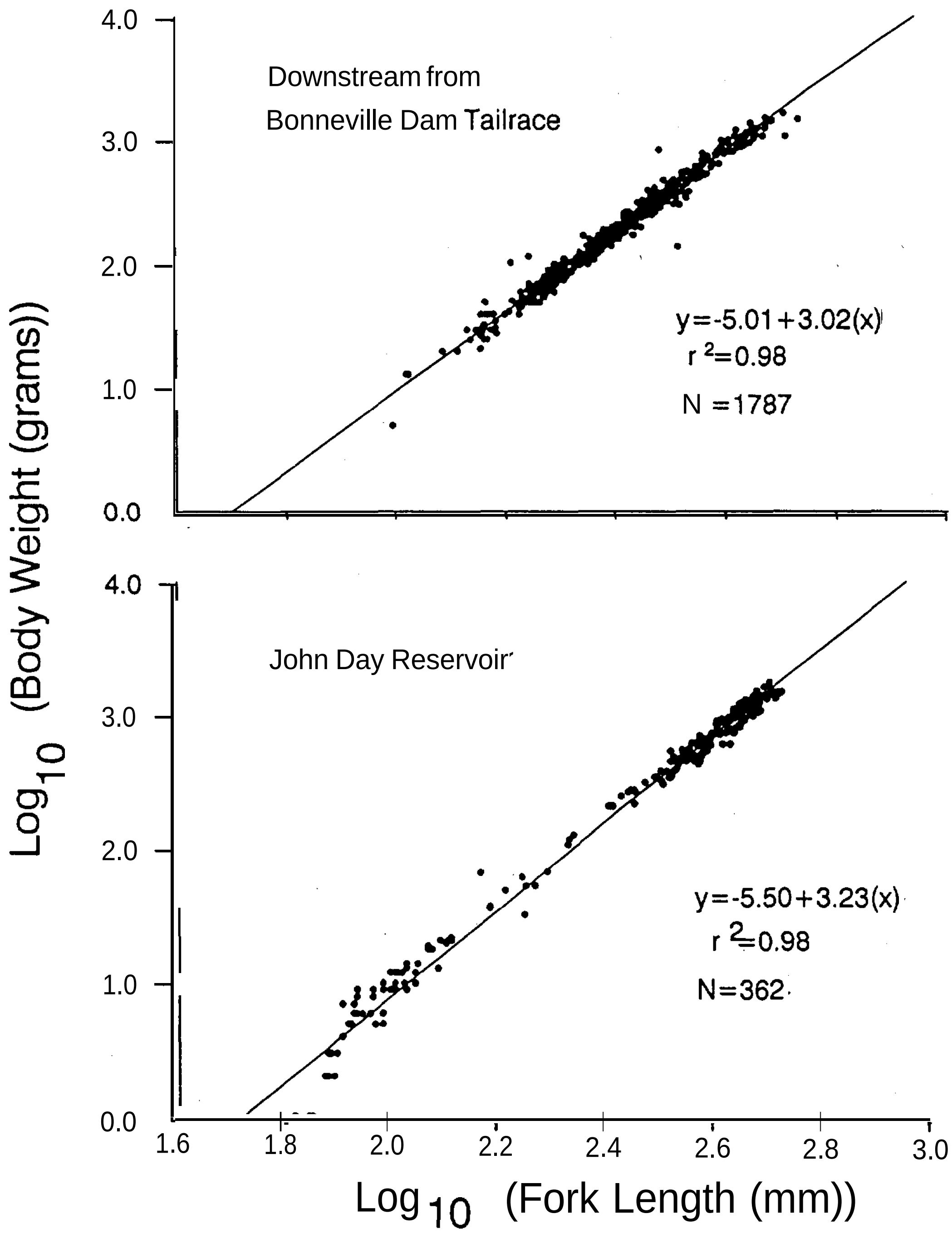

Figure 14. Relationship of weight to fork length for northern squawfish in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir.

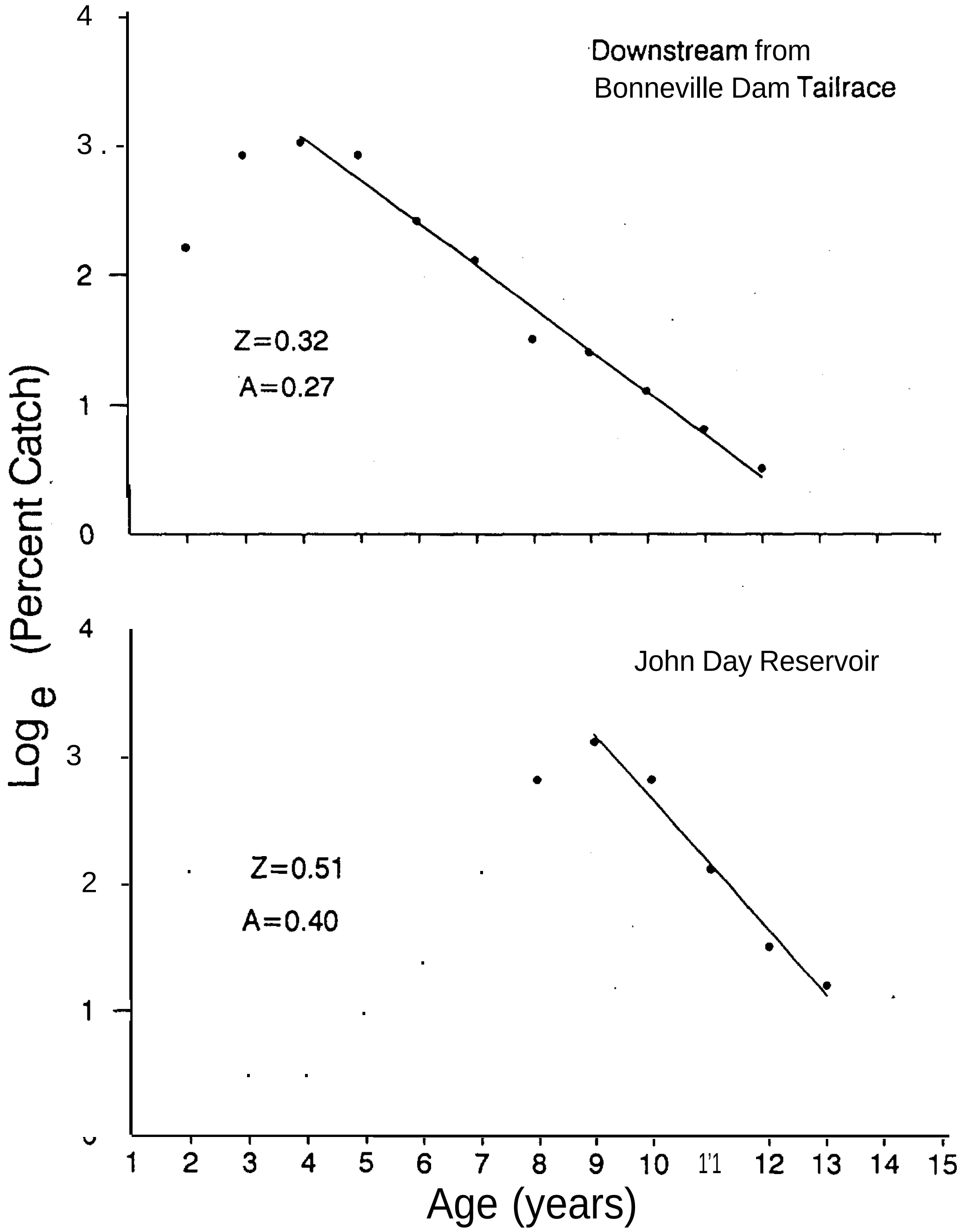

Figure 15. Catch curves for northern squawfish collected while'index sampling in the Columbia River downstream from Bonneville Dam tailrace and in John Day Reservoir. Z = total instantaneous mortality, A = annual mortality rate.

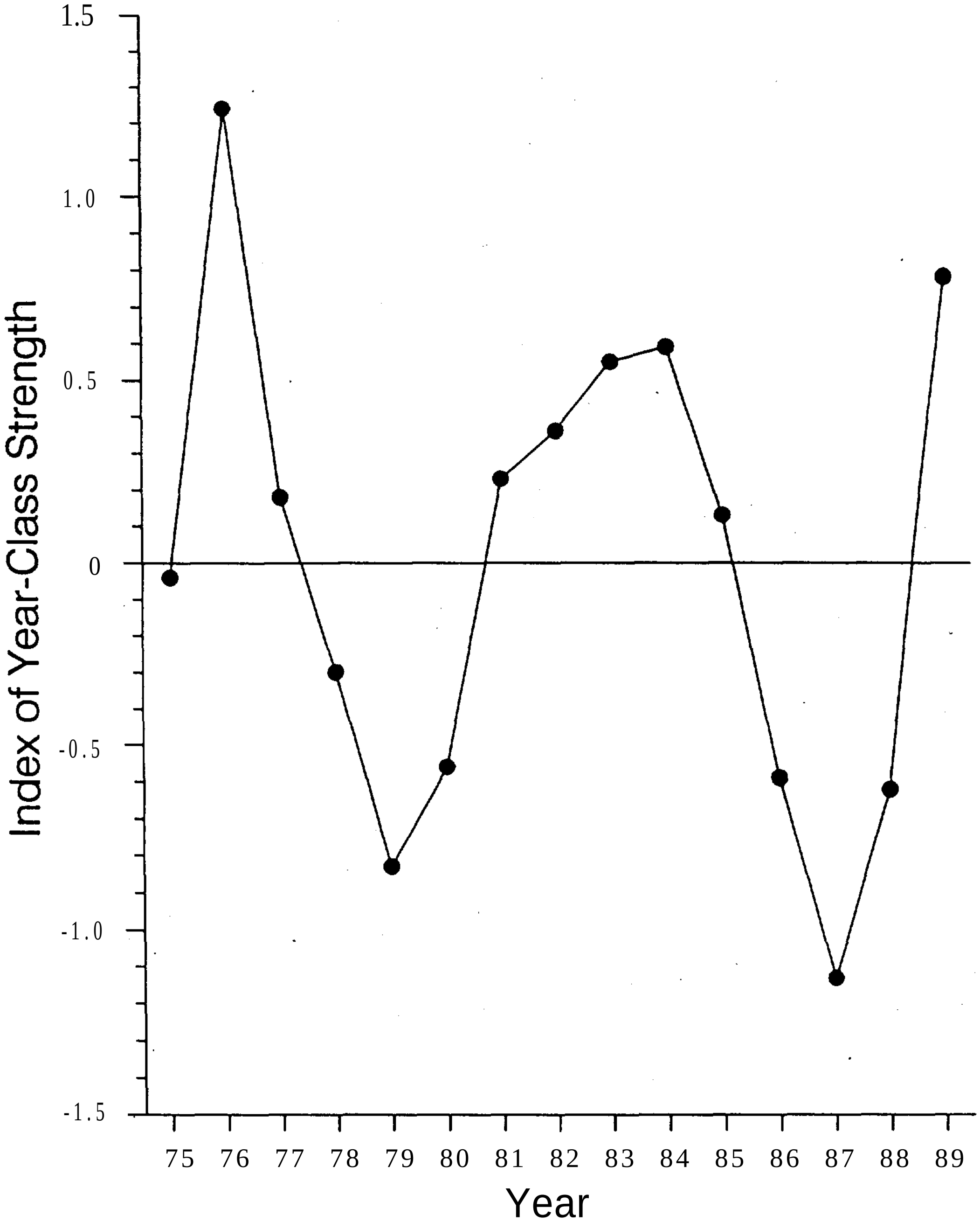

Figure 16. Index of year-class strength by year for-northern squawfish in John Day Reservoir.

Both male and female northern squawfish exhibited an increase in GSI in May. Escalation and peaking of GSI indicates reproductive preparedness if not actual spawning activity. Peak GSI values were followed by a relatively rapid decline to near resting levels in June. Spawning appears to occur over a period of eight or nine weeks from early May to late July. No evidence of a secondary spawning was indicated by our data; however, we did not sample over the entire year. GSI will continue to be monitored during 1993 to determine if changes in peak spawning activity are occurring. We will also continue to monitor sex ratio to determine if the percentage of females removed from the lower Columbia and Snake rivers changes with increased harvest.

Age, growth, mortality, and year-class strength were estimated using data obtained from northern squawfish scales, and sufficient ovary samples were collected to determine baseline fecundity information. Additional ovary and scale samples will be collected in 1993. Estimates of mortality using catch curve analysis are subject to bias associated with reading scales. The accuracy and precision of using scales to age northern squawfish has not been adequately determined. Preliminary sampling for young-of-the-year northern squawfish in 1992 indicated that placement of the first annulus is consistent with assigned backcalculated fork lengths. However, validation of aging techniques should be addressed further since scales have historically underestimated fish age (Beamish and McFarlane 1983). We will attempt to examine otoliths and identify methods of validation in 1993.

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APPENDIX A

Preliminary Evaluation of the Mechanisms Driving Response of Predator and Prey Fish Species to Sustained Northern Squawfish Fisheries in John Day Reservoir

Introduction

Subobjective 2.3 in our 1992 Statement of Work directed us to "work with the USFWS to begin detailed evaluation of the mechanisms driving response of predator and prey fish species to sustained northern squawfish fisheries in John Day Reservoir." We considered (1) response of year-class strengths for resident predator species, (2) response of northern squawfish distribution, and (3) response of prey species abundance. Our approach for each potential response was to (1) examine the adequacy of existing data to evaluate responses, (2) conduct a literature search to evaluate the feasibility of studying the mechanisms driving each response, and (3) if deemed feasible, develop an experimental design and sampling plan for future work.

Year-Class Strength

Our current data will enable us to examine year-class strength of northern squawfish and smallmouth bass. Age and growth analysis of northern squawfish has revealed that the youngest fish in our samples are 3 to 4 years of age. Year-class analysis gives us a 3 to 4 year old picture of year-class strength, which is adequate to characterize annual variation in northern squawfish year-class strength prior to predator control implementation. Although we have not yet aged smallmouth bass scale samples, we think the youngest fish in our samples will be 2 or 3 years of age, providing us with a more current picture of year-class strength. We have not collected spines from channel catfish for age and growth analysis. Catch rates of channel catfish and walleye in John Day Reservoir have been low and our sample sizes are inadequate for analysis of year class-strengths.

Although the literature on mechanisms affecting year-class strength of northern squawfish, smallmouth bass, and walleye is diverse, the effects of harvest on year-class strength have not been widely addressed. Modeling simulations on populations of northern squawfish (Rieman and Beamesderfer 1988) and smallmouth bass and walleye (Connolly and Rieman 1988) in John Day Reservoir indicated that variation in year-class strength had a marked impact on the magnitude of predation on juvenile salmonids. They concluded that any variable that affected year-class strength will influence predation. Of many variables examined, only the concurrent year-class strength of walleye was strongly correlated (negatively) with northern squawfish year-class strength (Rieman and Beamesderfer 1988). Year-class strength of smallmouth bass has been related to first year growth (Connolly and Rieman 1988), cold temperatures during spawning (Henderson and Foster 1957, Christie and

Regier 1973), and annual variation in water level (Montgomery et al. 1980). Year-class strength of walleye has been correlated with environmental variables such as flow and temperature (Machniak 1975; Fomey 1976; Huh et al. 1976; Colby et al. 1979; Toneys and Coble 1979; Connolly and Rieman 1988).

We tested the feasibility of sampling young predators in the non-restricted zone of the tailrace of John Day Reservoir during September 1992. We sampled embayments and beaches with an electrofishing boat and a beach seine for four days, two during daylight hours (9 a.m. to 7 p.m.) and two during night (7 p.m. to 1 a.m.). We compared total catch and catch per unit of effort (CPUE) of each predator, and examined length-frequency histograms to evaluate gear selectivity for small fish.

Catch rate for northern squawfish was greatest during nighttime beach seining (Appendix Table A-l). Reach seining was less effective than electrofishing for smallmouth bass, regardless of sampling time. No walleye or channel catfish were captured. Effective sampling for young walleye and channel catfish is probably limited by their relatively low abundance, and occurrence of channel catfish in habitats that are difficult to sample regardless of gear type. The 50-74 mm fork length interval comprised the largest proportion of the catch of northern squawfish (Appendix Figure A-l) and smallmouth bass (Appendix Figure A-2). A smaller peak was evident for northern squawfish at 125-149 mm. Estimated mean lengths of age 1 and age 2 northern squawfish in John Day Reservoir are 66 mm and 133 mm (Ward et al. 1992), which correspond to peaks in the length frequency histograms.

Appendix Table A-l. Catch rate (CPUE) of northern squawfish and smallmouth bass by beach seining and electrofishing during day (9 .m. to 7 p.m.) and night (7 p.m. to 1 a.m.). "n" is the number of seine hauls or 900 second electrofishing runs.

		Sampling gear			
		Beach Seine		Electrofishing	
Species	Sampling time	CPUE	(n)	CPUE	(n)
Northern squawfish	Day	0.7	(24)	4.3	(23)
	Night	18.9	(11)	6.3	(9)
Smallmouth bass	Day	1.8	(24)	9.7	(23)
	Night	2.6	(11)	19.0	(9)

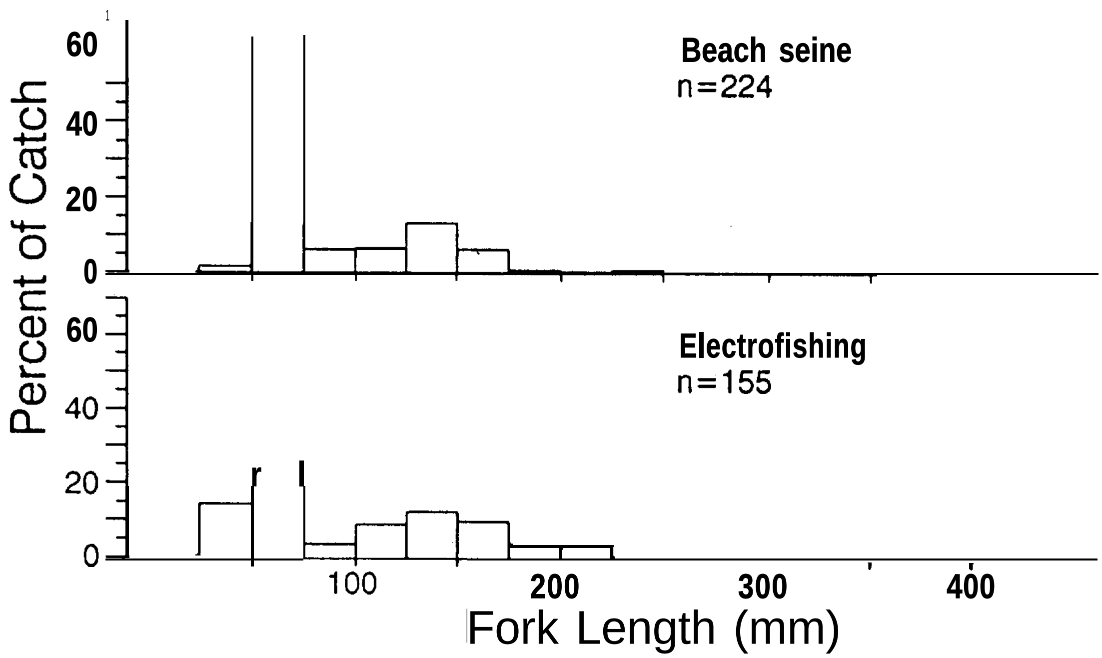
Sampling younger predators would facilitate examination of the strength of the current year class. However, we do not expect to see significant responses in year class strength to predator control until fisheries have been sustained for at least four to five years at a 10-20% exploitation rate. Additionally, it is unlikely that we could distinguish between environmental and harvest-related effects on recruitment.

Northern Squawfish Distribution

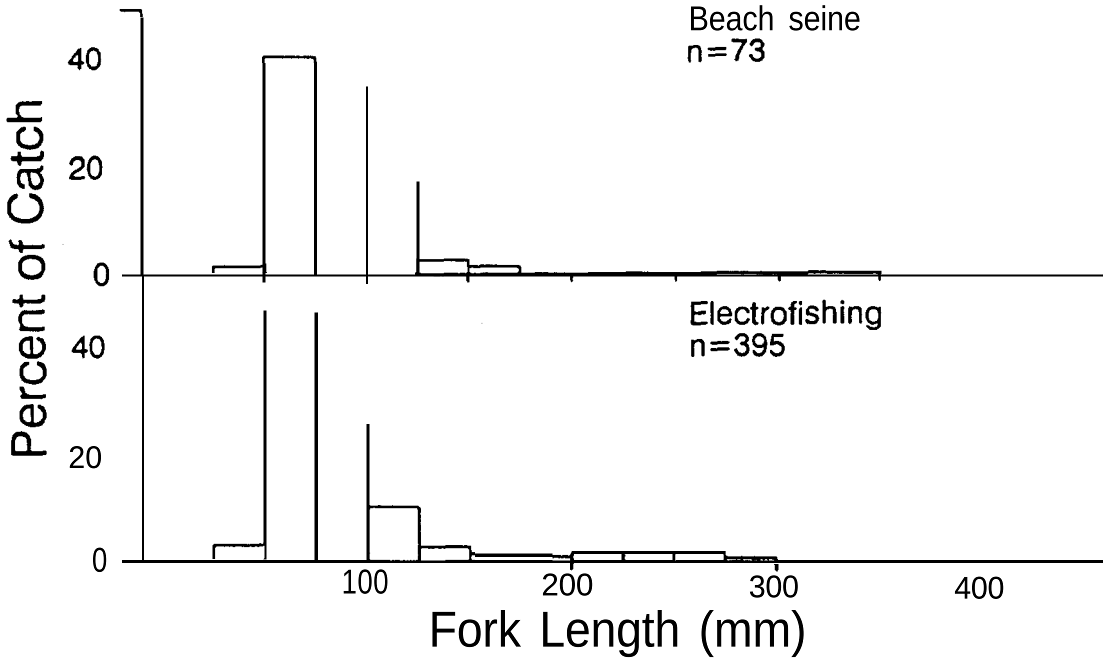
Our current data provides limited information on changes in northern squawfish distribution, although we cannot attribute changes to sustained fisheries. Dam-angling and sport-reward fishing effort has been concentrated in or near tailraces. We have examined movement of fish into and out of tailraces based on recapture locations of tagged fish. Previous research on northern squawfish movements in John Day Reservoir (Beamesderfer and Rieman 1988) supports our conclusion that fish range widely among reservoir areas. This implies that although fisheries are often concentrated near areas of easy access, all northern squawfish are potentially vulnerable to harvest. Conversely, fisheries may be exploiting localized, discrete populations within the reservoir to some extent. Reality probably lies somewhere in between these two extremes, and the question bears on the assumptions associated with our estimates of exploitation. We have addressed this uncertainty by expressing our exploitation estimates within a range that encompasses both situations, although a better understanding of northern squawfish distribution would be useful.

Uncertainties regarding northern squawfish distribution are also relevant to assumptions underlying simulated exploitation of northern squawfish in the Columbia River Ecosystem Model (Bledsoe 1990). The model assumes that northern squawfish harvested in a particular reservoir area are immediately replaced by fish from adjacent areas, maintaining an "equilibrium" density and abundance that reflects results of our abundance index sampling. In this scenario, intense fishing in one area (a "northern squawfish sink") could deplete the entire population of the reservoir.

We believe that telemetry experiments could help fill gaps in our understanding of distributional changes, although attributing changes to localized fishing pressure in a cause-effect way is unlikely. We have proposed extensive telemetry work for 1993 in conjunction with the U.S. Fish and Wildlife Service (USFWS) The USFWS will concentrate on tracking short-term movements in The Dalles and John Day Dam tailraces. We propose to examine movements throughout Bonneville and The Dalles reservoirs to (1) evaluate our assumption that northern squawfish occur mainly near shore, (2) evaluate movement among reservoir areas (forebay, midreservoir, tailrace non-restricted zone, and tailrace restricted zone) and (3) evaluate the extent of movement toward or away from areas of intensive harvest, such as the tailrace boat restricted zone. If necessary, we could simulate intense fishing by conducting short-term electrofishing removal similar to the Tanner Creek experiments conducted jointly by ODFW and USFWS in 1991 and 1992.



Appendix Figure A-l. Size composition of northern squawfish in beach seine and electrofishing samples. "n" is the total catch.



Appendix Figure A-2. Size composition of smallmouth bass in beach seine and electrofishing samples. "n" is the total catch.

Prey Species Abundance

From 1990 to 1992, we have collected data on relative abundance of non-predator species in John Day Reservoir during the course of northern squawfish abundance index sampling using electrofishing and gillnets. Although we did not effectively sample the entire fish community, we gathered data on the relative abundance of many species. Our ability to sample small individuals of most species has been limited, and some potential prey species, such as sculpins, were not sampled effectively due to gear selectivity.

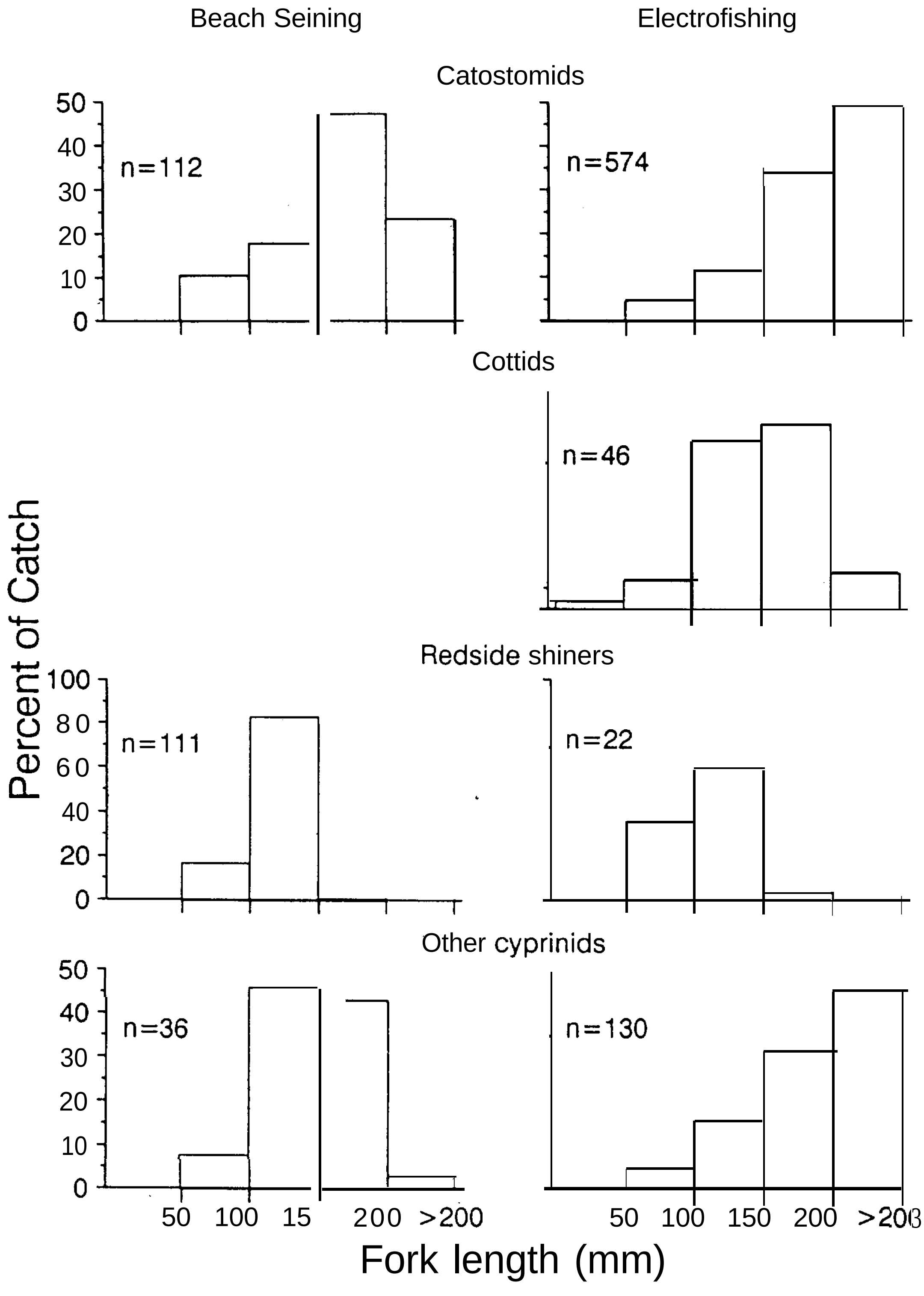
As part of our September beach seining feasibility test (see "Year-Class Strength"), we identified, counted, and measured (50-mm fork length intervals) all fish. We calculated catch rates from pooled day and night samples, and examined size composition of potential prey species to evaluate gear effectiveness. Important prey groups include catostomids, cottids, cyprinids, and percopsids, which together comprised 80-97% by weight of the non-salmonid component in the diets of resident predators in John Day Reservoir (Poe et al. 1988). Among predator species, only northern squawfish consume significant numbers of juvenile American shad when they become available in August. Nevertheless, American shad have increased in abundance since the mid-1980s. Their seasonal importance to predators may have grown as well.

Electrofishing catch rates were greater than beach seine catch rates for all taxa except northern squawfish and redside shiner (Appendix Table A-2). Catch rates were highest for juvenile American shad for both gears. Among other potential prey taxa, largescale sucker, northern squawfish, chiselmouth, carp, and redside shiner were effectively sampled by a combination of both gears. Catch rate of goldfish, peamouth, bridgelip sucker, sand roller, and cottids were very low for both gears. Size composition of catostomids, redside shiners, cyprinids (chiselmouth and peamouth), and cottids are summarized in Appendix Figure A-3. Reach seining captured a larger proportion of small (< 200 mm) catostomids, although beach seine catch rates were much lower than electrofishing. Electrofishing and beach seining were equally selective for 50-150 mm redside shiners. Among cyprinids, small (< 200 mm) peamouth and chiselmouth were more effectively sampled by beach seining. However, the total catch by electrofishing was much greater than in seine hauls. Carp and goldfish were not included because 96% were greater than 200 mm. Most northern squawfish were less than 100 mm (see Appendix Figure A-l in "Year-Class Strength"). A wide size range of cottids was sampled with electrofishing, although the total catch was very low. Too few cottids were captured in seine hauls to be included in Appendix Figure A-3.

Extensive sampling of prey species would provide information on the relative abundance of some prey species; however, obtaining adequate and representative samples demands considerable sampling effort. Using only electrofishing and beach seines, cottids, sandrollers, and small peamouth, bridgelip suckers, and carp may be poorly represented in samples. Additional gears would be required to effectively sample all prey species of appropriate sizes. Staffing and sampling requirements associated with research of this scope are prohibitive, given our present tasks associated with biological evaluation of the predator control program.

Appendix Table A-2. Mean CPUE of various species by beach seining and electrofishing. Effort was 35 seine hauls and 32 electrofishing runs.

	Mean CPUE	
Common name, scientific name	Beach seine	Electrofishing
American shad, Alosa sapidissima	99.7	106.9
Mountain whitefish, Prosopium williamsoni	0.2	0.5
Carp, Cyprinis carpio	--	5.4
Goldfish, Carassius auratus	--	0.8
Peamouth, Mylocheilus caurinus	0.3	0.6
Northern squawfish, Ptychocheilus oregonensis	6.4	4.8
Chiselmouth, Acrocheilus alutaceus	0.8	3.4
Redside shiner, Richardsonius balteatus	3.2	0.7
Bridgelip sucker, Catostomus columbianus	0.1	0.1
Largescale sucker, Catostomus macrocheilus	3.1	17.8
Brown bullhead, Ictalurus nebulosus	--	0.1
Sand roller, Columbia transmontana	0.1	--
Threespine stickleback, Gasterosteus aculeatus	co.1	--
Sculpin spp., Cottidae	0.1	1.4
Pumpkinseed, Lepomis gibbosus	0.2	0.9
Bluegill, Lepomis macrochirus	1.0	1.7
Black crappie, Pomoxis nigromaculatus	0.1	0.2
White crappie, Pomoxis annularis	co.1	0.1
Smallmouth bass, Micropterus dolomieui	2.1	12.3
Largemouth bass, Micropterus salmoides	1.7	12.9
Yellow perch, Perca flavescens	2.8	10.5



Appendix Figure A-3. Size composition of catostomids, redside shiners, other cyprinids (chiselmouth and peamouth), and cottids in beach seine and electrofishing samples. "n" is the total catch.

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APPENDIX B

Estimates of Exploitation Assuming Complete Mixing of Marked and Unmarked Fish and Random Allocation of Fishing Effort

T is the number of fish marked, M is the number of marked fish at large, LL is commercial longline, and Misc. are marked fish recaptured outside predator control fisheries or in other areas. P is time period. Dates for each period are as follows.

Period	Dates
1	before April 19
2	April 19 - April 25
3	April 26 - May 2
4	May 3 - May 9
5	May 10 - May 16
6	May 17 - May 23
7	May 24 - May 30
8	May 31 - June 6
9	June 7 - June 13
10	June 14 - June 20
11	June 21 - June 27
12	June 28 - July 4
13	July 5 - July 11
14	July 12 - July 18
15	July 19 - July 25
16	July 26 - August 1
17	August 2 - August 8
18	August 9 - August 15
19	August 16 - August 22
20	August 23 - August 29
21	August 30 - September 5
22	September 6 - September 12
23	September 13 - September 19
24	September 20 - September 26
25	September 27 - October 3

Appendix Table B-l. Exploitation of northern **squawfish** downstream from Bonneville Dam.

P	T	Recaptures				M	Exploitation		
		Sport	Dam	LL	Misc.		Sport	Dam	LL
1	590	--	--	--	3	--	--	--	
2	209	--	--	--	--	587	--	--	
3	290	--	--	--	--	796	--	--	--
4	135	--	--	--	5	1,086	--	--	--
5	211	--	--	--	1	1,216	--	--	--
6	250	20	--	--	2	1,426	0.0140	--	
7	180	20	--	--	1	1,654	0.0121		--
8	--	24	--	1	4	1,813	0.0132	--	0.0006
9	--	22	--	--	2	1,784	0.0123	--	--
10	--	26	--	1	11	1,760	0.0148	--	0.0006
11	--	18	3	--	2	1,722	0.0105	0.0017	
12	--	11	--	--	4	1,702	0.0065	--	--
13	--	12	--	--	1	1,687	0.0071	--	--
14	--	8	--	--	1	1,674	0.0048	--	
15	--	9	1	--	4	1,665	0.0054	0.0006	
16	--	3	--	--	1	1,651	0.0018		
17	--	3	--	--	1	1,647	0.0018		
18	--	2	--	--	3	1,643	0.0012	--	--
19	--	1	--	--	--	1,638	0.0006	--	--
20	--	2	--	--	--	1,637	0.0012	--	--
21	--	1	--	--	1	1,635	0.0006	--	
22	--	1	--	--	--	1,633	0.0006	--	
23	--	1	--	--	--	1,632	0.0006	--	--
24	--	1	--	--	--	1,631	0.0006		--
25	--	--	--	--	--	1,630	--		
Total	1,865	185	4	2	--	--	0.1097	0.0023	0.0012
Adjusted for tag loss							0.1149	0.0024	0.0013

Appendix Table B-2. Exploitation of northern squawfish in Bonneville Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	419			1	--		--
2	--	--	--	--	418	--	
3	--	--	--		418		
4	--	--	--		418		--
5	--	--	3	--	418		0.0072
6	--	1	2	1	415	0.0024	0.0048
7	122	4		2	527	0.0076	--
8	--	4	1	3	521	0.0077	0.0019
9	--	5	2	4.	513	0.0097	0.0039
10	--	2	3	5	502	0.0040	0.0060
11		--	--	7	492	--	
12	--		4	5	485	--	0.0082
13	--	3	--	1	476	0.0063	--
14	--	2	1	1	472	0.0042	0.0021
15	--	1	--	--	468	0.0021	
16	--	2		2	467	0.0043	--
17	--	1	--	--	463	0.0022	--
18	--	--	1	1	462	--	0.0022
19	--	1	--	--	460	0.0022	--
20	--	1	1	1	459	0.0022	0.0022
21			--		456		
22		--		--	456		
23	--	--		--	4 5 6		--
24	--	--		--	456		
25	--			--	456		--
Total	541	27	18	6	--	0.0549	0.0385
Adjusted for tag loss						0.0575	0.0403

Appendix Table B-3. Exploitation of northern squawfish in The Dalles Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	157	--	--	--	--	--	--
2	28	--	--	--	157	--	--
3	--	--	--	2	185	--	--
4	--	--	--	--	183	--	--
5	--	--	--	--	183	--	--
6	--	2	--	--	183	0.0109	--
7	--	2	--	--	181	0.0110	--
8	--	--	1	--	179	--	0.0056
9	--	2	--	--	178	0.0112	--
10	--	2	--	--	176	0.0114	--
11	--	1	1	--	174	0.0057	0.0057
12	--	1	--	--	172	0.0058	--
13	--	--	--	--	171	--	--
14	--	--	--	--	171	--	--
15	--	1	--	--	171	0.0058	--
16	--	--	--	--	170	--	--
17	--	--	--	--	170	--	--
18	--	--	--	--	170	--	--
19	--	--	--	--	170	--	--
20	--	1	--	--	170	0.0059	--
21	--	1	--	--	169	0.0059	--
22	--	--	--	--	168	--	--
23	--	--	--	--	168	--	--
24	--	--	--	--	168	--	--
25	--	--	--	--	168	--	--
Total	185	13	2	--	--	0.0736	0.0113
Adjusted for tag loss						0.0771	0.0118

Appendix Table B-4. Exploitation of northern squawfish in John Day Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	129	--	--	--	--	--	--
2	--	--	--	--	129	--	--
3	--	--	--	--	129	--	--
4	--	--	--	1	129	--	--
5	130	--	--	--	128	--	--
6	--	--	--	--	258	--	--
7	--	4	--	--	258	0.0155	--
8	--	1	3	‘1	254	0.0039	0.0118
9	--	--	1	--	249	--	0.0040
10	--	1	1	--	248	0.0040	0.0040
11	--	1	2	--	246	0.0041	0.0081
12	--	2	6	2	243	0.0082	0.0247
13	--	1	2	--	233	0.0043	0.0086
14	--	--	9	1	230	--	0.0391
15	--	--	2	--	220	--	0.0091
16	--	--	3	--	218	--	0.0138
17	--	--	1	--	215	--	0.0047
18	--	--	--	--	214	--	--
19	--	--	--	--	214	--	--
20	--	--	--	--	214	--	--
21	--	--	--	4	214	--	--
22	--	--	--	--	210	--	--
23	--	--	--	--	210	--	--
24	--	--	--	--	210	--	--
25	--	--	--	--	210	--	--
Total	259	10	30	--	--	0.0400	0.1279
Adjusted for tag loss						0.0419	0.1340

Appendix Table B-5. Exploitation of northern squawfish in McNary Reservoir.

		Recaptures				Exploitation	
P	T	'Sport	Dam	Misc.	M	Sport	Dam
1	34	--	--	--	--	--	--
2	--	--	--	--	34	--	--
3	--	--	--	--	34	--	--
4	--	--	--		34		--
5	73	--		1	34		
6	--	--	--	--	106	--	--
7	--	1	--	--	106	0.0094	--
8	--	--			105	--	--
9	--	--	--	1	105		
10	--	1	--		104	0.0096	
11	--	--	--	--	103	--	--
12	--	--	--	--	103	--	--
13	--	2	--	--	103	0.0194	--
14	--	1			101	0.0099	--
15	--	--			100		
16.	--	--	--	--	100	--	--
17	--	--	--	--	100	--	--
18	--	1	--	--	100	0.0100	--
19	--	--			99		--
20	--	--			99		
21	--	--	--	--	99	--	--
22	--	--	--	--	99	--	--
23	--	--			99	--	--
24	--	1			99	0.0101	
25	--	--			98	--	
Total	107	7	0		--	0.0684	0.0000
Adjusted for tag loss						0.0717	0.0000

Appendix Table B-6. Exploitation of northern squawfish in Ice Harbor Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	7	--	--	--	--	--	--
2	--	--	--	--	7	--	--
3	--	--	--	--	7	--	--
4	--	--	--	--	7	--	--
5	--	--	--	--	7	--	--
6	--	--	--	--	7	--	--
7	--	--	--	--	7	--	--
8	--	--	--	--	7	--	--
9	--	--	--	--	7	--	--
10	--	--	--	--	7	--	--
11	--	--	--	--	7	--	--
12	--	--	--	--	7	--	--
13	--	--	--	--	7	--	--
14	--	--	--	--	7	--	--
15	--	--	--	--	7	--	--
16	--	--	--	--	7	--	--
17	--	--	--	--	.7	--	--
18	--	--	--	--	7	--	--
19	--	--	--	--	7	--	--
20	--	--	--	--	7	--	--
21	--	--	--	--	7	--	--
22	--	--	--	--	7	--	--
23	--	--	--	--	7	--	--
24	--	--	--	--	7	--	--
25	--	--	--	--	7	--	--
Total	7	0	0	--	--	0.0000	0'. 0000

Appendix Table B-7. Exploitation of northern squawfish in Lower Monumental Reservoir.

P	T	Recaptures: Sport	Recaptures: Dam	Recaptures: Misc.	M	Exploitation: Sport	Exploitation: Dam
1	93	--	--	--	--	--	--
2	--	--	--	--	93		--
3	--	--	3	--	93		0.0323
4	121	--	1		90	--	0.0111
5	--	--	--	--	210	--	--
6	--	--	--	--	210	--	--
7	--	3	1	--	210	0.0143	0.0048
	--	--	1	--	206	--	0.0049
E	--	1	--	--	205	0.0049	--
10	--	--	--	2	204	--	--
11	--	1	--	--	202	0.0050	
12	--	--	--	--	201		--
13	--	--	--	--	201	--	--
14	--	--	1	--	201	--	0.0050
15	--	--	--	--	200	--	--
16	--	--	1	--	200	--	0.0050
17	--	--	1	1	199	--	0.0050
18	--	--	1	--	197	--	0.0051
19	--	--	--	--	196	--	--
20	--	--	1	--	196	--	0.0051
21	--	--	--	--	195	--	--
22	--	--	1	--	195	--	0.0051
23	--	--	--	--	194	--	--
24	--				194	--	--
25	--	--	--	--	194	--	--
Total	214	5	12			0.0242	0.0834
Adjusted for tag loss						0.0254	0.0874

Appendix Table B-8. Exploitation of northern squawfish in Little Goose Reservoir.

		Recaptures				Exploitation	
P	T	Sport	D a m	Misc.	M	Sport	Dam
1	48	--	--	--	--	--	--
2	315	--	--	--	4a	--	--
3	176	--	--	--	363	--	--
4	--	--	3	--	539	--	0.0056
5	--	--	1	--	536	--	0.0019
6	--	1	--	1	535	0.0019	--
7	--	4	11	1	533	0.0075	0.0206
a	--	3	3	2	517	0.0058	0.0058
9	--	11	4	--	509	0.0216	0.0079
10	--	10	2	3	494	0.0203	0.0041
11	--	3	--	1	479	0.0063	--
12	--	2	--	--	475	0.0042	--
13	--	2	1	--	473	0.0042	0.0021
14	--	2	6	1	470	0.0043	0.0128
15	--	1	--	--	461	0.0022	--
16	--	4	--	--	460	0.0087	--
17	--	4	--	--	456	0.0088	--
la	--	5	--	1	452	0.0111	--
19	--	4	2	--	446	0.0090	0.0045
20	--	1	1	--	440	0.0023	0.0023
21	--	2	--	--	438	0.0046	--
22	--	2	--	--	436	0.0046	--
23	--	2	--	--	434	0.0046	--
24	--	1	--	--	432	0.0023	--
25	--	--	--	--	431	--	--
Total	539	65	34	--	--	0.1343	0.0676
Adjusted for tag loss						0.1407	0.0708

Appendix Table B-9. Exploitation of northern squawfish in Lower Granite Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	120	--	--	--	--	--	--
2	--	--	--	--	120	--	--
3	--	--		--	120	--	--
4	--			--	120	--	--
5	--		--	--	120	--	--
6	--	2	--	--	120	0.0167	
7	--	--	--	--	118	--	
8	--	2		--	118	0.0169	--
9	--			--	116	--	--
10	--	4	--	--	116	0.0345	--
11	--	2	--	--	112	0.0179	
12	--	--	--	--	110	--	--
13	--	1		--	110	0.0091	--
14	--	2		--	109	0.0183	--
15	--			--	107	--	--
16	--	1	--	--	107	0.0093	--
17	--	2	--	--	106	0.0189	--
18	--	1	--	--	104	0.0096	--
19	--		--	--	103	--	--
20	--	--		--	103	--	--
21.	--	2		--	103	0.0194	--
22	--	--		--	101	--	--
23	--	--		--	101	--	--
24	--			--	101	--	--
25	--	1	--	--	101	0.0099	--
Total	120	20	0	--	--	0.1805	0.0000
Adjusted for tag loss						0.1891	0.0000

Appendix Table B-10. Exploitation of northern sguawfish systemwide.

		Recaptures					Exploitation		
P	T	Sport	Dam	LL	Misc.	M	Sport	Dam	LL
1	1,597	--	--	--	4	--	--	--	
2	552	--	--	--	--	1,593	--	--	
3	466	--	3	--	2	2,145	--	0.0014	--
4	256	--	4	--	6	2,606	--	0.0015	--
5	414	--	4	--	2	2,852	--	0.0014	--
6	250	27	3	--	1	3,260	0.0083	0.0009	--
7	302	43	12	--	--	3,479	0.0124	0.0034	--
8	--	39	10	1	6	3,726	0.0105	0.0027	0.0003
9	--	46	7	--	2	3,670	0.0125	0.0019	--
10	--	54	7	1	12	3,615	0.0149	0.0019	0.0003
11	--	32	4	--	4	3,541	0.0090	0.0011	--
12	--	21	10	--	6	3,501	0.0060	0.0028	
13	--	23	3	--	1	3,464	0.0066	0.0009	--
14	--	16	18	--	2	3,437	0.0047	0.0052	--
15	--	12	3	--	4	3,401	0.0035	0.0009	--
16	--	11	5	--	1	3,382	0.0033	0.0015	
17	--	10	2	--	2	3,365	0.0030	0.0006	--
18	--	9	3	--	3	3,351	0.0027	0.0009	--
19	--	9	2	--	--	3,336	0.0027	0.0006	--
20	--	5	3	--	--	3,325	0.0015	0.0009	--
21	--	6	--	--	5	3,317	0.0018	--	
22	--	3	1	--	--	3,306	0.0009	0.0003	--
23	--	3	--	--	--	3,302	0.0009	--	--
24	--	3	--	--	--	3,299	0.0009	--	--
25	--	1	--	--	--	3,396	0.0006	--	--
Total	3,837	373	104	2	--	--	0.1067	0.0308	0.0006
Adjusted for tag loss							0.1118	0.0323	0.0006

APPENDIX C

Estimates of Exploitation Assuming no Mixing of Fish Outside Areas They were Marked, and Fisheries Effort Limited to Areas Where Fiih Were Marked

Abbreviations and time periods are as described in Appendix B.

Appendix Table C-l. Exploitation of northern squawfish in Bonneville Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	1,160	--	--	1	--	--	--
2	--	--	--	--	1,159	--	--
3	--	--	--		1,159		--
4	--	--			1,159	--	--
5	--		3	--	1,159		0.0026
6	--	1	2	1	1,156	0.0009	0.0017
7	122	4	--	2	1,152	0.0035	--
8	--	4	1	3	1,268	0.0032	0.0008
9		5	2	4	1,260	0.0040	0.0016
10		2	3	5	1,249	0.0016	0.0024
11	--	--	--	7	1,239	--	--
12	--	--	4	5	1,232	--	0.0032
13	--	3	--	1	1,223	0.0025	--
14	--	2	1	1	1,219	0.0016	0.0008
15	--	1		--	1,215	0.0008	--
16	--	2	--	2	1,214	0.0016	--
17	--	1	--	--	1,210	0.0008	--
18	--	--	1	1	1,209	--	0.0008
19	--	1	--		1,207	0.0008	--
20	--	1	1	1	1,206	0.0008	0.0008
21	--	--	--	--	1,203	--	--
22	--	--	--		1,203	--	--
23	--	--	--	--	1,203	--	--
24	--	--	--	--	1,203		--
25	--	--	--		1,203		--
Total	1,282	27	18	--	--	0.0221	0.0147
Adjusted for tag loss						0.0232	0.0154

Appendix Table C-2. Exploitation of northern squawfish in The Dalles Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	232	--	--	--	--		
2	58		--	--	232		
3	--	--	--	2	290	--	--
4	--	--	--	- -	288	--	--
5	--	--	--		288		
6		2	--	--	288	0.0069	
7		2	--	--	286	0.0070	
8	--	- -	1	--	284	- -	0.0035
9	--	2	--	--	283	0.0071	--
10	--	2	--	--	281	0.0071	
11	--	1	1	--	279	0.0036	0.0036
12	--	1	--	--	277	0.0036	--
13	--	--	--	--	276	- -	--
14	--	--	--	--	276	- -	
15		1	--		276	0.0036	
16		--	--	--	275	--	--
17	--	--	--	--	275	--	--
18.	--	--	--	--	275	--	--
19	--	--	--	--	275	--	--
20		1			275	0.0036	
21	--	1			274	0.0036	
22		--	--	--	273	--	--
23	--	--	--	--	273	--	--
24	--	--	--	--	273	--	--
25	--	--			273		
Total	290	13	2		--	0.0461	0.0071
Adjusted for tag loss						0.0483	0.0074

Appendix Table C-3. Exploitation of northern squawfish in John Day Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	271	--		--	--		
2			--	--	271		
3			--	--	271		
4	--		--	1	271	--	
5	130	--	--	--	270		--
6	--		--		400	--	--
7		4	--	--	400	0.0100	--
a		1	3	1	396	0.0025	0.0076
9	--	--	1	--	391	--	0.0026
10	--	1	1	--	390	0.0026	0.0026
11	--	1	2	--	388	0.0026	0.0052
12		2	6	2	385	0.0052	0.0156
13		1	2	--	375	0.0027	0.0053
14	--	--	9	1	372	--	0.0242
15	--	--	2	--	362	--	0.0055
16	--	--	3	--	360	--	0.0083
17			1	--	357	--	0.0028
l a		--		--	356	--	--
19	--	--	--	--	356	--	--
20	--	--	--	--	356	--	--
21	--		--	4	356		
22	--		--	--	352	--	
23		--	--		352	--	
24	--	--	--	--	352	--	--
25	--	--	--	--	352	--	--
Total	401	10	30	--	--	0.0256	0.0797
Adjusted for tag loss						0.0268	0.0835

Appendix Table C-4. Exploitation of northern squawfish in McNary Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	116	--	--	--	--	--	--
2	--	--	--	--	116	--	--
3	--	--	--	--	116	--	--
4	--	--	--	--	116	--	--
5	73	--	--	1	116	--	--
6	--	--	--	--	188	--	--
7	--	1	- -	--	188	0.0053	--
8	--	--	--	--	187	--	--
9	--	--	--	1	187	--	--
10	--	1	--	--	186	0.0054	--
11	--	--	--	--	185	--	--
12	--	--	--	--	185	--	--
13	--	2	--	--	185	0.0108	--
14	--	1	--	--	183	0.0055	--
15	--	--	--	--	182	--	--
16	--	--	--	--	182	--	--
17	--	--	--	--	182	--	--
18	--	1	--	--	182	0.0055	--
19	--	--	--	--	181	--	--
20	--	--	--	--	181	--	--
21	--	--	--	--	181	--	--
22	--	--	--	--	181	--	--
23	--	--	--	--	181	--	--
24	--	1	--	--	181	0.0055	--
25	--	--	--	--	180	--	--
Total	194	7	--	--	--	0.0380	0.0000
Adjusted for tag loss						0.0398	0.0000

Appendix Table C-5. Exploitation of northern squawfish in Ice Harbor Reservoir.

P	T	Recaptures			M	Exploitation	
		Sport	Dam	Misc.		Sport	Dam
1	19						--
3	- -				19	--	--
4	--				19		
				--	19		
5	- -	--	--	--	19		
6	- -	--	--	--	19		
7	- -	--			19		--
8	- -				19		
9	- -	--	--	--	19		--
10	--	--	--	--	19	--	--
11	--				19	--	
12	--	--	--		19		
13	--				19		
14	--	--	--	--	19	--	--
15	--	--	--	--	19	--	--
16	--	--	--	--	19	--	--
17	--	--	--	--	19		--
18	--	--	--	--	19		--
19	--		--	--	19		
20	- -	--	--	--	19	--	--
21	--	--	--	--	19	--	--
22	- -				19		
23	- -		--	--	19		--
24	- -	--	--	--	19	--	--
25	- -	--	--	--	19	--	--
Total	19	0	0	--		0.0000	0.0000

Appendix Table C-6. Exploitation of northern sguawfish in Lower Monumental Reservoir.

		Recaptures				Exploitation	
P	T	Sport	D a m	Misc.	M	Sport	Dam
1	270	--	--	--	--	--	
2	--	--	--	--	270	--	
3	--	--	3	--	270		0.0111
4	254		1		267	--	0.0037
5		--	--	--	520	--	--
6	--	--	--		520	--	
7	--	3	1	--	520	0.0058	0.0019
8	--		1	--	516		0.0019
9		1	--	--	515	0.0019	--
10				2	514	--	--
11	--	1			512	0.0020	
12	--	--			511		
13					511	--	--
14			1	--	511	--	0.0020
15			--	--	510	--	--
16	--	--	1	--	510	--	0.0020
17	--	--	1	1	509		0.0020
18			1		507	--	0.0020
19	--		--	--	506	--	--
20			1	--	506	--	0.0020
21		--	--	--	505	--	
22	--	--	1	--	505	--	0.0020
23	--	--		--	504	--	--
24			--	--	504	--	
25	--	--	--	--	504	--	
Total	524	5	12			0.0097	0.0306
Adjusted for tag loss						0.0102	0.0321

Appendix Table C-7. Exploitation of northern squawfish in Little Goose Reservoir;

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	227	--	--	--	--	--	--
2	315	--	--	--	227	--	--
3	198	--	--	--	542	--	--
4	--	--	3	--	740	--	0.0041
5	--	--	1	--	737	--	0.0014
6	--	1	--	1	736	0.0014	--
7	--	4	11	1	734	0.0054	0.0150
8							
9	.. ..	11 3	a	2 1	718 710	0.0042 0.0155	0.0042 0.0056
10	--	10	-2	3	694	0.0144	0.0029
11	--	3	--	1	679	0.0044	--
12	--	2	--	--	675	0.0030	--
13	--	2	1	--	673	0.0030	0.0015
14	--	2	6	1	670	0.0030	0.0090
15	--	1	--	--	661	0.0015	--
16	--	4	--	--	660	0.0061	--
17	--	4	--	--	656	0.0061	--
18	--	5	--	1	652	0.0077	--
19	--	4	2	--	646	0.0062	0.0031
20	--	1	1	--	640	0.0016	0.0016
21	--	2	--	--	638	0.0031	--
22	--	2	--	--	636	0.0031	--
23	--	2	--	--	634	0.0032	--
24	--	1	--	--	632	0.0016	--
25	--	--	--	--	631	--	--
Total	740	65	34			0.0945	0.0484
Adjusted for tag loss						0.0990	0.0507

Appendix Table C-8. Exploitation of northern squawfish in Lower Granite Reservoir.

		Recaptures				Exploitation	
P	T	Sport	Dam	Misc.	M	Sport	Dam
1	196	--	--	--	--	--	--
2	--	--	--	--	196	--	--
3	--	--	--	--	196	--	--
4	--	--	--	--	196	--	--
5	--	--	--	--	196	--	--
6	--	2	--	--	196	0.0102	--
7	--	--	--	--	194	--	--
8	--	2	--	--	194	0.0103	--
9	--	--	--	--	192	--	--
10	--	4	--	--	192	0.0208	--
11	--	2	a-	--	188	0.0106	--
12	--	--	--	--	186	--	--
13	--	1	--	--	186	0.0054	--
14	--	2	--	--	,185	0.0108	--
15	--	--	--	--	183	--	--
16	--	1	--	--	183	0.0055	--
17	--	2	A-	--	182	0.0110	--
18	--	1	--	--	180	0.0056	--
	--	--	--	--	179	--	--
2':	--	--	--	--	179	--	--
21	--	2	--	--	179	0.0112	--
22	--	--	--	--	177	--	--
23	--	--	--	--	177	--	--
24	--	--	--	--	177	--	--
25	--	1	--	--	177	0.0056	--
Total	196	20	0	--	--	0.1070	0.0000
Adjusted for tag loss						0.1121	0.0000

Appendix Table C-9. Exploitation of northern squawfish systemwide.

P	T	Recaptures				M	Exploitation		
		Sport	Dam	LL	Misc.		Sport	Dam	LL
1	3,081	--	--	--	4	--	--	--	
2	582	--	--	--	--	3,077	--	--	
3	488	--	3	--	2	3,659	--	0.0008	
4	389	--	4	--	6	4,142	--	0.0011	
5	414	--	4	--	2	4,521	--	0.0009	
6	250	27	3	--	1	4,929	0.0055	0.0006	--
7	302	43	12	--	--	5,148	0.0084	0.0023	--
8	--	39	10	1	6	5,395	0.0072	0.0019	0.0002
9	--	47	7	--	2	5,339	0.0088	0.0013	--
10	--	54	7	1	12	5,283	0.0102	0.0013	0.0002
11	--	32	4	--	4	5,209	0.0061	0.0008	
12	--	21	10	--	6	5,169	0.0041	0.0019	--
13	--	23	3	--	1	5,132	0.0045	0.0006	--
14	--	16	18	--	2	5,105	0.0031	0.0035	--
15	--	12	3	--	4	5,069	0.0024	0.0006	
16	--	11	5	--	1	5,050	0.0022	0.0010	--
17	--	10	2	--	2	5,033	0.0020	0.0004	--
18	--	9	3	--	3	5,019	0.0018	0.0006	
19	--	9	2	--	--	5,004	0.0018	0.0004	--
20	--	5	3	--	--	4,993	0.0010	0.0006	--
21	--	6	--	--	5	4,985	0.0012	--	
22	--	3	1	--	--	4,974	0.0006	0.0002	
23	--	3	--	--	--	4,970	0.0006	--	--
24	--	3	--	--	--	4,967	0.0006	--	--
25	--	1	--	--	--	4,964	0.0004	--	
Total	3,837	374	104	2	--	--	0.0725	0.0208	0.0004
Adjusted for tag loss							0.0760	0.0218	0.0004

APPENDIX D

Tables of Backcalculated Lengths, Age at Length Keys, and Von Bertalanffy Growth Parameters

Appendix Table D-l. Mean backcalculated fork lengths (mm) at the end of each year of life for northern squawfish from John Day Reservoir, 1992.

Year Class	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	78														
1990	62	119													
1989	50	87	133												
1988	57	99	142	184											
1987	49	130	176	218	256										
1986	45	123	180	216	245	283									
1985	50	127	190	236	266	291	314								
1984	47	144	207	253	287	312	334	354							
1983	45	145	215	260	298	329	353	376	397						
1982	44	146	218	270	309	341	366	389	409	426					
1981	43	129	195	251	296	330	357	379	404	422	442				
1980	45	155	216	256	309	338	365	390	416	440	459	480			
1979	48	144	203	249	288	322	351	380	407	426	445	460	474		
1978	43	166	209	247	287	319	342	370	395	425	450	472	490	506	
1977	59	108	162	228	265	291	317	347	370	398	422	445	463	480	493
N	201	200	190	185	180	173	162	144	110	68	39	24	13	5	2
Mean	47	137	202	250	289	320	347	375	403	427	447	469	476	495	493
SD	9	30	35	35	35	36	35	34	32	31	28	26	27	28	23
Increment	47	90	65	48	39	31	27	28	28	24	20	22	7	19	--

Appendix Table D-2. Mean backcalculated fork lengths (mm) at the end of each year of life for northern sguawfish from the Columbia River downstream from Bonneville Dam tailrace, 1992.

Year Class	Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1991	85															
1990	47	103														
1989	43	116	165													
1988	43	117	162	198												
1987	44	135	188	223	256											
1986	46	137	201	240	267	295										
1985	45	147	202	242	279	310	339									
1984	46	144	200	246	286	322	346	368								
1983	47	142	199	241	283	323	357	384	409							
1982	47	144	202	251	292	328	360	391	415	440						
1981	46	146	206	250	293	328	360	389	414	435	453					
1980	46	131	201	250	291	327	357	386	412	437	458	479				
1979	47	129	201	260	306	345	378	404	428	447	469	490	503			
1978	49	158	220	253	297	323	349	389	417	450	475	495	511	529		
1977	47	112	165	225	250	288	320	352	380	404	432'	454	472	491	512	
1976	38	130	164	201	246	293	324	348	373	395	418	444	471	495	510	526
N	421	419	362	305	244	191	157	122	98	72	49	31	11	6	3	1
Mean	45	128	187	232	277	317	352	383	412	437	456	480	497	511	511	526
SD	8	27	31	34	32	32	31	30	28	30	29	31	23	32	19	--
Increment	45	83	59	45	45	40	35	31	29	25	19	24	17	14	0	15

Appendix Table D-3. Age-frequency distribution by length interval for a subsample of northern squawfish from John Day Reservoir, 1992.

Fork length interval (mm)	Age														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SO-74															
75-99															
100-124	1	4													
125-149		4	3												
150-174		2		21											
175-199				2	1										
200-224				2											
225-249					1										
250-274					13		5								
275-299					3	6									
300-324					1	1	3	4	1						
325-349							6	12	3						
350-374						1	3	11	8	1					
375-399							1	4	lo	5	2				
400-424								1	10	8	1	1			
425-449								2	6	4	8				
450-474									2	lo	1	5	2		
475-499									2		3	5	3	2	1
500-524										1		1	2		1
525-549														1	

Appendix Table D-4. Age-frequency distribution by length interval for a subsample of northern squawfish from the Columbia River downstream from Bonneville Dam tailrace, 1992.

Fork length interval (mm)	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
50-74		5														
75-99		20														
100-124	1	17	1	1												
125-149		8	7	4												
150-174		7	18	8												
175-199			18	13												
200-224			10	16	6	1										
225-249			4	9	15											
250-274				7	12	7										
275-299				3	9	10	3									
300-324					5	8	8	1								
325-349					6	6	5	4								
350-374						1	12	9	1	1						
375-399						1	6	3	10	1						
400-424							16	8		2	2					
425-449								14		6	5	4				
450-474									2	10	7	1				
475-499									1	3	3	10	1	1	1	
500-524											13		4			
525-549												1		1	1	1
550-574												1		1		

Appendix Table D-5. Von Bertalanffy growth parameters for northern squawfish captured in 1992. Linf = maximum asymptotic fork lenth, K = growth coefficient, and t0 = theoretical age at which fish length = 0.

Location	Linf	K	to
Downstream from Bonneville Dam tailrace	586	0.147	0.548
John Day Reservoir	528	0.191	0.845

REPORT H

Economic, Social, and Legal Feasibility of Commercial, Sport, and Bounty Fisheries on Northern Squawfish

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1992 Annual Report

CONTENTS

Page

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ABSTRACT

We report on our research conducted from April 1, 1992, through March 31, 1993, to analyze the economic, social and legal feasibility of commercial, sport, and bounty fisheries on northern squawfish (*Ptychocheilus oregonensis*). Northern squawfish were provided to this project from three removal fisheries -- the commercial longline fishery, the sport-reward fishery, and the dam angling fishery.

We evaluated the operations of the three fisheries -- commercial longline, sport-reward, and dam angling. We developed an extensive collection, transportation, storage and delivery system for northern squawfish landed by the commercial longline, sport-reward, and dam angling fisheries.

We continued to evaluate a range of alternative end uses for northern squawfish. These included minced food products, roe, fish meal, export food markets, and liquid fertilizer.

We conducted an assessment of social issues related to the four fisheries, including positive interactions as well as conflicts. We surveyed participants and employees of each. fishery as well as enforcement personnel to identify areas of potential concern in the continued operation of these fisheries.

INTRODUCTION

The 1992 season continued our research of the feasibility of alternative fisheries for northern squawfish (***Ptychocheilus oregonensis***) first begun in February 1989. This report summarizes our research activities and results during the 1992 performance period, from April 1, 1992, until March 31, 1993. The 1992 project has five objectives related to the continued evaluation of the economic feasibility of commercial and bounty fisheries on northern squawfish. These five objectives are listed below.

1. Continue to evaluate the economic effectiveness of sport, bounty, and commercial fisheries on northern squawfish.

2. Collect, transport, store, and distribute all northern squawfish collected during the 1992 fishing season.

3. Continue the development of value-added products.

4. Continue to explore new uses for northern squawfish.

5. Continue the evaluation of regulatory and social issues related to the conduct of sport, bounty, and commercial fisheries for northern squawfish.

This report presents results of research activities conducted under the five project objectives. Discussions are presented on five subject areas -- fishery operations, distribution of catch, catch utilization, social issues, and regulatory issues.

METHODS

Fishery Operations

Sites of fishery operations expanded in 1992. Harvest sites included eight mainstem dams and the John Day Reservoir of the Columbia River. Northern squawfish were harvested by three different types of fisheries -- commercial longline, sport-reward, and dam angling.

Northern squawfish harvested by these fisheries were provided to this project during different time periods. The dam angling fishery was conducted between April 19 and September 6. The sport-reward fishery operated between May 18 and September 27. The commercial longline fishery operated between May 16 and August 3 1.

Operations of the three northern squawfish test fisheries were monitored by this project for logistics of operations, collection and handling systems, total catch per site, agency expenditures, total expenditures, and actual or potential conflicts.

Sources of data to assess fishery operations varied by fishery. Commercial fishery operations were monitored by two data sources -- operating costs per fishing trip and agency expenditures. Data on operating costs were collected per trip and incorporated into a trip logbook form developed by the Oregon Department of Fish and Wildlife (ODFW). Data elements include catch, effort, incidental catch, operating expenses, and administrative expenses. The curtailed commercial fishery season precluded a telephone survey of commercial fishery observers or fishermen. Data on expenditures incurred by the ODFW to set up and operate the commercial fishery were provided by the project manager.

Operations of the dam angling fishery were monitored by two sources of data -- catch data and agency expenditures. Further assessments of dam angling fishery operations will be made through a survey of dam supervisors. The major questions of interest to the feasibility project concerning the dam angling removal method are the effectiveness (in terms of northern squawfish removals) per unit cost and the interactions with other project components, dam operations, and the general public. Data elements required for the feasibility analysis are fishing effectiveness expressed in catch per unit effort, incidental catch, gear, bait, time spent fishing, labor costs, and equipment costs.

Six sources of data provided monitoring of the sport-reward fishery -- vouchers, registration forms, catch weight, agency expenditures, a survey of creel clerks, and a survey of non-returning anglers. We revised the survey instrument used in 1991 to collect data from the sport-reward fishery. The angler survey included questions on time spent fishing, fishing method, gear used, catch, incidental catch, residence, distance travelled to fish, fishing experience, expenditures associated with fishing, experience with northern squawfish, and opinions about the northern squawfish sport-reward fishery. Data were entered throughout the 1992 fishing season; approximately 15,000 survey forms have been coded and processed to date. The design of the survey instrument was coordinated with the Washington Department of Wildlife (WDW). The sport-reward fishery survey form is presented in Appendix D.

The survey was administered to every participant in the sport-reward fishery returning to a registration site. The payment voucher certifying the number of northern squawfish caught was incorporated into the survey form to ensure a high level of survey response. Receipt of payment for landed squawfish was dependent on the completion of the survey form.

A significant number (approximately 65%) of anglers did not return to the registration site. The 1991 survey form was revised to be administered by telephone to a sample of non-returning anglers. The survey form is presented in Appendix D.

We were also interested in the creel clerks' perspective on fishery operations and suggestions for improvement. Creel clerk supervisors at each registration site were surveyed. Supervisors were contacted by telephone, interviewed about any problems encountered, and asked to' identify any areas of needed change in the operations of the sport-reward fishery. The 1992 telephone survey form used to interview creel clerk supervisors is presented in Appendix D.

Distribution of Catch

1992 is the second year of the Northern Squawfish Predator Control Program that has required an extensive fish handling and transportation network. The 1992 handling network was designed to accomplish two principal goals: (1) collect food-grade northern squawfish, and (2) accommodate the handling needs of the removal fisheries.

To satisfy these requirements, the handling network operated with the following components.

1. Oregon State University (OSU) purchased handling equipment from 1990-1992 including chest freezers, insulated and non-insulted commercial fishing totes, and coolers. This equipment was distributed to participating agencies and subcontractors.

2. OSU subcontracted five private fish processors who received, packaged, and froze the squawfish harvested by the sport reward and dam angling fisheries. The fish processors were at these locations:

Location	Processor Name
Longview, WA	Tri-River Smelt
Portland, OR	Point Adams Packing Company
Cascade Jocks, OR	Bonneville Fisheries
The Dalles, OR	Kingfish Trading Company
Richland, WA	Wellsian Cold Storage

3. Sport-reward technicians delivered their daily catch to the processors and picked up fresh coolers and ice for the next day. OSU employees picked up full coolers from Bonneville, The Dalles, and McNary dams and delivered them to Kingfish or Bonneville Fisheries.

4. For logistical and cost reasons, low volume and distant harvest locations (John Day Dam, Snake River dams, Snake River sport-reward sites) were not serviced by fish processors. The squawfish from these areas were either frozen in chest freezers and collected by OSU employees later or were delivered daily by Washington Department of Wildlife technicians to a local subcontractor who made arrangements for a rendering pick-up.

5. OSU subcontracted Americold Cold Storage in Wallula, Washington, and Nampa, Idaho, and Pacific Cold Storage in Portland. These facilities stored frozen squawfish and served as the pick-up locations for shipment to end-users.

6. OSU rented a 30,000-pound truck for delivering equipment to processors (coolers and totes), picking up frozen fish from remote locations, and transferring frozen fish from processors to cold storage facilities.

7. OSU subcontracted May Trucking in Portland to handle deliveries to Inland Pacific Fisheries in Payette, Idaho.

8. Stoller Fisheries picked up boxed fish from the cold storage facilities for delivery to the Spirit Lake, Iowa, processing plant.

9. OSU currently rents warehouse space from Intermountain Industrial Supply for storing equipment.

Catch Utilization

Catch of northern squawfish was utilized in five ways in the 1992 season -- two different minced food fish products, roe, food fish exports, fish meal, liquid organic fertilizer.

OSU Value-Added Product Experiments

Approximately 2,000 pounds of fresh and frozen northern squawfish were delivered to the Oregon State University Seafood Lab in Astoria, Oregon, for experimentation.

The first objective of the 1992 experimental work at the OSU Seafood Laboratory was to study the feasibility of using northern squawfish for surimi production and to evaluate the yields and compositional characteristics of surimi prepared from this species of fish. The effect of fish preprocessing storage time (freshness of raw materials) and surimi frozen storage time on the gel-forming ability and whiteness of surimi products was investigated. The interaction between frozen storage time and preprocessing storage time was also studied. An additional objective was to evaluate the roe from northern squawfish. A final objective was to evaluate mince made from frozen squawfish for texture characteristics and determine the shelf-life stability of the mince made with and without cryoprotectants.

About 350 kg northern squawfish were gathered at dam sites along the Columbia River through the sport bounty program in July 1992. Fish were packed in ice after capture and transported to the OSU Seafood Lab in Astoria within 24 hours. All fish were packed in ice chests with three layers of fish per chest. Each layer of fish was covered with a layer of ice. Excess water was continuously drained and additional fresh ice was added only to the top layer of fish during the storage period to‘replenish melted ice. The chests of iced fish were held in a thermostatically controlled cool room (4° C). At intervals of 0, 3, 6, 9, and 13 days, about 70 kg fish were taken from storage for surimi production. The **K** value, an index of fish freshness calculated as the ratio of the sum of hypoxanthine and inosine to the total amount of adenosine 5'-triphosphate (ATP) related compound, was determined by a modified HPLC procedure (Ryder 1985).

Surimi Production

The fish were hand planked (separation of musculature and bone from head, backbone, tail and viscera) prior to deboning to avoid contamination by the viscera and notochord material, which could influence color and flavor and catalyze rancidity. The planks were deboned with an Acacia Deboner Model 805; drum perforations were 0.4 cm in diameter (Acacia Tekkosho, Ltd., Japan). The belt tension was adjusted to remove skin from plank as well. The minced flesh was washed in polyethylene tanks with water and ice at a ratio of 1 part flesh to 3 parts water (w/w) and. gently stirred for 5 minutes, followed by holding for 5 minutes. Washed mince was dewatered in a Sano-Seisakusho screw press Model SD-8 (Acacia Tekkosho, Ltd., Japan). Two wash and three wash procedures were run to compare washing efficiency for squawfish surimi production. The last wash in both cases included 0.1% NaCl to facilitate dewatering. The press was operated slowly during the last wash to produce the lowest possible moisture content in the flesh. The dewatered flesh was refined with an Akashi strainer Model S- 1 (Akashi Tekkosho Co., Japan) to remove connective tissue, bone particles and skin. The refined flesh was cooled in the freezer for about 45 minutes to keep flesh at low temperature for the next mixing step. Surimi was prepared by mixing the refined flesh with 4.0% sucrose, 4.0% sorbitol, and 0.3% Brifosol 512 (B.K. Ladenburg Corp. North Hollywood, CA) in a Hobart Silent Cutter, Model VCM (Hobart Manufacturing Co., Troy, OH) for 2 minutes. Product temperatures were maintained near or below 10° C. Aliquot of 400 g surimi were packed into individual plastic trays, vacuum packaged and frozen at -18" C. The freshness of fish for surimi production was measured each time. Samples were taken during each surimi production unit operation for proximate analysis. Surimi quality was monitored by torsion test and color measurement after frozen storage for 0, 30, 90, 150, and 180 days.

Surimi Gel Preparation

Partially thawed surimi was used for the preparation of all gels. The moisture content of surimi was determined by microwave method developed by our lab. The formulations were calculated based on the percentage of moisture in the surimi. Seventy-eight percent moisture content was adjusted and 2% NaCl (total weight) was included in each formulation.

All formulations were chopped in a Stephan Vacuum Chopper/mixer (Stephan Machinery Corporation, Model UM-5) for 4 minutes. During the first minute, salt and ice was added. During the last three minutes, mixing was carried out under vacuum conditions. Caution was taken to keep the temperature below 10° C to diminish protein denaturation. The batters were extruded into stainless steel tubes (1.87 cm internal diameter by 17.75 cm length) using a sausage stuffer (Sausage Maker, Model 14208, Buffalo, N.Y.) without air pockets. The tubes had previously been sprayed with a lecithin-base release agent. The tubes were sealed at one end by a threaded cup and on the other by rubber stoppers and cooked in 90” C water bath for 15 minutes. The tubes were immediately cooled in ice water after cooking. The gels were removed from the tube and stored in sealed plastic bags under refrigeration (4°C). Gel forming ability was evaluated within 24 hours by torsion test.

Evaluation of Gel Properties

Torsion Test

Gel sample was cut into a dumbbell geometry and subjected to torsional shear in the modified Brookfield viscometer (Kim et al. 1986). The results were reported as shear strain and shear stress, which were calculated using the equation developed by Hamann and Lanier (1987). Stress values are indicative of gel strength and are affected by moisture and protein content while strain value is related to gel cohesiveness and is a better measure of gel-forming ability and protein quality.

ph Measurement

A 10-g sample of each gel was blended with *90* mL distilled water for 1 min using Osterizer pulsematic 10 blender (Oster Corporation, Milwaukee, WI) at frappe’ speed. The pH was measured using a standardized Corning Ph meter Model 250 (Coming Ciba Diagnostics Co., Coming, NY).

Color Evaluation

Color of the gels was measured using Minolta Chroma Meter CR-300 (Minolta Camera Co. Ltd., Osaka, Japan), which gave output in L*, a*, b* color coordinates, as described by the manual. This instrument was standardized by using a black plate and a standard white plate (perfect diffuse reflector; L*=82.13; a*=-5.24; b*=-0.55). In the CIE L*a*b* system, L* is a measure of light intensity, a* values represent the chromatic scale from green(negative a* values) to red (positive a*), and b* values represent the chromatic scale from blue (negative b*) to yellow (positive b*). Whiteness was calculated as $100-((100-L^*)^2+{}^*a^{*b*2})^{1/2}$.

Proximate Composition

The total protein, lipid, ash, and moisture content of flesh at each stage of processing was determined for each of the five lots of surimi prepared (AOAC 1984). Composition after each stage of processing was determined -- deboned flesh, flesh after the first, second and third wash, refined flesh and prepared surimi.

Squawfish Roe

Thirty-one squawfish were sampled for roe in late spring. Fish samples were collected from holding pens below the dams and were transported in ice to the OSU Seafood Laboratory. The fish arrived at the laboratory in excellent condition and were samples immediately.

Use of Frozen Squawfish for Mince

The objective of this experiment was to determine the potential for a mince being prepared from frozen squawfish. The mince was frozen with and without cryoprotectants and analyzed for texture qualities. Frozen squawfish was transported to OSU Seafood Lab in the frozen state. The fish were planked and a minced was obtained by the use of a deboner mentioned in previous sections. A K-value to determine freshness was run on the thawed fish.

Stoller Minced Food Product

On the basis of the successful 1991 experience with production of minced food products from northern squawfish, Stoller Fisheries of Spirit Lake, Iowa, requested access to large quantities of food grade northern squawfish in 1992. Stoller Fisheries processes freshwater rough fish primarily for the kosher market. Approximately 88,000 pounds of frozen food grade northern squawfish were shipped to Stoller Fisheries during the 1992 season.

Liquid Fertilizer

A total of 126,000 pounds of northern squawfish were shipped to Inland Pacific Fisheries Inc., Payette, Idaho, for liquid fertilizer processing.

Seafood Brokers

Approximately 600 pounds of frozen food grade northern squawfish were provided to two seafood exporters for market tests.

Mink Food

On the basis of successful 1991 feeding experiments, the OSU Experimental Fur Farm again requested northern squawfish. Approximately 9,500 pounds of industrial grade northern squawfish were delivered to the farm for feed.

Salmon Habitat Restoration Experiments

Approximately 320 pounds of northern squawfish were provided to the Oregon Department of Fish and Wildlife for stream enrichment research. Initial quantities of northern squawfish were used to test for research suitability. On the basis of the 1992 tests, requests for further supplies of northern squawfish will be received in 1993.

Rendering

Northern squawfish that were not of sufficient quality to be processed as either food or fertilizer were transported to a renderer. Approximately 44,400 pounds of northern squawfish were rendered in 1992.

Social and Regulatory Issues

The 1992 assessment of social issues and regulatory associated with the development of full-scale fisheries for northern squawfish is based on information from the operation of the three removal fisheries and on issues raised during the environmental. assessment process. Information on conflicts or other social issues occurring either on the water or on shore during the 1992 season was collected through surveys of participants and employees in each fishery.

Issues related to dam angling were identified by asking staff of the Columbia River Inter-Tribal Fish Commission (CRITFC) to summarize their experiences with the fishery, surveying the dam crew supervisors, and by contacting representatives of the U.S. Army Corps of Engineers in the Portland and Walla Walla districts.

Sport-reward fishery conflicts were identified through a summarization of angler comments on voucher forms, the survey of non-returning anglers, and a telephone survey of creel clerk supervisors. Enforcement issues were identified through survey comments, summaries of enforcement personnel, and project meeting summaries.

Concerns about the safety of human consumption of northern squawfish were addressed in 1990 through the provision of 11 samples of northern squawfish to the Oregon Department of Environmental Quality ,(DEQ) Division of Water Quality Planning, to test northern squawfish tissue and organs for dioxin contamination. Previous tests performed by the DEQ for pesticides (PCBs, chlordane, DDT derivatives) and heavy metals (mercury, aluminum, lead, arsenic) revealed levels safe for human consumption (Hanna 1990).

Samples of northern squawfish and sediments taken from eleven Columbia River sites (Hanna and Pampush 1991) were sent to the Environmental Protection Agency (EPA) Laboratory in Duluth, Minnesota, for dioxin tests in 1991. Due to several processing delays at the laboratory, dioxin test results were not received until October 1992.

RESULTS

Fishery Operations

Commercial Fishery

The commercial longline fishery was conducted by three contracted fishing crews and an ODFW vessel with three seasonal employees. Fishery oversight and management was provided by ODFW. The fishery was operated as a subsidized "reward" fishery. Fishermen were compensated $250 per day for each fishing day that met minimum requirements of time and gear in the water. In addition to the daily compensation, fishermen were paid $3 per fish for all fish over 11 inches long. Gear and bait were provided to the fishermen by the University of Washington project and by ODFW.

A total of 1,758 longlines and 161,458 hooks were set during the 1992 season. Harvested catch totaled 2,150 northern squawfish, of which 1,340 met the minimum size requirement and qualified for payment. This resulted in direct payments for northern squawfish of $4,020.

Direct agency expenditures made by ODFW for the commercial longline fishery through August 1992 are summarized by category in Appendix B. Direct expenditures totalled $113,725. Indirect expenditures made by ODFW and other projects for the operation of this fishery (primarily in time) are acknowledged, but unquantified.

The low levels of catch in the 1992 longline fishery (1340 qualifying fish) resulted in a high level of expenditure-per-squawfish removed at $84.87 per fish.

Dam Angling Fishery

The 1992 dam angling fishery was again conducted on eight Columbia and Snake River dams -- Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville. Management and oversight of the dam angling fishery was provided by the Columbia River Inter-Tribal Fish Commission, which subcontracted operations on some dams to tribal fishing crews. The focus of interest for the feasibility project in this fishery are fishing effectiveness (CPUE), incidental catch, and costs for gear, bait, and labor and equipment.

Total agency (CRITFC) expenditures and expenditure per fish removed by fishing crew in the dam angling fishery are presented in Appendix C. Expenditures include all expenditures dedicated to the operation and oversight of nine fishing crews -- crews located at Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental dams, a combined Little Goose and Lower Granite dams crew, a mobile crew and a volunteer angling group. Some crews were supervised directly by CRITFC and some through subcontractors.

Most crews are associated with dams, but some (Little Goose and Lower Granite combination, the mobile crew, and the volunteer crew) were not.

Catch figures in Appendix Table C-2 represent each crew's catch and may therefore not exactly correspond to catches reported for each dam. For example, the Lower Monumental crew fished Lower Monumental Dam and Ice Harbor Dam, The Dalles Dam, and John Day Dam at various times in the season. The crew's catch represents their catch from all dams at which they fished.

Total expenditure figures reported for each fishing crew in Appendix Table C-l include costs of project administration. Administrative costs associated with the dam angling fishery not directly allocable to particular crews were distributed among the crews on a proportional basis. Proportions of total administrative costs assigned to each crew ranged from .01 for the volunteer angling crew, to .17 to the combined Little Goose and Lower Granite crews. Crews that were supervised directly by CRITFC and crews that required extra oversight attention accounted for a higher proportion of total administrative costs.

Examples of total administrative costs apportioned among fishing crews include centrally procured supplies, CRITFC data processing equipment, CRITFC storage rental and project vehicle lease, administrative time spent drafting subcontractor agreements and work statements, attending coordination meetings, processing data, and writing reports.

Subtracted from total cost figures in Appendix Table C-l are fish handling costs, estimated at $.42 per fish. The fish handling costs, calculated at an estimated handling time of two minutes per fish, are those costs in excess of the cost of disposing of caught fish into the river. Fish handling costs are considered an "opportunity cost" of foregone catch through not being able to fish during the time fish are being processed.

Also not included in total costs are costs of developing work plans, which were unfunded, and costs of developing the 1993 statement of work, a total of approximately $37,000.

Costs per fish when all administrative costs are included ranged from a low of $14 per fish for The Dalles and McNary crews, to a high of $106 per fish for the Lower Monumental crew. Because most operating costs are fixed, cost per fish depends on the size of the catch; the larger the catch, the larger the number of fish among which to distribute the fixed costs, and the smaller the average cost per fish.

Appendix Table C-2 presents per-site operating costs, total catch, and costs per fish without administrative costs apportioned among sites. This cost calculation is made to present a cost-per-fish estimate that is comparable to those of the sport-reward fishery, which does not include project administrative costs in its estimates.

Without apportioned administrative costs, expenditures by crew per fish removed at several sites decrease to levels that are comparable to the per-site expenditures per fish removed in the sport-reward fishery. Removing the two most extreme cases -- the Lower Monumental and the combined Little Goose and Lower Granite crews -- from the calculation results in an average fishery-wide expenditure of $12.86 per fish removed, as compared to a fishery-wide figure of $9.68 in the sport-reward fishery (Appendix Table D-2).

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

Sport-Reward Fishery

The sport-reward fishery began on May 18 and encompassed 20 check stations along the Columbia and Snake rivers. We again used a combined voucher-survey form to collect information from participating anglers. Information, collected included fishing time and methods, expenditures, distance travelled, fishing experience, reasons for participating in the program, and various demographic variables. The 1992 survey-voucher form is shown in Appendix Figure D-l.

The sport-reward fishery involved agency expenditures for creel clerk wages, reward payments, uniforms, vehicles, fuel, oil, and miscellaneous equipment. These costs are summarized by registration check station through September in Appendix Table D-2 and Appendix Figure D-4. Expenditures at each registration site included basic labor and operating costs and thus did not vary much among sites. Catch rates did vary widely among sites, resulting in wide disparities in check station expenditures per fish removed. Average expenditures per fish removed varied between a low of $4.68 for LePage Park (Check Station 11) and a high of $45.66 for St. Helens (Check Station 3). Program costs not directly associated with check station operations are excluded from the calculations. These costs include various administrative and implementation costs for the program as a whole.

Analysis of the voucher-survey data reveals several areas in which angler participation varied among check stations. Not surprisingly, residence of anglers varied according to the location of the check station (Appendix Figure D-5). Anglers tended to use check stations closest to their homes.

Anglers varied in age from 14 to over 60, with the largest proportion of anglers in the 30-50 age bracket (Appendix Figure D-6). There were no apparent differences in age distributions among sites. A majority of anglers had high school and come college education (Appendix Figure D-7).

At all sites, the majority of anglers were experienced fishermen who had fished for over 10 years (Appendix Figure D-8). Most made over 21 trips per year; almost none were people who had begun to fish solely for the northern squawfish program (Appendix Figure

D-9). Anglers tended to be familiar with the fishing location at which they registered, with almost all making at least six trips per year to that location (Appendix Figure D-10).

The number of anglers in the fishing party varied very little across check stations. Most people fished in a party of two (Appendix Figure D-l 1). Similarly, the average number of hours fished also varied little, ranging 5-6 hours per day (Appendix Figure D-12). The number of northern squawfish caught per trip did vary across check stations. The lowest average catches were at St. Helens (Site 3); the highest at Columbia Point Park (Site 14; Appendix Figure D- 13).

The ways anglers spent money varied across check stations (Appendix Figure D-14). Expenditures on accommodation were a relatively small part of total expenditures for all sites except Columbia Point Park, Hood Park and Maryhill Park. Fishing supplies were a relatively small component of expenditures except for those fishing at LePage Park. For most sites, money spent on restaurants, groceries and accommodations comprised about half of total expenditures associated with the fishing trip.

The majority of anglers were repeat participants from the 1991 fishery. However, some sites attracted large numbers of new participants, notable M. James Gleason, Hamilton Island Boat Ramp, Bingen Marina, Dalles Boat Basin, LePage Park, Hood Park, and Green Belt Boat Ramp.

We asked anglers about their motivations for participating in the northern squawfish fishery. We asked anglers to assess the importance of four different factors in their decision to participate -- receiving a payment for squawfish, access to a recreational opportunity, covering expenses for other target species, and participating in a salmon enhancement activity. Results are presented in Appendix Figures D-16 through D-19. Receiving a payment for squawfish was seen to be very or somewhat important to the large majority of anglers, as was the access to a recreational fishing opportunity. The majority of anglers said the opportunity to cover fishing expenses was either very or somewhat important, although about 2530% at each site said this was not important. The opportunity to participate in a salmon enhancement activity was very important to the large majority of anglers.

The survey of non-returning anglers covered each registration site with as close to a 2% sample as possible. Telephone contacts were often difficult; if repeated tries to contact a sample member were unsuccessful, a substitute name was drawn from a "back up" sample. The number of completed surveys for each site ranged from seven at Windust Park to 50 at Covert's Landing (Appendix Table D-3).

Non-returning anglers spent an average of four hours fishing for northern squawfish and an average of one hour fishing for other species on the same trip. Fishing time for non-returning anglers was slightly less than time spent'by anglers who returned their catch to the registration site. Average time spent fishing for northern squawfish varied little among sites (Appendix Figure D-20).

The primary target species of non-returning anglers was northern squawfish at all sites. Other important target species for this group were salmon, bass, shad, sturgeon, and steelhead (Appendix Figure D-21).. The proportion of non-returning anglers catching other species incidentally to northern squawfish varied from 14.3% at Columbia Point and Windust Park to 75% at Ringold (Appendix Table D-5). The species composition of incidental catch is listed in Appendix Table D-6; bass was the most common incidentally caught species at all sites (239 caught by the sample contacted), followed by catfish (109), perch (59), carp (52), and sturgeon (45). Target species caught in combination with northern squawfish trips included bass (89), shad (73), catfish (30), sturgeon (19), and salmon (15; Appendix Table D-7).

An average of 26.1% of all non-returning anglers sampled caught northern squawfish. The percentage of that catch which qualified for payment (> 11") ranged from 0 to 100% (Appendix Table D-4).

Overall, non-returning anglers favored bank fishing (61.3 %) over boat fishing (38.7%), although the mix of fishing methods varied by site (Appendix Figure D-22). The bait most commonly used was nightcrawlers (43.2%; Appendix Table D-8).

The most pressing question about non-returning anglers from the fishery operation perspective was why they did not return to the registration site. For 82.6% of the non-returning anglers sampled, the reason was that they had not caught any fish to register. Other reasons given by a small percentage of anglers included too far to travel, too late to return when they stopped fishing, not worth the time for their small catch, and failure to fish for northern squawfish at all. Patterns were similar across sites (Appendix Figure D-23) with the exception of Cascade Locks (Station 8), where a larger percentage failed to return because it was too late when they stopped fishing than at any other site.

'We asked non-returning anglers the same questions about motivations for participating in the northern squawfish fishery as we asked returning anglers. A fair amount of variation among sites was evident in responses to questions about the importance of payment, having a recreation opportunity, a chance to cover fishing expenses, and participation in salmon enhancement (Appendix Figures D-24 through D-27). Overall, 54% of non-returning anglers said that payment for northern squawfish was important to their participation in the fishery, while only 14.6% felt payment was not important. The opportunity to cover fishing expenses was considered very important by a smaller proportion of non-returning anglers; only 24.6% thought it was very important in terms of their participation, while 37.5% thought it was not important at all. The recreational opportunity offered by northern squawfish was very important to the large majority (74.3%) of non-returning anglers. Contributions to salmon enhancement was very important to an even larger proportion of anglers, 84.3%. Answers to the motivation questions are very similar to those given by returning anglers.

We were interested to know if those anglers who did not return to the registration site were one-time participants in the northern squawfish program or whether they participated at other times. Of all anglers in the non-returning sample, participation and non-participation were split about evenly; 52% did not return northern squawfish for payment at any other time in 1992 and 48% did (Appendix Table D-9). Some anglers who did participate at other times during 1992 were responsible for large catches, as illustrated in Appendix Table D-9.

As a group, the sample of non-returning anglers took more fishing trips per year than the returning anglers. Non-returning anglers averaged 34 trips per year overall (Appendix Table D-10), as compared to 21 trips per year for returning anglers (Appendix Figure D-9).

We were interested to know whether the location of check stations were inconvenient to those anglers who did not return. As Appendix Table D-11 illustrates, check stations were judged inconvenient by only a small proportion of non-returning anglers -- 10.7% over all stations. The highest proportion of non-returning anglers judging check stations inconvenient were at Maryhill State Park (29.6%).

We also wanted to know whether those anglers who did not return to the check station in 1992 would be discouraged from participation in the fishery in 1993. The overwhelming majority of anglers (92.8% overall) said that they planned to participate in the fishery in 1993, giving a variety of reasons for their plans to participate (Appendix Table D-12).

The survey of creel clerks working in the sport-reward fishery supported the general conclusions of the two angler surveys. In questions about the adequacy of station operating hours, the registration process, the data collection process, staffing, equipment, and station security, the majority of creel clerks evaluated these program elements as good (Appendix Table D-13). Equipment, data forms, staffing, station security and the registration process received more “fair” or “poor” ratings than other program elements.

In terms of complaints heard by creel clerks from anglers, the most frequently heard complaints concerned registration time at sites and the quality requirements, which dictated their fish handling procedures. Check-in times, check-in paperwork, and litter in fishing areas also were subjects of complaints (Appendix Table D-14).

Distribution of Catch

The 1992 Northern Squawfish Predator Control Program harvested about 292,000 pounds of northern squawfish. Of that total, OSU attempted to collect food-grade squawfish from collection areas that received a total of 214,500 pounds. For the remaining 77,800 pounds, no attempt was made to collect food-grade fish; it was treated as industrial grade and converted to liquid fertilizer or animal feed (rendered).

Every northern squawfish received at a processing facility was graded according to quality (food-grade/industrial-grade). Food-grade fish were boxed and frozen. Industrial-grade fish were frozen in large totes. The condition of the squawfish upon arrival to the processing facility, and consequently the volume of food-grade fish collected, was affected by the handling practices of the sport anglers, Washington Department of Wildlife technicians, and anglers on the dams.

Overall, the food-grade collection network was successful; 42% of the fish handled by the processors were food-grade. Considering the nature of the fishery (most fish are caught by sport anglers) and the large number of collection points (19), 42% is slightly better than expected for a start-up effort.

Collection System

Total Volume Harvested in 1992	292,300 lbs
Total Volume Handled by Food-Grade Network	214,500 lbs

Quality	Volume (lbs)	% Total
Food-Grade	91,030	42.4
Industrial-Grade	123,470	57.6

Distribution System

We distributed northern squawfish to nine end-users. The potential value of the end-uses examined in 1992 ranged from fairly high (minced fish food products, whole fresh fish) to very low (liquid fertilizer, rendered animal feed).

End-User	Product	Lbs rec'd
Inland Pacific Fisheries Payette, Idaho	liquid fertilizer	126,000
Stoller Fisheries Spirit Lake, Iowa	minced fish	88,000
Rendering 3 collection sites	animal feed	44,400
OSU Mink Farm Corvallis, Oregon	mink food	6,000
Astoria Seafood Lab Spirit Lake, Iowa	value-added products	2,000
Richard Young Portland, Oregon	market testing	660
Oregon Fish and Wildlife Corvallis, Oregon	stream research	320
Thomas Mclean Seattle, Washington	market testing	55

Service Contracts

Preparing for the 1992 field season and the unknowns associated with implementing the food-grade collection network proved to be a difficult task. Intense media coverage of the sport-reward program before the 1992 season compelled OSU to set up a network capable of handling two or three times the 1991 harvest. Decisions concerning service contracts, renting vehicles, and appropriate staffing were made difficult because of the unknown potential of the sport-reward fishery. The following discussion explains and summarizes OSU 1992 handling expenditures.

Service contracts were developed with fish processors, renderers, cold storage facilities, trucking companies, and building owners.

Five processors participated in the 1992 program. They were located in Longview, Wash.; Portland, Ore.; Cascade Locks, Ore.; The Dalles, Ore.; and Richland, Wash., and all served as receiving, packaging, and freezing areas. These contracts were based on the level of services offered and ranged from $140/day to $250/day. Charges included overhead, freezing, packaging materials, ice, drop-box rent, trucking (if any), and four hours of labor. Because none of these processors were familiar with the program and the potential volume to be handled was completely unknown, the processing contracts were negotiated on a daily fee rather than a volume handled basis. The 1992 season has provided considerable insight as to how to set up future processor contracts.

Rendering was the preferred alternative at locations where processing facilities were not available and the harvest was expected to be low. Rendering contracts were set up with a butcher in Clarkston, Wash., and a market in Pullman, Wash. Squawfish from the sport-reward fishery were taken nightly to these locations and dumped into 55-gallon drums. The merchants made arrangements with a regional rendering company to pick up the carcasses a few times a week. The Pullman location charged a total amount for the season of $400 (a very low volume area) and the Clarkston location charged $10/55-gallon drum. A one-time rendering charge of $225 was paid to a Portland outfit for handling 9,000 pounds of poor quality squawfish that resulted from a freezer van breakdown.

Three cold storage facilities stored frozen squawfish -- Americold in Wallula, Wash.; Americold in Nampa, Idaho, and Pacific Cold Storage in Portland. These facilities charge by the volume handled and the length of time in the freezer.

May Trucking in Portland was contracted to transfer loads of frozen fertilizer-grade squawfish to cold storage in Nampa, Idaho, for later processing by Inland Pacific Fisheries.

OSU rented a fish drop-off location in Kahlotus, Wash.; an apartment in The Dalles to serve as a field station and an overnight stop for employees; and industrial warehouse space in Portland for equipment storage.

Personnel

The 1992 OSU handling crew totaled four technicians and one tech/administrator. The crew operated across the entire project area where they picked up frozen fish, delivered ice, picked up coolers from dams, delivered fish to end-users, repaired equipment, and investigated handling problem, areas. When on the road, personnel were given a travel per diem to cover meal costs (and motels when not staying at the field station/apartment).

Vehicles

A 30,000-pound truck was leased from Rollins Truck Rental in Portland and was used to deliver and retrieve equipment, deliver large totes of ice, pick up fish from chest freezer locations, and deliver frozen fish to cold storage facilities. This truck is non-refrigerated, has a 15,000-pound capacity, a 20-foot long cargo area, and costs about $2,300/month to operate.

Two half-ton pickups and a one-ton flatbed were leased from the OSU Motor Pool and used to pick up coolers from the dams, deliver coolers and ice, and commute employees to various work locations.

Equipment

The only significant equipment purchase made by OSU in 1992 was 550 48-quart coolers for use by the removal fishery personnel. Other equipment used during the field season was purchased in previous years (totes, freezers, pallet jacks, etc.). Other minor purchases included plastic bags, rope, duct tape, keys, hard hats, tools, and hardware.

Handling and Distribution Costs

A summary of the 1992 expenditures for fish handling and distribution appears in Appendix Table E-l.

Catch Utilization

OSU Value-Added Product Experiments

Product Yield in Surimi Unit Operations

Northern squawfish yielded 39.2% planks, which produced 27.5% machine-separated minced flesh based upon round weight (Appendix Table F-l). Two 3: 1 (water:flesh) wash procedures yielded 17.3% pressed flesh, which produced 16.2% refined product and 17.9% surimi (91.7% refined flesh plus 8.3% cryoprotectants) based upon round fish weight. The yield of surimi observed was lower than 22% that Thrash reported to be economically feasible. The lower yield may be attributed to the small amount of fish used for surimi production in each lot. The small size of fish also effected the surimi yield.

Composition of Processed Flesh

The composition of flesh through processing is summarized in Appendix Table F-2. The difference in flesh moisture content among first, second, and third wash/press exchange reflected different operation procedures. The wash procedure removes water soluble components, particularly sarcoplasmic protein, which impedes the gel-forming potential of surimi. It also removes fat, ash, pigment and substances that affect the stability of proteins during subsequent frozen storage. After two washes, lipids were reduced by 22.3 % and ash by 50%. There was little difference between the second and third wash. The gel-forming ability of the surimi, measured by torsion test for the second wash and the third wash samples, showed no significant differences (data not shown). It is suggested that the two-wash regime was suitable for squawfish surimi production. We also found that moisture content of the flesh was higher after refining for both the two-wash and three-wash regime. This is probably due to the refining process causing elevated moisture content by separating connective tissue, bone particles and skin residue that was lower in moisture content. Removal of these constituents also increased protein content by dry weight from 88.7% to 90.8%. The moisture content of refined flesh decreased in the surimi due to the incorporation of cryoprotectants. A net reduction of 50.2% in lipid and 65.5 % in ash content was observed by processing minced flesh into refined flesh.

Effect of Preprocessing Ice Storage on pH and Gel-forming Ability of Surimi During Frozen Storage

Fish freshness was affected by preprocessing ice storage. The K value against ice storage time is shown in Appendix Figure F-l. The K value increased rapidly in the first six days. After fish was stored in ice for nine days, the K value reached 74.3%. It is not recommended to process fish if the K value of fish exceed 75% (Ehira 1976).

However, there was little correlation between K value and gel strength measurements of the squawfish surimi. In most species, a high K value indicates breakdown of metabolic products including protein. This does not appear to be the case for squawfish since gel strength remained relatively high even using fish kept nine days on ice. Since different fish species have different K value patterns, our results suggest that squawfish could be used for processing although K value reached 75% after storage in ice for nine days.

There was no significant difference in strain and stress value when K value was increased with time although the Day 0 and Day 3 sample have higher strain and stress values (Appendix Figures F-2 and F-3). All treatments maintain gel-forming ability well during three months of storage except Day 13 sample, which decreased to 1.71 in strain value. According to the traditional Japanese standard, a strain of 1.8 could be considered as an acceptable grade of surimi.

Our results demonstrated that approximately nine days preprocessing time may be the acceptable time that squawfish can be stored in ice before it is made into an acceptable grade of surimi after long-time frozen storage. There were no significant differences in pH of surimi due to preprocessing ice storage. pH values remain between 6.7 to 6.9 and do not change during frozen storage.

Color of the Gels and Changes During Frozen Storage

Hunter L*, a*, b* values of gel derived from surimi made from 0 day fish are shown in Appendix Table F-3. The squawfish surimi was more red and yellow and less lighter in color compared to standard surimi color. The preprocessing time did not change the color of the gel. There was little change in whiteness during the first three-month storage period. However, the b* was a little higher than the initial value, which served as the best single indicator of color changes (Wasson 1992).

The washing process of surimi is apparently an efficient means of preventing browning reactions during frozen storage, probably by the removal of water soluble compounds, such as enzymes, proteins, and haem pigments. The color of squawfish could be improved by using fillet instead of plank with skin for deboning.

Squawfish Roe

Of the 31 fished sampled, eight were males and 23 were females. The average length of the female fish was 15.77 inches and the average weight was 2.2 lbs. The average weight of the roe in the female fish was 0.26 lbs or 12% of the body weight. For the most part the roe was non-uniform in color varying from a gray color to olive green. Several of the roe had non-uniform color within the same sample.

The size of the roe was variable as well, from 1 to 2.5 mm. An organoleptic evaluation was undertaken for the roe and scored on the basis of appearance (combination of color, defects and overall appearance). On a scale of 0 to 5, the highest score was 4 while the lowest was 2. Lack of uniformity for color and size were considered some of the greater defects. These investigators feel that it would be difficult to harvest and sell squawfish mainly for the roe content. The low percent of roe to body weight, the non-uniform color and size would make it difficult to be economically feasible for a commercial venture. Results are shown in Appendix Table F-4.

Use of Frozen Squawfish for Mince

The K-value was 68%, which is high and indicates that there was serious deterioration of the fish before freezing. Torsion tests were run on the mince fish and were found to be:

Shear Stress	28,800
Shear Strain	1.45

The stress value is adequate, but the strain value is less than desired for a initial value and indicates the mediocre condition of the frozen fish. The quality of the fish was most likely due to poor handing of the raw product, and time and temperature abuse before the fish was frozen.

Mince prepared from the frozen fish was divided into four sample lots. One lot was washed, using a similar procedure mentioned in previous reports. This lot was further divided into unmodified washed mince and washed mince mixed with cryoprotectants. An unwashed lot was also divided into samples with and without cryoprotectants.

All samples were placed into 500-g plastic containers, vacuum sealed and frozen at -30° C. These samples were transferred to -20° C frozen storage and sampled at 30, 90, and 150 days by the torsion method. The torsion method uses a twisting module that records stress (related to gel hardness) and strain (related to gel elasticity).

As shown in Appendix Figures F-l and F-2, the washed sample mixed with cryoprotectants had superior stress and strain values to the other samples and there was little loss texture characteristics during the frozen storage. There was significant loss of strain for the washed mince if cryoprotectants were not added.

There was little change in the oxidative rancidity of either the washed or the unwashed mince over the first three months, as shown in Appendix Figure F-3. There was a slight rise from Month 3 to 5, but not sufficient to reject the product. There was little microbiological change over the frozen shelf-life of the product, as shown in Appendix Figure F-4.

Liquid Fertilizer

Deliveries of approximately 126,000 pounds of northern squawfish to Inland Pacific Fisheries in Payette, Idaho, were processed into fish fertilizer. The process has been previously assessed to be satisfactory, and no new information has been added in 1992. Fertilizer processing is a relatively low valued end use, with previously estimated exvessel prices of $.02-$.05 per pound if fish were marketed.

Minced Food Product

Stoller Fisheries again processed northern squawfish into a minced food product in 1992. All squawfish over 9 inches long were processed into mince. The remainder were processed into fish meal. Approximately 15 % , or 12,000 lbs, of northern squawfish delivered were too small to process into mince. The presence of small fish in the mix lowered the total yield.

The quality of fish received by Stoller Fisheries was good. Fish was freshly frozen and well-packaged. Less expensive packaging materials would also be acceptable for food fish shipments. The mince was processed by itself and not mixed with other species.

The best estimate of exvessel level prices for northern squawfish if marketed is between $.05/lb and $.15/lb.

Renderers

The 44,400 pounds of industrial grade northern squawfish delivered to renderers was combined with other protein sources and eventually processed into animal feed.

Mink Feed

Surplus industrial grade northern squawfish was collected by the OSU mink farm to use as mink feed. No feeding experiments were supported in 1992.

Seafood Brokers

Northern squawfish delivered to brokers was used to test the possibilities of export markets on the Asian region. Initial results indicate estimates of exvessel prices consistent with domestic use as mince, between $.05/lb and $. 15/lb.

Salmon Habitat Restoration

Assessment of northern squawfish flesh for its suitability in salmon stream enrichment experiments indicates that the fish is acceptable in this use.

Social and Regulatory Issues

Commercial Fishery

The 1992 commercial longline fishery operated at such high cost ($84.87 in direct expenditures per fish removed, at much higher unit cost if administrative costs were accounted for) and low levels of catch that it was discontinued in August 1992. Highly restrictive regulations imposed on this fishery continue to result in low fisherman interest and high monitoring costs. Conflicts with target fishery seasons (salmon) in Zone 6 and a reputation as a low-status “trash” fishery limit the operational possibilities of this fishery in the mode used to date.

Dam Angling Fishery

The dam angling fishery operated without notable conflict in 1992. Some minimal tension between dam anglers and sport-reward fishery participants continues to exist and will likely always exist as sport-reward participants judge higher catches-per-unit-of-effort to be available to them in restricted areas close to the dams. The availability of fish in near-dam areas to dam anglers and not to sport-reward anglers has caused resentment among a small proportion of sport anglers.

Columbia River Inter-Tribal Fish Commission (CRITFC) personnel, who provide management oversight of dam angling crews, noted some very favorable interactions in 1992 between tribal fishery technicians in the Bonneville crew and members of The Dalles Rod and Gun Club who volunteered as anglers. The fishery technicians supervised the volunteer anglers on three fishing periods at the Bonneville Dam.

A further positive outcome of the 1992 dam angling fishery noted by CRITFC personnel was the opportunity for tribal members, many of whom are commercial fishermen, to develop both the skills and acceptance as co-managers of the Columbia River’s fishery resources.

Sport-Reward Fishery

The sport-reward fishery was the largest of the three fisheries in terms of budget, geographic scope, and numbers of people involved. Approximately 37,500 anglers registered to fish for northern squawfish during the 1992 season. Over 15,000 anglers returned their catch for payment and filled out the angler survey. Due primarily to the large numbers of people involved, most of the social and regulatory issues that arise are related to this fishery.

Continuing conflict with other on-water users is evident in this fishery. Angler complaints were received about crowding with other anglers and with commercial fishermen, although few complaints of actual gear damage from conflict with other anglers or commercial fishermen were received. Some complaints were received about speeding boats, and a larger number about jet skiers. Some anglers complained about overcrowding on boat ramps, the size of boat ramps, and the wait time to launch.

Other comments made by anglers often enough to take note include questions about the voucher survey, requests that all northern squawfish be eligible for payment regardless of size, requests that dams be opened to anglers for fishing, comments about the enjoyment received from fishing, comments about the need for more flexible registration systems that would cut down on travel time and use of gas, requests that earnings from the northern program be tax-free, requests for more information on fishing techniques and the biology of northern squawfish, and criticisms of rude creel clerks and Native American commercial fishing.

The sport-reward fishery is also the source of the largest number of enforcement problems. Several issues plagued enforcement personnel throughout the 1992 season. The most important issue has to do with legitimate ownership of northern squawfish and establishing the location of catch. Both parts of this issue relate to establishing the eligibility of a northern squawfish for payment. Northern squawfish must be checked in by a registered angler to be eligible for payment. If northern squawfish can be transferred between anglers, there is no requirement that an angler in possession of northern squawfish at the time of interception by enforcement personnel be registered to fish in the fishery. This makes it extremely difficult for enforcement personnel to determine whether an unregistered angler in possession'of northern squawfish caught those fish in eligible waters or from waters outside the system included in the predator control program. The greatest potential for abuse of the northern squawfish payment system lies in the possibility of party fishing for northern squawfish outside the area of the predator control program, with delivery of large numbers of ineligible fish to check stations for payment. Establishing legitimate ownership of northern squawfish and legitimate source of catch are continuing problems for enforcement personnel.

The survey of a sample of non-returning anglers revealed few social or regulatory issues related to their participation in the fishery. For a few of the non-returning anglers, hours of registration site operation or location of the registration site contributed to their failure to return northern squawfish for payment, For the vast majority, however, failure to catch qualifying northern squawfish was the reason for not returning to the site. Anglers participated at other times in the fishing season, and most planned to participate again in 1993. Conflicts with other anglers or with other river uses were not mentioned as factors in their fishing trips.

For the creel clerks employed in the sport-reward fishery, interaction with the public was seen overall as a positive aspect of their job. Some problems arose with security at isolated' registration sites; 19% saw station security as only fair or poor.

Contaminant Tests

Dioxin test results have now been received from the Oregon Department of Environmental Quality. They are presented in the Interim Report (Appendix A). The dioxin test results are also included with results of tests for organic pesticides and heavy metals and presented in Appendix G.

DISCUSSION

Fishery Operations

Commercial Fishery

Operations of the commercial fishery have been discontinued for the foreseeable future. Extremely low catch rates in 1992 and the resulting high costs per fish removed indicate significant problems with achieving cost-effectiveness comparable with the other two removal fisheries.

To date, fears about incidental catch of game or protected species have driven the choices of gear and regulations in the commercial fishery. The overriding incidental species concerns have hindered the development of a commercial fishery through the development of rules that are inconsistent with the operational flexibility required of commercial fisheries.

One way to further explore commercial fishery feasibility would be to redesign the fishery to conform more closely with standard commercial fishery operations. This approach would rely on the active participation of commercial fishermen in the design, implementation, and oversight stages. The 1992 fishery did include an advisory board of fishermen, but this board was not active nor was it a participant in the design of regulations under which the fishery operated. Commercial fishermen experienced in the harvest of "rough fish" work throughout the region and would be available to operate an experimental fishery on a contract basis. Incidental catch concerns would be addressed in this type of fishery through on-board observation and monitoring of fishery operations.

Dam Angling Fishery

Catches of dam angling crews varied widely, leading to similar variations in expenditures per fish removed in this fishery. Compared to the sport-reward fishery, average costs per fish removed were somewhat higher. However, the sport-reward fishery had large levels of administrative costs (costs associated with program operation not specific to a particular site) that were not included in the budget presented. A cost-effectiveness comparison between the sport-reward and dam angling fisheries is not possible without a full accounting of costs associated with each program.

The reasons for the wide disparity among catches by crews are not apparent from the data used to prepare this report. It would be useful to know whether crew organization or contracting arrangements affect crew performance in ways that can be modified for the 1993 fishery.

Sport-Reward Fishery

The wide variation in cost per fish removed among sites justifies a reassessment of the number of registration sites and their location for 1993. The base level of operating costs per site suggests efficiencies to be realized through the, consolidation of the number of sites and increased streamlining of operations. High administrative costs associated with the large number of registration stations, employment of biologists at sites, and quality control difficulties associated with a large number of individual fishermen result in high costs per squawfish removed from the system.

In general, anglers are satisfied with the reward aspect of the fishery, although there is a minority that requests higher reward payments and questions the existence of commercial or dam fisheries. However, the large numbers of anglers who see the recreation opportunity provided by northern squawfish fishing and the contribution to salmon enhancement as important motivations for their participation indicate that an increase in the reward is not necessary for continued participation. It may even be possible to decrease the reward payment and continue participation at levels high enough to accomplish removal goals. Midlevel reward payments ($2 per fish) were in the original experimental implementation plan, but were never instituted.

Complaints about processing time at stations continue; perhaps angler processing time could be streamlined in 1993 through changes in site operations and biological sampling procedures. More flexible registration procedures would be appreciated by a large segment of the angling Population. The creel clerk survey supported the complaints of some anglers about lengthy processing times, although overall creel clerks were more concerned with poor equipment and needs for improved station security.

The fears about the high numbers of non-returning anglers being related to poor check station location or discouragement with the fishery were not borne out by the survey. The overwhelming reason for not returning to the check station site was failure to catch northern squawfish on that trip. However, poor catch on one trip did not discourage anglers from either further participation in the 1992 fishery or plans to participate in the 1993 fishery. Check stations were evaluated to be conveniently located by the large majority of anglers surveyed.

Distribution of Catch

Overall, the 1992 food-grade collection network was a success, but many improvements can be made to make a future operation run much more efficiently, collect a greater percentage of food-grade squawfish, and cost considerably less. In 1993 and beyond, the handling network will be operated with two major objectives, realizing these objectives will affect all the agencies participating in the removal program: (1) incorporate as much private sector participation possible, and (2) minimize handling and distribution costs.

Handling Recommendations

1. Overall handling must improve; conscientious handling should be considered part of the job.

2. Fish must be iced immediately, the melt-water drained after the fish are chilled, and iced again. Once the fish are chilled to near freezing, the ice will melt at a very slow rate.

3. Ice should be used judiciously; huge amounts of ice were wasted in 1992.

4. Any fish that are cut open or are in obviously poor condition should be separated from other fish at all times.

5. Fish that get dirty should be cleaned before they are iced.

6. Dam anglers should drop their fish directly into coolers with ice. There is no need to kill them.

7. Washington Department of Wildlife technicians should drop fish directly into coolers as they are being counted and should not remove them from the coolers afterwards.

8. During the 1993 field season, OSU will transfer ownership of handling equipment (coolers, freezers, and totes if necessary) to the agencies who use this equipment in the field. In the context of a network operated principally by the private sector, efficiencies will be realized by equipment ownership and accounting that is under each project's control.

9. A 65% to 75% rate of food-grade collection in 1993 is an attainable goal.

Future Handling Network Recommendations

‘Experience in 1992 has led to the following recommendations for future set up and operation of the fish handling network.

1. Subcontract local fish processors, meat markets, or cold storage facilities to serve as receiving and packaging locations. These facilities should have enough freezer space to store at least a week’s worth of frozen fish (preferably more) and have ice available. Ideally, someone would be present in the evenings to receive the incoming squawfish and process them that night. The contracts should include a fixed overhead/labor rate with additional payment based on the volume handled. These contracts could be put out as competitive bids, but it seems that one is lucky to find even one processor in a given area that can satisfy the needs of the program.

2. In as many locations possible, the Washington Department of Wildlife should hire technicians who can work in the field and process fish in the evening. A setup of this type is by far the least expensive handling option available because it greatly reduces redundant labor charges and other “hidden” costs. People who have’worked for local processors in the past would be good candidates for these jobs and could train others to grade fish as well. This ideal situation is not available everywhere, but has potential in 1993 for Longview, Clarkston, and Cascade Locks. This system should be pursued as a first option in all locations possible.

3. Subcontract a trucking outfit or fish processor who delivers fish regionally to pick up frozen squawfish from the food-grade collection locations. This task could be put out as a competitive bid in the future. This service would eliminate the need for OSU to pick up fish in a large rental truck.

4. Agencies operating removal fisheries in remote, low volume locations (Snake River dams, John Day Dam, Lyon’s Ferry sport-reward site) should become responsible for disposition of their catch. This could be storage in chest freezers and monthly deliveries to a processing location or establishing a rendering pickup system with a local merchant. It is extremely inefficient to contract someone to pick up fish from these locations. This system should also apply to the Merwin Trap fishery unless it begins to yield enough squawfish to justify food-grade handling.

5. Bonneville, The Dalles, and possibly McNary dams should deliver their catch daily to a fish processing location (if one is available in the area). The coolers full of iced squawfish would be placed in a lockable drop-box where ice and fresh coolers would be available for the next day. Delivering large totes of ice to the dams is a negotiable issue, but for cost considerations should be avoided if possible. CRITFC should plan on purchasing their own coolers for 1993 because OSU will have no property control over equipment used by dam anglers.

6. Any handling network should be administered by someone who is familiar with both the harvest and handling aspects of the overall program. Private sector fish processors are not familiar with the handling requirements and goals of this fishery, so one must know how the system should operate before negotiating contracts.

After a workable private sector system has been developed, then the question arises as to who should pay for it. It seems that two possible options exist (or some combination of these two).

1. The participating agencies pay for the fish handling services themselves (include the charges in their budgets).
2. A single entity sets up and pays for handling services (the current system). A handling administrator submits a budget to pay for all handling services.

Roth have advantages and disadvantages, but Option 2 probably provides more flexibility in the event of changes in the removal program that seem to be inevitable.

Catch Utilization

OSU Value-Added Product Experiments

The results of this investigation suggest that squawfish could serve as a resource for the production of surimi. Surimi quality is maintained well during the first three months of frozen storage. A good grade of surimi can be made from fish that has been stored in ice up to nine days. This is unusual as Alaska pollock and Pacific whiting undergo significant deterioration after three days of ice storage.

Roe from northern squawfish is varied in color and size. It constitutes approximately 12% of the weight of the female squawfish. Because of the quality and color characteristics, it would be unlikely that squawfish could be harvested for its roe.

In general, the mince made from frozen squawfish held up well in frozen storage if cryoprotectants were used before re-freezing. The initial strain value was lower than mince made from fresh fish and is due to (1) the denaturation of proteins in the native state during frozen storage and (2) the fact that fish were not frozen immediately after capture as indicated by the high K-value. Nonetheless the results are encouraging as they show that frozen squawfish can be used as a mince at a later time period. This would simplify the handling and storage of squawfish caught at the dams. Also the production of mince would occur when enough raw material has been stored.

Liquid Fertilizer

This product form is a feasible outlet for supplies of northern squawfish on a technical basis, but since estimated prices will be relatively low, fertilizer does not offer the greatest potential for cost recovery. Fertilizer processing remains a viable alternative for processing industrial-grade fish that have no higher values use.

Minced Food Product

Minced food products continue to be the highest valued use for food-grade northern squawfish. The Interim Report (Appendix A) presents a comparative assessment of various end uses of northern squawfish compared to their incremental handling costs.

The presence of small fish in the mix represent a loss from minced food processing. According to Stoller Fisheries, experience with other “rough” fish fisheries (carp and suckers) suggests that continued large-scale removals of northern squawfish may actually increase average size of fish.

Contaminant levels (DDT, DDE) in northern squawfish organs are high enough to present problems when northern squawfish is processed alone as fish meal. Mixing with less contaminated species has resulted in meals with acceptable levels.

Renderers

The 44,400 pounds of industrial-grade northern squawfish delivered to renderers was combined with other protein sources and eventually processed into animal feed.

Mink Feed

Surplus industrial-grade northern squawfish was collected by the OSU mink farm to use as mink feed. No feeding experiments were supported in 1992.

Seafood Brokers

Northern squawfish delivered to brokers was used to test the possibilities of export markets on the Asian region. Initial results indicate estimates of exvessel prices consistent with domestic use as mince, between $.05/lb and $.15/lb.

Salmon Habitat Restoration

Assessment of northern squawfish flesh for its suitability in salmon stream enrichment experiments indicates that the fish is acceptable in this use.

Utilization Conclusions

We now have two years of consistent estimates of an exvessel price range for northern squawfish of $.05-$.15 per pound in food use, and $.02-$.05 per pound in industrial use. Given this information and the level of interest in utilization of northern squawfish, it is time to consider the design and implementation of a mechanism by which users can pay for the fish. If small amounts of northern squawfish were still provided free of charge to potential users for experimentation, it would benefit the long-term program in terms of maximizing the exposure of northern squawfish to all potential users.

Given the successful experience with food-grade processing and the potential for future marketing, it is time to consider an application to the U.S. Food and Drug Administration (FDA) for a market name. Previous inquiries with the FDA indicated that there is no impediment to the assignment of a market name other than to avoid duplication with existing names.

Social and Regulatory Issues

Fisheries

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

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

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

Continuing comments criticizing Native American commercial fishing on the Columbia River, albeit in small numbers, indicate that there is a public education need associated with this program that has been unaddressed. Comments to the effect that commercial fishing on the river should be banned, that Native Americans should be restricted to the use of poles or dipnets only, that Native American fishing should be limited to subsistence use only, or that Native Americans are the cause of the salmon problem, all indicate a basic misunderstanding about Native American fishing rights, their historical place in the river system, and their place in the larger arena of fishery management. For the continued smooth operation of a Northern Squawfish Predator Control Program as well as for fishery management in general, it would be worthwhile to produce some educational materials that clearly describe the realities of resource ownership and treaty rights. Concepts such as rights retained by Native Americans when signing treaties as contrasted to rights assigned to Native Americans by non-natives are apparently not understood by a persistent minority of anglers.

Contaminant Tests

Low levels of dioxin contamination in northern squawfish flesh indicate no problems for long-term utilization of this fish. Previous tests for organic and heavy metal contaminants indicate no problem with human consumption. The only contaminant problem posed by northern squawfish is from DDT and DDE levels in organs when squawfish are processed into fish meal without a mix of other species.

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APPENDIX A

Interim Report on Harvest, Handling, Utilization, and Regulation

INTERIM REPORT ON THE FEASIBILITY OF HARVEST, HANDLING, UTILIZATION AND REGULATION OF NORTHERN SQUAWFISH

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TABLE OF CONTENT;

INTERIM REPORT ON THE FEASIBILITY OF HARVEST, HANDLING, UTILIZATION AND REGULATION OF NORTHERN SQUAWFISH

INTRODUCTION

This report presents a consolidation and summary of research activities conducted by Oregon State University between 1989 and 1992 on four components of the fishery for not-them squawfish (*Ptychocheilus oregonensis)*: harvest, handling, utilization and regulation. The report is a four-year retrospective on how we began, what we did, and what we found out as part of the research project "Development of a System-wide Predator Control Program: Stepwise Implementation of a Predation Index, Predator Control Fisheries, and Evaluation Plan in the Columbia River Basin". The report consolidates information contained in annual reports and other project-related information. For purposes of readability the report does not contain citations.

The first section of the report presents a description of the research background: what was known about not-them squawfish and its utilization at the beginning of the project, the factors affecting the approach to utilization, and the constraints within which the harvest, handling, utilization and regulation of northern squawfish operated.

The second section of the report describes the evaluation of methods of northern squawfish removal, handling, utilization and regulation. In this section we describe our research objectives and the process we used to meet those objectives.

The third section of the report presents the results of the evaluation, presenting comparisons between alternate harvest methods, handling methods, utilization methods, and regulatory approaches.

The final section presents recommendations on each of the four research components based on the evaluation of project activities through 1992.

Information on 1992 operations is preliminary. At the time of this report writing, all projects are still entering data and making final assessments of the 1992 season.

BACKGROUND

We began our evaluation activities in 1989. Although predation research had been conducted on northern squawfiih prior to that time, 1989 was the first year that harvest technology and predation experiments resulted in yields of fish. 1989 was also the beginning of the attempts to implement northern squawfish population control through harvests.

The existence of yields and the potential for large quantities of northern squawfish to be harvested raised the issue of utilization for the first time. The project was faced with the need to dispose of northern squawfish yields. In the crudest terms, the choice was between using the harvested fish or burying them. On the assumption that public stewardship responsibilities dictated that utilization of a natural resource was more responsible than disposal, we proceeded to investigate the feasibility of utilization alternatives. We began with an assessment of what was known about northern squawfish and its utilization.

Underutilization of Northern Squawfish

Northern squawfish had long been considered a "trash" or "junk" fish. Native Americans had traditionally consumed only very small amounts of northern squawfish. Anglers typically killed and threw back and northern squawfish caught incidentally. Commercial fishermen did not land northern squawfish because markets did not exist. With the exception of a few people who canned northern squawfish for home consumption, the fish was not utilized.

A major reason for the lack of utilization of northern squawfish was the characteristics of the fish. Although the flesh of northern squawfish was sweet and mild, the fish contained a large number of small barbed bones which made it difficult and time consuming to eat. The appearance of the fish was not a barrier to human consumption.

Another reason for the underutilization of northern squawfish was tradition. Tradition plays an important role in human consumption of fish. Consumer preferences for fish are often the result of practices established over several years. Historical choices made for preferred species will sometimes label a less desirable species as "trash" fish because the preferred species is at levels of abundance capable of filling consumption needs. Species preferences carry down through generations and may remain fixed even after abundance levels of the preferred species are no longer equal to all human consumption needs. Once a fish has been labeled "trash", it is often difficult to overcome that historical perception.

Associated Research

Conversations with fish brokers and other researchers revealed that Sacramento blackfish (*Orthodon microlepidotus*), a species with characteristics similar to those of northern squawfish, were sold in California market areas with Asian population concentrations. A research project in progress to assess harvest methods and market potential for Sacramento squawfish (*Ptychocheilus grandis*) had been hindered in the development of markets by dioxin contamination of the fish.

On the basis of these conversations, we determined that outlets for experimentation with northern squawfish as human food would likely be those serving Asian consumers.

Constraints to Northern Squawfish Utilization Experiments

We developed our assessment approach within the context of several constraints: legal, biological, health, regulatory, and social.

The legal constraint within which utilization. of northern squawfish must be conducted is the Oregon statute which classifies northern squawfish as "food fish", and as such prohibits any disposal which constitutes "wanton waste" or "destruction". Burying of northern squawfish was determined to fall into the wanton waste category.

The biological constraint within which we planned the utilization assessment was a high level of uncertainty about the characteristics of northern squawfish yield. Neither the size nor the stability of yields from the predation control project were known. We knew that concentrations of northern squawfish would be available seasonally due to both spawning aggregations and salmon smolt migration times.

The public health constraint within which we developed was the need to ensure that contaminant levels in northern squawfish were low enough to allow human consumption. The experience with Sacramento squawfish alerted us to the possibility of contamination of northern squawfish in the Columbia River from organic sources, heavy metals, or dioxin.

The major regulatory constraint for the harvesting and utilization of northern squawfish was the need to avoid destructive overlap between the harvest of northern squawfiih and other fisheries. Incidental catch of closely regulated species were of particular concern.

Social constraints to harvest and utilization consisted of the need to avoid approaches to harvest or handling which caused conflict with existing river activities, including recreational and commercial fishing, nonfishing water activities, boat ramp use, enforcement problems, or negative public perceptions.

Project Objectives

One objective of the predator control program was to control predation on juvenile salmonids through the achievement of target levels of northern squawfish removals. In consultation with researchers within the Oregon Department of Fish and Wildlife, we determined that **within** this overall program objective of target removals, the objective of the "feasibility" project would be the following: 1) to assess alternative approaches to harvest, handling, and utilization and to evaluate their relative cost-effectiveness; 2) to evaluate regulatory and social issues related to the control program as a whole 3) to evaluate removal fisheries for social impacts in their contribution to target removal goals.

Evaluation Criteria

To say that an activity is feasible means it is workable, practical, or attainable. One aspect of feasibility, then, is whether as activity is workable within the existing constraints. The assessment. of feasibility of various program components is properly done within the context of the overall program goals.

A second aspect of feasibility involves tradeoffs. If a range of alternatives is workable, then choosing among alternatives is a matter of looking at the tradeoffs between alternatives in light of the overall objective.

The least-cost focus of the feasibility project objectives led to the adoption of cost-effectiveness as a standard for evaluation of alternatives. It is worth noting why cost-effectiveness was chosen as an evaluation criterion rather than cost-benefit analysis since cost-benefit analysis more commonly comes to mind in the evaluation of activities.

A cost-benefit analysis requires the quantification of both costs and benefits of a particular activity or project. Inputs to the activity are costs; outputs from the project are benefits. If outputs from the activity are fixed, benefits are fixed. When benefits are fixed and only costs are variable, the appropriate basis for comparison between alternatives is cost. The question is: for a given benefit (output), what is the range of costs represented by alternatives?

The predator control project fixes output through its specification of target removal goals for northern squawfish. The goal is not to eradicate northern squawfish through the maximum possible output, but rather to achieve predation control through target removal levels which alter northern squawfish population size and age structure. Because output is fixed, the appropriate evaluation criterion is cost-effectiveness; the minimum cost approach to a given output.

The cost-effectiveness question applies to removal methods, handling methods, and utilization methods. The questions that this project asks are: What are the least-cost alternatives for meeting target goals of fish removal? What are the least-cost alternatives for handling the fish removed? What are the least-cost alternatives for achieving northern squawfish utilization that avoids "wanton waste"?

The above is not to suggest that the only benefits resulting from the conduct of removal fisheries for northern squawfish are biological benefits of predator reduction. Economic benefits associated with harvest, handling, and utilization activities accrue to the economy at large. Economic benefits include the economic impact of expenditures by fishermen, increases in employment, and purchase of support services. Social benefits also accrue, such as an increase in recreational fishing opportunities and an opportunity to participate in salmon enhancement. An assessment of these benefits is included in this report.

Summary of Background

The background knowledge with which we began our assessment of utilization alternatives may be summarized in the following way. Northern squawfish had no general history of harvest or utilization. It was a bony fish with sweet-tasting flesh. Oregon state law required that we avoid wasteful or destructive use of the harvest. The size and time flow of northern squawfish yields were unknown. Harvest methods and times must be set to minimize the problem of incidental catch. Harvest, handling and utilization methods must minimize the likelihood of conflict with either activities or enforcement problems.

EVALUATION PROCESS

Building on the background information we acquired, we developed our procedure for evaluation. Given the approach to control populations of northern squawfish through harvest, and the concurrent need to regulate the harvest, handle catch and ensure utilization, the major research task was to assess the alternatives for each fishery component. We evaluated the characteristics of the fish, contaminant levels, removal methods, handling methods, product forms, market potential, regulations, social issues, and enforcement issues.

Fish characteristics

We began with an understanding that northern squawfish was extremely bony. We conducted both sensory and chemical evaluations to determine other species characteristics. We conducted small-scale sensory evaluation tests with consumers and owners of restaurants and markets. Chemical analyses of northern squawfish flesh were conducted by the Oregon Department of Agriculture (ODA), OSU Department of Food Science and Technology, and by private users to assess nutritive composition.

Contaminant levels

We arranged with the Oregon Department of Environmental Quality (DEQ) to include northern squawfish in fish tissue tests they conducted in 1989. Both flesh and organs of Northern squawfish were tested for pesticides (PCB's, chlordane, DDT derivatives) and heavy metals (mercury, aluminum, lead, arsenic). We subcontracted with the DEQ to arrange the testing of samples of northern squawfish for dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF)). The DEQ contracted with the Duluth, Minnesota lab of the Environmental Protection Agency (EPA) to perform the tests.

Removal Methods

We evaluated the three major removal methods - sport angling, commercial longlining, and dam angling - on the basis of cost per unit catch, social issues, regulatory issues, handling requirements, and enforcement problems.

Data were collected on the sport-reward fishery through several means. Anglers who registered in the fishery were surveyed about their fishing time, fishing methods, expenditure patterns while fishing, miles traveled to fish, experience fishing, assessment of problems associated with fishing for northern squawfish, and views of the northern squawfish program. Anglers were given a questionnaire to fill out with the voucher for payment. Anglers who registered to fish but did not return to the check-out station were surveyed through telephone interviews. Creel clerks who staffed the sport-reward fishery sites were surveyed about. fishery operations at the end of the fishing season. Data on catch, effort and expenditures per site were provided by the sport-reward fishery administrators. Information on enforcement issues was obtained through interviews with enforcement personnel.

Data on the commercial fishery were collected through four sources. Logbooks recording catch, effort, and expenditures were filled out by fishery participants. Commercial fishery observers and commercial fishermen were surveyed about fishery operations. Data on payments per fish and total fishery expenditures were provided by commercial fishery administrators. Information on enforcement issues was obtained through interviews with enforcement personnel.

Data on the dam angling fishery were collected through three sources. Weekly catch and effort reports as well as total fishery expenditure reports were provided by the dam fishery administrators. A summary of issues related to dam fishing operations was also provided by dam fishery administrators. Information on enforcement issues was obtained through interviews with enforcement personnel.

Data on some experimental harvest methods was also collected. Purse seine operations provided data on catch, effort, and expenditures. The same data were provided for the Merwin trap operations.

Handling' Methods

The scope of the fish collection and distribution program has been dependent on two factors: the fish removal program and the end-use program. The evolution of the fish handling system reflects the expansion of the magnitude and geographic scale of the removal fisheries as well as the changing focus of the end-use evaluation. The pickup and distribution system evolved from a cooperative effort between researchers in 1989 to an expanded specialized program involving five employees in 1992.

Large volumes of fish in 1991 and 1992 harvested under a "full-scale" fishery implementation plan required the development of a handling system which was responsive to rapid changes in quantities and location of harvest. Total program harvest increased almost twelve-fold between 1990 and 1991. In addition, attention was paid to the development of a fish grading system which would provide as much food quality fish as possible for utilization-

Data on volume of fish, distances traveled, expenditures and fish quality were collected for each year of fish handling. The costs of the fish handling program were evaluated in four components; administrative/operating costs, on-site costs, off-site costs and coordination costs. These costs are discussed below and summarized in Table 1.

Administrative/operation (admin/op) costs include all costs associated with the design, set-up and implementation of a basic fish-handling system which will remove fish from landing site and dispose of them. These costs vary according to both the scale of operation and the configuration of the program. Included in admin/op costs are administrative and handling labor, field stations, equipment, vehicles, and service to sites (pick up and delivery). The magnitude of admin/op costs in any fishing year is Sensitive to several factors: numbers of harvest sites, geographic dispersion of harvest sites, projections of removals, fish handling setups at harvest sites, and the delineation of 'responsibility between respective projects. Once these factors are determined at the beginning of a fishing year, total admin/op costs remain fixed. Average admin/op costs per fish decrease as the numbers of fish landed increase. Admin/op costs are not sensitive to a particular end use for the fish.

On-site costs include the costs related to the handling and pickup of fish onsite. These costs vary according to the setup of operations onsite and the quality control system in place. Included in these costs are the design and implementation of a handling system, training materials for on-site employees, interim handling and storage onsite, and equipment for quality control. On-site costs are sensitive to the setup onsite, the end use of the fish, and the degree to which onsite employees comply with quality control requirements.

-Off-site costs include all costs incurred away' from harvest sites related to handling fish for a particular end use. These costs include additional sorting and storage needs, packaging and ultimate transportation to users. Off-site costs are sensitive to the type of end use and to the volume of fish handled, but are only indirectly sensitive (through quality outcomes) to fish handling at harvest sites.

Coordination costs are those costs associated with the administration of a particular handling arrangement. Coordination costs are sensitive to the degree of complexity in removal sources and end uses. They are also sensitive to the effectiveness of preseason planning and the extent to which the responsibilities of all cooperating parties are clearly delineated and enforced.

A sub-objective of the feasibility research project was to develop a plan for the transferral of fish handling responsibilities to the private sector. Components of the private sector plan must include a description of the supply sources and location, a discussion of quality control issues at harvest sites and during transportation and handling, a discussion of transportation and storage logistics, an evaluation of costs under alternative approaches, and recommendations for project contracting conditions which will ensure adequate coordination between private parties and the predator control project.

Product Forms

The development of products which will utilize the entire catch and avoid "wanton waste" requires a consideration of product forms which can accommodate both food grade and industrial grade fish. We tested the suitability of northern squawfish for processing into various product forms listed in Table 2. These product forms were tested through a combination of private and public sources. Experiments were conducted by rough fish processors, fish meal producers, bait dealers, fertilizer producers, fish brokers, a mink producer and the Astoria Seafood Laboratory of the Coastal Oregon Experiment Station, Oregon State University. Experimental product forms include fillet, boned mince, mince with binders and cryoprotectants, roe, liquid fertilizer, fish meal, fish oil, animal food and bait.

Data on product form experiments were collected through a combination of forms. The, Astoria Seafood Lab work was summarized in annual reports. Interviews were conducted with market testers to obtain feedback on whole-fish and mince product. Reports on fish meal and oil composition were obtained from producers. Market reports on acceptance of privately produced **mince** were provided. The fertilizer producer was interviewed to ascertain costs and price constraints. The results of mink feed trials were reported in a written summary. Bait users and fish brokers were interviewed about product suitability.

Market Potential

Data on costs, prices and market potential of northern squawfish in various product forms were obtained from the end users listed above. Users were asked to provide information on special handling requirements, costs of processing, estimates of raw product prices, and other information about the market in which they sell their product.

We investigated the requirements necessary for the assignment of an alternative name for northern squawfish for the purposes of marketing. We contacted the U.S. Food and Drug Administration (FDA) to determine whether impediments existed in using a market name. We also contacted tribal representatives and other researchers to enquire about alternative traditional names for northern squawfish.

Regulations

Regulations pertaining to existing commercial and sport fisheries in the Columbia River were reviewed for consistency with planned deveiopment of fisheries for northern squawfish. Particular attention was paid to restrictions on gear, incidental catch, season timing, and fishing location. In 1990 we began what will be a continuing process of identification of issues specifically related to the regulation of fisheries for northern squawfish. A detailed questionnaire was circulated to state fishery agencies, public utility districts, the Columbia River Inter-Tribal Fish Commission, The U.S. Army Corps of Engineers, FPAC members and CBFWA members. Recipients were asked to identify any issues related to the development of fisheries for northern squawfish which were in conflict with existing regulations or presented potential conflicts- A follow-up survey was made of these same interests in 1991.

Social Issues

We were interested in identifying issues associated with fisheries for northern squawfish which were either costs or benefits associated with the conduct of the fisheries. Social costs include crowding on the water or boat ramps, commercial-sport gear conflicts, coordination difficulties, etc. Benefits include provision of additional recreational fishing opportunities to the angling public. We identified the existence and relative magnitude of social costs through a monitoring procedure established for each fishery. Conflicts and negative external effects of the commercial longline fishery were identified through two means: post-season interviews with commercial fishermen participants and commercial fishery employees. Conflicts and coordination issues were identified for the dam angling fishery through post-season summaries provided by dam fishery administrators and fishery agency observers. Conflicts and other social issues associated with the sport-reward fishery were identified through the angler questionnaires, a survey of nonreturning anglers, and a survey of fishery employees.

Enforcement Issues

Issues related to the enforcement of regulations associated with the commercial longline, dam angling, and sport-reward fisheries were identified through informal surveys of enforcement personnel. Questions were asked about particular problems created by each of the three fisheries and about additional enforcement burden, if any, created by each fishery.

Summary of Evaluation Process

Fish characteristics, contaminant levels, removal methods, handling methods, product forms, market potential, regulations, social issues and enforcement issues were evaluated using a variety of data. Sources of information included laboratory tests, market trials, experimentation by fish processors, participant surveys, employee surveys, enforcement contacts, published legal and regulatory documents, agency surveys, logbooks, private sector consultation, and consultation with other researchers-

EVALUATION RESULTS

This section summarizes the results of our evaluations of fish characteristics, contaminant levels, removal methods, handling methods, product form, market potential, regulations, social issues, and enforcement.

Fish Characteristics

Sensory, technical and chemical evaluations conducted on whole, filleted and minced northern squawfish yielded consistent results across evaluating groups; consumers, restaurant owners, retail market owners, processors and laboratories.

Sensory evaluations indicate that northern squawfish fillets have a flaky texture, bland to sweet taste, and good appearance. The coloration of the flesh is acceptable, and no objectionable odor exists. Ease of handling is acceptable. The large number of barbed bones is a problem for fillet consumption- Deboned mince of northern squawfish has a firm texture and a bland taste adaptable to a range of seasonings. Washing is required to remove blood deposits from processing.

Technical evaluations indicate that northern squawfish has superior potential in the production of engineered seafoods from mince. Engineered seafood have advantages over natural-form seafoods of increased shelf life in frozen storage and an increased versatility of use. A key factor in a species' suitability as an engineered product is its ability of the mince to form a gel. Northern squawfish was found to have superior gel strength lasting over a longer period than most ocean-caught fish. Northern squawfish also has demonstrated good shelf life with the addition of cryoprotectants.

Chemical evaluations for protein, ash, fat and fatty acids indicate the following: protein content is roughly 18%, a level between levels for carp (17%) and yellow perch (19%). Ash content is approximately, 1.4%, a level similar to carp and exceeding yellow perch. Total fat content is low, roughly .6% as compared to yellow perch at .9%. Fatty acids are in general below levels in carp and yellow perch. Northern squawfiih is a low-fat, moderately high protein fish. In minced form, both protein and ash proportions decline with successive washings.

Contaminant Levels

Contaminant tests performed by the Oregon DEQ and the EPA indicate that northern squawfish is suitable for human consumption without advisories.

Tests for pesticide contamination (PCB's, chlordane, DDT derivatives) indicate that all pesticide levels in northern squawfish sampled are below FDA action levels .

Tests for heavy metal contamination (mercury, aluminum, lead, arsenic) indicate that all heavy metal levels in sampled northern squawfish are below FDA action levels.

Tests for dioxin contamination (TCDD and TCDF) indicate all samples with detectable concentrations of TCDD (10 of 15 samples) were below FDA action levels of 25 ppt. and above EPA guideline levels of .07 ppt. TCDD concentrations are similar to other resident fish in the Columbia River system. Neither the FDA or EPA have adopted criteria to establish action levels of TCDF at this time. However, TCDF is considered to be approximately one-tenth as toxic as TCDD.

The Washington Department of Health has reviewed data from the Columbia River and has determined that a fish consumption advisory for the general population is not warranted at this time. The Oregon Health Division has reviewed TCDD data for fish from the Columbia River and has not issued a fish consumption advisory.

Removal Methods

The three major removal methods - the commercial longline fishery, dam angling fishery, and sport-reward fishery vary widely in types of operation, costs of operation, administration, oversight, and quantities of fish removed. Contributions of each removal fishery to total catch in 1990, 1991, and 1992 are summarized in Table 3.

Commercial longline fishery:' In the three years of its operation the commercial longline fishery has contributed little to overall removal goals (Table 3). Landed catch has been low and costs high relative to the other two fisheries. The fishery has been plagued by low levels of participation and low catch per unit effort since its inception. Expenditures in the commercial longline fishery per fish removed have been very high.

Commercial fishermen have been interviewed to document their perspective on problems with fishery operation. Their assessment of problems includes difficulties with preordained fishing hours, seasons, rules on employment of gear, and what is seen as invasive oversight by onboard observers.

Observers who worked on commercial fishery vessels were interviewed in 1992. Their summary of fishery operations notes problems in excessive paperwork and equipment problems, and some problems related to low levels of fishermen participation, such as overstaffing and fishermen resentment of the level of observer coverage.

Remuneration systems in the commercial fishery have included a monthly stipend in 1990, a per-fish payment without stipend in 1991, and a combined stipend/per-fish payment in 1992. Remuneration approaches have been revised each year in response to ‘feedback from ‘participating fishermen. Levels of compensation appear to have been set at levels high enough to cover normal operating costs.

The combined sources of information suggest that the fishery has suffered from the perception of low status, competition with other fishing activities available to commercial fishermen, and rigid constraints imposed on fishery operations, but not necessarily from inadequate compensation for participating fishermen-

Dam angling fishery: The dam angling fishery expanded its operation by 33% between 1990 and 1991, from 6 to 8 dams. The number of dams in this fishery remained fixed between 1991 and 1992. In contrast, sport-reward fishery increased the number of check-in stations by 375% between 1990 and 1991, and by 33% between 1991 and 1992. The dam angling fishery share of total removals has declined over the time period in part due to the increase in the sport-reward fishery and in part due to a decrease in dam landings in 1992 (Table 3).

Various assessment of dam angling operations indicate that coordination, safety and security issues related to fishing off the dams have been or continue to be resolved. The dam fishery has had duties of removal and assisting in biological evaluation which at times have worked against each other. Coordination with other projects continues to improve.

Personnel in the dam angling fishery continue to have occasional difficulties with public perceptions that anglers are unfairly catching “sport” fish. Public education efforts could be directed at this problem.

Snort-reward fishery: In the three years of its operation, the sport reward fishery has continually expanded the scale of its operation, from 4 sites in 1990 to 15 sites (+375%) in 1991 to 20 sites (+33%) in 1992. In 1992 the sport-reward fishery operated 20 check-in sites over a 300 mile area of the Columbia and Snake Rivers.

Both absolute numbers of removals as well as the proportion of total removals accounted for by the sport-reward fishery has increased as the fishery has expanded (Table 3).

As it has grown, the sport-reward fishery has attracted an larger and more diverse population of anglers from a wider geographic area. Some sites routinely attract single-day fishermen traveling less than 40 miles to fish, while others attract fishermen traveling 100 or more miles who spend three days fishing.

A relatively high (59% in 1992) percentage of anglers who register to fish for northern squawfish do not return to the station to check in fish. Anglers who did not return to the site spent about two-thirds of their fishing time targeting northern squawfish. The major reason for anglers not returning has been the lack of qualifying catch of northern squawfish. The second most important reason is that anglers returned after hours when. the check station was closed. However, these anglers were not permanently disaffected with the northern squawfish program. Almost 90% of those surveyed said they expected to participate in the sport-reward fishery again. The most important reasons these anglers gave for participation in the northern squawfish program were recreation and the opportunity to earn money. Participation in salmon enhancement was also important to many.

Operations of the sport-reward fishery were assessed in a survey of creel clerk supervisors in 1991. Check-in procedures, operating hours, the data collection process, data forms, and staffing levels tended to be evaluated as effective by the majority of clerk supervisors. The majority evaluated equipment at sites to be inadequate. The assessment of 1992 operations is in progress.

Handling Methods

Handling methods employed during the feasibility project have increased in complexity as the project changed. In 1990, with total removals of 16,900 fish, the handling system was comprised of a single employee, one truck, some uninsulated totes and a few chest freezers. The rapid expansion of the removal program in 1991 required a focus on the rudiments of handling large volumes of fish. The handling system expanded to four employees, four trucks, insulated and uninsulated totes, and numerous chest freezers. Quality control considerations were sacrificed to the more pressing need to dispose of an almost twelve-fold increase in quantities landed. By 1992 a system was in place for handling large volumes of fish, and more attention could be placed on system design for quality control. The handling system consisted of five employees, three trucks, several fish processors, and numerous coolers. In 1992 30% of all fish handled were'food grade; of the sites which were targeted for food grade, 37% food grade resulted.

Property control of both fish and equipment has surfaced as an increasingly important issue as the scale of program operation has increased. A significant number (120) of portable coolers were lost from the project in 1992. Discrepancies between numbers of fish caught by removal projects and the number of fish handled suggest that a certain number of northern squawfish may be "recycling" through the system, perhaps being caught in a removal fishery then checked into the sport-reward fishery for payment. We are continuing to look for other sources of discrepancies.

Table 4 lists rough estimates of handling cost by component: admin/op, on-site, off-site, and coordination costs. These estimates were derived on the basis of best knowledge to date of handling requirements and associated charges associated with particular end uses. Cost estimates are presented to illustrate the relative magnitude of cost components and the changes in those costs as the end-use mix changes. We discuss three end uses which cover the quality spectrum and which have accounted for the majority of fish utilization to date. These end uses comprise two grades of fish; industrial and food. Rendering represents the lowest quality industrial use, fertilizer a higher quality industrial use, and food the highest quality food use.

Admin/op costs are fixed per season once the scale and scope of the program is established. Late planning and changes program operation combined with uncertainty about actual levels of removals have required administration and operation planning for northern squawfish handling to proceed on a "worst-case" basis, resulting in fixed costs per season which are higher than the minimum required. Although total admin/op costs are fixed once a season begins, average admin/op costs per fish decreases as -the volume of fish handled increases. For the volume of fish handled in 1992, admin/op costs are estimated to'range between $.40 and $.45 per pound.

On-site costs vary within season according to the efficiency of on-site handling and the end use for which the fish are being handled. Our best estimate of the range of costs added to basic admin/op costs as a consequence of handling for a particular end use are: rendering $.08 per pound; fertilizer $. 10 per pound; and food $. 12 per pound.

Off-site costs also vary within season according to the volume of fish handled and the end use for which they are being handled. Our best estimates of the range of off-site costs added to basic admin/op costs and to on-site costs are: rendering $.08 per pound; fertilizer $.12 per pound; food $.16 per pound.

Total variable costs associated with particular end use are the sum of on-site and off-site costs. For rendering these costs are $. 16 per pound, for fertilizer $.22 per pound, and for food $.28 per pound.

Coordination costs are time costs associated with the amount of planning, the delineation of responsibilities between projects, and the complexity of end uses. These costs are unquantified here; they may be low, medium or high in any given season depending on the effectiveness of the preseason planning, the predictability of operations, and the communication between projects.

As noted, each of the three types of end uses is associated with variable costs in addition to the fixed administrative/operating costs to dispose of a volume of fish. The costs vary according to the handling required for a particular end use either on-site or off-site. The three end uses also vary in the degree to which they offer the possibility of cost-recovery through the sale of northern squawfish. Table 5 presents a summary of estimated $ per pound recoverable on a per pound basis. Per pound prices will vary according to market conditions at the time of sale; table values are based on a range of estimates provided to this project by experimental users in 1991.

Rendering is the least-cost alternative if no cost recovery is possible. Rendering is considered as the baseline against which other alternatives are compared. The existence of food and fertilizer markets makes cost-recovery possible through the sale of fish. Food use offers the potential for greatest cost-recovery, at our best current estimate of $. 10 - $. 15 per pound, followed by fertilizer, at our best current estimate of $.02 - $.05 per pound. Under cur-tent conditions, rendering involves a processing charge and offers no potential for cost recovery through sale of raw product to renderers.

Depending on the price at which northern squawfish is sold, the opportunity exists to recover from 33% to 83% of fertilizer cost margin over the rendering baseline. From 83% to 125% of the food cost margin over baseline can be recovered. High quality fish sold for food use pays for the extra cost of handling once exvessel price reaches $.12 per pound. At $.15 per pound, high quality fish more than pays for the extra handling required.

We present an example of the effect of different end uses on variable handling costs in Table 6. We look at the variable costs (on-site + off-site) costs of handling 300,000 pounds of northern squawfish for four combinations of uses: A. all rendered; B. 50% rendered/50% fertilizer; C. 50% rendered/50% food; D. 50% fertilizer/50% food. Fertilizer is evaluated at its minimum and maximum estimated prices ($.02, $.05). Food is also evaluated at its minimum and maximum prices ($. 10, $.15).

All combinations of uses are compared to the "baseline" rendering costs. We look at two separate cases: variable costs associated with end uses when there is no cost-recovery, and variable costs associated with end uses when cost-recovery occurs. There are other possible combinations involving different shares and more than two uses, but these four combinations are sufficient to illustrate the affect of end uses and cost-recovery on costs of handling.

All cost comparisons are conducted in terms of variable costs associated with different end uses. Fixed costs of administration and operation are assumed to be constant regardless of end use, as are coordination costs.

Case 1 in Table 6 involves no sale of fish and results in no cost recovery. Variable cost differences between the different end uses are a function of differences in handling requirements on-site and off-site. If all 300,000 pounds of fish are rendered (Alternative A), variable costs are $48,000. If half the fish are used as fertilizer and half rendered (Alternative B), an additional $9,000 over the baseline is incurred for a total variable cost of $57,000. This is a 19% increase over baseline variable costs.

If half the fish are directed at a food use instead of fertilizer (Alternative C), variable costs are an additional $18,000 over baseline rendering costs, an increase of 38%. Dividing the fish between fertilizer and food uses (Alternative D) is the most expensive alternative without cost recovery. Alternative D incurs an additional $27,000 (56%) over the rendering baseline for a total variable cost of $75,000.

Food and fertilizer uses add to handling costs because they require more exacting handling than rendering. However, food and fertilizer uses offer a market potential that rendering does not. Case 2 includes cost recovery realized through the sale of northern squawfish for food

($.05-$. 10) and fertilizer ($.02-$.05) uses.

If all fish are rendered (Alternative A), no cost recovery occurs. If fish are divided between rendering and fertilizer uses, $3,000 is realized in cost recovery if fish are sold at $.02 per pound; $7,500 in cost recovery if fish are sold at $.05 per pound. At a price of $.02, variable handling costs are 12.5% more than the rendering baseline. At $.05 per pound, variable handling costs are 3.1% more that baseline rendering costs.

If fish are divided between rendering and food (Alternative C), a cost recovery of $15,000 is realized if fish are sold at $.10 per pound; $22,500 if sold at $.15 per pound. Variable costs of the rendering/food combination are 6.3% above the rendering baseline if the food price is $.10 per pound; and 9.4% lower than the rendering baseline if the food price is $.15 per pound.

The fertilizer/food combination (Alternative D) realizes a cost recovery of $18,000 if sold at the low end of both price ranges ($.02;$. IO), an 18.7% increase over the rendering baseline. At the high end of the price range ($.05; $.15) the cost savings is $30,000, a 6.3% decrease from the price of the rendering baseline.

For the 300,000 pounds handled, at the costs and prices given, the most cost-effective combination is Alternative C, the rendering/food combination. Cost recovery allows the direction of fish at these end uses to proceed at costs which are lower than the baseline costs of rendering.

Aside from the baseline rendering (Alternative A) we did not consider single-use end uses of all fertilizer or all food. In practical terms, given the types and dispersion of removal fisheries encompassed by the northern squawfish program, we will continue to receive a range of grades of fish. This eliminates the possibility of an all-food-grade choice. Directing all fish to fertilizer is possible, but this entails disposing of food grade fish at less than their maximum value. A combination of uses which capitalizes on different grades will offer the greatest potential for cost recovery and therefore be more cost-effective than a single use.

Product Forms

Experiments on various product forms were designed to address the workability aspect of feasibility. We were interested in testing a range of products to determine the technical practicality of using northern squawfish in each one. Of the several product forms tested, Table 7 summarizes the characteristics and feasibility of each according to tests performed to date. Feasibility is assessed on the basis of technical aspects of processing and producer/consumer responses to product form. The cost-effective component of utilization is addressed in the “discussions” section.

Processing yields were calculated for both headed and gutted and mince product forms. Headed and gutted yields from round fish ranged from 46 to 54%. Minced yields from round fish ranged from 304%. Yields range according to the size of the fish and the compatibility between fish size and shape and processing equipment.

Rendering: Northern squawfish have been rendered and combined with other fish and animal byproducts to product animal feed. Northern squawfish are suitable for this use.

Liquid fertilizer: Northern squawfish was found acceptable in the production of liquid fertilizer when used in combination with carp to enhance oil content. The production process requires fish free of contamination from sand.

Whole fish as food: Whole fish were found to have acceptable appearance, odor, texture and taste, but unacceptably large numbers of bones.

Fillets: Fillets were judged to have good taste, color and texture, but are unacceptable unless deboned.

Mince: Mince is found to have good appearance and color, bland taste, firm texture, good shelf life, superior gel strength, and is versatile in different final products. Mince requires washing for appearance and a binder to improve mixing. Shelf life is improved with the addition of cryoprotectants.

Sutimi: Northern squawfish has a long shelf life on ice and prepares a firm mince suitable for surimi. Variable supply and low volumes limit its use in this product form, but combination with other species may be possible. Accumulation of northern squawfish in frozen storage until sufficient quantities are available for surimi processing is also possible.

Roe: Variable color and size of northern squawfish roe renders it unacceptable for food consumption.

Mink food: Feeding trials indicate an acceptable nutrient content of northern squawfish in mink diet.

Bait: Nothern squawfish were acceptable forms of crawfish and crab bait, although due to the low oil content are not as desirable as other bait sources. Northern squawfish was successfully used as grizzly bear bait for a tagging experiment in Northern Idaho.

Fish meal: Northern squawfish were found to be an acceptable ingredient in fresh water fish meal production, but unacceptable (based on a single trial) as an ingredient in marine fish meal.

Export product: Northern squawfish have been experimented with in 1992 as an export product. Results from these trials are not yet available.

Market Potential

The results of the evaluations of market potential of the product forms listed above are presented in this section. Market potential is evaluated on the basis of supply (quantity, quality, and cost of supply in each form) and demand (quantity demanded in this form, area of demand, seasonality of demand). Results are summarized in Table 8.

For many product forms, product attributes are not a constraint to marketability. The key issue in marketability is the match of quantity demanded with the timing, quality and quantity of product supplied. Northern squawfish is an input to production in several end uses, e.g. mince, meal or fertilizer. The quantity demanded of ‘northern squawfish is therefore influenced by not only the price and attributes of northern squawfish, but also by the price and attributes of substitute raw products available to processors. Market potential of northern squawfish depends critically on its ability to compare favorably on a price basis with these substitutes.

Rendering: Renderers will process northern squawfish for a fee. The fish can then be combined with other fish and animal byproducts to product animal feed. Because rendering requires an additional expenditure, it offers a disposal alternative rather than market potential.

Liquid fertilizer: Industrial grade northern squawfish is easily supplied for processing into liquid fertilizer. Demand for northern squawfish in fertilizer processing exists. The potential of cost-recovery through this end use depends on the continued operation of use of northern squawfish.

Whole fish as food: The unacceptably large numbers of bones in northern squawfish preclude any market potential in this form, unless an export market develops.

Fillets: The same problems with bones as indicated for whole fish limit market potential to deboned forms of fillets.

Mince: Mince has several positive qualities, has received good market acceptance, has the interest of an estabtished producer, and has good market potential.

Surimi: Mince has good properties for surimi. Market potential in this area will depend on experimentation with other species in combination and on the general availability of supply of established surimi species.

Roe: Poor color and size attributes indicate little market potential.

Mink food: Trials indicate an acceptability of northern squawfish in mink diet. However, the industry is small and there is no indication of commercial interest in northern squawfish as feed.

Bait: Nothern squawfish was an acceptable but not premium bait for crawfish and crab. Quantity demanded is limited, with expected price at around $.15 per pound. Demand would strengthen if substitutes were less available, but quantity would still be limited.

Fish meal: Acceptability of northern squawfish in fresh water fish meal production indicate some market potential, mostly as a byproduct of mince production.

Export product: Market potential for whole fish as exports with other fresh water species is still unknown-

Regulations

The survey of Columbia River authorities identilied a number of issues related to the regulation of the sport-reward fishery. These issues were addressed through various actions.

Incidental catch in northern squawfish fisheries, particularly of salmon and steelhead, was perhaps the most pressing issue-facing the regulation of northern squawfish activities. The predator control program has responded to this concern through the development of a weekly reporting system on incidental catch throughout the fishing season.

A second issue raised was the need to include enforcement personnel of the Columbia River Inter-Tribal Fish Commission in the review of plans for any fishery which will operate in Zone 6. All fisheries activities affect the ability of enforcement personnel to carry out their responsibilities- This problem has been addressed on a system-wide scale with program and enforcement personnel participating in a post-season enforcement meeting. The purpose of the meeting is to incorporate enforcement evaluation into the next season's planning.

A need was identified for the State of Washington to reclassify northern squawfish as foodfish and require a license for its capture. Reclassification is a necessary precondition to the operation of a commercial fishery on northern squawfish. To date, reclassification has not taken place.

The need to develop regulations associated with the development of commercial fisheries for northern squawfish was also identified as a need. To date, commercial fishing for northern squawfish has been addressed on a year-to-year basis without long term planning for the type of fishery operations or the interaction of a commercial fishery for northern squawfish with fisheries for other species.

Monetary compensation for sport anglers was raised as a potential problem but has not proven to be a hindrance to sport-reward fishery operations in Oregon, Washington, or Idaho.

The use of "in-lieu" sites by the angling public has continued to be allowed by treaty tribes.

Safety and security issues on the dams were the final issue raised in the survey. To date, preseason plans have been submitted and preseason meetings conducted with personnel of the U.S. Army Corps of Engineers. Corps personnel are satisfied with this process and with the safety procedures in place.

Social Issues

Program staff, fisheries employees, anglers, enforcement personnel and the general public all have had input to the definition of issues related to the conduct of the predator control program. Matters of inter-project cooperation create possibilities for conflict as well as possibilities for mutual benefit. In general, inter-project *cooperation* has been good and improves as the project matures.

Commercial Fishery: A major issue in the commercial fishery is differences in cultures between fisheries agencies and commercial fishermen. There is a conflict between bureaucratic requirements for paperwork and monitoring and the operating styles of commercial fishermen. An “agency” fishery emphasizes predictability, control, record keeping, and monitoring. A commercial fishery usually places a premium on variability in schedule, innovation, and independence. Commercial fishing is often the most efficient method of fishery removal but to capture that efficiency it requires flexibility to innovate and develop new techniques.

Commercial fisheries for northern squawfish have also been handicapped by being defined as “low status” and unknown. Individual uncertainty about personal association with the fishery, uncertainty about yields, and the existence of established fishing alternatives create an environment of reluctant participation.

Also at issue are conflicts between commercial fishermen in Zone 6 and recreational anglers. Gear conflicts have been recorded as has an expression of resentment on the part of some sport-reward anglers about commercial fishermen catching fish which are perceived to be the property of anglers. This is a minority view but one that has been well vocalized.

Some commercial fishery observers noted the positive interactions they had with commercial fishermen. Observers indicated that they valued the opportunity to interact with someone from another culture and to learn about cultural practices and historical fishing practices on the Columbia River.

Dam Angling: Anglers working on dams have experienced some of the same verbal assaults by sport-anglers as have commercial fishermen working in Zone 6. The conflict appears to be over perceptions of “rights” to catch fish in the sport-reward program, perceptions of unfair access to sites not available to sport anglers, and perceptions that dam catches will result in lower catch per unit effort in the sport fishery.

There has also been positive interaction between anglers on dams and the general public. Dam anglers have often served as a source of information on Native American culture as well as on the predator control program.

The location of the darn angling fishery requires that extra safety and security precautions are part of the dam angling fishery. Safety and security systems require close cooperation with Corps of Engineer personnel. This cooperation has been effective.

Coordination difficulties between fish removals and biological workups which were present earlier in the program have been resolved through changes in operations.

Sport-Reward Fishery: Issues related to the operations of sport-reward sites are the most common identified by anglers. One issue related to the operating hours of sport-reward sites. Of the surveyed anglers not returning to sites in 1991, 15% did not return because the site was closed. Some indicate a need for a streamlined check-in and check-out process and less onerous reporting requirements at the end of the fishing day. A common objection is to the minimum 11" size for payment.

Conflicts exist at some boat ramps about crowing and disrepair. On-water conflicts exist between anglers and other water users due to crowding. Some anglers object to the existence of legitimate commercial fishing activities, perceiving river fish to be "their" fish.

A major benefit of the sport reward fishery is its provision of additional recreational opportunities for anglers. Anglers are appreciative of the opportunity to recover some costs of fishing for a species which does not offer benefits of other recreational species (e.g. trophies or food).

Another benefit expressed by anglers is the opportunity to participate in salmon enhancement activities. Anglers have also expressed active interest in the utilization of northern squawfish. Working against this perception of positive benefits from program participation is the "killer squawfish" image promoted in program literature. The purpose of the predator control program is to mitigate imbalances in an ecological system where some species are harvested and others are not, and in doing so to achieve higher levels of smolt survival. These goals offer the opportunity for public education about biological communities and their interdependencies. 'Portraying one species as a "killer fish" rather than simply as a species well-adapted to the still-water environments created by reservoirs sabotages any opportunity for general public education in this area.

Enforcement Issues

The primary enforcement issues associated with the northern squawfish predator control program arise out of the introduction of new and unique fisheries into a heavily used system.

One issue relates to the monitoring responsibilities of enforcement personnel. 'Angler fishing for northern squawfish falls within the purview of Oregon Department of Fish and Wildlife enforcement because a license is required to fish. Angler fishing does not fall directly within the purview of either Washington Department of Wildlife or Washington Department of Fisheries enforcement since it is classified as neither a game nor a food fish, and a license is not required to catch it. Northern squawfish falls into a grey area of no defined enforcement authority, and represents an increased enforcement burden on existing enforcement personnel. In the fall of 1992 a meeting which includes enforcement representatives of the Columbia Inter-Tribal Fish Commission, the Washington Department of Wildlife, the Washington Department of Fisheries, and the Oregon Department of Fish and Wildlife will be held to begin the design of a coordinated enforcement program for northern squawfish.

A second enforcement issue relates to the reward payment for northern squawfish in the sport fishery. At an average of 2 Ibs. per fish, a $3 per fish payment equals $1.50 per pound, a price which exceeds the exvessel price of most fish. The size of the reward payment is high enough to create incentives to land large numbers of fish from sources outside the system, creating a monitoring and enforcement burden to the program. The reward payment also creates an incentive for program personnel to "recycle" caught fish through the system for payment This problem has been addressed through tail clipping of all fish taken in removal fisheries. Discrepancies between data on total catch versus total numbers of fish handled suggest that despite the tail clipping system the problem continues to exist. We are pursuing all possible explanations for the discrepancies in numbers of fish caught and fish handled.

A third enforcement problem concerns property loss. This is a new problem in 1992 which is just beginning to be addressed.

Summary of Evaluation Results

Both sensory and technical characteristics of northern squawfish make it suitable for a variety of uses. The large number of bones in the fish make mince products most appropriate for human consumption. Levels of contaminants are not high enough to pose a risk to humans. Northern squawfish are suitable in a range of product forms. The greatest market potential exists for food, fertilizer, and meal. Of the three major removal methods, the commercial longline fishery has had the greatest difficulties in organization, participation, and levels of catch. The sport-reward fishery and dam angling fishery are generally comparable in terms of costs per fish removed. Relative cost effectiveness between the two is heavily influenced by changes in catch-per-unit-effort. Some conflicts remain in the operation of the dam angling and sport-reward fisheries. These conflicts are primarily with a minority of the public participants who object to crowding and to multiple fisheries for northern squawfish. Handling costs are sensitive to program organization as well as to the types of end uses. A comparison of handling costs for different end-use combinations indicates that the food/rendering or food/fertilizer combinations are the most cost-effective. Regulations for experimental commercial fisheries still need to be developed. A reclassification of northern squawfish as food fish in Washington would allow commercial fisheries to proceed on commercial fisheries in that state. Enforcement responsibilities remain to be clearly defined. Plans to prevent further illegal recycling of northern squawfish and further property loss need to be developed.

DISCUSSION AND RECOMMENDATIONS

Removal Methods

The breakdown of expenditure data into time proportions for removal, administration, and biological evaluation is still incomplete for all removal fisheries. Rough estimates on 1991 expenditure data indicate that a wide disparity exists between costs per fish removed in the commercial fishery and in the other two fisheries.

The commercial fishery estimate of around $180 per fish removed is high because the fixed costs of design implementation and administration were averaged over very small numbers of fish removed. If catch rates had been higher, average cost per fish removed would fall. In evaluating the commercial fishery, the appropriate questions are concerning reasons why catch rates were so low. As indicated above, participation rates were low and enthusiasm of those participating was lacking.

Commercial fisheries as previously structured are not cost-effective. There is little opportunity for cost recovery with these fisheries given a structure that specifies gear, times of operation, methods of operation, requires significant levels of paperwork and observation which is considered intrusive by fishermen. However, this conclusion does not necessarily apply to all commercial fisheries. Commercial fisheries do offer potential for efficient removals of northern squawfish if allowed to operate on a flexible experimental basis.

Once adjusted for total administration and oversight costs and for time spent in activities not directly related to removals (e.g.biological evaluation), darn angling and sport-reward fisheries are likely to be within $2-3 of each other in average expenditure per fish removed, at approximately $14-$17. The two fisheries have developed to be complementary rather than substitute activities, covering different areas of the river and targeting different concentrations of northern squawfish. Catch-per-unit-effort is higher in the dam fishery but total catches are higher in the sport-reward fishery.

Of the three alternatives available, the commercial fishery as it has been structured is not cost-effective in meeting program goals. Based on the preliminary analysis of expenditures applied to removals, the combination of dam angling and sport-reward fisheries is the most cost-effective alternative. It should be noted that to say that the dam-sport combination is relatively cost-effective is not the same thing as saying the two fisheries operate at minimum cost.

Recommendations:

1. Discontinue commercial fisheries as previously structured.

2. Experiment with new commercial fisheries on a pilot fishery basis in consultation with an experienced “rough fish" fisherman. Ensure observer coverage to monitor incidental catch.

3. Continue sport-reward and dam angling fisheries as complementary operations. Establish operating goals of minimizing cost of fish removed for these projects Explore approaches to decreasing administration costs of each fishery. Clearly define removal, handling, and evaluation responsibilities.

4. Continue fishery monitoring on a smaller-scale. Reduce the information requirement from anglers. Monitor catch, effort and financial performance. Monitor conflicts and coordination problems.

Handling Methods

Costs of handling northern squawfish are sensitive to the degree of coordination and task sharing which exists between removal fisheries. and handling operations.

Because the program is dispersed over a large geographic area, logistical planning has a significant influence on handling costs. Vehicle rental, road miles, and travel time account for a large part of the fish handling budget. An efficient program-wide transportation system significantly reduces basic administrative/operations costs.

The locations of field stations relative to receiving and processing locations also affects handling costs. The greater the distance between field stations and processing locations, the higher are the operating costs. The location of the 1992 WDW field office for the Longview sport-reward area at the processing facility represented an ideal situation.

The distribution of fish handling responsibilities among projects also affects overall handling costs. Efficiency gains will be realized to the extent that on-site handling is supervised and performed on each project. The “internalization” of handling costs will affect cost savings.

Cost-recovery through sale is dependent on an effective quality control program. A key to good quality control is good design and effective reinforcement. On-site supervision of quality requirements is much less costly than external supervision.

The further incorporation of the private sector into the fish handling program requires the clear delineation of responsibilities and predictability in program operations. A contract to handle fish will not be amenable to ad *hoc* changes in operations-

Recommendations:

1. Stabilize the overall predator control program at some level which allows smooth planning and transitions from one season to the next.

2. Minimize the costs of fish handling for the entire predator control project, rather than for individual projects. Internalize as many fish handling responsibilities to each project as possible.

3. Develop fish handling plans for sport-reward sites and for dams which will minimize handling. costs to the project as a whole without compromising removal goals. Explicitly account for portions of budgets dedicated to fish handling so they will not be counted as removal costs.

4. Implement a permanent quality control system with incentives to comply.

Product Form

A wide array of product forms has been tested. The list is not exhaustive but the variety is sufficiently extensive to provide adequate information to interested commercial users on the product potential for northern squawfish. The process of experimentation itself has brought northern squawfish to the attention of fish processors and fish brokers and created interest in utilization.

In the interest of minimizing total program costs, attention should now shift to ensuring some cost recovery for the northern squawfish catch. Questions regarding purchase of northern squawfish have been directed at the OSU project by private sector representatives. The main hindrance **to** date in recovering costs through purchase of not-them squawfish has been the absence of a mechanism to transfer payments from the private sector to the predator control program or to an appropriate public entity.

A major question any private sector representative will have is the quantity and quality of northern squawfish which will be available in a given season.

Recommendations:

1. Discontinue experimentation with different product forms.

2. Distribute information on products tested and test results in report format to any interested private party.

3. Develop a contracting mechanism to implement private sector payments for northern squawfish whether for food or industrial uses. Set a goal of maximum cost recovery to the predator control program.

4. Develop an incremental program of private bidding for access to the not-them squawfish yield.

5. Develop long term program goals on yields and scale of operation. Stability in yields will enhance involvement of the private sector as purchasers of northern squawfish.

6. Conduct baseline monitoring of utilization contracts.

Market Potential

The greatest market potential for northern squawfish is in mince, fish meal (as a byproduct of mince) and fertilizer. These uses have accounted for the bulk of fish utilized to date and offer the potential to absorb large volumes of fish in the future. Export of northern squawfish as food fish along with other underutilized species remains a possibility but only a theoretical one at this point in time.

The evaluation of market potential has generated enough information for reasonable decisions to be made regarding the disposition of northern squawfish. Under current cost and price conditions, the most cost-effective alternative for utilization is the food/rendering or food/fertilizer combination. The food/rendering combination has the slightly lower cost of the two but has the disadvantage of requiring weekly deliveries of fresh fish to renderers. The food/fertilizer combination entails slightly higher costs, but has the advantage of allowing frozen fish to accumulate in storage for large-volume deliveries. The exact combination for maximizing the recovery of costs and thereby minimizing total costs of handling will depend on the quality of fish removed and handled, the costs of handling and prices of sale in a given year.

<u>Recommendations:</u>

1. Discontinue further experiments in market potential of northern squawfish. Disseminate the information acquired to date in booklet format to all interested private sector parties.

2. Maximize the amount of cost recovery to the northern squawfish program by directing northern squawfish to the food/rendering combination or

food/fertilizer combination.

3. Sell northern squawfish to private sector interests through contract.

4. Maintain flexibility to provide small experimental quantities of northern squawfish to fish brokers.

5. Build quality-control requirements into all removal projects.

6. Conduct baseline monitoring of market transactions, quality control, and coordination between removal fisheries and end uses.

Regulations

Safety, enforcement, site-access, and incidental cost issues have all been addressed. A remaining area still unaddressed is the classification of northern squawfish as food fish in the state of Washington in order to allow commercial harvesting. Another area related to Washington regulations is the lack of licensing requirements for fishing for northern squawfish, which increases the difficulty of monitoring.

Perhaps the most pressing unaddressed area with regard to regulation is the lack of a system of regulations which would encourage experimental commercial fisheries for northern squawfish and protect against incidental catch concerns. The regulations under which the experimental commercial fishery were promulgated in 1990- 1992 prevented the flexibility needed by commercial fishermen to operate successfully.

Recommendations:

1. Reclassify northern squawfish as food fish in the State of Washington.

2. Require a license for recreational capture of northern squawlish in the State of Washington.

3. Develop a proposal for experimental commercial fisheries both in Zone 6 and in the lower river which are consistent with incidental catch concerns and other regulation needs.

4. Open commercial fishing opportunities for experiment on a least-cost basis.

Social Issues

Interproject cooperation continues. to improve. The monitoring of social factors through interviews with sport anglers, dam anglers, and other project personnel is an effective mechanism for staying on top of program-wide issues which need to be addressed.

There are two major issues which need to be addressed immediately. The first is the negative perception that a vocal minority of sport-reward anglers and the general public have of the commercial fisheries in Zone 6 and the angling off the dams. There is ample evidence to suggest that some people perceive Native American fishermen to be intruders as commercial fishermen on the water and as anglers on dams, catching fish which “belong” to the sport-reward fishery.

Although these comments are expressed by a minority, they are expressed often enough to indicate a problem in perception that should be addressed. Public education about the predator control fishery and the role played by the dam fishery could address part of the problem. It would also be useful to create public educational materials that address the system-wide problems on the Columbia River with enough historical perspective to increase awareness of Native American rights.

The second issue is the “killer squawfish" representation in program literature. This term has been adopted by many anglers who use it in their survey forms to express why they are participating in the program. The imagery of a killer not only does not promote public awareness of the program’s goals, it hinders awareness by diverting attention from the idea of bringing a system into balance to the idea of a “bad” species.

Recommendations:

1. Develop public education materials which present the activities of the predator control program in the context of problems facing the river as a whole. Use the opportunity to educate the public more broadly on Columbia River issues.

2. Develop public education materials which portray the historical role of Native Americans in the Columbia River system and raise levels of consciousness about treaty rights.

3. Discontinue the “killer squawfish" terminology.

4. Direct program public education materials toward the “ecosystem balance” approach which emphasizes the positive aspects of harvesting a population to bring a multispecies community into balance.

5. Continue to monitor social interactions within and between removal fisheries and the program as a whole.

Enforcement Issues

Preventing payment for unauthorized fish, property control, and a clear definition of enforcement responsibilities continue to be the major enforcement issues facing the predator control program.

The question of enforcement responsibilities is being addressed through meetings between enforcement personnel and program personnel. The incorporation of enforcement representatives into the design of fishery operation plans should ensure fishery operations which are easier to monitor.

The question of payments for unauthorized fish is a more difficult one. Illegal fish can come from either outside or inside the program. Fish from outside sources fall within the purview of enforcement personnel. Fish from inside the project that are being "recycled" through the system pose a more difficult enforcement problem.

Property control is another issue which needs to be addressed before the next season. Better inventory control systems, better monitoring, and strong sanctions imposed on program personnel will be required to prevent program losses of property.

Recommendations:

1. Continue active coordination between enforcement and implementation personnel in the design of plans for removal fisheries.

2. Design a roving "spot-check" program for all removal fisheries to monitor for tail clipped fish.

3. Design a cooperative property control program which involves all project administration. Agree on sanctions to be imposed and procedures to be used for the program as a whole.

TABLES

Table 1. Components of handling costs for the northern squawfish predator control program.

Cost Component	Type	Sensitive to:
Admin/Op	fixed per season	# harvest sites dispersion of harvest sites projected removals on-site setup delineation of responsibility
On-Site	variable	on-site handling end use quality control compliance
Off-Site	variable	off-site handling end use volume of fish
Coordination	variable	preseason planning complexity of program complexity of end uses delineation of responsibility

Table 2. Product forms for northern squawfish tested, 1989-1992.

User	Apprux. Lbs. N. Squawfish	Product Form
Multiple-use processor	154,265	liquid fertilizer
Renderer	134,000	mixed fish/animal meal for feed
Rough fish processor	130,000	fish mince fish meal, oil
Mink Grower	9,500	mink feed
Seafood Lab	2,200	frozen mince, surimi, roe
Fish meal processor	2,000	fish meal
Restaurants & Markets	1,986	whole; fillet
Restaurants & Markets	60	frozen boxed mince
Bait crab crawfish bear	1,500	whole; cut
Fish brokers (export)	600	whole frozen

Table 3. Removals by fishery and percent of total program removals, 1990-1993.

Fishery	1990 # Removed'	(%)	1991 # Removed	(%)	1992 # Removed	(%)
Commercial longline	1,400	(8)	1,100	(.5)	1,880	(.1)
Dam angling	11,000	(65)	40,000	(20)	27,500	(13)
Sport-reward	4,500	(27)	158,000	(79)	184,ooo	(87)
Total	16,900		199,100		213,380.	

Table 4. Estimates of cost per pound of different components of northern squawfish handling system.

Cost Component	Cost Per Pound Handled
Admin/Op	. Fixed per Season (ave. cost/lb. declines as total lbs. increase) $.40 - $.45 for 1992
On-Site	
rendering	$.08
fertilizer	.10
food	.12
Off-Site	
rendering	.08
fertilizer	.12
food	.16
Coordination	
rendering	variable with extent of pre-season planning, contracts, delineation of responsibilities
fertilizer	
food	

Table 5. Total variable costs (on-site + off-site) per pound and cost recovery per pound for three end uses of northern squawfish.

End Use	On-Site+Off-Site Cost per Pound	Cost Margin over Rendering	Cost-Recovery per Pound	% Cost Margin over Baseline which is Recoverable
Rendering	$.16	$ 0	$0	0%
Fertilizer	$.22	$.06	$.02 - .05	33-83%
Food	$28	$.12	$.10 - .15	83- 125%

Table 6. Estimated variable costs of handling 300,000 pounds of northern squawfish for different end uses.

End Use	Variable Cost	$ Change from Baseline	% Change from Baseline
Case 1: No cost-recovery			
A. All Rendered (baseline)	$48,000	---	---
B . Render/Fen (.5/.5)	$57,000	+ $9,000	+ 19%
C. Render/Food (.5/.5)	$66,000	+ $18,000	+ 38%
D. Fert./Food (.5/.5)	$75,000	+ $27,000	+ 56%
Case 2: Cost-recovery			
A. All Rendered (baseline)	$48,000	---	---
Cost-recovery: 0			
B . Render/Fert. (.5/.5)			
fert.@$.02/lb.	$54,000	+ $6,000	+ 12.5%
fert.@$.05/lb.	$49,500	+ $1,500	+ 3.1%
Cost-recovery: $3,000 @ .02/lb.; $7,500 @ $.05/lb.			
C. Render/Food (.5/.5)			
food@$.10/lb.	$51,000	+ $3,000	+ 6.3%
food@$.15/lb.	$43,500	- $4,500	- 9.4%
Cost-recovery: $ 15,000 @ $.10/lb.; $22.500 @ $.15/lb.			
D. Fert./Food (.5/.5)			
(fert.@.$02/ food@$.10)	$57,000	+ $9,000	+ 18.7%
(fert. @.05/ food@$.10)	$45,000	- $3.000	- 6.3%
Cost-recovery: $18,000 ($.02; $.10); $30.000 (8.05: $.15)			

Table 7. Characteristics and feasibility of various product forms tested for northern squawfish.

Product Form	Characteristics	Feasible
Round (human use)	good size good appearance good taste large # bones	no
Fillets	good appearance good texture good taste large # bones	no
Mince	firm texture bland caste needs binder versatile use	yes
Roe	variable size variable color med. firm texture	no
surimi	good shelf life good mince quality firm texture	yes
Fertilizer	liquid combine with carp acceptable quality requires clean fish	yes
Fish Meal	nutritive comp. of carp substitute for carp flesh and entrails	yes
Fish Oil	combine with other fish use byproducts	yes
Bait	cut pieces acceptable not first quality	under some conditions
Export market	whole round	unknown

Table 8. Summary of market characteristics and market potential of northern squawfish product forms.

Product	Market Characteristics	Market Potential
Round (human use)	good availability minimal processing low to no demand	poor
Fillets	machine processing demand unknown quality good	unknown
Mince	steady supply versatile product	good
Roe	poor availability low demand	poor
Surimi	seasonal supply variable quantity quality good	unknown
Fertilizer	seasonal supply variable quantity quantity demanded unknown	good
Fish meal	byproduct of mince	good
Fish oil	byproduct of mince	unknown
Bait	not premium quality substitutes available	poor
Export market	unknown	unknown

APPENDIX B

Commercial Longline Fishery

Appendix Table B-l. Agency expenditures by category in the 1992 commercial longline fishery for northern squawfish, preliminary date.

Expenditure category	Total ODFW expenditure
Salaries/wages	$47,805
Fringe benefits	11,785
Supplies	939
Operation & maintenance	6,603
Bait	7,105
Payment for squawfish	4,020
Travel	11,941
Overhead	23.527
TOTAL	$113,725

APPENDIX C

Dam Angling Fishery Expenditures

Appendix Table C- 1. Agency total expenditures and expenditure per fish removed for the 1992 dam angling fishery, by fishing crew.

Fishing Crew	Total Expenditure (components explained in text)	Total Catch	Expenditure Per Fish Removed
Bonneville	$92,220	3,356	$27.48
The Dalles	90,877	6,692	13.58
John Day	79,444	3,422	23.22
McNary	96,020	6,960	13.80
Ice Harbor	12,352	186	66.41
Lower Monumental	65,737	618	106.37
L.Goose/L. Granite	262,509	3,537	74.22
Mobile Crew	78,276	2,997	26.12
Volunteer Angling	2.835	100	28.35
Total	$780,270	27,868	$28.00

Appendix Table C-2. Crew-specific expenditures, total catch, and expenditure per fish removed for the 1992 dam angling fishery.

Fishing Crew	Crew Expenditures (components explained in text)	Total Catch	Crew Expenditure Per Fish Removed
Bonneville	$67,020	3,356	$19.97
The Dalles	59,377	6,692	8.87
John Day	54,244	3,422	15.85
McNary	72,920	6,960	10.48
Ice Harbor	6,052	186	32.54
Lower Monumental	38,437	618	62.60
L.Goose/L.Granite	226,809	3,537	64.12
Mobile Crew	44,676	2,997	14.91
Volunteer Angling	2,100	100	7.35
Total	$570,270	27,868	$20.46

APPENDIX D

Sport-Reward Fishery

SPORT REWARD VOUCHER

LAST NAME

FIRST NAME M.I.

STREET

CITY STATE ZIP

MO DAY YR DOCUMENT # SOCIAL SECURITY #

NUMBER OF QUALIFYING SQUAWFISH:

VOUCHER #:

NUMBER OF QUALIFYING SQUAWFISH (print):

SIGNATURES:

CREEL CLERK

ANGLER
(Signed in Presence of Creel Clerk)

Keep record of voucher #. Please send completed voucher as soon as possible. Voucher void after 10/15/92.

Appendix Figure D- 1. Sport-reward fishery survey form.

ANNUAL QUESTIONS: TO BE ANSWERED ONLY ONCE PER FISHING YEAR

A1. HAVE YOU FILLED OUT THIS SECTION IN 1992?
1. YES 2. NO

IF NO, PLEASE ANSWER BELOW
IF YES, THANK YOU. NO NEED TO FILL OUT AGAIN

A2. How many fishing trips do you usually make per year?

1. 0	5. 16-20
2. 1-5	6. 21-25
3. 6-10	7. >25
4. 11-15	

A3. Of these trips, number in this general location:

1. 0	5. 16-20
2. 1-s	6. 21-25
3. 6-10	7. >25
4. 11-15	

A4. Years you have been a sport fisherman:

1. <1	3. 6-7
2. 1-3	4. 8-9
3. 4-s	5. 10 or more

AS. Did you fiih in the squawfiih control program last year?
1. YES
2. NO

A6. State of residence:
1. OREGON
2. WASHINGTON
3. IDAHO
4. OTHER (please specify): ___________

A7. Age:

1. 14-M	5. 51-60
2. 21-30	6. 61-70
3. 31-40	7. >70
4. 41-50	

A8. Education:

1. GRADE SCHOOL	5. COLLEGE DEGREE
2. HIGH SCHOOL	6. GRADUATE DEGREE
3. SOME COLLEGE	
4. VOC. OR TECH. OR COMMUN. COLL.	

A8. How did you hear about the squawfish control program?
1. NEWSPAPER
2. RADIO
3. TV
4. WORD OF MOUTH
5. STATE FISHERY AGENCY
6. OTHER (please specify)

____

A9. How important are the following factors in your participation in the squawfiib control program?

A. PAYMENT FOR SQUAWFISH
1. Very important
2. Of some importance
3. Not important

B. RECREATION OPPORTUNITY
1. Very important
2. Of some importance
3. Not important

C. COVERING EXPENSES FOR OTHER TARGET SPECIES
1. Very important
2. Of some importance
3. Not important

D. PARTICIPATING IN SALMON ENHANCEMENT PROGRAM
1. Very important
2. Of some importance
3. Not important

A10. COMMENTS:

____

____

____

VOUCHER #:

PLEASETURN TO BACK SIDE OF FORM FOR QUESTIONS ABOUT THIS FISHING TRIP

TRIP QUESTIONS: TO BE ANSWERED EVERY TRIP. Members of a single household fishing and submitting voucher together: Main angler in household answer questions for entire household. Members of separate households fishing individually or together, submitting separate vouchers: Each registered angler should answer questions for hint/her self. (If group expenditures made for #7,8,9, enter amount of your individual expenditure only.)

PLEASE FILL TN OR CIRCLE THE APPROPRIATE ANSWER

T1. Number of anglers in your party:
PEOPLE

T2. Number of hours spent fishing for squawfiih: HRS PER PERSON

T3. Miles traveled (one way) to fish at this reservoir:

1.	<20	4.	60-79
2.	20-39	5.	go-99
3.	40-59	6.	100 or more

T4. If staying away from home, number of days you stayed in the area this trip:

1.	<1	5.	4
2.	1	6.	5
3.	2	7.	>5
4.	3		

T5. Primary reason for this trip: (circle only one)
1. SQUAWFISH
2. OTHER FISH
3. COMBINATION OF OTHER FISH/ SQUAWFISH
4. NONFISHING ACTIVITY
5. OTHER (please specify)

T6. If you stayed overnight, type of accommodation:
1. MOTEL
2. STATE PARK
3. NATIONAL PARK CAMPGROUND
4. PRIVATE CAMPGROUND
5. FRIEND OR RELATIVE
6. OTHER (please specify) ____________________

T7. Approximate amount spent on this trip to purchase:

FOOD
1. RESTAURANTS: $____________
2. GROCERY STORE: $____________

OTHER
3. ACCOMMODATIONS: $____________
3. GAS: $____________
4. FISHING SUPPLIES: $____________
5. BAIT: $____________
6. OTHER (please specify): ____________________

T8. Primary fishing method you/(your party) used: (circle only one)
1. BOAT, ANCHORED
2. BOAT, DRIFTING
3. BOAT, TROLLING
4. SHORE
5. ANGLING, SURFACE
6. ANGLING, BOTTOM
7. OTHER (please specify): ____________

T9. Primary bait or tackle you&our party) used: (circle only one)
1. WORMS
2. CUT FISH BAIT
3. SPINNERS
4. SPOONS
5. FLATFISH
6. SURFACE PLUGS
7; HOOK AND LINE WITH 1 HOOK
8. HOOK AND LINE WITH >1 HOOK
9. OTHER (please specify): ____________

T10. Approximate purchase price of primary tackle used: ____________________

T11. Any problems encountered while fishing: ON BOAT RAMP OR WATER (please specify): ____________________

Telephone Questionnaire for Non-returning Anglers
Northern Squawfish Sport-Reward Fishery 1992

Angler Name: ________________ Interviewer Name: __________ Date: _______

Our records show that you registered to fish for northern squawfish at ____________ (location) on __________ (date) but did not return to the site to register your catch. We would like to ask you a few follow-up questions about your fishing experience to help us identify any areas of needed improvement in our program.

1. How many hours did you fish for northern squawfish that day? ______ HRS.

2. How many hours did you fish for other species that day? ______ HRS.

3. What was your primary target species? ______________________________

   Other target species? ______________________________

4. Did you catch any northern squawfish?

   YES ____ NO ____

   If yes: Number <11" _______ Number >11" _______

6. While you were fishing for northern squawfish did you catch any other species?

   YES ____ NO ____

Species	Number
____________________	______________
____________________	______________
____________________	______________
____________________	______________

Appendix Figure D-2. Sport-reward fishery non-returning angler survey form.

7. While you were fishing for species (other than squawfish) what did you catch?

Species	Number
______________________	________________
______________________	________________
______________________	________________
______________________	________________

8. What fishing method(s) did you use to fish for northern squawfish?

____

9. Reason for not returning to site:

____

10. How important are the following factors in terms of their importance to you in participating in the squawfish fishery?

A. Payment for squawfish
   1. Very important
   2. Somewhat important
   3. Not important

B. Recreational opportunity
   1. Very important
   2. Somewhat important
   3. Not important

C. Opportunity to cover expenses while targeting game species
   1. Very important
   2. Somewhat important
   3. Not important

D. Participating in salmon enhancement
   1. Very important
   2. Somewhat important
   3. Not important

11. Did you return any squawfish for payment in 1992? YES___ NO-

If yes: # squawfish returned: ______________________________

12. Were the 1992 check stations conveniently located for you? YES___ NO__

If no: what new locations would you propose? ______________________________

13. How many fishing trips do you typically make per year (all locations)? _______

14. Of these fishing trips, number in this general location: ______________________

15. How many additional fishing trips do you typically make per year to participate in the squawfish program?

____

16. Do you plan to fish in the 1993 sport-reward fishery for northern squawfish?

Y E S NO _____ .

Reason:______________________________

Thank you for your time.

Telephone Questionnaire for Creel Clerk Evaluation of the 1992 Sport-Reward Fishery

Interview date: ____________

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

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

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

Appendix Figure D-3. Sport-reward fishery creel clerk survey form.

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

a. operating hours: good ___ fair ___ poor ___

recommendations: ______________________________

____

b. registration process: good ___ fair ___ poor ___

recommendations: ______________________________

____

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

recommendations: ______________________________

____

d. data forms: good ___ fair ___ poor ___

recommendations: ______________________________

____

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

recommendations: ______________________________

____

f. staffing: good ___ fair ___ poor ___

recommendations: ______________________________

____

g. equipment: good ___ fair ___ poor ___

recommendations: ______________________________

____

h. interaction with public: good ___ fair ___ poor ___

recommendations: ____

____

i. station security: good ___ fair p o o r ___

recommendations: ____

____

j. other recommendations: _____________________________________

____

____

____

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

____

____

____

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

____

____

____

____

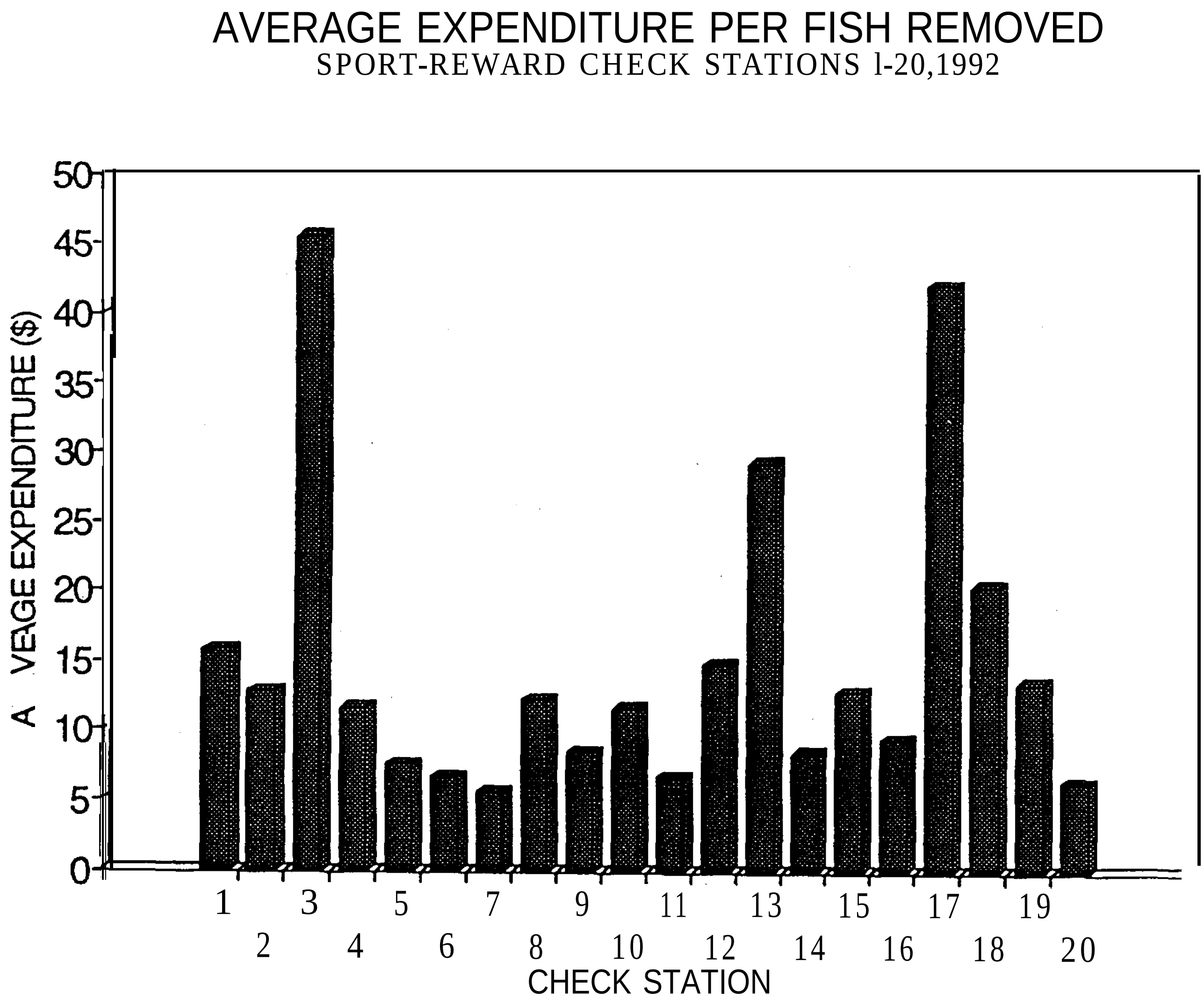
THANK YOU FOR YOUR HELP.

Appendix Table D-l. Sport-reward fishery check station codes, 1992.

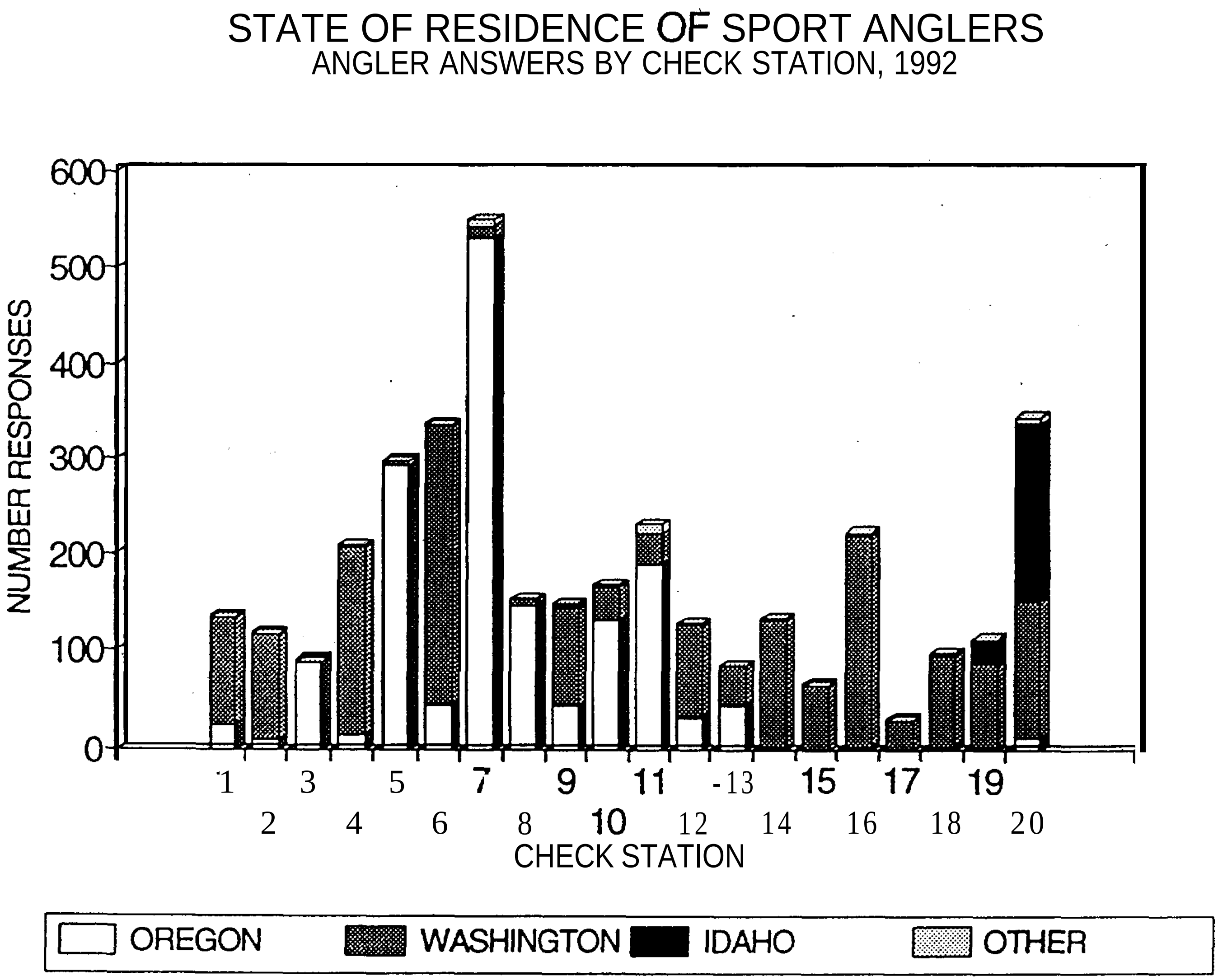
Check Station	Code
Willow Grove	1
Kalama Marina	2
St. Helens	3
Vancouver	4
M. James Gleason	5
Hamilton Island	6
Covert's Landing	7
Cascade Locks	8
Bingen	9
Dalles	10
LePage Park	11
Maryhill State Park	12
Plymouth	13
Columbia Point	14
Ringold	15
Hood Park	16
Windust Park	17
Lyons Ferry State Park	18
Boyer Park	19
Green Belt	20

Appendix Table D-2. Agency total expenditures and expenditure per fish removed for sport-reward fishery by check station, station-specific expenditures only.

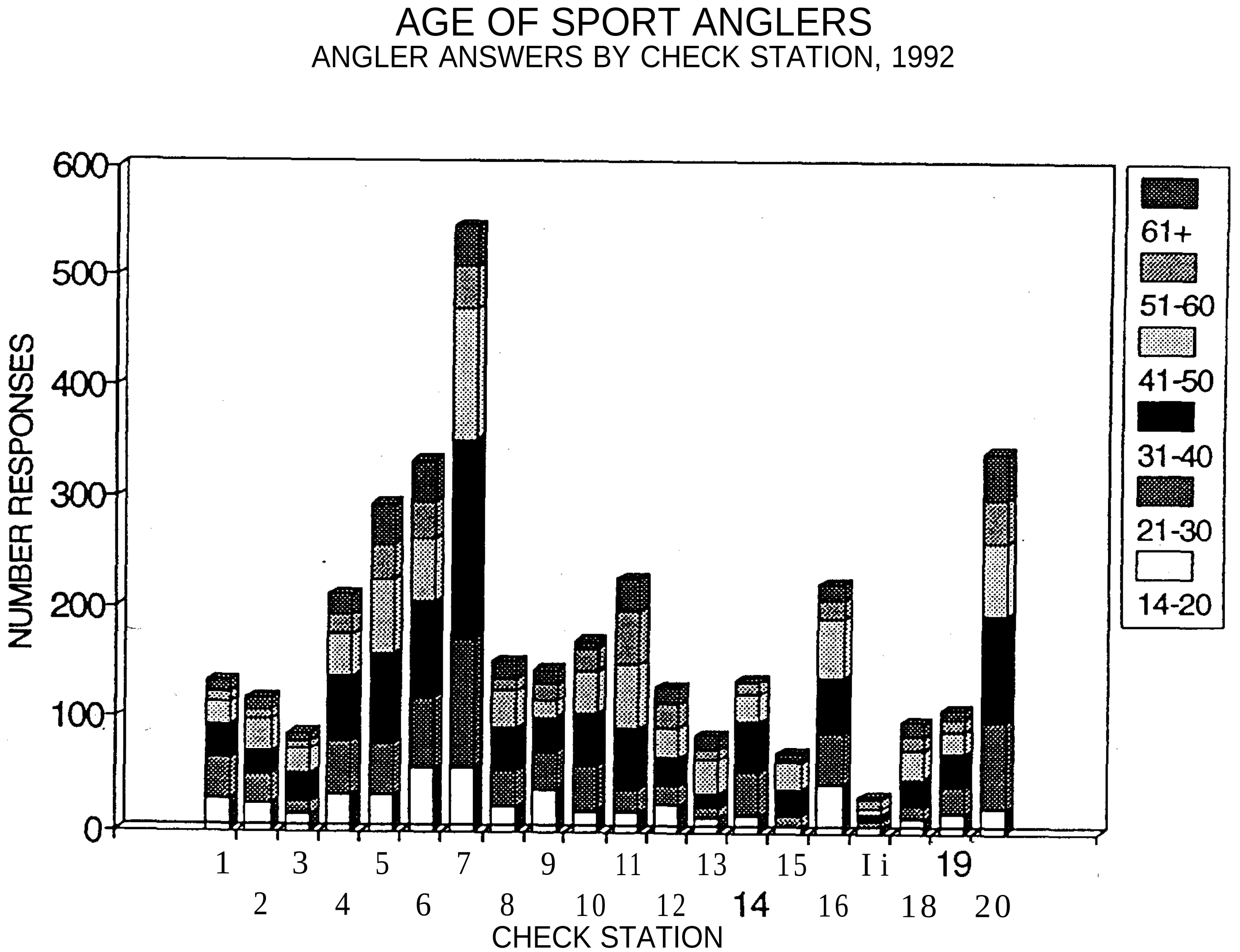
Check Station	Total Expenditure (including payment per fish)	Total Catch	Expenditure Per Fish Removed
Willow Grove	$89,665	5,677	$15.79
Kalama Marina	88,203	6,659	13.25
St. Helens	73,469	1,609	45.66
Vancouver	101,224	8,655	11.70
M. James Gleason	116,822	15,351	7.61
Hamilton Island	113,632	17,039	6.67
Covert's Landing	135,017	23,836	5.66
Cascade Locks	83,512	6,779	12.32
Bingen	90,550	10,575	8.56
Dalles	78,535	6,705	11.71
LePage Park	79,031	16,896	4.68
Maryhill State Park	75,823	5,072	14.95
Plymouth	71,961	2,454	29.32
Columbia Point	93,265	11,030	8.46
Ringold	65,962	5,103	12.93
Hood Park	85,498	9,037	9.46
Windust Park	61,821	1,464	42.23
Lyons Ferry State Park	63,692	3,113	20.46
Boyer Park	79,583	5,850	13.60
Green Belt	136.840	21.382	6.40
TOTAL	$1,784,105	184,286	$9.68



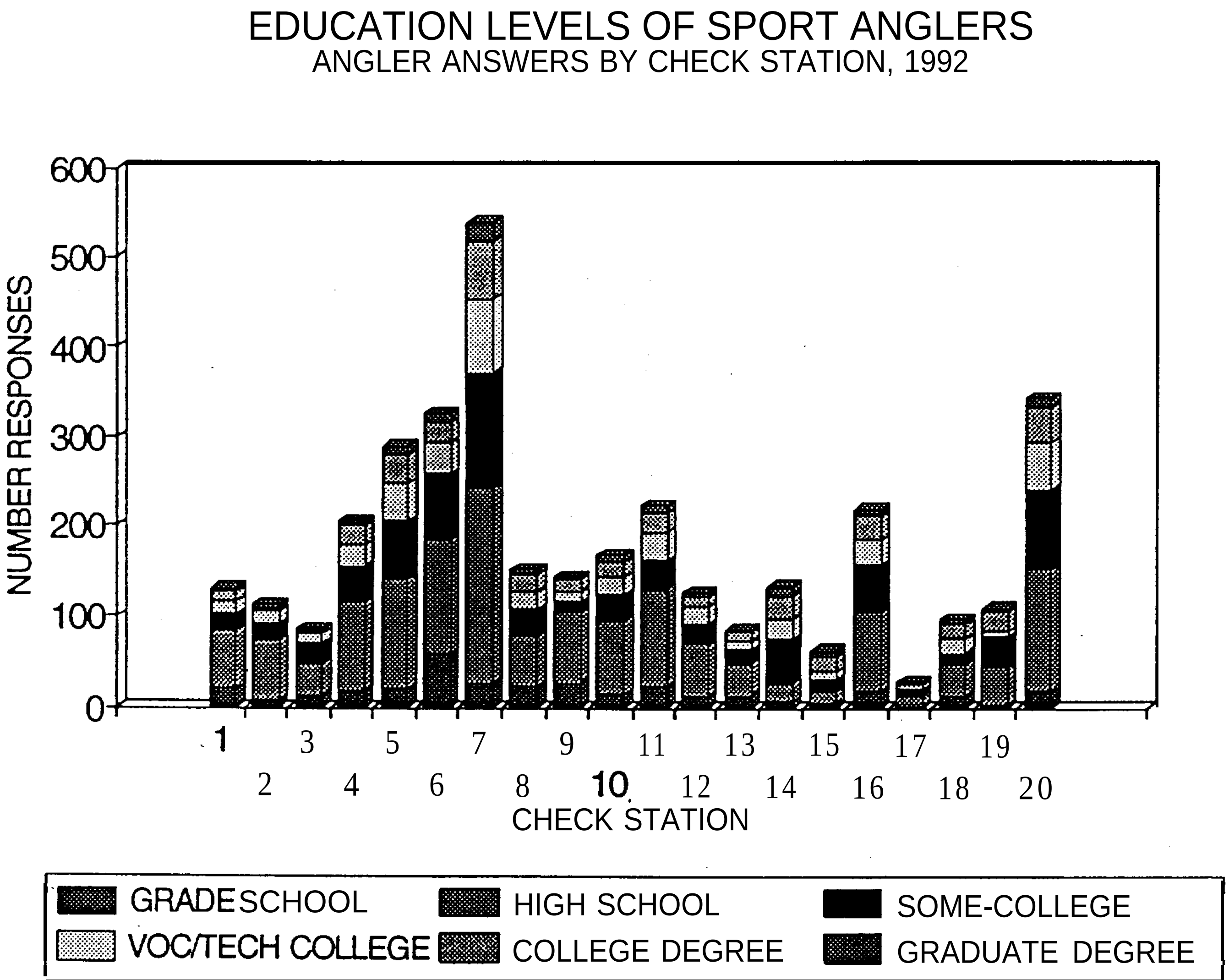
Appendix Figure D-4. Average agency expenditure per fish removed.



Appendix Figure D-5. State of residence of sport anglers.

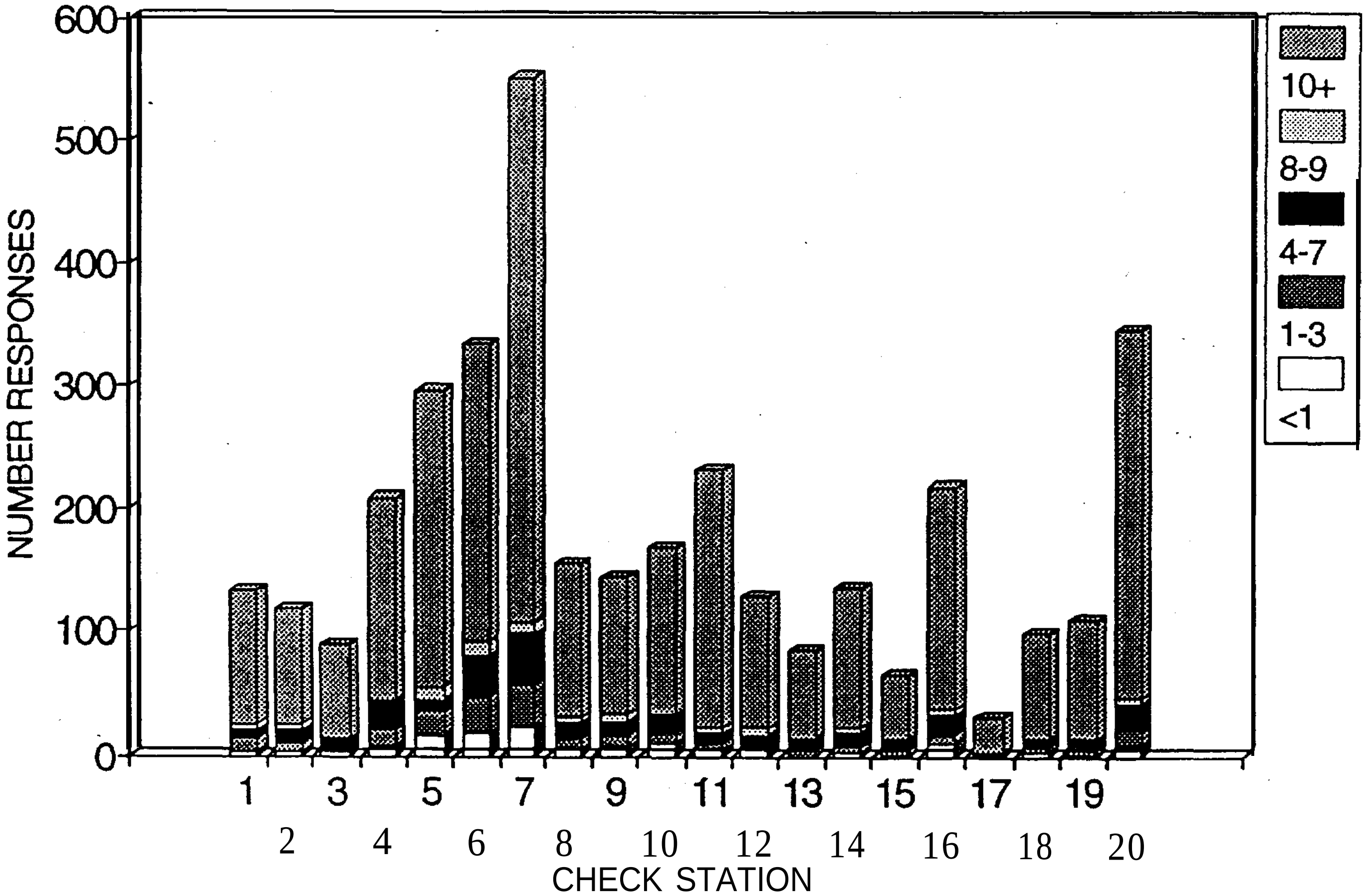


Appendix Figure D-6. Age of sport anglers.

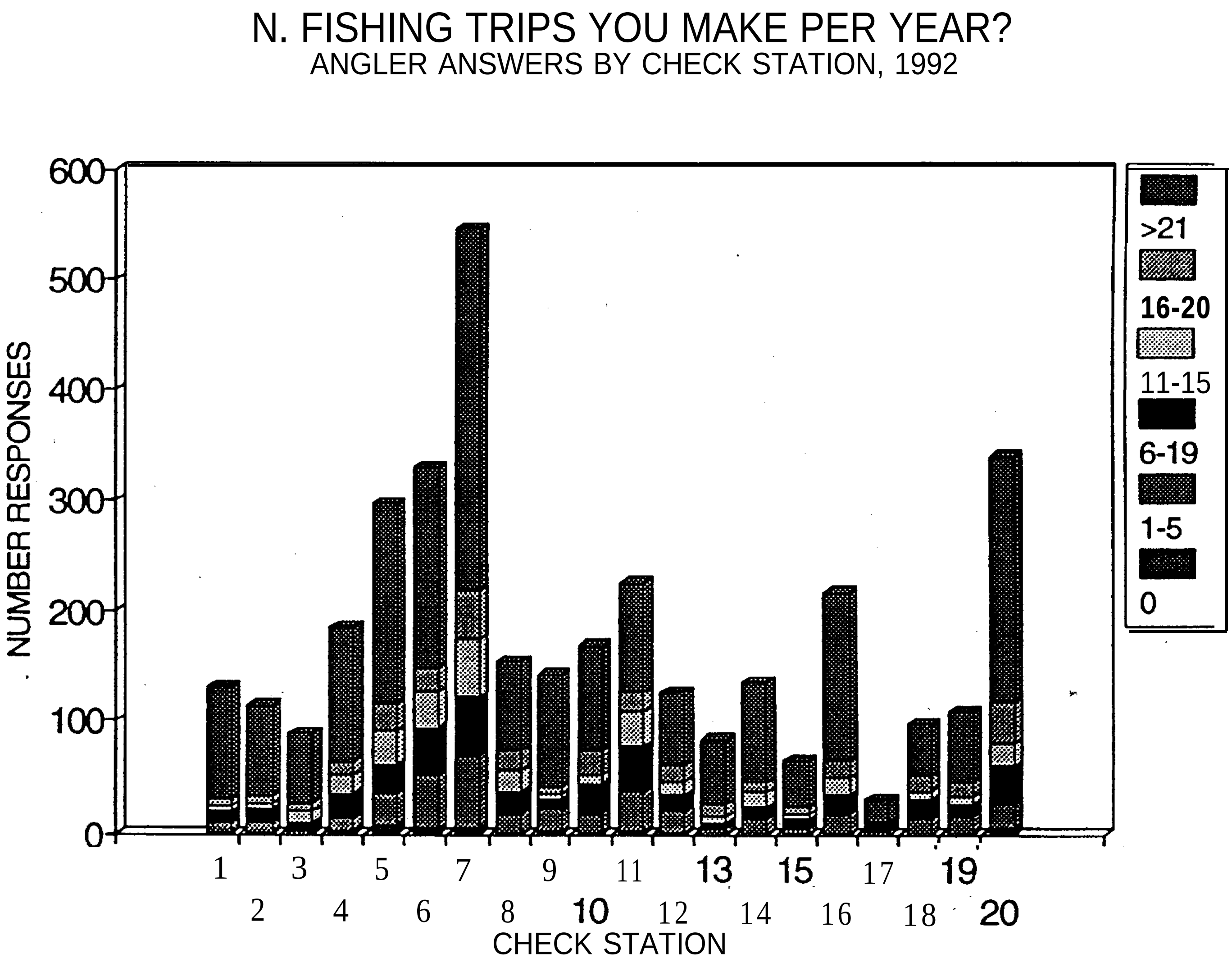


Appendix Figure D-7. Education levels of sport anglers.

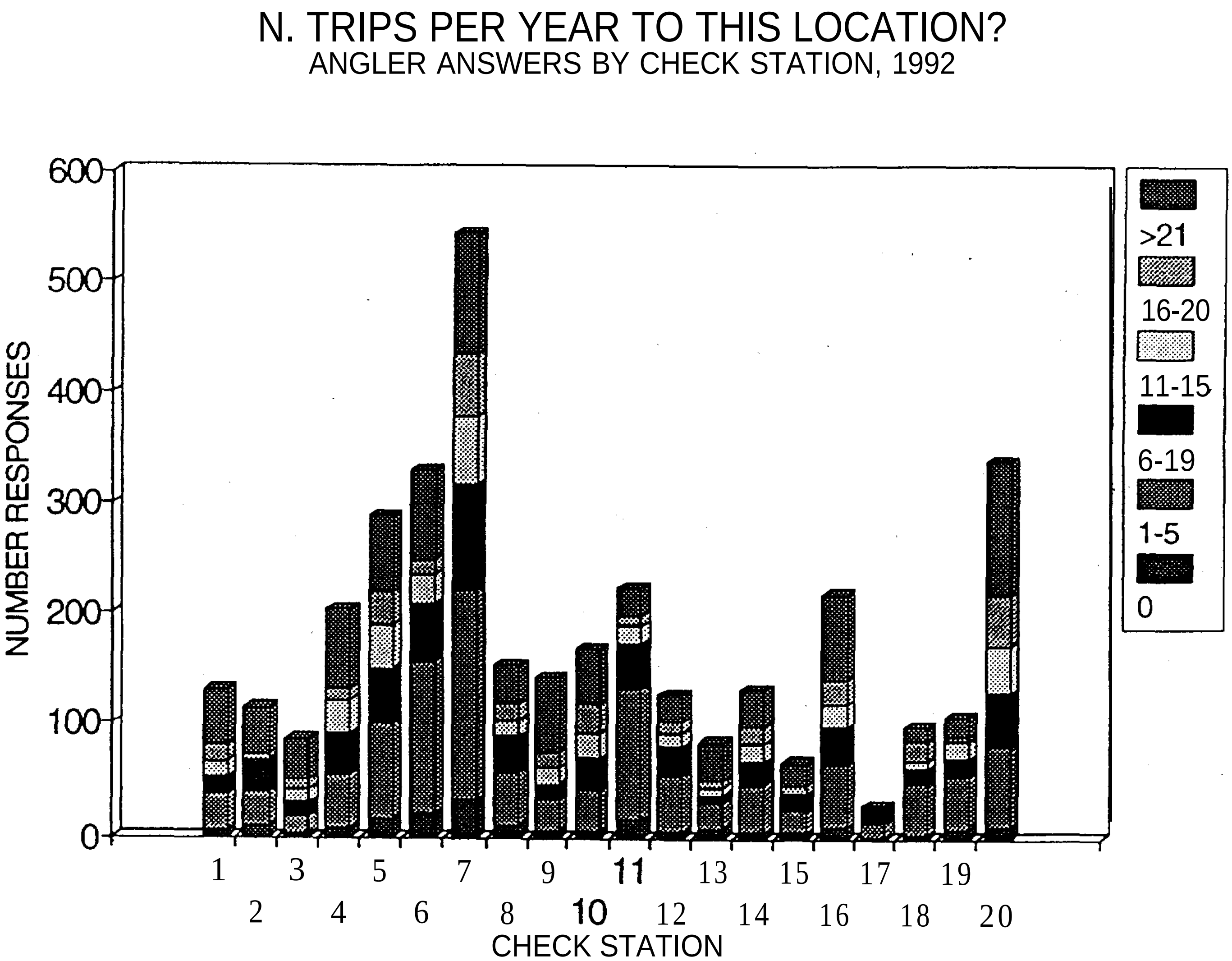
N. YEARS YOU HAVE FISHED?
ANGLER ANSWERS BY CHECK STATION, 1992



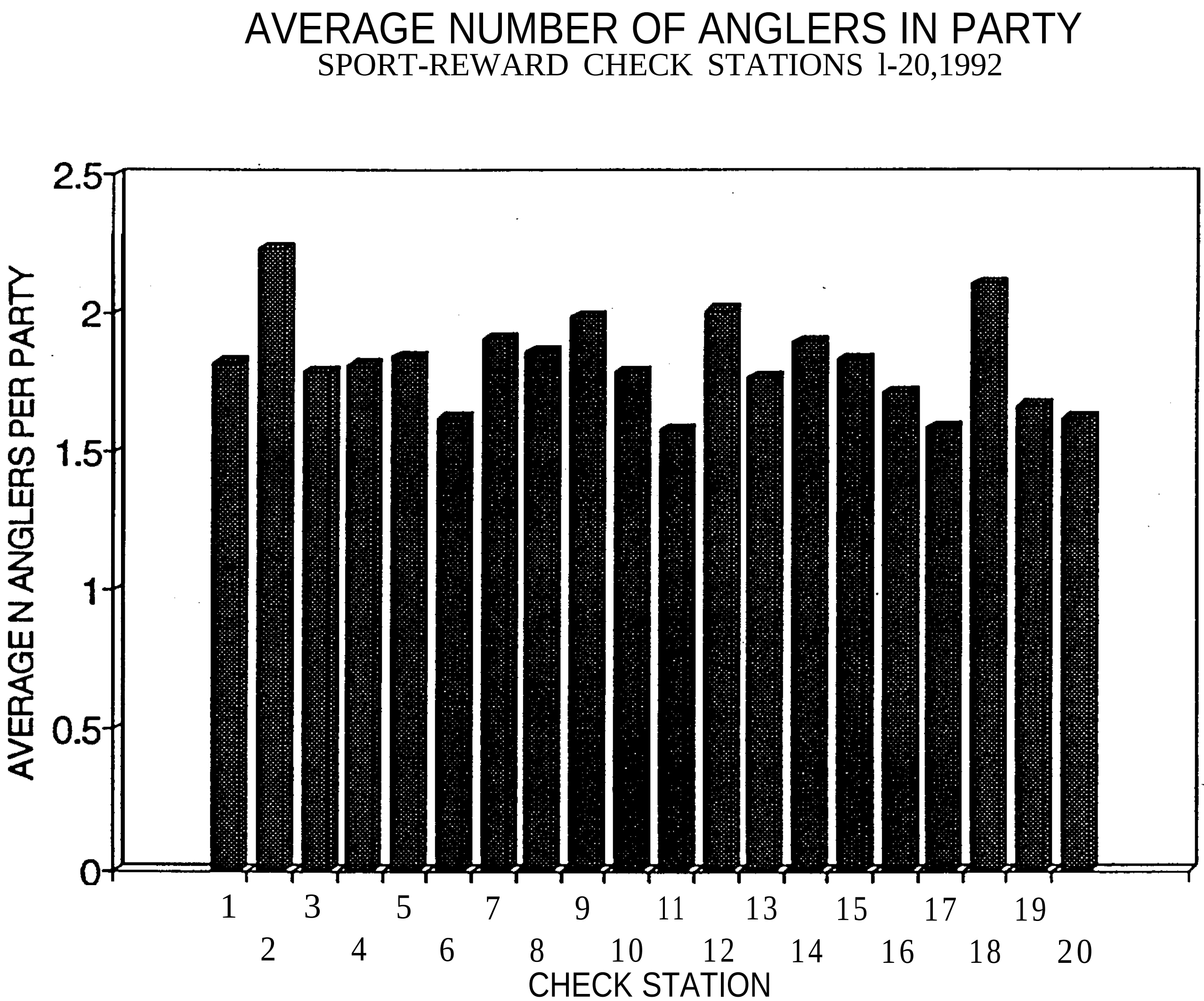
Appendix Figure D-8. Number of years sport anglers have fished.



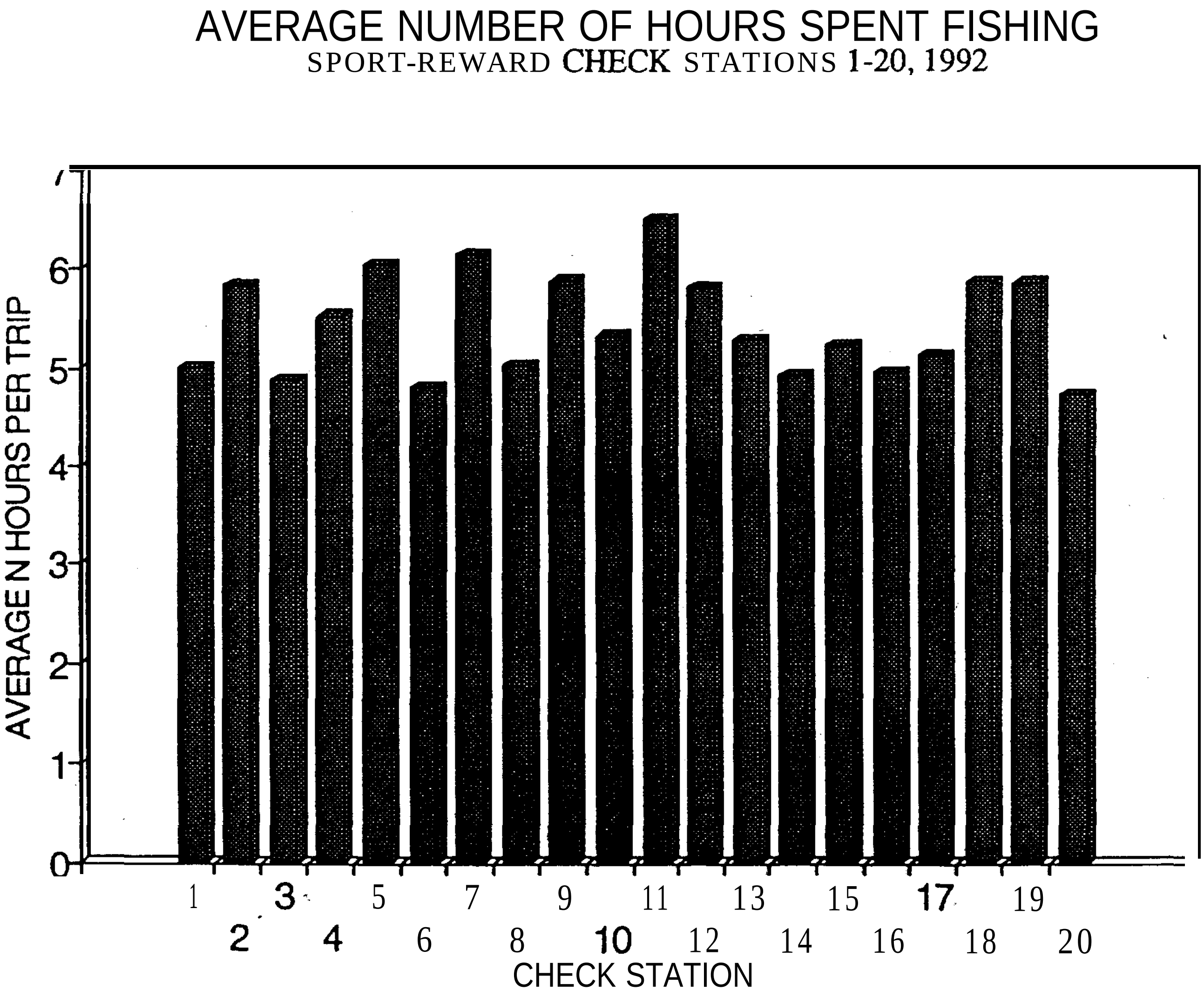
Appendix Figure D-9. Number of sport fishing trips made by anglers per year.



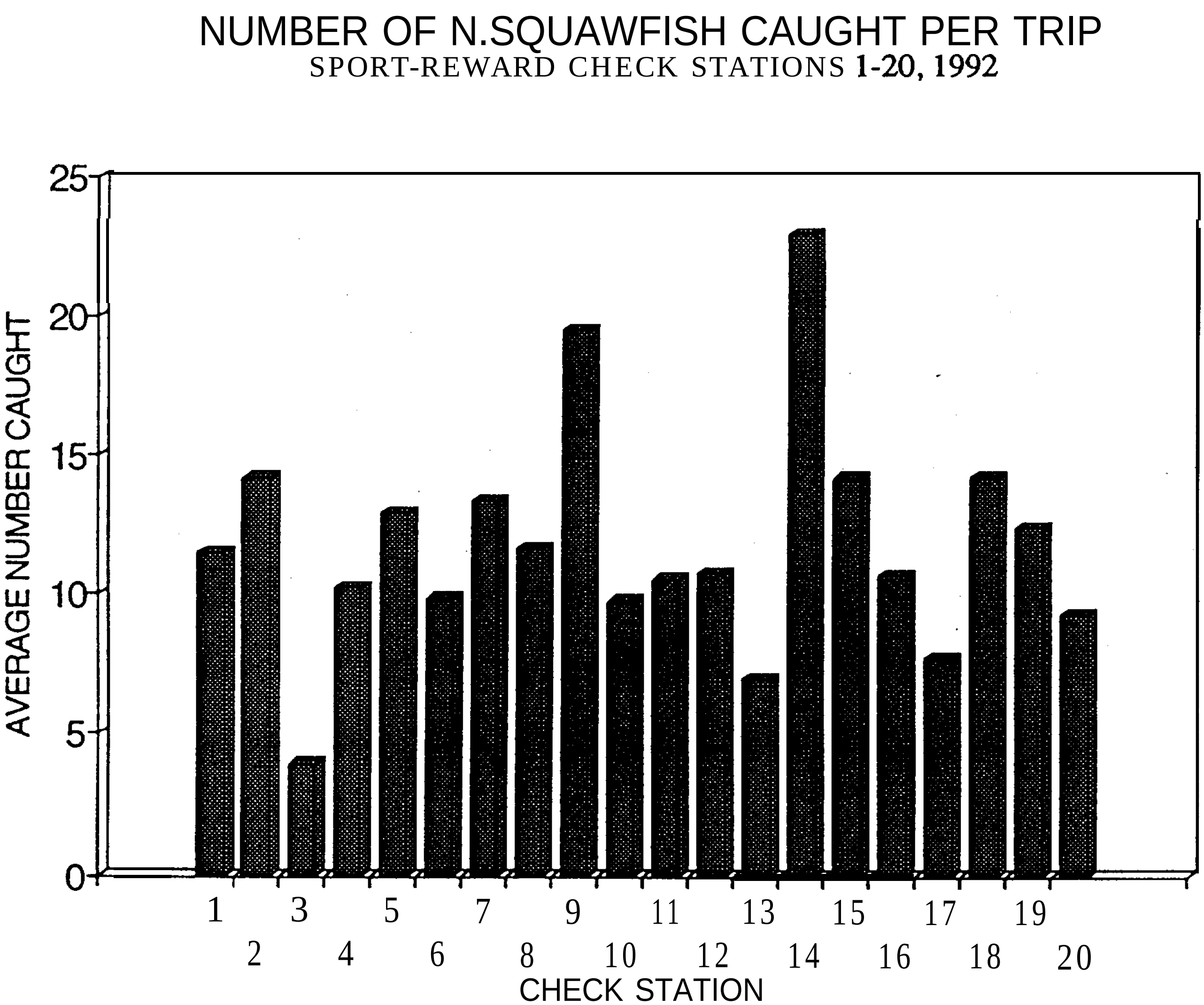
Appendix Figure D-10. Number of sport fishing trips to check station location.



Appendix Figure D-l 1. Average number of sport anglers in party.

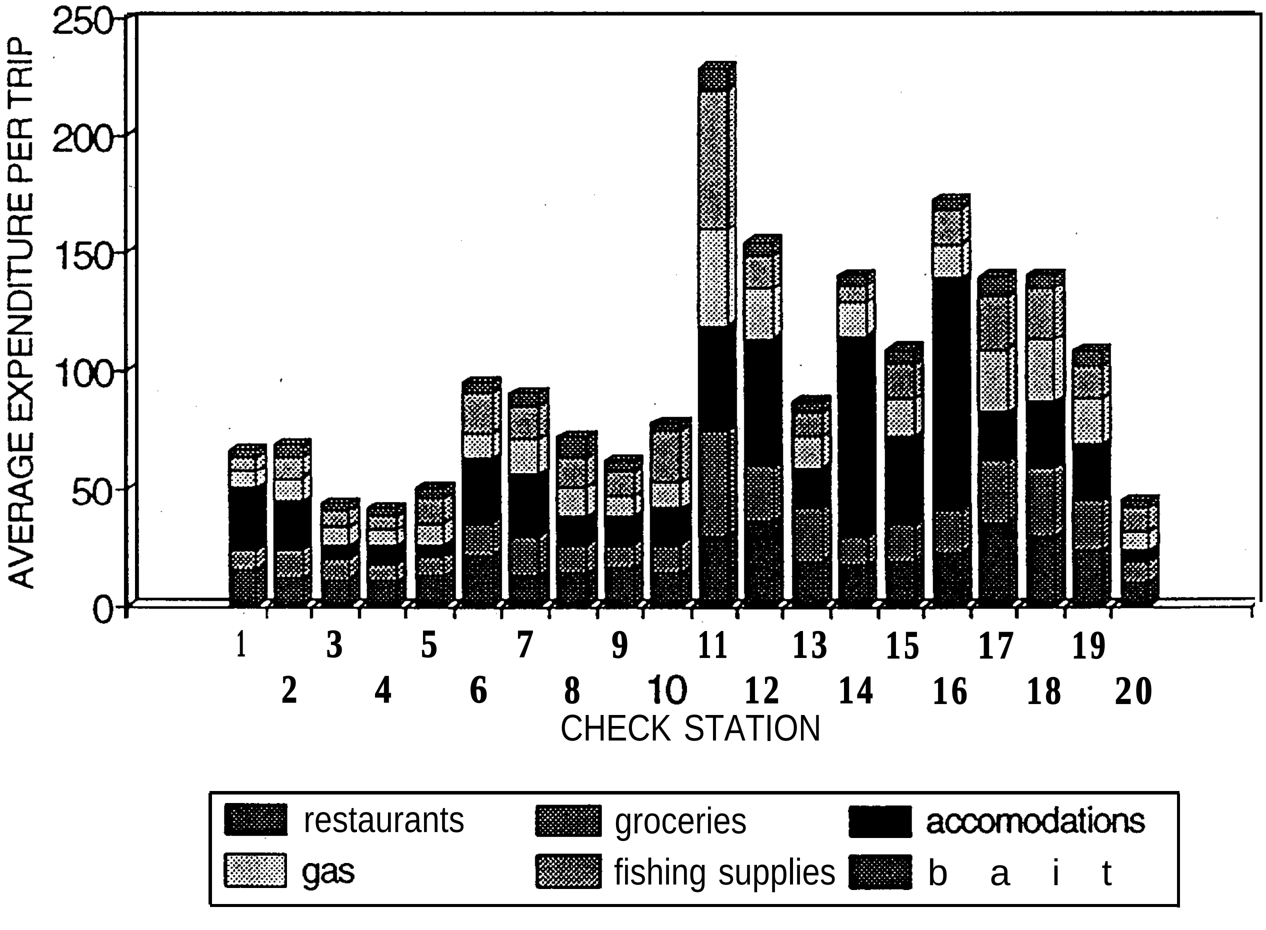


Appendix Figure D-12. Average number of hours spent fishing.

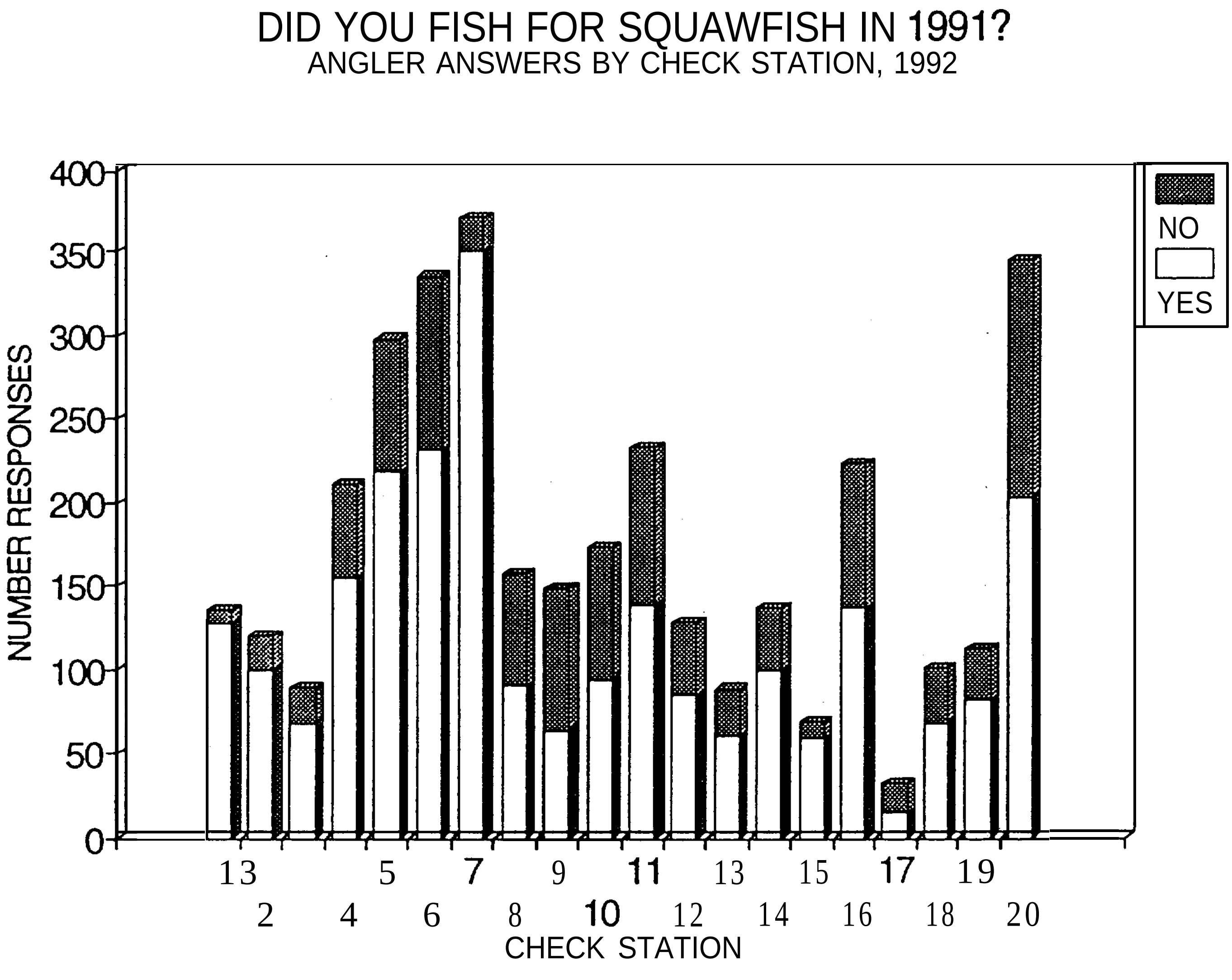


Appendix Figure D- 13. Number of northern squawfish caught per trip.

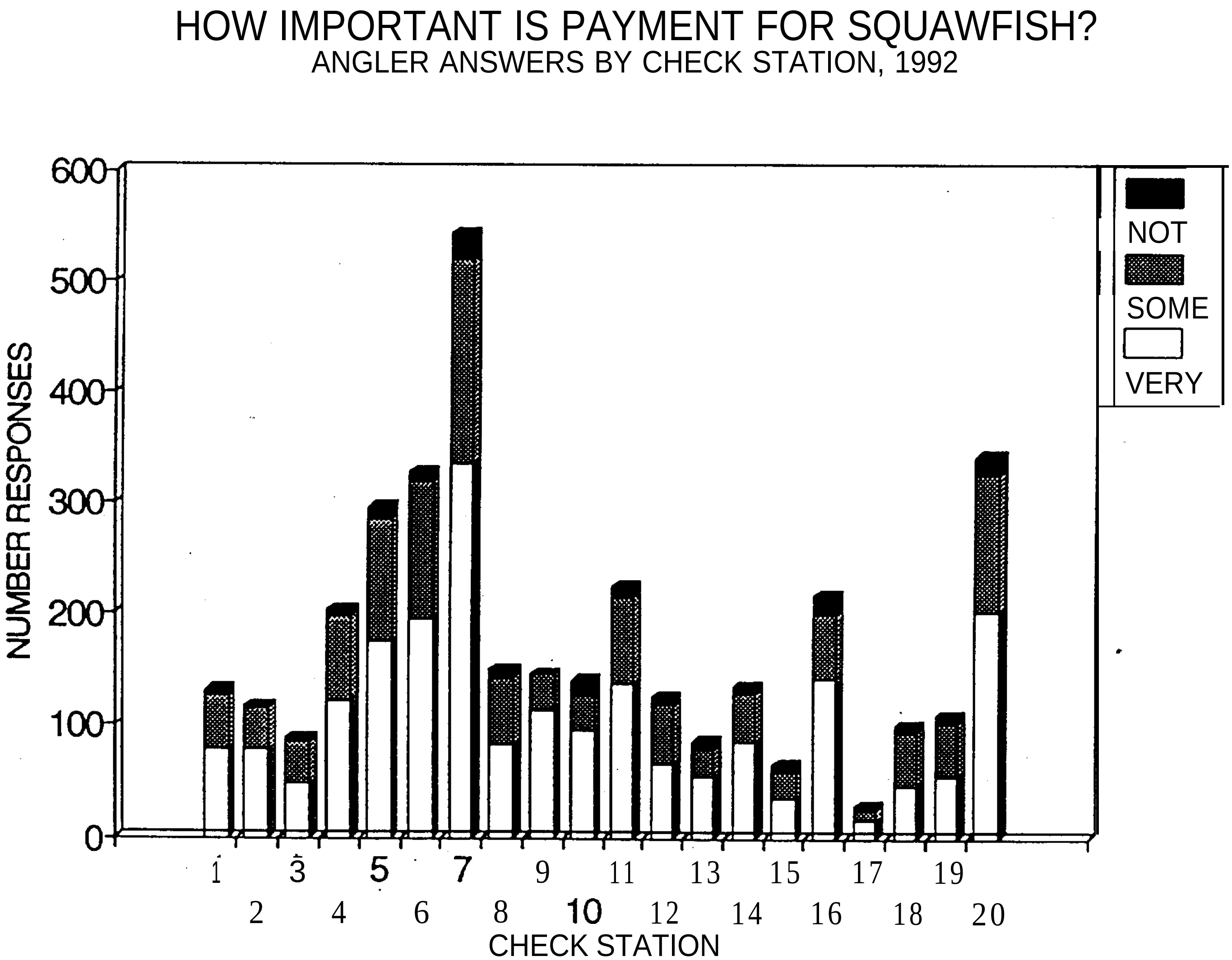
ANGLER EXPENDITURES BY CATEGORIES
SPORT-REWARD CHECK STATIONS l-20,1992



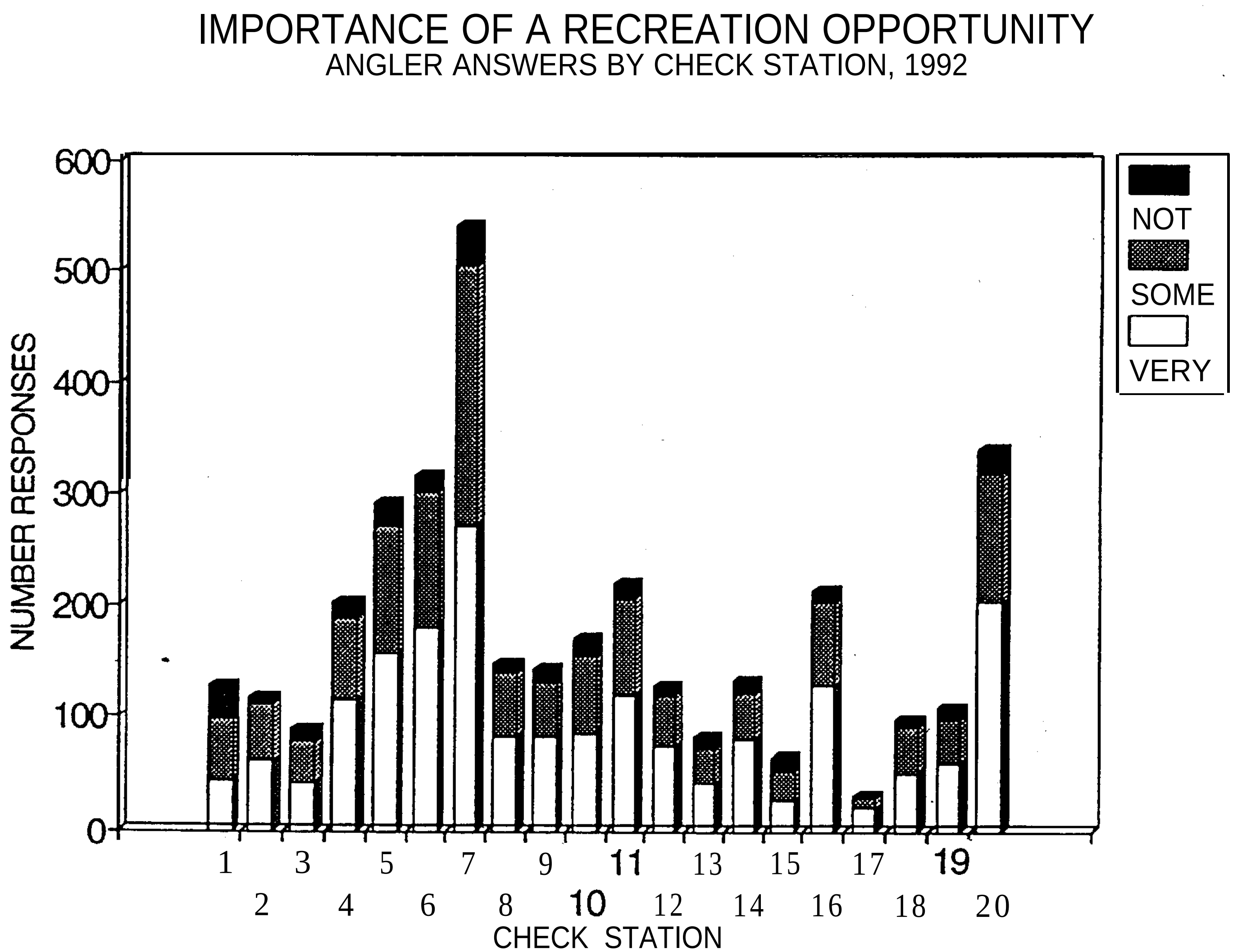
Appendix Figure D-14. Angler expenditures by category.



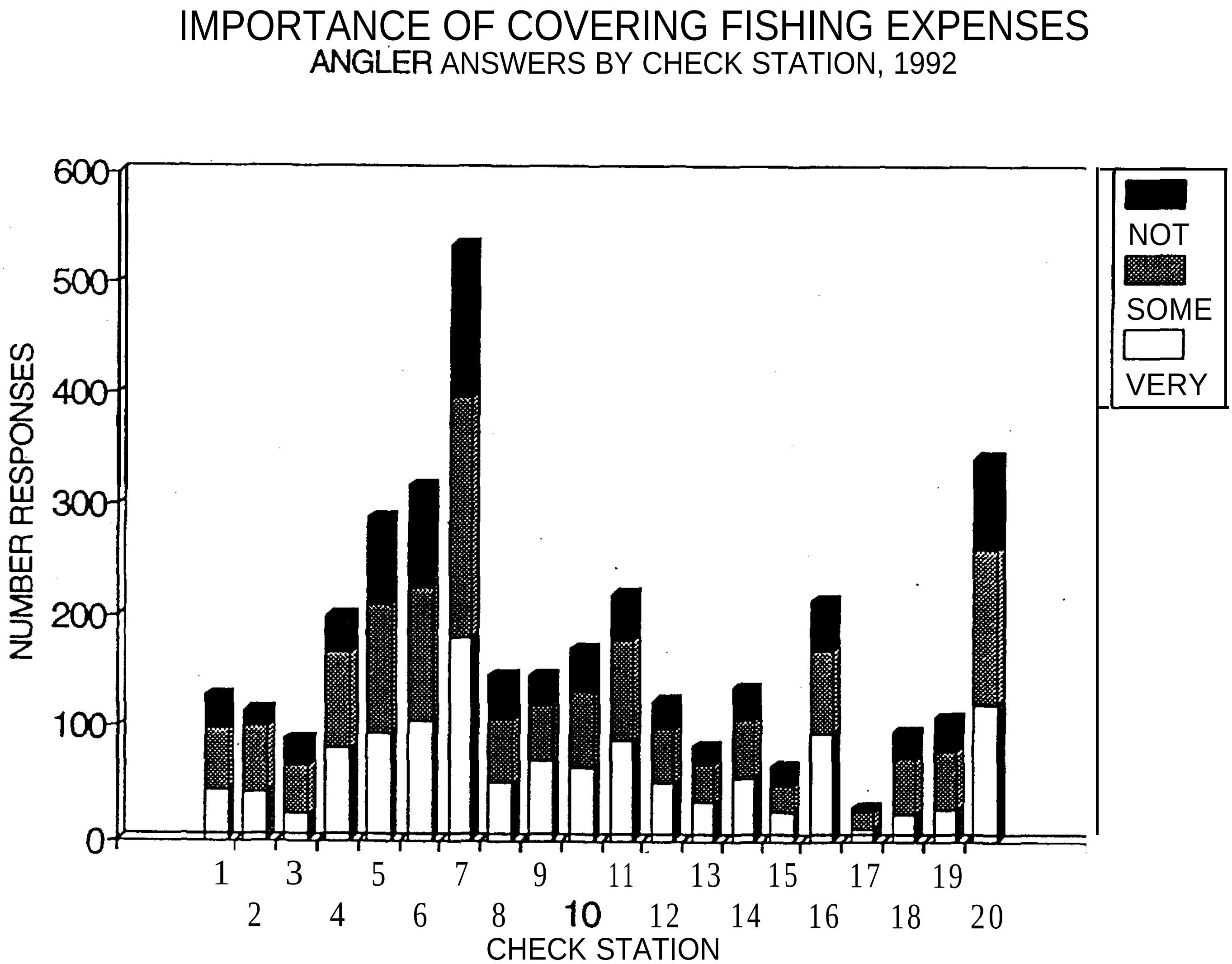
Appendix Figure D-15. Previous participation in the northern squawfish fishery.



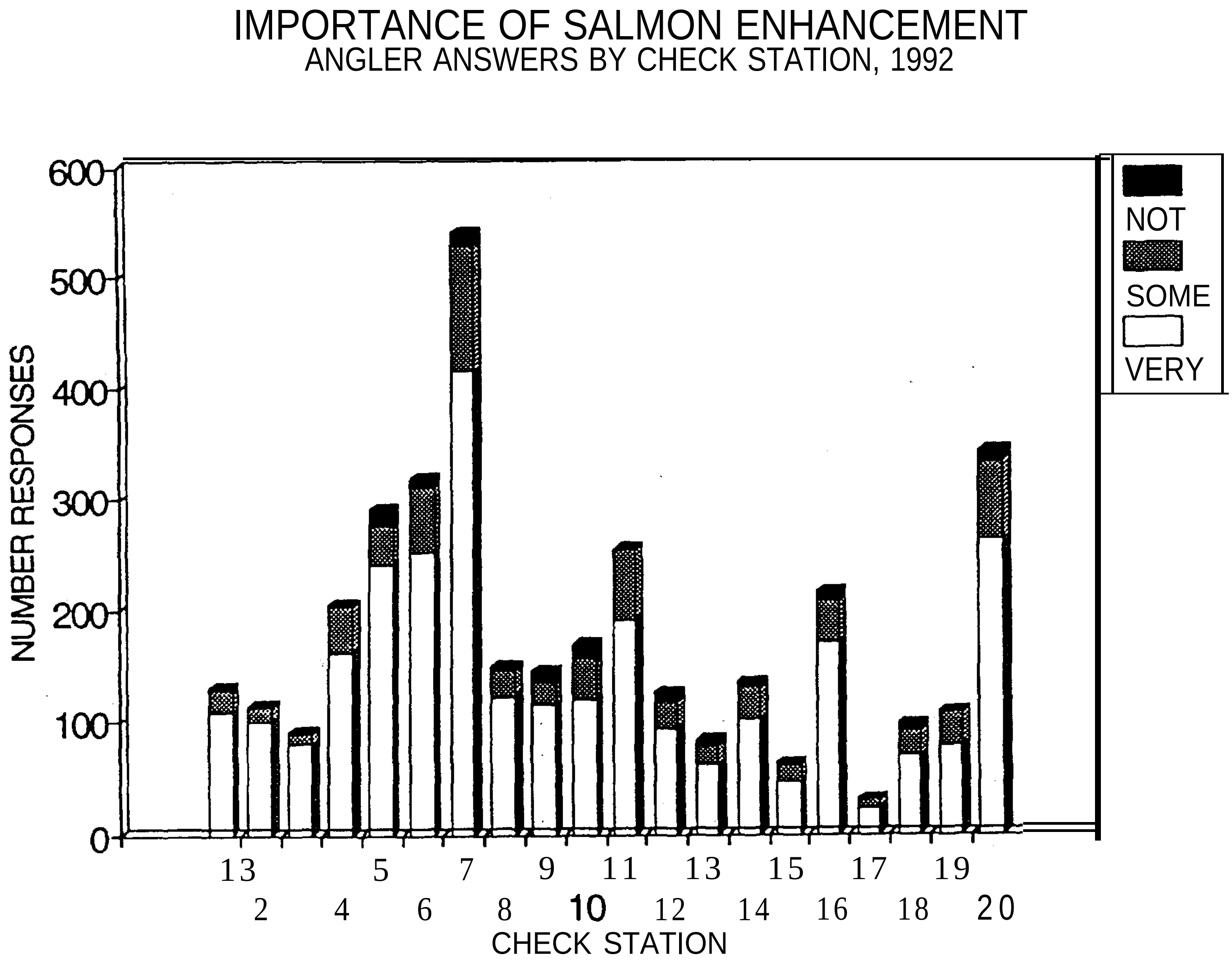
Appendix Figure D-16. Importance of payment for squawfish to anglers.



Appendix-Figure D-17. Importance of the recreational fishing opportunity to anglers.



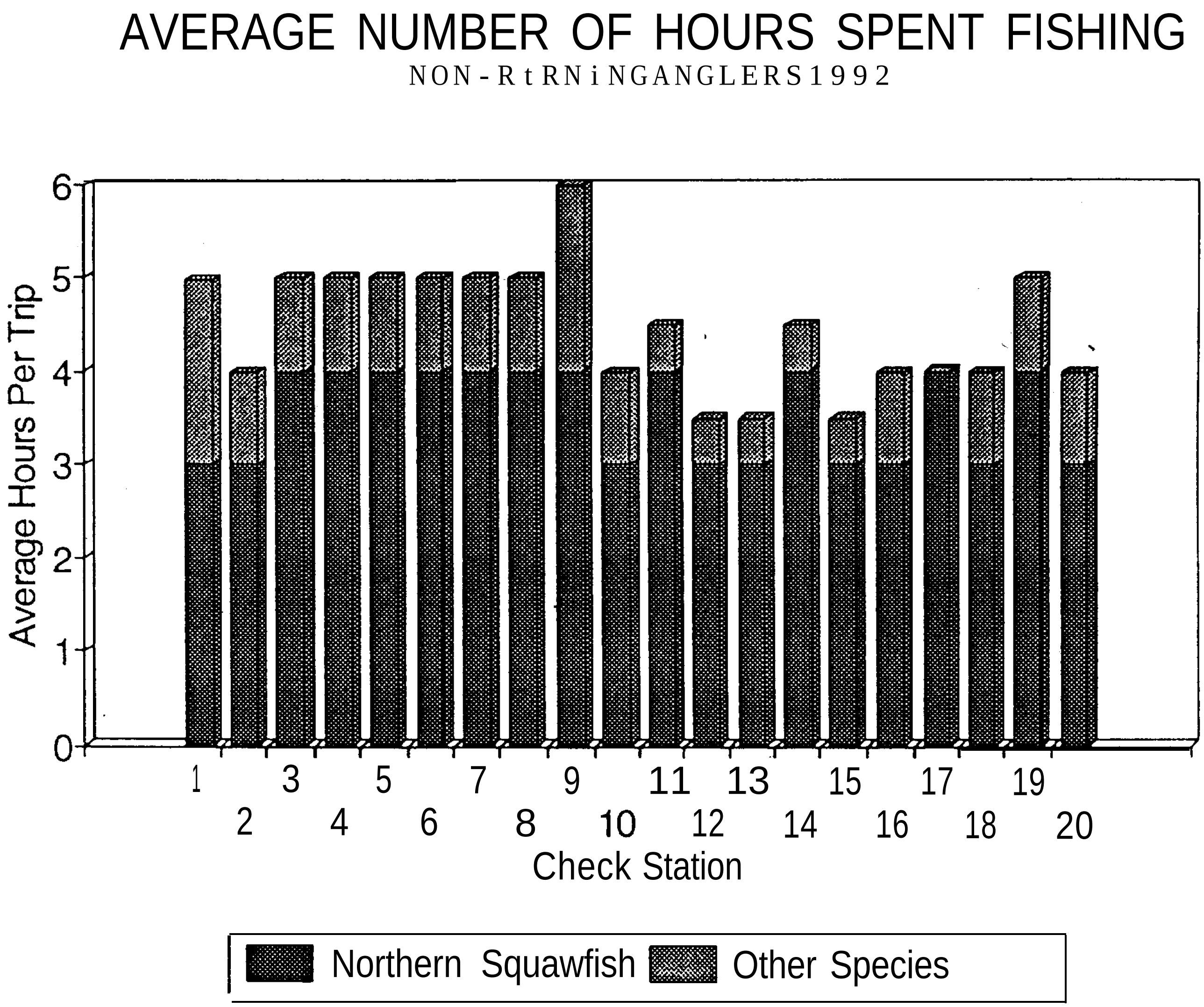
Appendix Figure D-18. Importance of covering fishing expenses to anglers.



Appendix Figure D-19. Importance of salmon enhancement to anglers.

Appendix Table D-3. Number of responses from each site, 1992 non-returning angler survey.

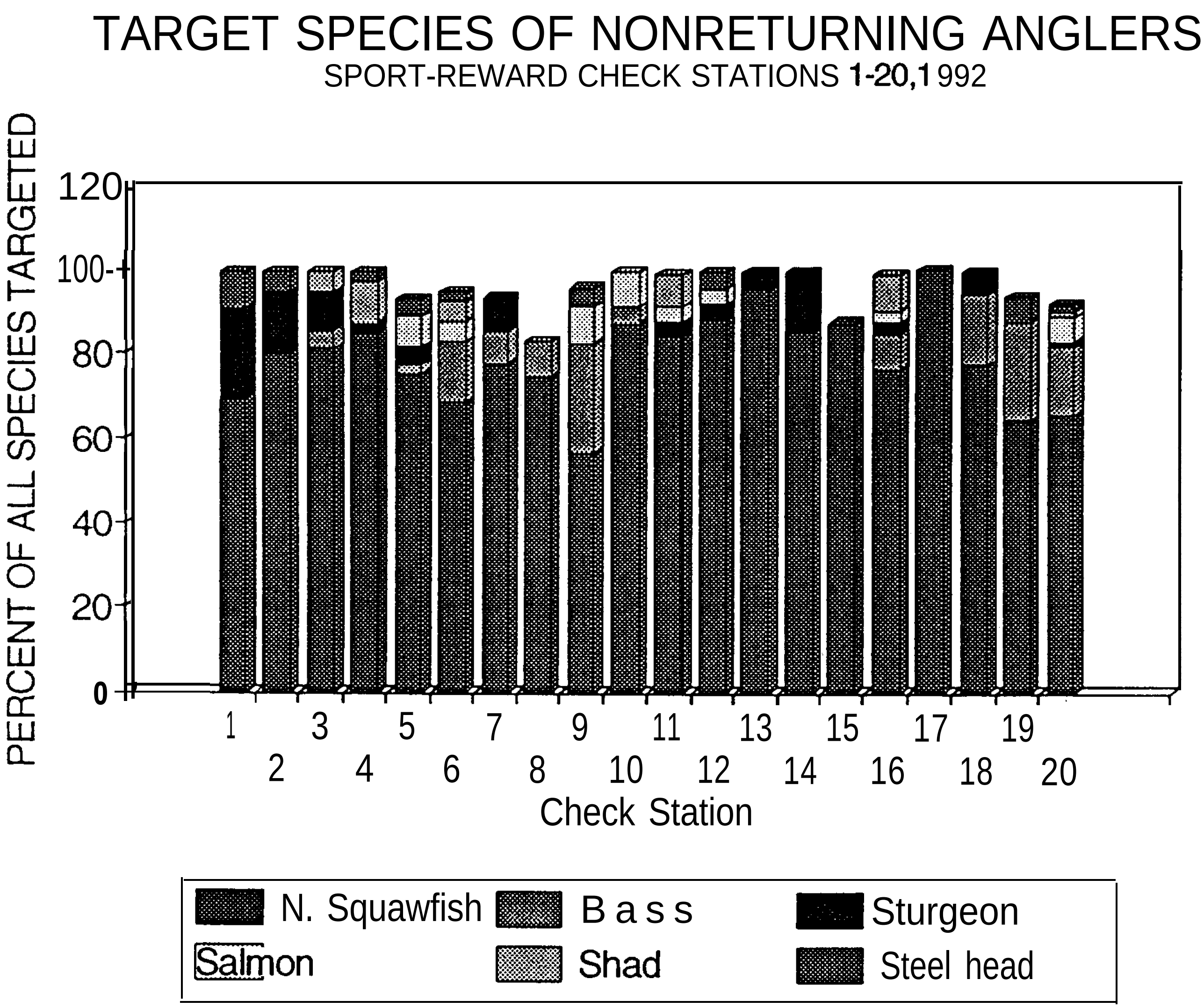
Check Station	N Responses
Willow Grove	23
Kalama Marina	21
St. Helens	22
Vancouver	41
M. James Gleason	45
Hamilton Island	44
Covert's Landing	50
Cascade Locks	23
Bingen	23
Dalles	26
LePage Park	25
Maryhill State Park	27
Plymouth	22
Columbia Point	14
Ringold	8
Hood Park	37
Windust Park	7
Lyons Ferry State Park	18
Boyer Park	17
Green Belt	67



Appendix Figure D-20. Average number of hours spent fishing for northern squawfish and other species, non-returning anglers.

Appendix Table D-4. Percent of non-returning anglers who caught northern squawfish and percent of northern squawfish caught which qualified for payment.

Check Station	% Catching N. Squawfish	% Catch > 11"
All Sites Combined	26.1	10.9
Willow Grove	26.1	10.0
Kalama Marina	33.3	5.9
St. Helens.	45.5	3.5
Vancouver	41.5	7.7
M. James Gleason	26.7	16.0
Hamilton Island	4.6	100.0
Covert's Landing	20.0	9.7
Cascade Locks	17.4	55.6
Bingen	17.4	50.0
Dalles	19.2	18.8
LePage Park	48.0	-1.9
Maryhill State Park	36.0	0
Plymouth	27.3	0
Columbia Point	21.4	0
Ringold	62.5	0
Hood Park	37.8	4.0
Windust Park	28.6	0
Lyons Ferry State Park	22.2	0
Boyer Park	5.9	100.0
Green Belt	14.9	30.8



Appendix Figure D-21. Primary target species of non-returning anglers.

Appendix Table D-5. Frequency of incidental catch while fishing for northern squawfish, non-returning anglers.

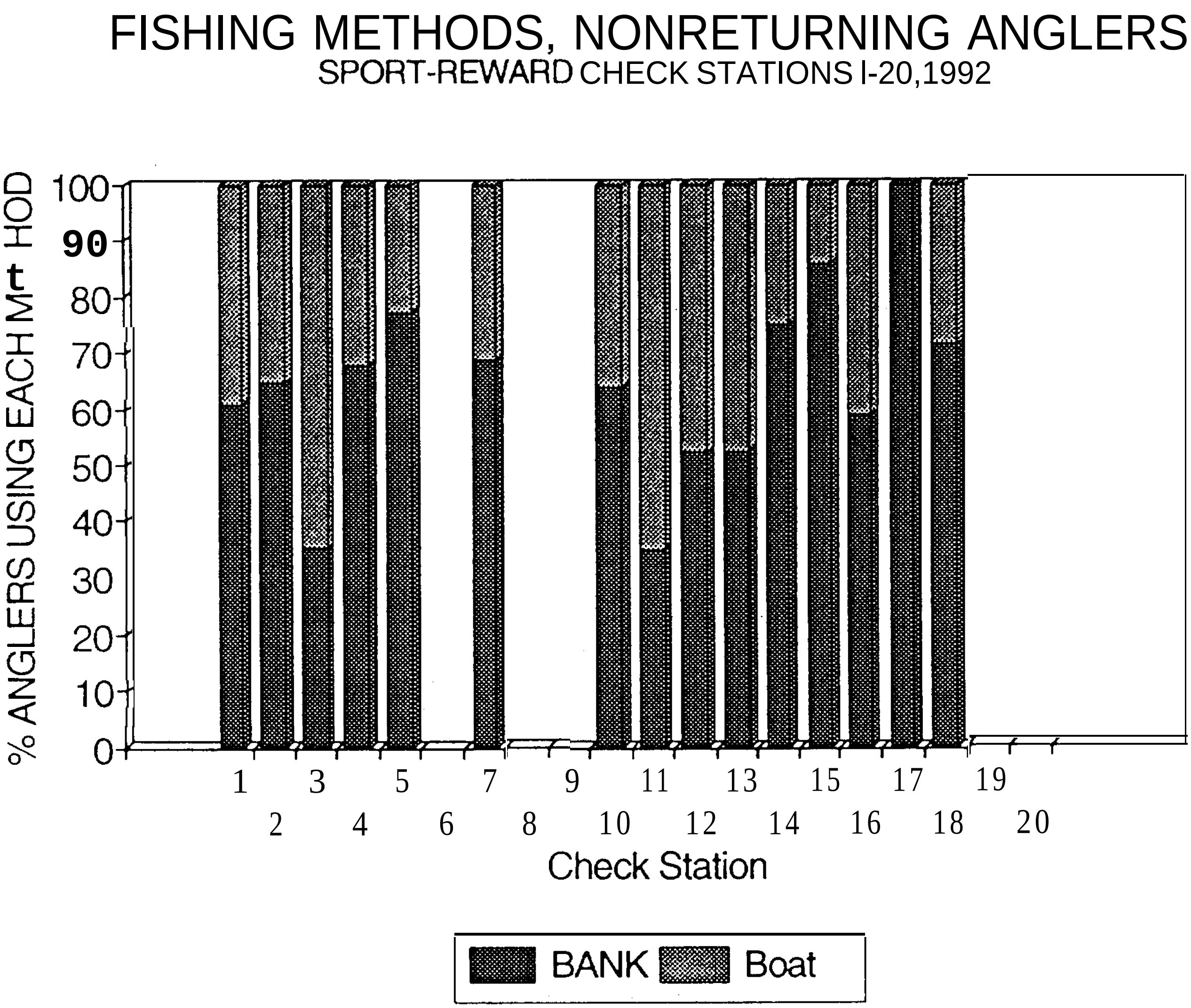
Check Station	% Catching Non-Squawfish Species
All Sites Combined	26.1
Willow Grove	39.1
Kalama Marina	40.0
St. Helens	45.5
Vancouver	31.7
M. James Gleason	35.6
Hamilton Island	38.6
Covert's Landing	30.0
Cascade Locks	60.9
Bingen	47.8
Dalles	46.2
LePage Park	40.0
Maryhill State Park	40.7
Plymouth	22.7
Columbia Point	14.3
Ringold	75.0
Hood Park	35.1
Windust Park	14.3
Lyons Ferry State Park	27.8
Boyer Park	23.5
Green Belt	44.8

Appendix Table D-6. Species composition of incidental catch, non-returning anglers.

Species	N Caught at All Sites
Sturgeon	45
Trout	18
Steelhead	9
Perch	59
Shad	41
Carp	52
Bullhead	11
Suckers	18
Flounder	13
Bass	239
Peamouth	23
Catfish	109
Chub	10
Salmon	29

Appendix Table D-7. Target species caught in combination with northern squawfish trips, non-returning angler survey, all sites.

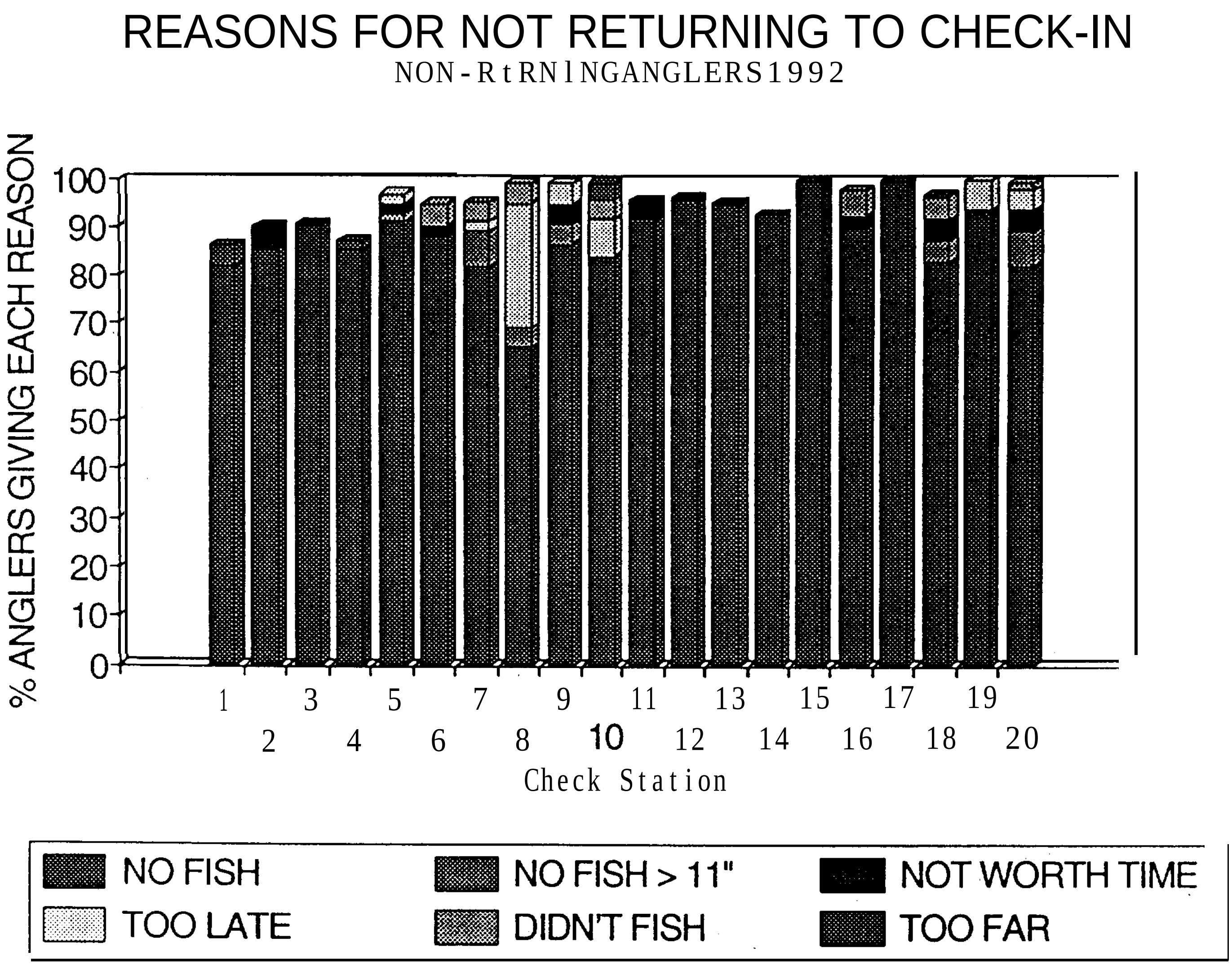
Species	Number Caught
Bass	86
Shad	73
Catfish	30
Sturgeon	19
Salmon	15
S teelhead	8
Trout	6
Chub	6
Suckers	5
Carp	2



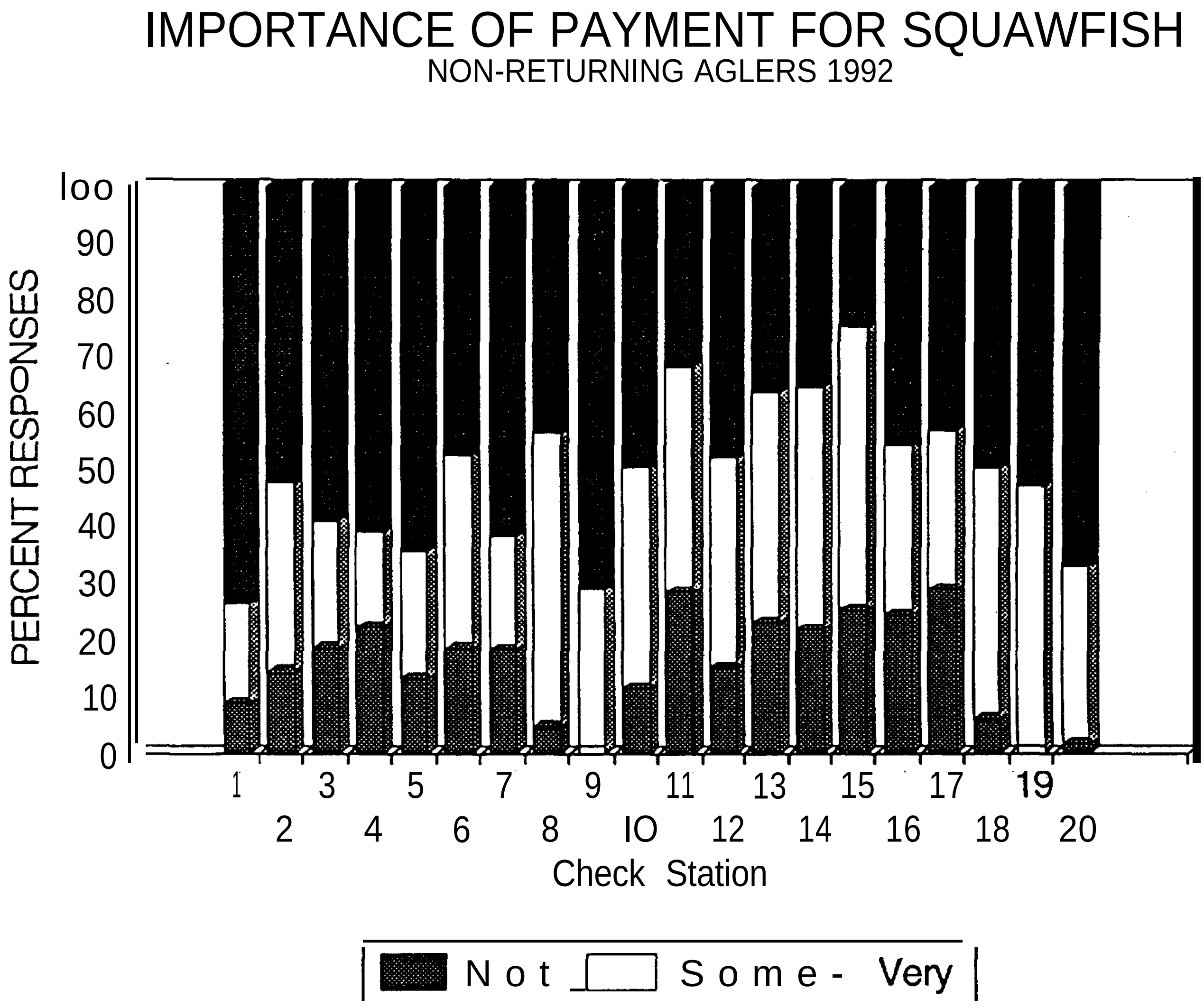
Appendix Figure D-22. Fishing methods used by non-returning anglers.

Appendix Table D-8. Bait and tackle used by non-returning anglers, all sites.

Bait or Tackle	% Non-Returning Anglers Using
Nightcrawlers	43.2
Lures	14.4
Jigs	6.0
Plugs	5.0
Grubs	5.0
Chicken Skin	3.6
Spinners	3.0
Liver	2.3
Shrimp	2.3
Plastics	2.3
Smelt	.9



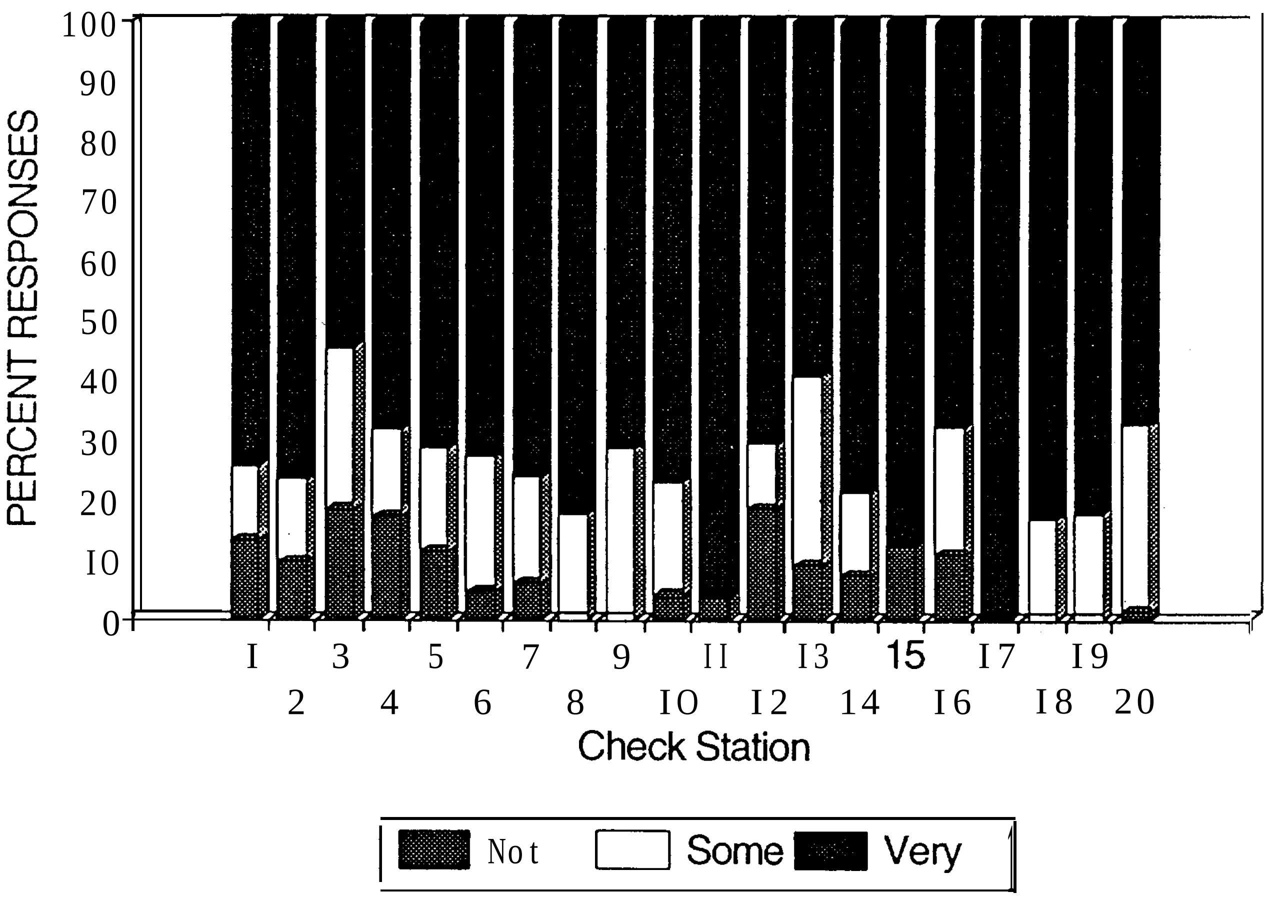
Appendix Figure D-23. Angler reasons for not returning to the registration site.



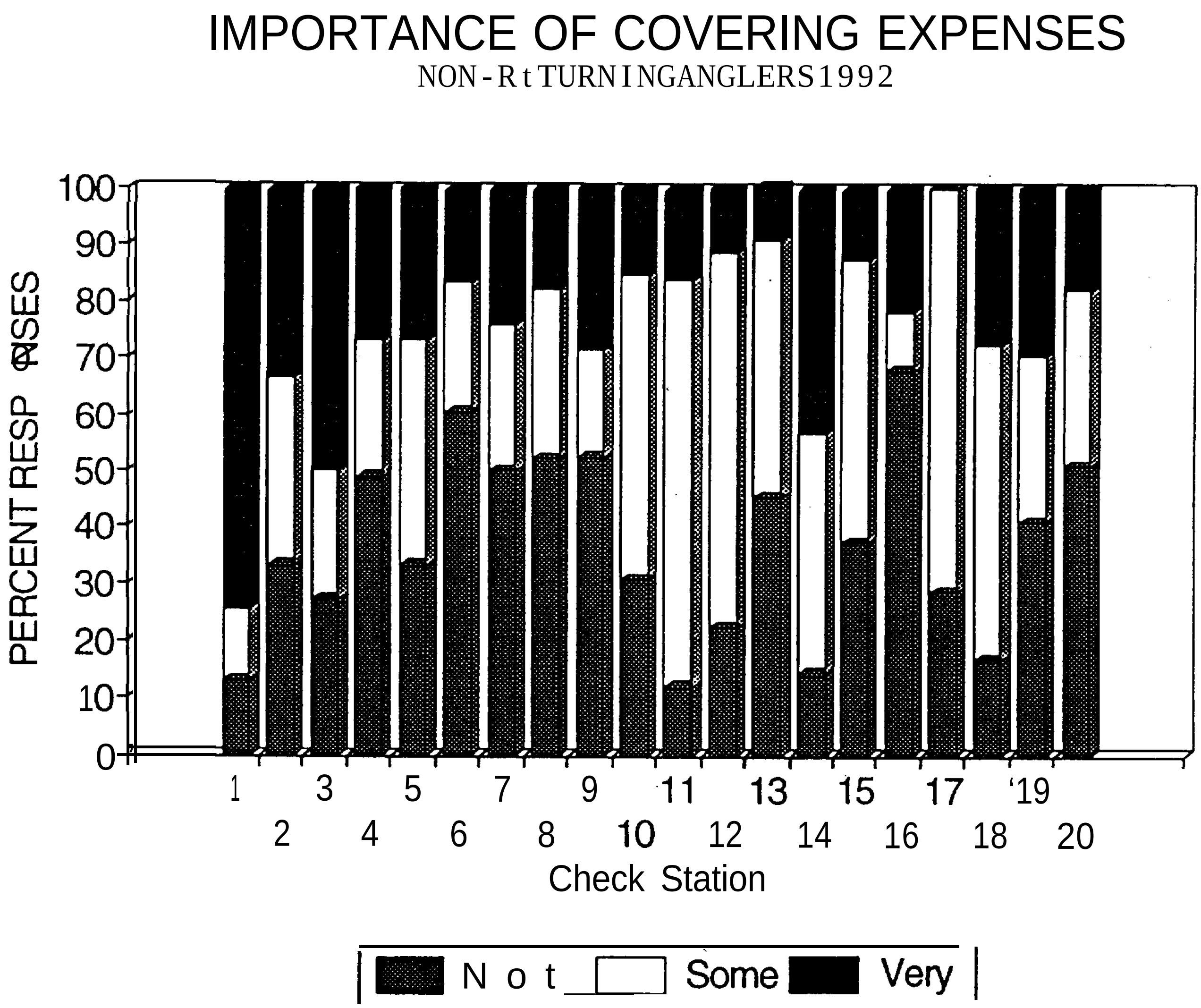
Appendix Figure D-24. Importance of payment for northern squawfish to participation in the sport-reward fishery, non-returning anglers.

IMPORTANCE OF A RECREATION OPPORTUNITY

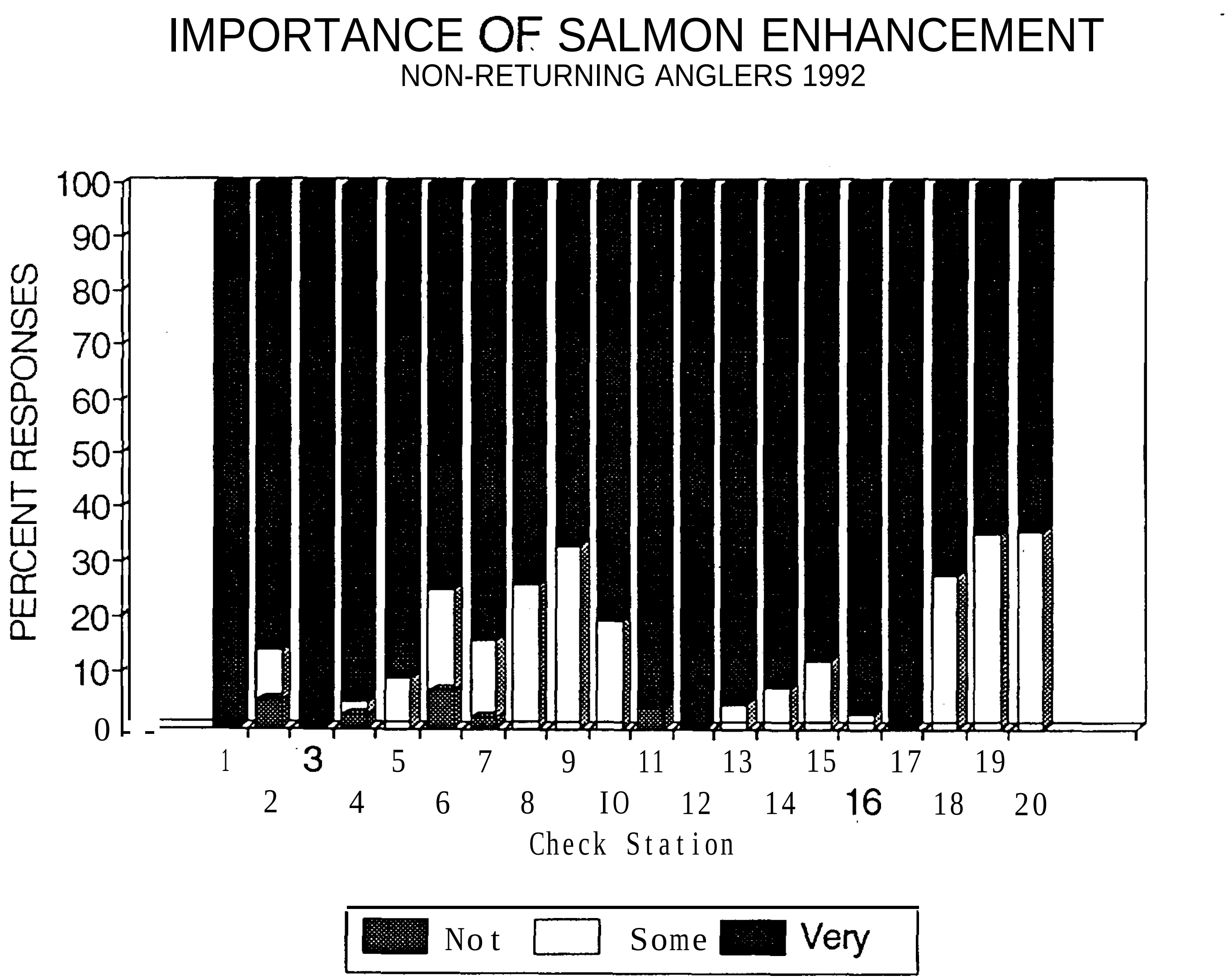
NON-RETURNING AGLERS 1992



Appendix Figure D-25. Importance of recreation to participation in the sport-reward fishery, non-returning anglers.



Appendix Figure D-26. Importance of the opportunity to cover fishing expenses to participation in the sport-reward fishery, non-returning anglers.



Appendix Figure D-27. Importance of contributing to salmon enhancement to participation in the northern squawfish fishery, non-returning anglers.

Appendix Table D-9. Percent of non-returning anglers who returned northern squawfish for payment at least once in 1992 and average number returned.

Site Returned	% Returning Fish	% Not Returning Fish	Ave. #
All Sites Combined	48.0	52.0	1
Willow Grove	56.5	43.5	38
Kalama Marina	57.1	42.9	69
St. Helens	40.9	59.1	72
Vancouver	41.5	58.5	207
M. James Gleason	48.9	51.1	127
Hamilton Island	52.3	47.7	91
Covert's Landing	54.0	46.0	145
Cascade Locks	40.9	59.1	226
Bingen	56.5	43.5	21
Dalles	53.9	46.1	90
LePage Park	44.0	56.0	31
Maryhill State Park	59.3	40.7	7
Plymouth	31.8	68.2	62
Columbia Point	61.5	38.5	120
Ringold	25.0	75.0	21
Hood Park	64.9	35.1	34
Windust Park	42.9	57.1	44
Lyons Ferry State Park	55.6	44.4	12
Boyer Park	29.4	70.6	221
Green Belt	31.3	68.7	
	54		

Appendix Table D-10. Average number of fishing trips taken by non-returning anglers each year.

Site Trips Squawfish	Ave. N Trips Per Year	Ave. N Trips This Location	Ave. N Additional for Northern
All Sites Combined	34	9	
Willow Grove	54	43	7
Kalama Marina	67	46	9
St. Helens	66	56	7
Vancouver	53	39	11
M. James Gleason	47	37	10
Hamilton Island	53	25	6
Covert's Landing	45	34	12
Cascade Locks	50	36	11
Bingen	29	17	6
Dalles	59	31	8
LePage Park	44	21	6
Maryhill State Park	39	25	8
Plymouth	47	29	7
Columbia Point	65	28	11
Ringold	61	50	23
Hood Park	56	50	22
Windust Park	56	44	24
Lyons Ferry State Park	41	24	7
Boyer Park	52	33	11
Green Belt	48	31	4

Appendix Table D-l 1. Non-returning angler assessment of check station convenience.

Site	% Anglers Judging Sites Convenient	% Anglers Judging Sites Inconvenient
All Sites Combined	89.3	10.7
Willow Grove	78.3	21.7
Kalama Marina	90.5	9.5
St. Helens	77.3	22.7
Vancouver	87.8	12.2
M. James Gleason	84.4	15.6
Hamilton Island	95.5	4.5
Covert's Landing	92.0	8.0
Cascade Locks	95.7	4.3
Bingen	91.3	8.7
Dalles	96.2	3.8
LePage Park	92.0	8.0
Maryhill State Park	70.4	29.6
Plymouth	86.4	13.6
Columbia Point	85.7	14.3
Ringold	100.	0
Hood Park	97.3	2.7
Windust Park	85.7	14.3
Lyons Ferry State Park	83.3	16.7
Boyer Park	94.1	5.9
Green Belt	95.5	4.5

Appendix Table D-12. Percent of non-returning anglers who plan to fish for northern squawfish in 1993.

Site	% Yes	% No	Most Frequently Cited Reason For Majority Answer
All Sites Combined	92.8	7.2	money
Willow Grove	95.7	4.4	money
Kalama Marina	95.2	4.8	money
St. Helens	90.9	9.1	money
Vancouver	92.7	7.3	recreation
M. James Gleason	95.6	4.4	money
Hamilton Island	95.5	4.5	money
Covert's Landing	92.0	8.0	money
Cascade Locks	91.3	8.7	money
Bingen	95.7	4.3	money
Dalles	96.2	3.8	recreation
LePage Park	84.0	16.0	recreation
Maryhill State Park	92.6	7.4	recreation
Plymouth	86.4	13.7	recreation
Columbia Point	100.	0	recreation
Ringold	100.	0	money
Hood Park	97.3	2.7	money
Windust Park	87.5	12.5	money
Lyons Ferry State Park	100.	0	recreation
Boyer Park	88.2	11.8	salmon enhancement
Green Belt	13.4	86.8	not worth it

Appendix Table D- 13. Creel clerk evaluation of the 1992 sport-reward program (N=2 1).

Program Component	Good (%)	Fair (%)	Poor (%)	NA (%)
Operating Hours	90.5	9.5	0	0
Registration Process	85.7	14.3	0	0
Check-in Process	76.2	0	0	19.1
Data Forms	71.4	19.1	9.5	0
Data Collection	90.5	9.5	0	0
Staffing	85.7	14.3	0	0
Equipment	61.9	33.3	4.8	0
Station Security	81.0	4.8	14.2	

Appendix Table D-14. Frequency of angler complaints about various aspects of the sport-reward fishery, as reported by creel clerks (N=2 1; % creel clerks having received the complaint).

Type of Complaint	Many	Some	Few	None	NA
Boat Ramps					
overcrowding	0	4.8	19.5	66.7	9.5
size	4.8	0	33.3	52.4	9.5
wait time to launch	0	4.8	19.0	67.0	9.5
Fishing.					
angler crowding	0	4.8	19.1	76.2	0 '
commer. fisherman crowding	0	4.8	4.8	90.5	0
gear damage from anglers	0	0	4.8	90.5	4.8
gear damage from commer.	0	0	9.5	85.7	4.8
speeding boats	0	4.8	23.8	61.9	9.5
jet skiers	4.8	9.5	42.9	42.9	0
water skiers	0	9.5	33.3	57.1	0
litter in water	9.5	14.3	28.6	47.6	0
litter on banks	9.5	9.5	47.6	33.3	0
Registration/Check-In					
registration time	14.3	4.8	52.4	28.6	0
registration paperwork	4.8	4.8	33.3	57.1	0
other anglers	0	4.8	33.3	57.1	0
check-in time	9.5	4.8	38.1	4.8	0
check-in paperwork	9.5	0	14.3	4.8	71.4
fish quality requirements	14.3	9.5	19.1	52.4	4.8

APPENDIX E

Handling and Distribution of Northern Squawfish

Appendix Table E-l. Northern squawfish handling and distribution budget summary through October 1992.

Category	Item		Total Cost
Service Contracts:	Processors		
	Rendering		
	Cold Storage		
	Trucking		
	Rentals		
		Subtotal	
Personnel:	4 Technicians		
	Tech/administrator		
	Per diem		
		Subtotal	
Vehicles:	30,000 lb.		11,500
	Pickups		12,500
		Subtotal	24,000
Equipment:	Coolers		24,800
	Miscellaneous		3,000
		Subtotal	27.800
		TOTAL	**$294,500**

Appendix Figure E-l. Transfer of handling and distribution responsibilities.

TRANSFER OF OREGON STATE UNIVERSITY NORTHERN SQUAWFISH HANDLING AND TRANSPORTATION RESPONSIBILITIES TO THE PRIVATE SECTOR

Jon Pampush
December 2, 1991

History of the Northern Squawfish Collection and Transportation Network

In 1990, the Columbia River Northern Squawfish Predator Control Program was implemented on a scale that was expected to begin removing large numbers of northern squawfish. As part of the economic evaluation of the program, Oregon State University became responsible for developing a system for collecting and identifying end-users for the harvested squawfish. The 1990 removal program was essentially a pilot scale effort with most activity restricted to the McNary Pool. The collection and transportation system was also small scale; one employee, a few chest freezers, and a two-ton pickup truck.

Harvested squawfish were bagged by Oregon Department of Fish and Wildlife technicians and frozen in chest freezers provided by OSU. As needed the OSU employee emptied the freezers and delivered the frozen fish to a cold storage facility. Most of the 40,000 Ibs. of squawfish harvested that year were converted to liquid fertilizer by Inland Pacific Fisheries in Payette, Idaho. A small quantity of food-grade squawfish was processed by the Astoria Seafood Laboratory and test-marketed in the Portland area.

In 1991 the removal program was expanded considerably creating the need for an expanded handling network. Two hundred and fifty thousand pounds of northern squawfish was harvested, most of which was converted to animal feed by a rendering facility in Portland Inland Pacific Fisheries received about 50,000 Ibs. The 1991 handling and transportation system was intended to be an expanded version of the 1990 system, but the unexpected large volume of squawfish that was harvested in May and June of 1991 required modification of the handling program during the height of the harvest period.

Inland Pacific Fisheries was unable to process the squawfish during the field season causing a rapid accumulation of frozen squawfish in cold storage. Fearing huge cold. storage charges, running out of tote space, and the prospect of no one processing the fish in the near future, the decision was made to have the remaining 1991 catch (July through September) disposed of at a rendering facility in Portland At this point of the 1992 season, there was no large volume food-grade market for the harvested squawfish.

TO date, the most significant market prospect for northern squawfish was identified in July of 199 1. Larry Stoller of Stoller Fisheries in Spirit Lake, Iowa ran a series of processing and marketing tests and determined that northern squawfish is an excellent **source** of fish flesh for his principal product "gefilte fish" (kosher minced fish). From this point on Stroller has been interested in marketing whatever quantities of food-grade northern squawfish that becomes available and has served as a handling and transportation consultant.

In 1992, the handling and transportation system was designed to accommodate the collection of food-grade northern. squawfish. OSU contracted the services of five fish processors to receive, package, and freeze food-grade squawfish and handle the remaining industrial-grade that would later be processed by Inland Pacific Fisheries. Stoller Fisheries received about 90,000 lbs. of food-grade squawfish fish during the summer of 1992, Inland Pacific Fisheries received about 145,000 lbs. for fertilizer production, and about 73,000 lbs. was rendered.

Issues Related to the Transfer of Handling Responsibilities to the Private Sector

Throughout the development of the Northern Squawfish Predator Control Program there has been a desire among the participating agencies to transfer as much of the fish handling and transportation responsibilities as possible **to the** private sector. However, many features of the removal program have made immediate transfer of these responsibilititis to the private sector difficult if not impossible for the following reasons:

1. The removal program has expanded (geographically and level of harvest) every year since its inception in 1990. Complete privatization of the handling phase cannot occur until the removal program stabilizes and yields become predictable from year to year.

2. Each year, new information about end-uses becomes available. Accommodating the Stoller food-grade market required a drastic modification of the 1991 handling program. Should the removal program. continue long term and produce predictable yields, someone may become interested in processing the harvest locally. Local processing would create the need for further modification of the existing food-grade handling program.

3. There is disagreement about how much the agericies conducting the removal fisheries should be responsible for handling fish. Some have expressed the view that the agencies should do virtually no handling (even in the field) and others have felt that considerable agency handling is necessary to operate a efficient, cost-minimizing program.

4. Because the program involves several agencies conducting different fisheries with unpredictable results, it has been necessary for OSU (up to this point) to maintain considerable direct handling responsibilities to accommodate the "unknowns."

The above mentioned problems must be resolved before a long term private sector operated handling program can be implemented. In 1993, every effort should be made to design and accommodate a handling program that will be functional, efficient, and cost-minimizing.

Current Private Sector Participation in the Handling Program

In 1992, OSU sub-contracted five private fish processors and a trucking outfit with the intention of collecting large volumes of food-grade squawfish for processing by Stoller Fisheries. Sport reward technicians and OSU employees delivered iced squawfish in coolers to the processors where they were graded, boxed and frozen. Squawfish in poor condition were frozen in totes for later conversion to organic fertilizer by Inland Pacific Fisheries. In some locations, it was not practical to collect food-grade squawfish and squawfish from these locations were either converted to fertilizer or rendered. For the most part the system was successful and produced 90,000 Ibs. of food-grade squawfish.

About 75% of OSU's 1992 handling and transportation budget was paid to private sector sub-contractors for services related to handling squawfish. The 1992 season should be considered a successful transition year.

The following is a description of the 1992 fish processor/food-grade collection system:

* OSU purchased handling equipment from 1990 - 1992 including chest freezers, insulated and non-insulted commercial fishing totes, and coolers. This equipment was distributed to participating agencies and sub-contractors.

* OSU sub-contracted five fish processors who received, packaged and **froze** the squaw-fish harvested by the sport reward and dam angling fisheries. The fish processors were at these locations:

<u>Location</u>	<u>Processor Name</u>
Longview, WA	Tri-River Smelt
Portland, OR	Point Adams Packing Company
Cascade Locks, OR	Bonneville Fisheries
The Dalles, OR	Kingfish Trading Company
Richland, WA	Wellsian Cold Storage,

* Sport reward technicians who operated in areas serviced by a fish processor delivered their catch daily to these locations and here they were restocked with fresh coolers and ice for the next day. OSU employees picked up full coolers from Bonneville, The Dalles, and McNary Dams and delivered them to nearby processors.

* For logistical and cost reasons, low volume and distant harvest locations (John Day Dam, Snake River dams, Snake River sport reward area) were not serviced by fish processors. The squawfish from these areas were either frozen in chest freezers and collected by OSU employees or were delivered by WDW technicians to a subcontractor who made arrangements for a rendering pick-up.

* OSU sub-contracted Americold Cold Storage in Wallula, WA; Americold in Nampa, ID; and Pacific Cold Storage in Portland. These facilities stored frozen squawfish and served as the pick-up locations for shipment to end-users.

* OSU rented a 30,000 lb truck for delivering equipment to processors (coolers and totes), picking up frozen fish from remote locations, and transferring frozen fish from processors to cold storage facilities.

* OSU sub-contracted May Trucking in Portland to handle deliveries to Inland Pacific Fisheries in Payette, Idaho.

* Stoller picked up boxed fish from the cold storage facilities for delivery to the Spirit Lake, Iowa processing facility.

* OSU currently rents warehouse space from Intermountain Industrial Supply for storing equipment.

Overall, the 1992 season went fairly well demonstrating that this type of arrangement best accommodates the participating agencies and the collection of whole, frozen, boxed food-grade squawfish. For 1993, a few basic changes in the program should increase efficiency, increase food-grade yield, and reduce costs. In 1992 the removal program harvested about 292,300 pounds of northern squawfish. Of that total, OSU attempted to collect food-grade from 214,500 pounds.

The following is a breakdown of the food-grade squawfish handling system for the 1992 season:

Total Volume Harvested in 1992.................................... .292,300 lbs
Total Volume Handled by Food-Grade System...............214,500 lbs

Food-Grade Handling System Analysis:

End-Use	Volume (lbs)	% Total
Food-Grade	91,030	42.4
Non Food-Grade	123,470	57.6

A 42% rate of food-grade collection for the 1992 pilot season should be considered a success, but in the future 65%-75% food-grade should be attainable. This could be accomplished by improving angler and agency handling as well as modifications in the overall handling program.

End-Use Alternatives

Identifying end-uses for the squawfish and developing a system that can accommodate these products is an issue that needs discussion. OSU has identified three, possibly four, entities that can utilize the volume of squawfish that is expected to be harvested in 1993. Other groups are currently test-marketing squawfish, but for now only the following are known to be capable of processing large volumes of squawfish:

1. Stoller Fisheries - Spirit Lake, Iowa. Stoller fisheries has processed about 130,000 lbs of Columbia River northern squawfish (food-grade and fishmeal). Stoller's principal product is gefilte fish, a pickled kosher product. Of the three major consumers of the squawfish harvested by the removal program, Stoller has shown the most interest among them and has paid for much of the end-use transportation costs. Stoller has served as a fish handling consultant during the 1991 and 1992 seasons.

2. Inland Pacific Fisheries - Pavette. Idaho. Inland **Pacific Fisheries** processes liquid organic fertilizer. **IPF has been receiving frozen squawfish free** of charge for three seasons. **IPF tends to process squawfish in the fall** after the field season **is over and** is **a questionable long-term participant**

3. Darling/Delaware Rendering - Portland, Oregon. Darling/Delaware produces animal feed from animal byproducts. This outfit is essentially a disposal service and they charge up to $50/ton to handle the squawfish. The rendering option has been considered a last resort in the past.

4. Global Feed Consortium - Bellingham, Washington. Global Feed is a fishmeal/fertilizer manufacturer and a **recent** end-use development with promising prospects. Global Feed may be able to process the industrial-grade squawfish at a considerable savings compared to Darling/Delaware. Global Feed uses a mobile processing unit that may be ideal for accommodating the squawfish handling program. This unit can save on transportation costs and Global feed does not charge a disposal fee.

An analysis of the cost effectiveness of accommodating each of these end-users revealed little difference between them (see OSU 1992 Interim Report). In 1993 OSU will again set up a food-grade collection system intended to produce whole frozen squawfish for Stoller Fisheries and other interested parties who can utilize whole frozen squawfish. The fate of the industrial-grade fish is unknown at this point (hopefully the industrial-grade will be a relatively small volume in 1993).

Recommendations for Future Handling Programs and Incorporation of the Private Sector

The following points concerning the characteristics of private sector fish handling and transportation systems should be considered before recommendations for further private sector involvement in the squawfish program are discussed:

1. Private sector fish processors design handling and processing systems around fisheries that are market driven and include features such as non-payment for low quality fish and non-participation when it is no longer profitable. The squawfish removal program clearly does not operate under these conditions.

2. The purpose of the squawfish program is to remove squawfish - not to create a profitable commercial fishery. Any end-use or handling program is a byproduct of the primary goal of removing squawfish and will never operate at the cost efficiency of a true commercial fishery. The best one can do is to design a handling system that is the least expensive within the context of the program objectives.

3. The sport angling public must be accommodated because they represent the "commercial fishermen" of the squawfish removal program. Private fish processors are unfamiliar with this concept since they operate systems designed to turn a profit - not accommodate "inefficient" fisherman.

4. It would be unwise to entirely transfer the administration of the squawfish handling program to a fish processor who intends to operate the program in a way that is familiar to him/her. The result would probably be a program that is quite efficient but short on accommodating the participating agencies and the public. The squawfish handling program should be set up and overseen by an administrator who is familiar with both the removal and the handling phases of the overall program.

With the above introductory points in mind, a description of the best long term private sector squawfish handling scenario follows, The principal goal of OSU's future handling program is to collect as much food-grade squawfish possible.at the least cost. To accomplish the goal of minimizing handling costs, much of the fish handling responsibilities should be distributed among all program participants.

Uncertainties about the availability and cost of facilities and services prevent a detailed specification of the 1993 handling plan. Furthermore, there is still some questions about the extent to which the agencies are willing to contribute to fish handling.

Recommended general characteristics of future food-grade northern squawfish handling programs:

* Contract local fish processors, meat markets, or cold storage facilities to serve as receiving and packaging areas. These facilities should have enough freezer space to store at least a weeks worth of frozen fish (preferably more). Ideally, someone would be present in the evenings to receive the incoming squawfiih and process them that night. In the future these contracts could probably be put out for competitive bid, but it seems that one is fortunate to find even *one* qualified contractor in a given area anyway.

* In as many locations possible, Washington Department of Wildlife should hire technicians who can work in the field and process fish in the evening. A setup of this type is by far the least expensive handling option available because it greatly reduces redundant labor charges and other "hidden" costs. People who have worked for local processors in the past would be good candidates for these jobs and could train others to grade fish as well. This ideal situation is not available everywhere but has potential in 1993 for Long-view, Clarkston, Pullman, and Cascade Locks. This system should be pursued as a first option in all locations.

* Contract a fish processor who trucks fish regionally to pick up frozen squawfish from the food-grade collection locations. Point Adams Packing Company in Portland travels weekly to all of the food-grade squawfish receiving and storage locations. This task could be put out as a competitive bid in the future. This service would eliminate the need for OSU to pick up fish in an expensive-to-operate rental truck.

* In distant, unproductive harvest locations (Snake River Dams, John Day Dam, Lyon's Ferry Sport Reward site) set up a system where the agencies operating in these areas are responsible for disposition of their catch. This could be storage in chest freezers with occasional deliveries to a processing location or establishing a rendering pickup system with a local merchant. OSU can make pre-season arrangements for drop-off locations but does not intend to visit these areas during the season. In 1993 OSU will make permanent 'the transfer of chest freezers (and totes if necessary) to the agencies operating in these areas. This situation should apply to the Merwin Trap fishery as well unless it begins to yield enough squawfish to justify food-grade handling.

* Bonneville, The Dalles, and possibly McNary Dams should deliver their catch daily to a fish processing location. The coolers full of iced squawfish would be placed in a lockable drop-box where ice and fresh coolers would be available for the next day. Delivering large totes of ice to the dams is a negotiable issue but for cost considerations should be avoided if possible. Columbia River Intertribal Fish Commission should plan on purchasing their own coolers for 1993 because OSU will have no property control over equipment used by dam anglers.

Budgeting Options fo: Future Handling Programs

After a workable **private** sector system has been developed then the question arises as to who should pay for it. There are two reasonable scenarios (or some combination of the two):

1. **The** agencies pay for the fish handling services themselves (include the **charges** in their budgets).

2. A single entity sets up and **pays** for handling services (the current system). A handling administrator submits a budget to pay for all handling services.

Both of these options have advantages and disadvantages, but option 2. probably provides more flexibility in the event of the inevitable changes associated with the removal program.

Conclusion

In summary, further transfer of squawfish handling responsibilities to the private sector with the intention of reducing costs and increasing food-grade production is possible. To accomplish this goal the harvesting agencies must assume more individual handling responsibility as well as some of the associated costs.

For as long as a handling program exists, it is necessary that it be administered by someone who **is** familiar with both the harvest and handling aspects of the program. This would insure a set-up that is accommodating to the program's principal goal - removing northern squawfish. Private fish processors are not familiar with this type of fishery because they operate programs that deal with fewer fish harvesters and contain price incentives for quality control.

Quality control will continue to be an important element of the fish handling problem. Agency supervisors must be prepared to take action against employees who handle fish poorly. Without interagency cooperation and an overall perception that fish handling is an important part of the job, then any type of handling program will be a failure.

APPENDIX F

Catch Utilization

Appendix Table F-l. Yield of flesh from squawfish surimi processing'

Samples	Percent of round weight (%)					
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	**Mean±S.D.**
Round fish	100.0	100.0	100.0	100.0	100.0	100.0f0.0
Planked	42.8	39.6	37.7	40.8	35.1	**39.2±2.6**
Minced flesh	26.4	31.4	24.2	29.2	26.3	**27.5±2.5**
Washed flesh	17.4	20.0	15.3	la.5	15.3	**17.3±1.8**
Refined	16.0	19.8	14.0	17.1	14.2	**16.2±2.1**
Surimi	17.9	21.6	16.2	la.5	15.5	**17.9±2.1**

[1] Surimi sample were processed with 2 wash cycles at 1:3 mince:water ratio.

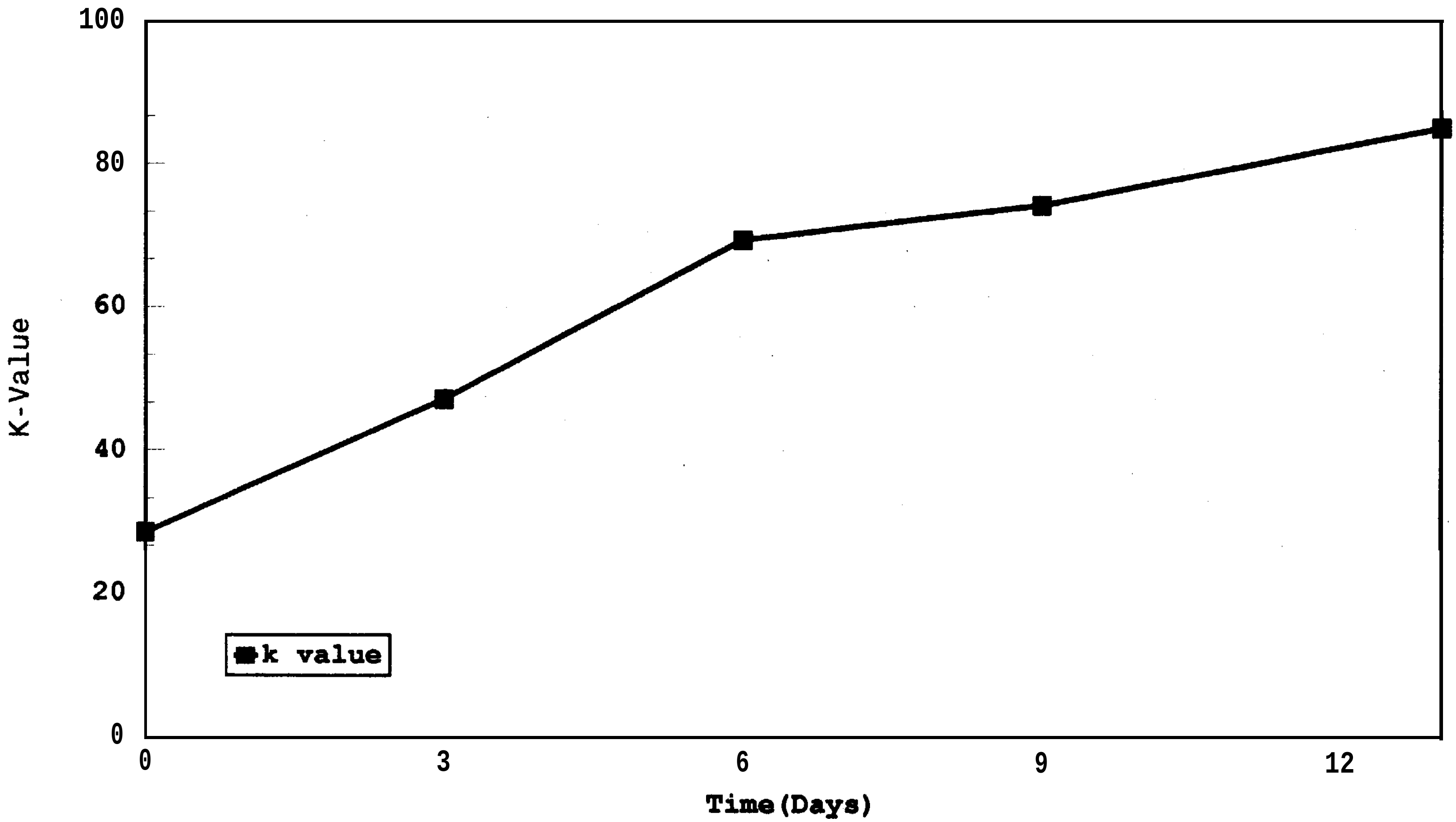
Appendix Table F-2. Mean composition (% wet wt) of flesh derived from surimi processing[a,b]

Samples	Moisture	Protein'	Lipid	Ash
Deboned	77.94±0.07[c]	17.91f0.50	3.23±0.01	1.22f0.02
Flesh, first wash	79.23±0.02	17.73f0.24	2.58f0.05	0.65f0.01
Flesh, second wash	78.74f0.05	18.86f0.08	2.51f0.04	0.61f0.05
Flesh, third wash	80.48±0.08	17.38f0.33	1.96f0.04	0.50f0.01
Refined, second wash	79.48f0.07	18.54f0.05'	1.78f0.03	0.48f0.01
Refined, third wash	80.32±0.09	17.98f0.22	1.61f0.04	0.42±0.01
Surimi, second wash	72.10f0.05	17.54±0.10	1.96±0.03	0.80f0.02
Surimi, third wash	72.95f0.06	16.90f0.12	1.21f0.02	0.83f0.01

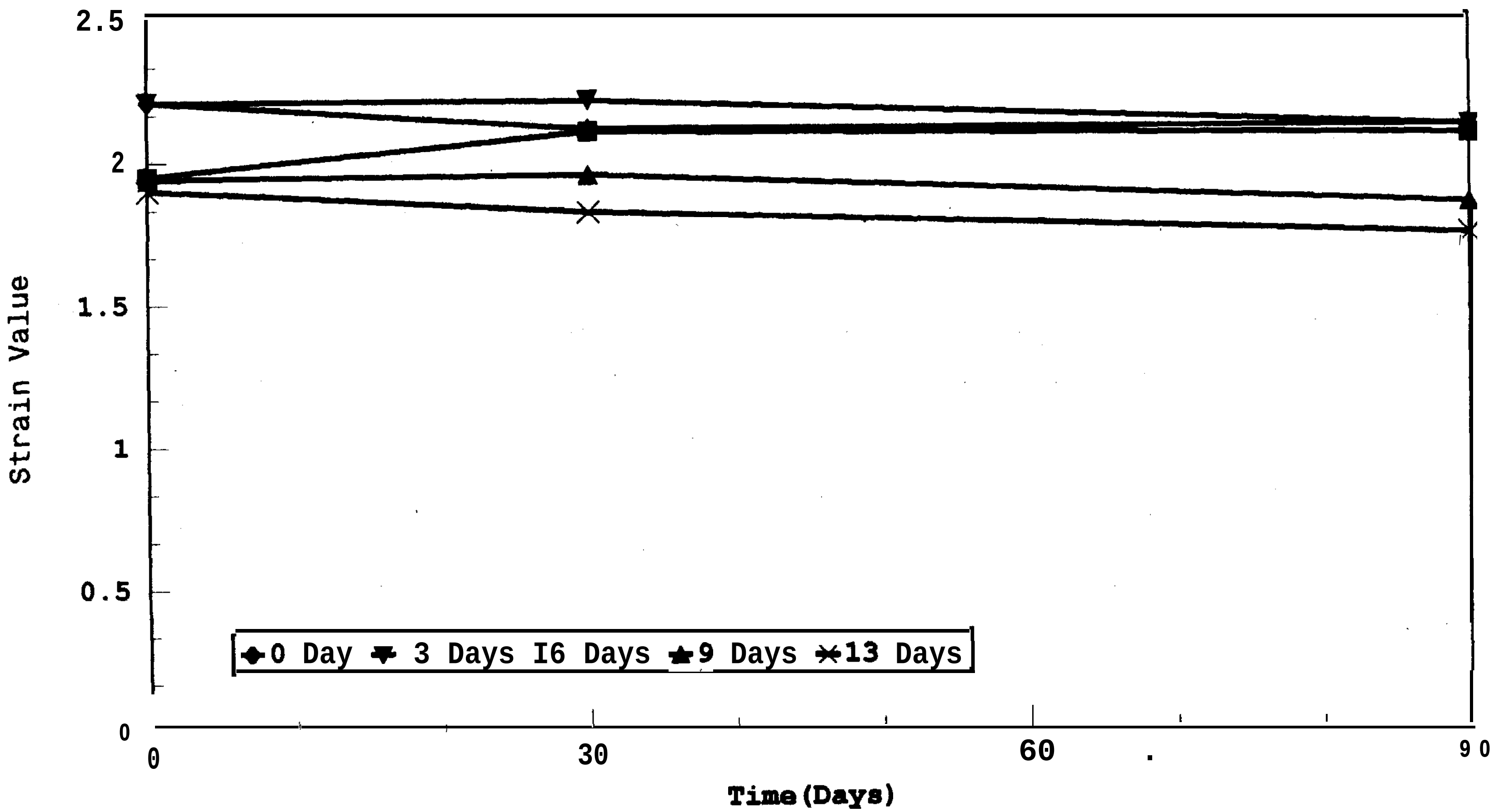
[a] Samples were determined in triplicate.
[b] Surimi was composed of washed and refined mince mixed with 4% sucrose, 4% sorbitol and 0.3% polyphosphates as cryoprotectants.
[c] Mean ± S.D.

Appendix Table F-3. CIE color values of cooked gels from squawfish surimi held in frozen storage.

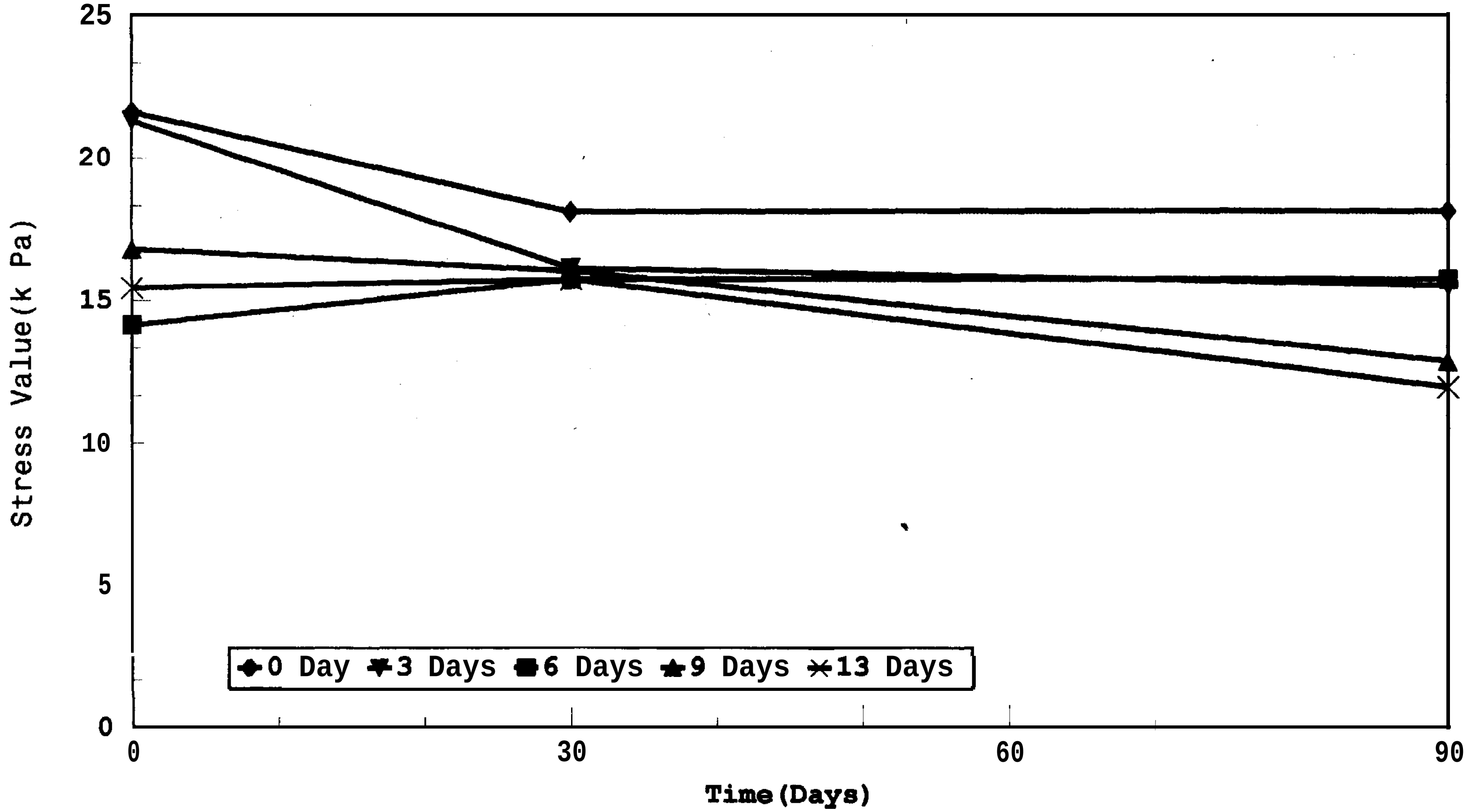
Storage Days	L*	a*	b*	whiteness
0	81.25	-3.51	7.90	79.35
30	81.37	-3.48	8.38	79.28
90	82.01	-3.20	8.85	79.75



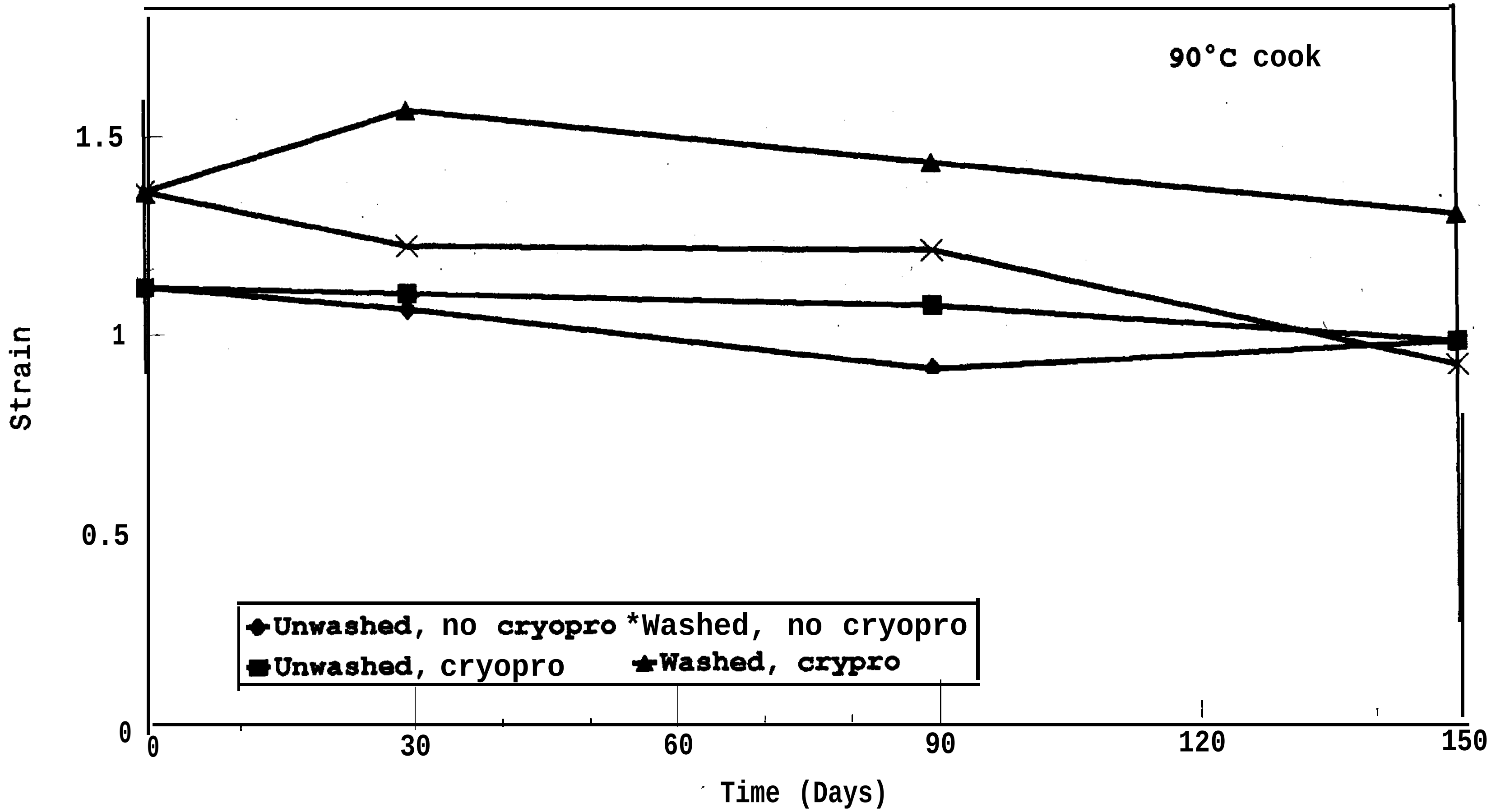
Appendix Figure F-l. Freshness of northern squawfish during ice storage.



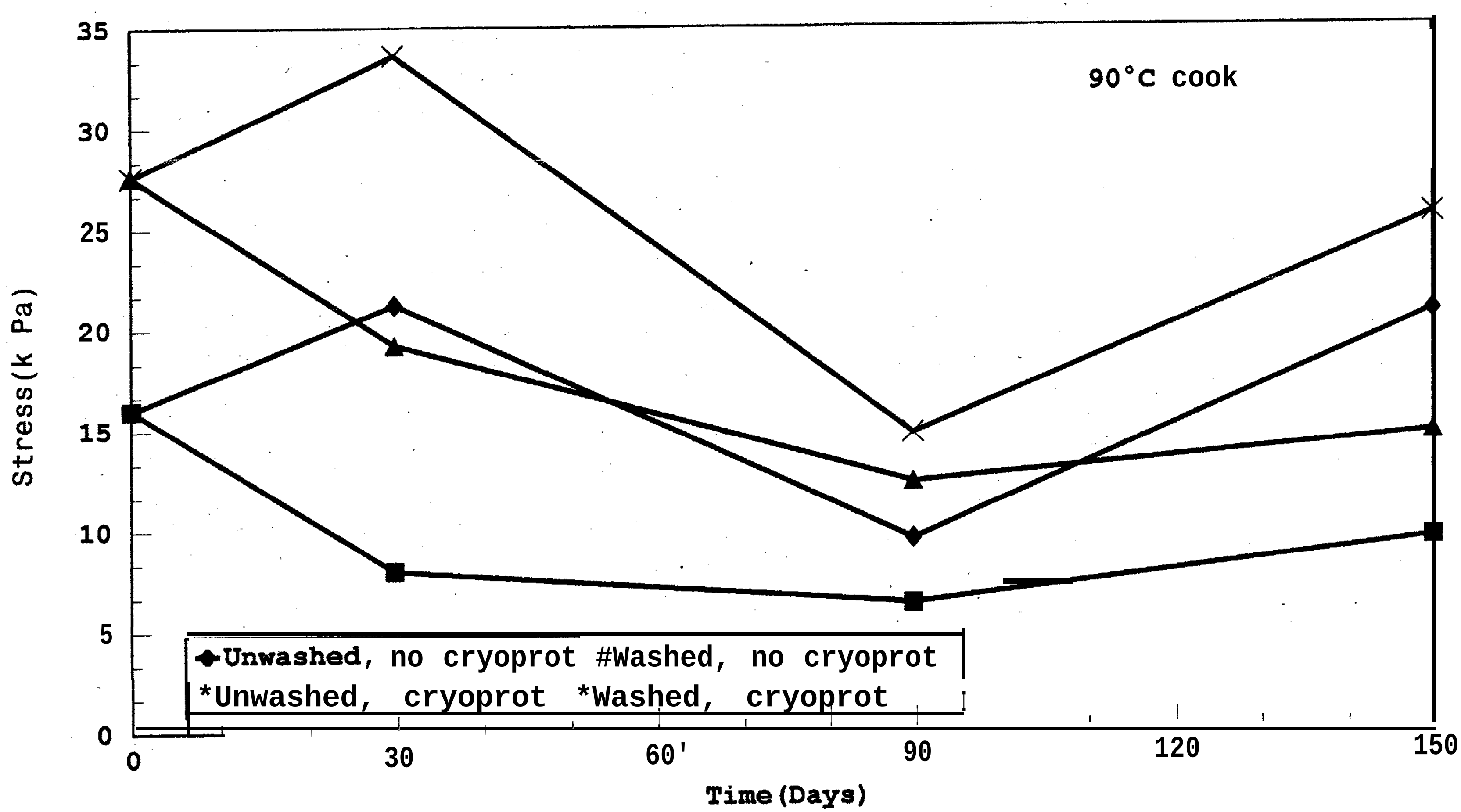
Appendix Figure F-2. Change in strain value of squawfish **surimi** during frozen storage.



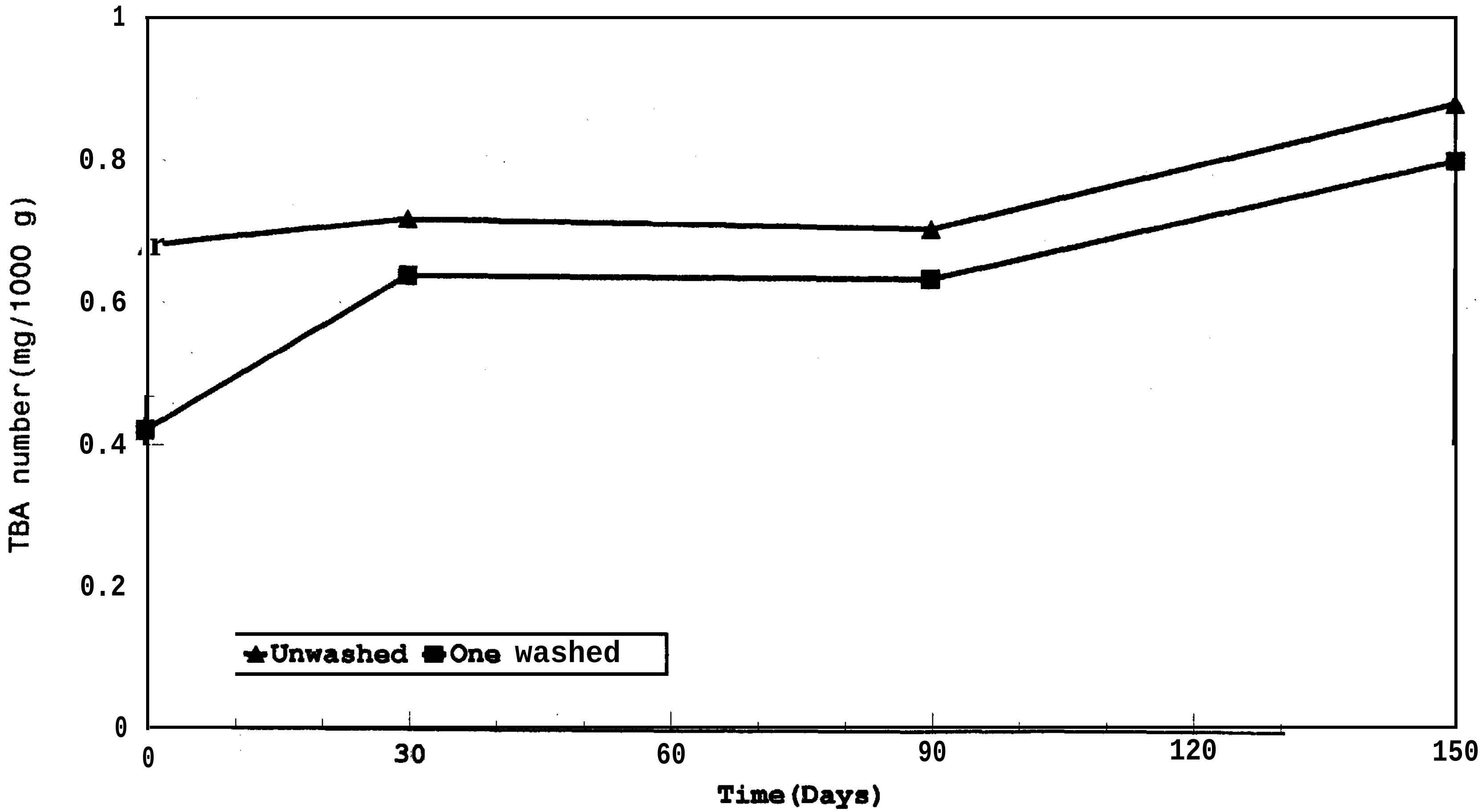
Appendix Figure F-3. Change in stress value of squawfish surimi during frozen storage.



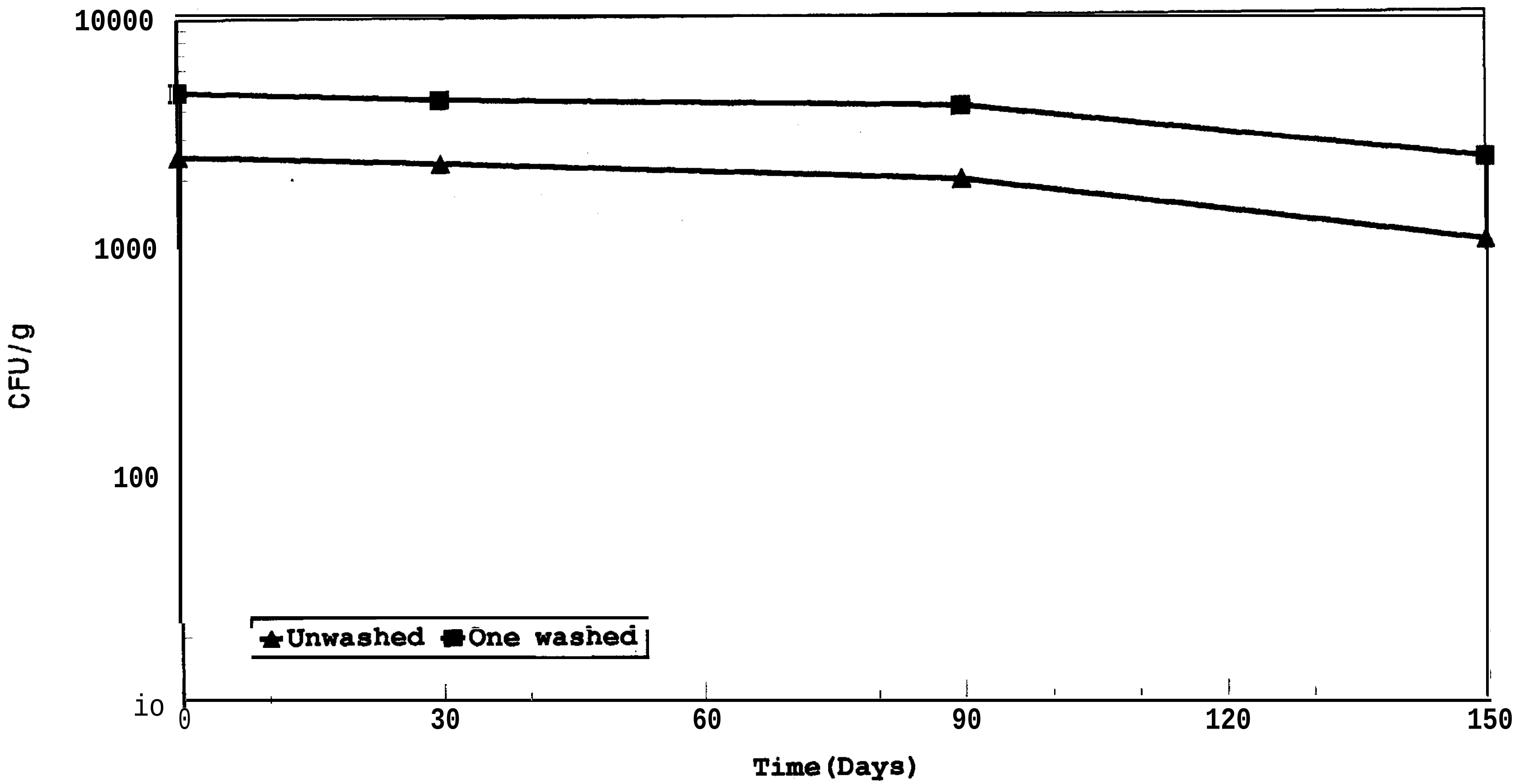
Appendix Figure F-4. Frozen squawfish mince effect of storage time on strain value.



Appendix Figure F-5. Frozen squawfish mince effect of storage time on stress value.



Appendix Figure F-6. Changes in TBA values frozen squawfish mince.



Appendix Figure F-7. Changes in total plate count frozen squawfiah mince.

Appendix Table F-4. Evaluation of color, texture, size and weight of squawfish roe.

WHOLE FISH QUALITY = SCORE OF 0-5 (5 HIGHEST): COMBINATION OF ODOR, EYE APPEARANCE, TEXTURE, SKIN COLOR, & BLEMISHES.

FILLET QUALITY = SCORE 0-5 (5 HIGHEST): COMBINATION OF ODOR, COLOR, TEXTURE & BLEMISHES.

ROE APPEARANCE = SCORE O-5 (5 HIGHEST): COMBINATION OF COLOR, BLEMISHES, BLOOD, INTACT SKEIN, & OVERALL APPEARANCE.

ROE TEXT = SCORE5 (0 = MUSHY & 5= VERY FIRM).

ROE SIZE = SCORE O-5 (SMALL GLASS BEAD [2.5mm] = 1 & LARGE BEAD [6.5mmD [6.5mm = 5)

DATE: 5/29/92 Squawfish

FISH LENGTH	FISH WEIGHT	WHOLE FISH QUALITY	FILLET QUALITY	Color/comments	Roe Appearance score	ROE TEXTURE	ROE SIZE	ROE WEIGHT
12	447	4	4	A male no Roe	-	-	-	-
16.5	1040	3	4	A male no Roe	-	-	-	-
16	812	3	3	A male no Roe	-	-	-	-
15	720	5	4	A male no Roe	-	-	-	-
12.5	433	5	5	A male no Roe	-	-	-	-
11.5	326	5	5	A male no Roe	-	-	-	-
16	1145	5	5	A male no Roe	-	-	-	-
13	406	5	5	A male no Roe	-	-	-	-
13	400	5	4	Gray	0	-	0	6
15	803	5	5	Gray	3	4	0	87
15	890	5	5	gray green	3	4	0	87
17	1301	5	5	gray green	3	4	.5	142
18.0	1199	5	5	Lt gray/loose eggs	2	3	.5	153
20.0	2192	4	5	Lt green olive	3	4	.5	308
17.0	1273	5	5	Lt green olive	3	4	.2	172
17.0	1290	5	2	Lt green olive	3	4	.3	186
15.5	755	5	4	Lt green olive	4	4	1	90
19	2145	5	4	Lt green olive	4	4	1	285
16	1135	5	5	Lt green olive	4	4	0	155
16.5	1248	5	5	Lt green olive	4	4	1	213
18	1080	4	4	Lt green olive	4	3	1	93
13	578	4	4	Lt green olive	4	3	1	70
16	1140	4	4	Lt green olive	4	4	0	165
16	1085	4	5	Lt green olive	3	4	.2	103
13.5	542	4	5	Lt grn olive/loose eggs	2.5	4	.2	40
17.0	1202	5	5	Med. Brown	3.5	4	.5	154
15.7	721	5	5	Med. Brown/loose eggs	3	4	.5	61
12	360	4	4	medium Brown	4	4	0	25
14.5	600	5	4	medium Brown	4	4	1	75
15	750	4	4	Medium Brown	4	3	0	49
13	473	4	5	Medium Brown	3	3	.2	36

Total Number of fish sampled 31
Number male of fish sampled 8
Number female of fish sampled 23

Average length of all fish 15.33 inches
Average length of male fish 14.06 inches
Average length of female fish 15.77

Average weight of all fish 919.06 grams
Average weight of male fish . 666.12 grams
Average weight of female fish 1007.04 grams

Average weight roe 119.78 grams

APPENDIX G

Contaminant Tests

Evaluation of Tests for Dioxin Contamination of Columbia ***Rivef*** Northern Squawfish

Gene Foster
Oregon Department of Environmental Quality
Water Quality Division
Portland, Oregon

October 1992

Evaluation of Tests for Dioxin Contamination
of Columbia River Northern Squawfish

Note: This report was submitted to OSU in October 1992. The report is a summary of toxicity evaluations performed by the Environmental Protection Agency Laboratory in Duluth, Minnesota on samples of northern squawfish. Samples were collected at 9 sites in the Columbia River in 1991.

Analysis is performed for both 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF). Results are given in terms of TCDD only. Neither the Food and Drug Administration nor the Environmental Protection Agency have adopted criteria action levels for TCDF. However, TCDF is considered to be approximately one-tenth as toxic as TCDD.

Introduction

Squawfish samples *were* collected from nine stations, eight on the Columbia River and one on the Columbia Slough. These samples were analyzed for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF). Samples were composites of at least five individuals. Whole body samples were collected at all stations. In addition, at six of the stations steak samples were prepared from the whole body samples. Samples were collected by either electrofishing or netting. Samples were placed on ice and shipped to the DEQ laboratory where they were frozen. Samples were shipped on ice to the USEPA/ERL Duluth Laboratory for analysis.

Squawfish whole body samples were collected at the following locations:

CR 1: River Mile 38 near Tenasillahe Island *
CR 2: River Mile 60 near Longview *
CR 3: River Mile 84 near St. Helens *
CR 4: River Mile 103 at Oregon Slough *
CR 5: River Mile 185 at The Dalles *
CR 6: River Mile 200 at Miller Island
CR 7: River Mile 220 near the mouth of the John Day River
CR 9: River Mile 300 upstream of McNary Dam
CS 1: River Mile/ on the Columbia Slough * .

* = Steak and whole body samples collected at this station.

Results

A total of fifteen samples were analyzed for TCDD and TCDF. TCDD was detected in eleven samples and ranged from 0.4 to 3.9 ng/kg-wet weight (ppt) and had a median of 2.5 ppt for detected values. TCDF was detected in all samples and ranged from 1.5 to 35.5 ppt and had a median value of 17.4 ppt.

Ten samples were collected and analyzed downstream of Bonneville Dam. TCDD was detected in seven of the samples and ranged from 0.4 to 3.9 ppt with a median for detected values of 2.5 ppt. TCDF was detected in all ten samples and ranged from 1.5 to 35.5 ppt with a median of 13.45 ppt. There were five samples collected and analyzed from upstream of Bonneville Dam. TCDD was detected in four of the samples and ranged from 1.3 to 3.6 ppt with a medina for detected values of 2.7 ppt. TCDF was detected in all five samples and ranged from 16.2 to 34.9 ppt with a median of 22.7 ppt.

Steak samples were collected at six stations. TCDD was detected in three samples and ranged from 0.40 to 1.20 ppt with a median for detected values of 1.00 ppt. TCDF was detected in the six steak samples and ranged from 1.50 to 17.40 ppt with a median of 12.55 ppt.

Discussion

The squawfish TCDD concentrations are similar to those found in other resident fish from the Columbia River system (DEQ files 1992). Squawfish samples collected downstream of The Dalles Dam had higher concentrations of TCDD than carp collected from the same areas. Squawfish collected upstream of The Dalles Dam had lower concentrations of TCDD than carp collected from the same areas.

The FDA TCDD guideline concentration (developed in the Great Lakes) for the consumption of fish is 25 ppt. The USEPA reference level derived from the USEPA water quality criteria at a 1X10-6 cancer risk level is 0.07 ppt. All samples collected from the Columbia River and Columbia Slough were below the FDA guideline concentration of 25 ppt. All samples with detectable concentrations of TCDD were above the USEPA reference level of 0.07 ppt.

The Washington Department of Health has reviewed data from the upper Columbia River and has determined that a fish consumption advisory for the general population is not warranted at this time. The Oregon Health Division has reviewed TCDD data for fish from the Columbia River and has not issued a fish consumption advisory. The issue of safe consumption of fish collected from the Columbia River may be addressed by the Columbia River Bi-State Study in the next year or two.

Columbia River 1990
Fish Tissue Summary: TCDDs/TCDFs

Station #	Species	Sample Type	2,3,7,8 TCDD	2,3,7,8 TCDF	TEC	% Lipid
CR #1	carp	wb	2.36 u	4.10		9.85
	D carp	wb	2.25 u	3.61 u		9.37
	carp	st	1.20	3.20		7.36
	sqwfsh	wb	3.00	22.80		6.81
	sqwfsh	st	1.20	12.30		4.72
	cryfsh	wb	U	2.3		
CR #2	carp	wb	1.84 u	5.00		7.47
	carp	st	0.87 u	2.60		4.52
	sqwfsh	wb	2.50	27.20		7.63
	squfsh	st	1.34 u	12.80		4.44
	cryfsh	wb	0.3	2.7		
CR #3	carp	wb	1.18 u	2.90		7.20
	carp	st	0.40	2.00		5.10
	squfsh	wq	3.90	35.50		6.30
	squfsh	st	1.00	14.10		3.00
	cryfsh	wb	u	1.4		
CR #4	carp	wb	1.63 u	2.20		7.40
	carp	st	0.80	2.80		5.40
	squfsh	wb	2.50	22.00		5.70
	sqwfsh	st	0.40	8.70		2.60
	cryfsh	wb	U	1.3		
CR #5	carp	wb	2.20	6.90		12.40
	carp	st	1.50	6.10		9.20
	sqwfsh	wb	3.60	34.90		7.20
	sqwfsh	st	2.30 u	17.40		3.00
CR #6	carp	wb	4.30	16.70		19.M
	carp	st	5.60	14.80		13.10
	sqwfsh	wb	2.60	34.10		8.60
CR #7	carp	wb	7.70	6.40		8.84
	carp	st	4.80	4.90		7.50
	sqwfsh	wb	1.30	16.20		2.92
CR #8	carp	wb	4.70	IS.10		14.90
	carp	st	4.80	11.00		10.30

Columbia River 1990
Fish Tissue Summary: TCDDs/TCDFs

Station #	Species	Sample Type	2,3,7,8 TCDD	2,3,7,8 TCDF	TEC	% Lipid
CR #9	carp	wb	5.00	15.00		12.29
	carp	st	5.60	15.50		9.70
	squfsh	wb	2.80	22.70		3.74
cs #1	carp	wb	1.55 u	1.10		7.43
	carp	st	1.80 u	0.90		4.10
	sqwfsh	wb	1.09 u	3.30		5.04
	squfsh	st	1.20 u	1.50		2.00
	cryfsh	wb	u	0.5		

sqwfsh = squawfish
cryfsh = crayfish

wb = whole body
st = steak
u = not detected at concentration indicated

2,3,7,8 TCDD = 2,3,7,8-Tetrachlorodibenzo-p-dioxin
2,3,7,8-TCDF = 2,3,7,8-Tetrachlorodibenzofuran
TEC = toxic Equivalency Concentration

Columbia River 1990
Tissue Summary Results: **All Stations**

TCDO, TCDF, & PCBs

Units **= pg/g (ng/kg)** or **part** per **trillion**

Parameter	**Number of Samples**	**Number of** Detects	**Minimum**	**Median**	**Maximum**	**EPA/TV**	FDA	**NYS/DEC Non** Carcinogenic	**NYS/DEC Carcinoge**
TCDO	41	**25**	0.3	2.6	7.7	0.07	2s	3	2.3
TCDF	41	40	0.5	6.65	35.5				
3,3'4,4' TeCBP	20	**20**	90	**217**	**909**	**2464.8**	**2000000**	llooo	
2,3,3'4,4' PeCBP	20	20	1724	4289	21162	2464.8	**2000000**	110000	
3,3'4,4'5 PeCBP	20	19	**45**	**88**	232	2464.8	**2000000**	110000	

Units = ng/g (ug/kg) or parts per billion

Parameter	**Number of Samples**	**Number of** Detects	**Minimum**	**Median**	**Maximum**	**EPA/TV**	FDA	**NYS/DEC Non** Carcinogenic	**NYS/DEC Carcinoge**
Monochloro	**20**	**2**	**8.86**	**20.6**	32.33	**2464.8**	**2000000**	**110000**	
Dichloro	20	12	0.25	1.59	5.23	**2464.8**	**2000000**	**110000**	
Trichloro	**20**	**20**	0.69	9.89	25.81	**2464.8**	**2000000**	**110000**	
Tetrachloro	20	20	13.43	40.09	105.28	**2464.8**	**2000000**	**110000**	
Pentachloro	20	20	41.84	**95.19**	229.08	2464.8	**2000000**	**110000**	
Hexachloro	20	20	79.62	218.87	360.47	**2464.8**	**2000000**	**110000**	
Heptachloro	20	20	**69.56**	143.65	306.02	**2464.8**	**2000000**	**110000**	
Octachloro	**20**	20	10.6	34.44	68.42	**2464.8**	**2000000**	**110000**	
Nonachloro	20'	20	0.93	5.01	10.34	**2464.8**	**2000000**	**110000**	
Decachloro	20	20	0.24	0.73	1.47	**2464.8**	**2000000**	**110000**	
Total **PCBs**	20	20	371.68	593.01	1153.2s	**2464.8**	**2000000**	**110000**	

TCDO = 2,3,7,8-Tetrachlorodibenzo-p-dioxin
TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl
PeCBP = Pentachlorobiphenyl
HxCBP = Rexachlorobiphenyl

Columbia River 1990
Tissue **Summary Results: Squawfish**

TCDO, TCDF, & PCBs

units = *pg/g (ng/kg)* or **part per** trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC Yal Carcinogenic	NYS/DEC Carcinogenic
TCDO	15	11	0.4	2.5	3.9	0.07	25	3	2.3
TCDF	15	15	1.5	17.4	35.5				
3,3'4,4' TeCBP	9	9	121	381	909	2464.8	2000000	110000	
2,3,3'4,4' PeCBP	9	9	2119	11896	21162	2464.8	2000000	110000	
3,3'4,4'5 PeCBP	9	9	68	138	232	2464.8	2000000	110000	
Units = ng/g (ug/kg) or part per billion									
Monochloro	9	1		8.86		2464.8	2000000	110000	
Dichloro	9	5	0.25	1.42	2.19	2464.8	2000000	110000	
Trichloro	9	9	0.69	9.17	20.44	2464.8	2000000	110000	
Tetrachloro	9	9	13.43	46.13	105.28	2464.8	2000000	110000	
Pentachloro	9	9	69.11	102.06	229.08	2464.8	2000000	110000	
Hexachloro	9	9	139.75	232.12	360.47	2464.8	2000000	110000	
Heptachloro	9	9	69.26	162.82	306.02	2464.8	2000000	110000	
Octachloro	9	9	10.6	29.53	68.42	2464.8	2000000	110000	
Nonachloro	9	9	0.93	3.09	10.34	2464.8	2000000	110000	
Decachloro	9	9	0.24	0.47	0.93	2464.8	2000000	110000	
Total PCBs	9	9	371.68	711.65	1153.25	2464.8	2000000	110000	

TCDD = 2,3,7,8- Tetrachlorodibenzo-p-dioxin
TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl
PeCBP = Pentachlorobiphenyl
HxCBP = Hexachlorobiphenyl

Columbia River 1990
Tissue Summary Results: Carp

TCDD, TCDF, & PCBs

Units = pg/g (ng/kg) or part per trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC Non Carcinogenic	NYS/DEC Carcinogenic
TCDD	21	13	0.4	4.7	7.7	0.07	'25	3	2.3
TCDF	21	20	0.9	4.5	16.7				
3,3'4,4' TeCBP	11	11	77	163	453	2464.8	2000000	110000	
2,3,3'4,4' PeCBP	11	11	1724	3935	128%	2464.8	2000000	110000	
3,3'4,4'5 PeCBP	11	10	45	68	205	2464.8	2000000	110000	
Units = ng/g (ug/kg) or parts per billion									
Monochloro	11	1		32.33		2464.8	2000000	110000	
Dichloro	11	7	0.54	1.59	f.23	2464.8	2000000	110000	
Trichloro	11	11	1.35	11.29	25.81	2464.8	2000000	110000	
Tetrachloro	11	11	17.04	39.06	66.72	2464.8	2000000	110000	
Pentachloro	11	11	41.84	90.48	191.46	2464.8	2000000	110000	
Hexachloro	11	11	79.62	210.03	355.11	2464.8	2000000	110000	
Heptachloro	11	11	87.95	132.18	222.3	2464.8	2000000	110000	
Octachloro	11	11	24.81	34.82	48.69	2464.8	2000000	110000	
Nonachloro	11	11	2.71	5.45	6.96	2464.8	2000000	110000	
Decachloro	11	11	0.49	1.14	1.47	2464.8	2000000	110000	
Total PCBs	11	11	417.28	554.87	930.5	$64.8	2000000	110000	

TCDD = 2,3,7,8- Tetrachlorodibenzo-p-dioxin
TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl
PeCBP = Pentachlorobiphenyl
HxCBP = Hexachlorobiphenyl

Columbia River 1990
Tissue Summary Results: Crayfish

Tam; **TCDF, & PCBs**

Units = pg/g (ng/kg) or part **per** trillion

Parameter	**Number** of **Samples**	**Number** of **Detects**	**Minimum**	Median	**Maximum**	EPA/TV	FDA	**NYS/DEC Non** Carcinogenic	**NYS/DEC** Carcinogenic
TCDD	5	1		0.3		***0.07***	***25***	***3***	***2.3***
TCDF	S	**5**	0.5	***1.4***	***2.7***				

TCDD = 2,3,7,8- Tetrachlorodibenzo-p-dioxin
TCDF = 2,3,7,8-Tetrachlorodibenzofuran

Columbia River 1990
Tissue Summary Results: Squawfish - Downstream of Bonneville Dam

TCDD, TCDF, & PCBs

Units = pg/g (ng/kg) or part per trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC Non Carcinogenic	NYS/DEC Carcinogenic
TCDD	10	7	0.4	2.5	3.9	0.07	2s	3	2.3
TCDF	10	10	1.5	13.45	35.5				
3,3'4,4' TeCBP	5	5	381	593	909	2464.8	2000000	110000	
2,3,3'4,4' PeCBP	5	5	2783	15649	21162	2464.8	2000000	110000	
3,3'4,4'5 PeCBP	5	5	138	172	232	2464.8	2000000	110000	

Units = ng/g (ug/kg) or parts per billion

Parameter	Number of Samples	Number of Detects	Minimum	Median	Maximum	EPA/TV	FDA	NYS/DEC Non Carcinogenic	NYS/DEC Carcinogenic
Monochloro	5	1		8.86		2.465	2000	110	
Dichloro	5	4	0.57	1.7	2.19	2.465	2000	110	
Trichloro	5	5	9.17	15.51	20.44	2.465	2000	110	
Tetrachloro	5	S	46.13	72.66	105.28	2.465	2000	110	
Pentachloro	5	5	69.11	107.37	229.08	2.465	2000	110	
Hexachloro	5	5	162.01	182.U	360.47	2.465	2000	110	
Heptachloro	5	5	69.26	168.88	306.02	2.465	2000	110	
Octachloro	5	5	10.6	34.15	54.44	2.465	2000	110	
Nonachloro	5	5	0.93	4.08	7.48	2.465	2000	110	
Decachloro	5	5	0.24	0.58	0.93	2.465	2000	110	
Total PCBs	5	5	424.91	n2.23	1153.25	2.465	2ooo	110	

TCDD = 2,3,7,8-Tetrachlorodibenzo-p-dioxin
TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl
PeCBP = Pentachlorobiphenyl
HxCBP = Hexachlorobiphenyl

Median values calculated fran detected values

Columbia River 1990
Tissue Summary Resul:s: Squawfish - Upstream of Bonneville Dam

TCDD, TCDF, & PCBs

Units = pg/g (ng/kg) or part per trillion

Parameter	Number of Samples	Number of Detects	Minimum	Median.	Maximum	EPA/TV	FDA	NYS/DEC Non Carcinogenic	NYS/DEC Carcinogenic
TCDD	5	4	1.3	2.7	3.6	0.07	2s	3	2.3
TCDF	5	5	16.2	22.7	34.9				
3,3'4,4' TeCBP	4	4	121	190	294	2464.8	2000000	110000	
2,3,3'4;4' PeCBP	4	4	2119	4289	11896	2464.6	2000000	110000	
3,3'4,4'5 PeCBP	4	4	68	a0	133	2464.8	2000000	110000	

Units = ng/g (ug/kg) or parts per billion

Parameter	Number of Samples	Number of Detects	Minimum	Median.	Maximum	EPA/TV	FDA	NYS/DEC Non Carcinogenic	NYS/DEC Carcinogenic
Monochloro	4	0				2.465	2000	110	
Dichloro	4	1		0.25		2.465	2000	110	
Trichloro	4	4	0.69	2.87	7.04	2.4665	2000	110	
Tetrachloro	4	4	13.43	17.48	39.71	2.465	2000	110	
Pentachloro	4	4	87.68	99.05	153.59	2.465	2000	110	
Hexachloro	4	4	139.75	232.92	24D.64	2.465	2000	110	
Heptachloro	4	4	71.79	122.25	200.45	2.46s	2000	110	
Octachloro	4	4	14.71	21.96	6a.42	2.465	2000	110	
Nonachloro	4	4	1.63	2.16	10.34	2.465	2000	1 1 0	
Decachloro	4	4	0.32'	0.42	0.79	2.46s	2000	110	
Total PCBs	4	4	371.68	518.14	765.98	2.46s	2000	110	

TCDD = 2,3,7,8- Tetrachlorodibenzo-p-dioxin
TCDF = 2,3,7,8-Tetrachlorodibenzofuran

TeCBP = Tetrachlorobiphenyl
PeCBP = Pentachlorobiphenyl
HxCBP = Hexachlorobiphenyl

Median values calculated from detected values

Appendix Table G-l. FDA foodstuff action levels for selected contaminants.

	FDA Foodstuff Action Level (ppm)
Chlorinated Pesticides and PCBs	
alpha-BHC	0.3
beta-BHC	0.3[a]
Lindane	0.5[b]
Heptachlor	0.3
Heptachlor epoxide	0.3
Aldrin	0.3[c]
Dieldrin	
p,p' DDE	5.0
p,p' DDD	5.0
p,p' DDT	5.0
p,p' Methoxychlor	5.0
Chlordane	0.3
PCB Group 1	2.0
PCB Group 2	2.0
PCB Group 3	2.0
PCB Group 4	2.0
PCB Group 5	2.0
Heavy Metals	
Mercury	1.0
Arsenic	[d]
Cadmium	[d]
Chromium	[d]
Copper	[d]
Lead	[d]
Zinc	[d]

[a] Level established for rabbit meat. No level established for fish.
[b] Level established for eggs. No level established for fish.
[c] Level established for sum of Dieldrin and Aldrin values.
[d] No FDA action level established.

Appendix Table G-2. Results of tests for organic contaminants in northern squawfish.

DEPARTMENT OF ENVIRONMENTAL QUALITY LABORATORIES
Analytical Records Report

PRELIMINARY report, results are NOT conclusive. Printed by

CASE NAME: 890371 JOHN DAY RESERVOIR
SUBMITTER: Vigg, Steve
FUND CODE: 3250 205J(5)- Nonpoint Source

ITEM #	RESULT	UNITS	TEST
001 Small Fish, Edible portion 05/03/89			
	ATTACHed		Chlorinated Pesticides in Tissues, Fish Tissue
002 Large Fish, Edible portion 05/03/89			
	ATTACHed		Chlorinated Pesticides in Tissues, Fish Tissue
003 Small Fish, Liver 05/03/89			
	ATTACHed		Chlorinated Pesticides in Tissues, Fish Tissue
004 Large Fish, Liver 05/03/89			
	ATTACHed		Chlorinated Pesticides In Tissues, Fish Tissue

RECEIVED
JUN 16 1989
Water Quality Division
Dept. of Environmental Quality

Department of Environmental Quality
Laboratories and Applied Research
Organic Section

6C
CHLORINATED PESTICIDES AND PCBs
Complies with EPA NPDES Method 608 and
RCRA Method 8080

Date: 1 June 1939

Lab #: 898371
Sample: 1-FISH
Iter #: I

55

koun t MG/KG	Parameter	CAS Registry Number
<0.003	alpha-BHC	313846
(9.003	beta-SHC	319857
<0.003	Lindane	58899
<0.003	Heptachlor	76448
<0.003	Aldrin	309002
<0.003	Heptachlor epoxide	1024573
<0.003	p,p' DDE	72559
<0.003	Endrin	72208
<0.003	p,p'DDD	72548
<0.003	p,p'DDT	50293
<0.003	p,p'Methoxychlor	72435
0.011	Dieldrin	60571
<0.003	Chlordane	57749
(0.012	PC8 Group 1	11104282
<0.006	PCB Group 2	11141165
<0.003	PCB Group 3	53469219
<0.003	PCS Sroup 4	11097691
<0.003	PCB Group 5	11096625
ND	Total PCS	

PCB Group 1 includes PCB 1221 and is calculated as 1221.
PCB Group 2 includes PCB 1232 and in s calculated as 1232.
PCB Group 3 includes PCB'S 1016, 1242 and 1248 and is calculated as 1242.
PC8 Group 4 includes PCB 1294 and is calculated as 1254.
PCB Group 5 includes PCB's 1268 and 1262 and is calculated as 1264.

ND No PCB's observed above indicated detection limit.

Department of Environmental Quality
Laboratories and Applied Research
Organic Section

PRELIMINARY
DATE:

GC
CHLORINATED PESTICIDES AND Peas
Complies with DA NPDES Method 608 and
RCRA Method 8080

Date: 1 June 1989

Lab #: 830371
Sample: E-FISH 590
Item #: 2

Amount MG/KG	Parameter	CAS Registry Number
<0.003	alpha-BHC	319846
<0.003	beta-BHC	319857
<0.003	Lindane	58899
<0.003	Heptachlor	76448
<0.003	Aldrin	309002
<0.003	Heptachlor epoxide	1024573
0.073	p,p' DDE	72559
<0.003	Endrin	72248
0.007	p,p'DDD	72548
<0.003	p,p'DDT	50293
<0.003	p,p'Methoxychlor	72435
<0.003	Dieldrin	60571
<0.003	Chlordane	57749
<0.012	PCB Group 1	11104282
<0.006	PCB Group 2	11141165
<0.003	PCB Group 3	53469219
0.113	PCB Group 4	11097691
8.641	PCB Group 5	11096825
0.154	Total PCB	

PCB Group 1 includes PCB 1221 and is calculated as 1221.
PCB Group 2 includes PCB 1232 and in s calculated as 1232.
PCB Group 3 includes PCB'S 1016, 1242 and 1248 and is calculated as 1242.
PCB Group 4 includes PCB 1254 and is calculated as 1254.
PCB Group 5 includes PCB's 1268 and 1252 and is calculate4 as 1266.

NO No PCB's observed above indicated detection lirit.

PRELIMINARY
DATE:

Department of Environmental Quality
Laboratories and Applied Research
Organic Section

6C
CHLORINATED PESTICIDES AND PC%
Complies with EPA NPDES Method 608 and
RCRA Method 8080

Date: 1 June 1989

Lab #: 890371
Sample: REDFISH
Item #: 3 550

Amount MG/KG	Parameter	CAS Registry Nurber
<0.003	alpha-BHC	319846
<0.003	beta-BHC	319957
<0.003	Lindane	58899
<0.003	Heptachlor	76448
0.03	Aldrin	309002
<0.003	Heptachlor epoxide	1024573
0.785	p,p' DDE	72559
<0.003	Endrin	72248
4.248	p,p'DDD	72548
<0.003	p,p'DDT	50293
0.004	p,p'Methoxychlor	72435
0.037	Dieldrin	60571
<0.003	Chlordane	57749
<0.012	PCB Group 1	11104282
<0.006	PC3 Group 2	11141165
(0.003	PCB Group 3	53469219
<0.003	PCB Group 4	11597691
<0.003	PCB Group 5	11096825
ND	Total PCB	

PCB Group 1 includes PCB 1221 and is calculated as 1221.
PC9 Group 2 includes PCB 1232 and in s calculated as 1232.
PCB Group 3 includes PCB'S 1016, 1242 and 1248 and is calculated as 1242.
PCB Group 4 includes PC6 1254 and is calculated as 12%.
PC3 Group 5 includes PCB's 1260 and 1252 and is calculated as 1268.

ND No PCB's observed above indicated detection limit.

Departaent of Environaent·l Quality
Laboratories and Applied Research
Organic Section

PRELIMINARY
DATE:

6C
CHLORINATED PESTICIDES AND PCBs
Corplias with EPA NPDES Method 608 and
RCRA Method 8080

Date: 1 June 1989

Lab #: 891371
Saaple: BLUFISH
Itea #: 4

550

Aaount MG/KG	Paraaeter	CAS Registry Nuaber
<0.003	alpha-3HC	319841
<0.003	beta-BHC	319857
<0.003	Lindane	56399
a.33	Heptachlor	76448
<0.003	Aldrin	309002
<0.003	Heptachlor epoxide	1024573
3.13	p,p' ODE	72559
a.74	Endrin	72288
0.99	p,p'DDD	72548
<0.003	p,p'DDT	50293
<0.003	p,p'Methoxychlor	72435
<0.003	Dieldrin	60571
<0.003	Chlordane	57749
<0.012	PCB Group 1	11104282
<0.006	PCB Group 2	11141165
<0.003	PCB Group 3	53469219
<0.003	PC3 Sroup 4	11097691
<0.003	PCB Sroup 5	11096825
ND	Total PCB	

PCB Group 1 includes PCB 1221 and is calculated as 1221.
PCB Group 2 includes PCB 1232 and in s calculated as 1232.
PCB Group 3 includes PCB'S 1016, 1242 and 1248 and is calculated as 1242.
PCB Group 4 includes PCB 1224 and is calculated as 1254.
PC8 Group 5 includes PCB's -1266 and 1262 and is calculated as 1260.

MD No PCB's observed above indicated detection liait.

PRELIMINARY
DATE: ____

FATS / LIPIDS

LAB #	ID #	FISH TYPE	ppm *	% *
890371-3250	1-Fish	Squawfish	12555	1.256
	2-Fish	Squawfish	5180	0.518

* wet method
(wet weight basis)

Appendix Table G-3. Results of tests for heavy metal contaminants in northern squawfish.

WEDNESDAY OCTOCER 4th, 1989

CASE NAME: 830371 JOHN DAY RESERVOIR
SUBMITTER: Gates, Richard F. COLLECTOR: Vigg, Steve
FUND CODE: 3250 205J(5)- Nonpoint Source

ITEM #	RESULT	UNITS	TEST
001 Small Fish, Edible portion 05/03/89			
	0.98	mg/Kg dry	Wtrcury, Fish Tissue
	<0.15	mg/Kg dry	Arsenic, Fish Tissut
	C0.04	mg/Kg dry	Cadmium, Fish Tissue
	<0.15	mg/Kg dry	Chromium, Fish Tissue
	1.4	mg/Kg dry	Copper, Fish Tissue
	<0.15	mg/Kg dry	Lead, Fish Tissue
	23.3	%	% SOLIDS, Fish Tissue
	22	mg/Kg dry	Zinc, Fish Tissut
	ATTACHed		Chlorinated Pesticides in Tissues, Fish Tissue
002 Large Fish, Edible portion 05/03/89			
	3.20	mg/Kg dry	Mercury, Fish Tissut
	<0.15	mg/Kg dry	Arsenic, Fish Tissue
	<0.04	mg/Kg dry	Cadmium, Fish Tissue
	<0.15	mg/Kg dry	Chromium, Fish Tissue
	1.2	mg/Kg dry	Copper, Fish Tissue
	<0.15	mg/Kg dry	Lead, Fish Tissut
	23.0	%	% SOLIDS, Fish Tissue
	19	mg/Kg dry	Zinc:, Fish Tissue
	ATTACHed		Chlorinated Pesticides in Tissues, Fish Tissue
003 Small Fish, Liver 05/03/89			
	ATTACHed		Chlorinated Pesticides in Tissuts, Fish Tissue
004 Large Fish, Liver 05/03/89			
	ATTACHed		Chlorinated Pesticides in Tissues, Fish Tissue

REPORT I

Columbia River Ecosystem Model (CREM): Modeling Approach for Evaluation of Control of Northern Squawfish Populations Using Fisheries Exploitation

Prepared by

Dr. LJ. (Sam) Bledsoe, PJ.
Amy L. Bleich
Helen Rudd

Center for Excellence in
Space, Earth and Life Sciences
-Computer Sciences Corporation
Lanham, Maryland

1992 Annual Report

CONTENTS

INTRODUCTION

This report provides an estimate of the current season juvenile salmonid mortality changes resulting from 1992 predator fisheries and an estimate of the future effect of such fisheries based on a variety of predator population dynamics assumptions. This report also includes the description of EZ-CREM, a user interface to the Columbia River Ecosystem Model (CREM) developed to allow biologists to analyze data with CREM.

The objectives of this contract included tasks intended to result in:

1. Revised seasonal, reservoir specific projections of juvenile salmonid mortality in response to the predator fishery control program.

2. A user interface for version of the computer model to be used by the researchers and the project managers.

3. Long-term systemwide projections of salmonid mortality.

To meet Objectives 1 and 3 of the contract, the following numerical studies were preformed:

1. Effect of Predation on Apparent Reservoir Residence Time in Tagging Studies of Juvenile Salmonids.

   In the absence of predators, the salmonid residence time could be calculated simply by averaging the arrival times for the distribution of salmon downstream. In reality, however, predation could affect the shape of that distribution. It was necessary to validate the observed residence times of the salmonids in the model with experimental tagging studies. This could be done by comparing the empirical data to the simulated residence times obtained by varying the predation rates in a representative reservoir. The rationale for performing this study was the need to quantitatively determine the effect of predation on the average salmonid residence time.

2. Study of Salmonid Mortality Sensitivity to Various Simulation Parameters.

   To provide the fisheries management with accurate projections of the juvenile salmonid mortality in response to predation, it is necessary to be aware of the sensitivity of mortality to various assumptions used by CREM with respect to the forcing function parameters. Important parameters are the catchability coefficients, maximum temperature effect, velocity threshold, spawning effect, and flow-dependent residence time parameters.

The "Methods" section describes in detail the methods and the relevant mathematical equations used in all the modeling and simulation studies. This section also provides information on the sources of the observed data and explains various assumptions made with respect to predator population sizes, model parameters, etc. The section entitled "Results" presents the results of various numerical studies and projections in the appropriate tabular and/or graphical form. The "Discussion" section presents analyses of the numerical data, comparison between the simulation and the empirical results, and possibilities in model improvement. The appendix to the report contains the EZ-CREM User's Guide.

OBJECTIVES

1. Provide estimates of predation-related juvenile salmonid mortality for Columbia and Snake River projects based on the most recent research data, and revised estimates of salmonids mortality in response to existing and proposed predator control measures and other management actions.

2. Develop a user interface for versions of CREM to allow researchers and project managers to operate the model to investigate the consequences of management alternatives in the system. Implement a system of menus and graphic output modules for a PC based version of CREM 2.1.

3. Provide estimates of the probable long-term consequences of the present and possible alternative predator control programs on squawfish and salmonid mortality.

METHODS

Effect of Predation on Apparent Reservoir Residence Time in Simulated Tagging Studies of Juvenile Salmonids

In the Columbia River Ecosystem Model (CREM; Bledsoe et al. 1990), downstream progress of juvenile salmonids is determined using a mean residence time (rt) measured in days. This residence time characterizes ***only*** the movement of the salmonids and is used along with other factors to determine the time of arrival at the downstream dam.

It is important to determine the effects of predation on the apparent residence time of subyearling chinook salmon through simulated tagging experiments. The results can be used to estimate the extent to which predation biases the residence time determined by tagging experiments.

CREM Version 2.1 (described in detail in Bledsoe et al. 1992) was used to model the passage of juvenile salmonids through the John Day Reservoir. Salmonid residence times were determined with reference to baseline conditions of predator density and river flow. Rather than the constant residence time described in Bledsoe et al. (1990), these simulations assumed that residence time is inversely proportional to river flow. The computation of residence time takes the form:

$$rt(i,j) = prt2(i,j)*area(j)/Fl + prt1(i,j)$$

where:

rt(i,j) = residence time of salmonid group i in region j,
prt2(i,j) = flow-dependant residence time parameter of salmonids group i in region j,
area(j) = area of region j,
Fl = daily river flow into reservoir, and
prt1(i,,j) = flow-independent residence time parameter of salmonid group i in region j.

In a normal simulation, one of the two parameters, prtl and prt2, will be set to zero and the other will be non-zero depending upon flow-independent (prt 1 > 0, prt2 = 0) or flow-dependent (prt1 = 0, prt2 > 0) residence times. For flow-dependent rt's, if the value of prt2 is set to the mean of depth for a reservoir region, the residence time will be approximately equal to the neutrally buoyant particle travel time in the region. If fish are hypothesized to move more slowly than water travel by a factor Xl < 1 ., the prt 2 should be increased by a factor 1./X1.

Chinook subyearling migrants have been shown to lag river flow by a factor of 1./2.5. Table 1 gives values of prt2 for subyearling chinook 0 and other stocks; prt 1 is set uniformly to zero for the residence time exercise. Prt2 values are set to mean reservoir depths for non-chinook 0 species ("other") and 2.5 times greater for chinook 0s.

Table 1. Values of the residence time parameter prt2 for subyearling chinook 0 and other stock. Prtl is set to 0.

		i (Salmonid Group)		
		1 (Ch 0)	2 (Others)	3 (Tagged)
j (Region)	1 (Tailrace)	20.0	8.0	20.0
	2 (Mid-bay)	56.5	22.6	56.5
	3 (Forebay)	91.0	36.4	91.0

The baseline for predator densities in the reservoir regions was based on estimates proportional to the 1991 electroshock predator density indices as described in Bledsoe et al. 1992. The baseline river flow came from 1957 flow data, which was used to represent a typical case of seasonal river flow.

In the simulated tagging experiments, three **salmonid** groups pass into John Day reservoir:

1. Subyearling chinook, representing observed 1990 passages.

2. All other salmonids, representing observed 1990 passages.

3. "Tagged" subyearling chinook, released at intervals of 20 days throughout the season.

The first two groups produce prey densities appropriate to the observed passages in the 1990 season, allowing for the appropriate density-dependent predator response. The third, tagged, group is small relative to the other two. Each release of the tagged group into the reservoir is compared to the arrival of that group at the downstream dam to determine average residence time.

The average residence time of subyearling chinook from a release is determined as follows:

$$RT_i = \frac{\sum_{t=0}^{19} n_{ti} t}{\sum_{t=0}^{19} n_{ti}}$$

where:

RT_i = the average residence time of the **ith** release,
n_{ti} = the number of tagged fish arriving at the downstream reservoir on day t after release i, and
t = number of days since the last release.

Each tagged release simulation is performed twice. The first assumes that predators are present in numbers estimated for that season. The second assumes that only 1% of the estimated numbers are present to determine the predator effect on apparent residence time. The simulations were performed for different river flow rates with release staggered at intervals of 20 days throughout the season. To confirm that the tagged group was small enough to avoid perturbing the residence times, the studies were repeated with tagged groups of varying sizes.

The two studies simulate the release of 100 tagged fish on each release day. The first case assumes the baseline river flow, and the second case assumes that the flow rate is 50 % of baseline. In addition, each of these studies includes a simulation with predator density of 200% of the baseline.

Long-Term Systemwide Salmonid Mortality Projections

CREM (Version 2.1) was first used to project long-term (1990 through 1995) juvenile salmonid mortalities due to predation by northern squawfish in 1990 (Bledsoe et al. 1992). Those estimates were based for all years on 1990 values of the driving functions (passage numbers, fishing effort). Only three of the lower Columbia River reservoirs were included in that study -- John Day, The Dalles and Bonneville.

The updated study performed this year provided the projections of salmonid mortality due to predation in the extended Columbia-Snake River system, which included the eight reservoirs listed below. The estimates of total annual mortalities were calculated for each of the years 1992 through 2000, based on the latest available information, e.g. 1992 predator removal and electroshock data.

The catch from the following fisheries was included in the calculation of the projections: Oregon and federal electroshock, sport fishing, and dam angling. Commercial fishing in 1992 took place only below Bonneville Dam (outside of the region covered by the LONGCREM simulator), and therefore was not included in the calculations.

The LONGCREM model was used to project salmonid mortality from 1992 to 2000. The model currently incorporated in LONGCREM covers the Snake and lower Columbia River systems by successive execution of CREM (Version 2.1) for each year in the following reservoirs: Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville. To provide more complete data for the future predator control analyses, the salmonid mortality projections were produced using two predator population regrowth scenarios:

a) assuming no regrowth of the predator population numbers (i.e., births equal natural mortality), and

b) assuming 10% annual predator population regrowth.

Both scenarios were modelled with the same fishing effort and the same catchabilities. The predicted mortalities are presented in the "Results" section of this report.

Study of Mortality Sensitivity to Various Model Parameters

One of the main objectives of this project has been accurate prediction of salmonid mortality for future years. While the CREM parameters have been carefully chosen based on fishery efforts, biological facts, observed data, etc., it was necessary to determine how a change in any of the parameters that are central to the simulation could affect the predicted salmonid mortality. Some parameters could be more sensitive than others to large- or small-scale perturbations. If such parameters were discovered, they could be further optimized by the LONGCREM (see Bledsoe et al. 1992).

First, LONGCREM was executed with the standard parameter values, using the 1991 predator catch and the, salmonid passage data. The mortality for Snake River chinook subyearlings was calculated to be 95% at the estuary. Then several parameters were singled out for the mortality sensitivity study, parameters determining flow-dependent residence time, maximum temperature effect, spawning effect, predator catchability coefficients, and velocity threshold.

For each of these parameters LONGCREM was executed twice, at the 200% parameter value and at 50% parameter value, while the other parameters remained' intact at their standard values. Chinook mortality was noted after each simulation. The degree of perturbation (%) of a given tested parameter was the same for all the reservoirs, while the actual parameter values were reservoir-specific. The change in mortality with respect to parameter perturbation is displayed in the form of a "tornado" diagram in the "Results" section of this report.

EZ-CREM Package: Menu-driven User Interface to CREM

The Columbia River Ecosystem Model (CREM) affords the user extensive control over a wide range of model parameters and driving functions that are read from several input files. The simulation model is optimized for use by experienced computer programmers and simulation experts rather that the average fishery scientist. For the purposes of fisheries management, most of the conditions of simulations require little modification. However, number and format of the input files makes it awkward to work with the subset of conditions that managers or field biologists might want to modify.

To provide these users with a more effective management tool for projections of salmonid mortality and predator removal, the CREM (Version 2.1) software was modified and bundled with utility programs into the EZ-CREM package. The package was designed to be executed on any IBM AT personal computer or compatible. It allows for a "user-friendly" way to interact with the CREM model. This package consists of the following parts.

1. An overall driver that provides a menu to control the other programs in the package.

2. Three menu-driven utilities that modify existing CREM input files and produce new ones to suit user requirements. Specifically, the utilities modify the predator removal effort file, the control parameters file, and the model parameters file. The menus allow the user to select groups of parameters to examine and modify without reference to the format of the files that contain them.

3. A modified version of the CREM program that allows the user to change the distribution of predators in the reservoir and the projected effectiveness of different gear types, which are used for predator removal in different areas of the reservoir.

4. An output module in which selected CREM output information is displayed at user-specified intervals during the simulation execution.

When invoke, EZ-CREM allows the user to specify a simulation parameter file, or to continue with the default file. After reading all parameters and data for forcing functions, EZ-CREM allows the user to display and modify selected parameters before beginning the simulation.

As the simulation proceeds, intermediate output of predator population and of cumulative salmonid mortality is displayed on the screen at each output time-step. The output of the final time-step at the end of the execution remains on the screen and can be printed using the “print screen” key on the keyboard.

The EZ-CREM package is enhanced by adding initial parameter display/modification panels and by streamlining the output displays, either through more detailed tabular output or through graphical displays at the end of the simulation.

Utilities were developed that allow the user to modify the information in the input files that drive the model. Rather than install all the utilities in the EZ-CREM program itself, making the program large and the menus complex, development concentrated on a package of programs to accompany EZ-CREM that can be used to modify input files before EZ-CREM is invoked, In this way, EZ-CREM is a modular package that can be easily updated as new or modified scientific mechanisms are added to the original ecosystem model. These utilities will allow the EZ-CREM user to access and modify the contents of the simulation parameters and the CREM parameter file. In both cases, the utilities allow the user to specify the file for input and output, and select groups of parameters from a main menu. The parameters for a selected group appear on submenu panels for modification.

The utilities were integrated with EZ-CREM into an “umbrella” menu system that can be enhanced to accommodate new capabilities as needed to allow EZ-CREM to be used by field biologists to perform inseason analysis of to-date squawfish mortalities and adjust effort levels to meet management targets. An EZ-CREM user’s guide is provided in Appendix A.

RESULTS

Simulated Tagging Study

In each table of results, average residence time and total number to tagged salmonids arriving at the downstream dam are reported for each simulated release. Note that differences tabulated in all cases are between the simulation with 100% baseline predation and the simulation with 1% of baseline predation.

Table 2. Long-term projected salmonid mortality due to predation (no regrowth in predator population assumed); Study 1 - baseline flow, 100 tagged fish/release.

Flow Rate: 100%		Size of each release: 100 fish						
Julian date of Release		111	131	151	171	191	211	231
Average Residence Time (days)								
Predator Pop.	200%	9.0	7.8	7.8	8.0	7.8	9.1	6.5
	100%	9.0	7.8	7.9	8.4	8.8	8.5	6.5
	1%	9.1	7.9	8.0	8.7	9.3	9.3	6.3
	Diff.	-.1	-.1	-.1	-.3	-.5	-.8	-.2
Total Arriving at Downstream Dam from Release								
Predator Pop.	200%	68	88	79	48	33	26	21
	100%	73	92	84	61	53	40	26
	1%	77	96	90	75	76	78	53
	Diff.	-4	-4	-6	-14	-23	-38	-27

Table 3. Long-term projected **salmonid** mortality due to predation (10% yearly regrowth in predator population assumed); 50 % baseline flow, 100 tagged fish/release

Flow Rate: 50%		Size of each release: 100 fish						
Julian date of Release		111	131	151	171	191	211	231
		Average Residence Time (days)						
Predator Pop.	200%	10.8	9.0	8.8	8.6	8.2	8.9	6.7
	100%	10.8	9.1	8.8	9.0	9.2	8.8	5.9
	1%	10.9	9.2	9.0	9.2	9.7	9.6	6.1
	Diff.	-.1	-.1	-.2	-.2	-.5	-.8	-.2
		Total Arriving at Downstream Dam from Release						
Predator Pop.	200%	43	66	62	35	22	10	8
	100%	46	72	69	47	40	30	14
	1%	49	79	78	61	61	63	41
	Diff.	-3	-7	-9	-14	-21	-33	-27

Long-Term Mortality Projections

The annual mortality results for the juvenile salmonids were obtained from a series of LONGCREM simulations for the nine subsequent years, each assuming no regrowth of the predator population numbers (i.e., births equal natural mortality) and a continuation of the same fishing efforts with the same catchabilities. These predicted mortalities are shown in Table 4. The **salmonid** mortalities due to the predation model with 10% annual population regrowth are shown in Table 5. The following notation is used in both tables: **ch0s -** Snake River'chinook subyearlings; **ch0c** - Columbia River chinook subyearlings; **other -** all other salmonids species: **coho,** sockeye, chinook yearlings, steelhead.

Table 4. Tagged release simulation results - baseline flow, 100 tagged fish/release (Study 1). Projected **salmonid** mortality **(%)** due to predation (no regrowth in predator population assumes).

		1992	1994	1996	1998	2000
Little Goose	**ch0s**	45.08	26.10	13.77	**6.96**	3.56
	ch0c					
	other					
Lower Monumental	**ch0s**	55.74	45.25	33.76	24.02	16.86
	ch0c					
	other					
Ice Harbor	**ch0s**	38.71	33.79	28.73	24.13	20.05
	ch0c					
	other					
McNary	**ch0s**	49.93	26.09	14.35	10.50	9.81
	ch0c					
	other					
John Day	**ch0s**	57.91	45.86	39.51	41.10	42.45
	ch0c	46.95	29.82	18.35	16.20	15.39
	other	2.25	0.96	0.24	0.10	0.05
The Dalles	**ch0s**	13.69	8.21	6.64	6.44	12.86
	ch0c	12.86	5.62	2.90	2.07	2.25
	other	0.70	0.16	0.03	0.00	0.00
Bonneville	**ch0s**	33.58	19.11	15.14	14.97	15.11
	ch0c	28.96	12.72	6.49	5.10	4.83
	other	1.60	0.35	0.07	0.02	0.00
Total % Mortality	**ch0s**	98.20	92.04	83.30	77.51	75.39
	ch0c	68.34	42.23	25.90	22.16	21.32
	other	4.63	1.46	0.34	0.12	0.07

Table 5. Tagged release simulation results - 50% baseline flow, 100 tagged fish/release (Study 2). Projected salmonid mortality (%) due to predation (10% yearly regrowth in predator population assumed).

		1992	i994	1996	1998	2000
Little Goose	ch0s	45.08	30.04	16.35	9.77	5.76
	ch0c					
	other					
Lower Monumental	ch0s	55.74	49.87	43.14	36.01	29.44
	ch0c					
	other					
Ice Harbor	ch0s	38.71	37.18	35.45	33.20	34.84
	ch0c					
	other					
McNary	ch0s	49.93	28.46	16.35	10.53	3.18
	ch0c					
	other					
John Day	ch0s	57.91	47.08	42.29	40.60	40.69
	ch0c	46.95	32.72	24.06	19.48	17.15
	other	2.25	0.96	0.24	0.10	0.05
The Dalles	ch0s	13.69	8.15	6.14	5.90	13.30
	ch0c	12.86	6.18	3.08	2.13	2.97
	other	0.70	0.16	0.04	0.01	0.02
Bonneville	ch0s	33.58	19.58	14.16	13.58	13.58
	ch0c	28.96	13.98	6.88	5.11	4.71
	other	1.60	0.34	0.07	0.02	0.01
Total % Mortality	ch0s	98.20	93.84	88.06	83.33	81.36
	ch0c	68.34	45.74	31.50	25.26	23.44
	other	4.63	1.46	0.35	0.12	0.07

DISCUSSION

Conclusions of the Tagging, Study

In Study 1, using 100% of the baseline flow rate, the reduction of the predator population by 99% produced an increase in residence times ranging from no change to less than one day. The typical baseline river flow data used in this study is shown in Figure 1. The variation in the increase during the season follows the passage curve of the untagged chinook subyearlings. (see Figure 2) and appears to be an effect of prey density. To determine average residence time, each release of the tagged group into the reservoir is compared to the arrival of that group at the downstream dam (see Figure 3).

In Study 2, using 50% of the baseline flow rate, the difference in residence times with and without predators ranges from no change to a 7/10 of a day increase.

The effect on survival of the tagged fish is more pronounced. In Study 1, the tagged release of Day 2 11 had an 64% survival rate under 100% predation and 92 % under 1% predation. In Study 2, the respective survival rates for that day are 53% and 83%. The effects of predation on prey survival are magnified by lower rates of flow. This result is expected, since the migration speed is proportional to the flow rate; less flow results in longer periods of exposure to predation.

These results indicate that predators produce a negligible increase in the observed mean residence times of salmonid prey passing through the reservoir. The difference increases with increasing prey density and/or with decreasing flow, but remain negligible relative to the expected variability in passage time and subsequent mortality in the real system. This result implies that measures of residence time, such as Miller and Sims (1984), can be taken as direct measures of salmonid migration rates with no significant bias due to the high predation rates occurring in the reservoir. The size of the bias induced by predation in apparent residence times is less than 10% even in cases of low flow (50%) or normal and high predation (200% of normal). Since the variability in residence times in actual tagging experiments varied from five to over 100 days, the bias induced by predation can be regarded as negligible relative to this natural variability.

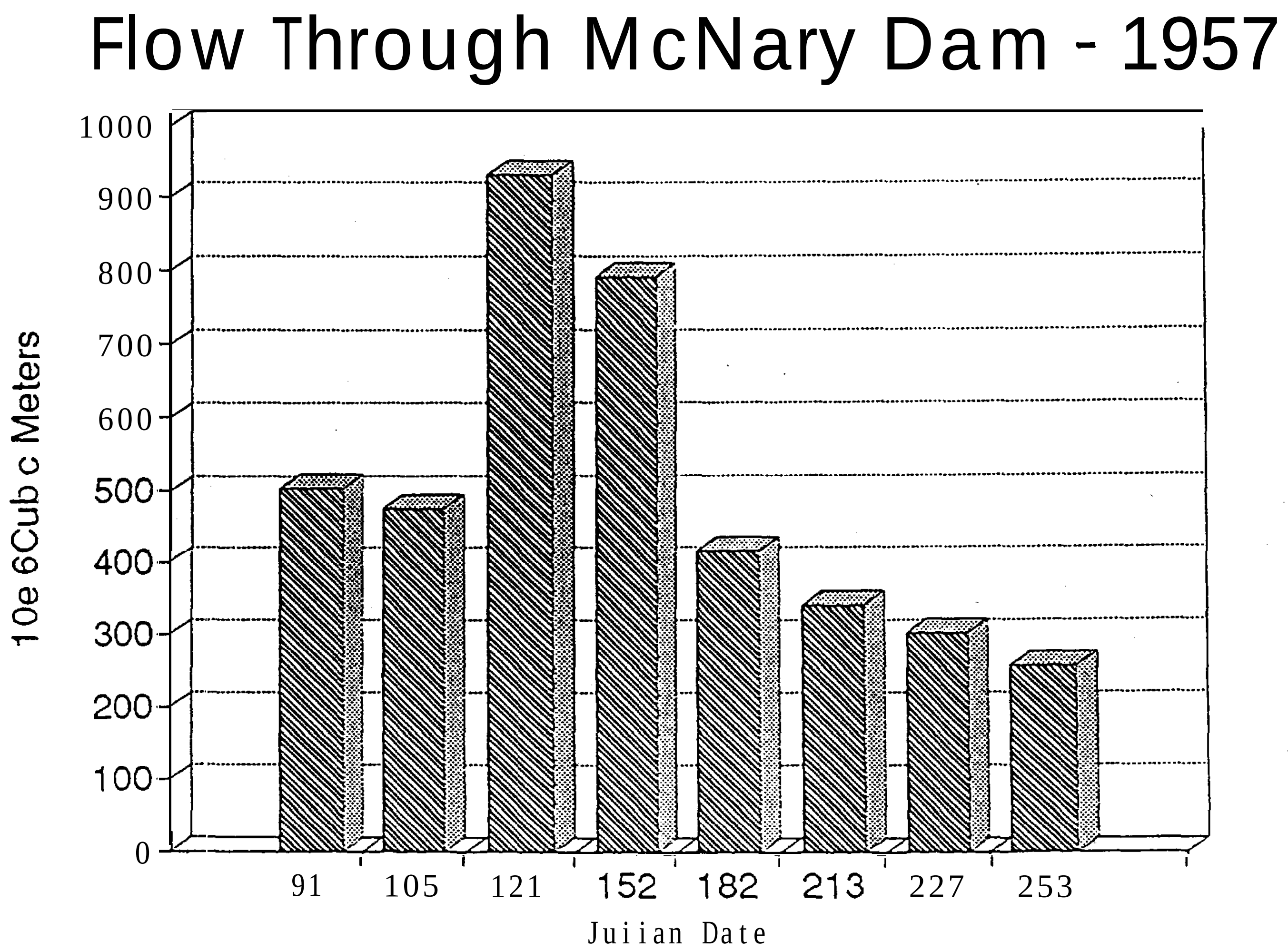


Figure 1. Flow through McNary Dam -1957.

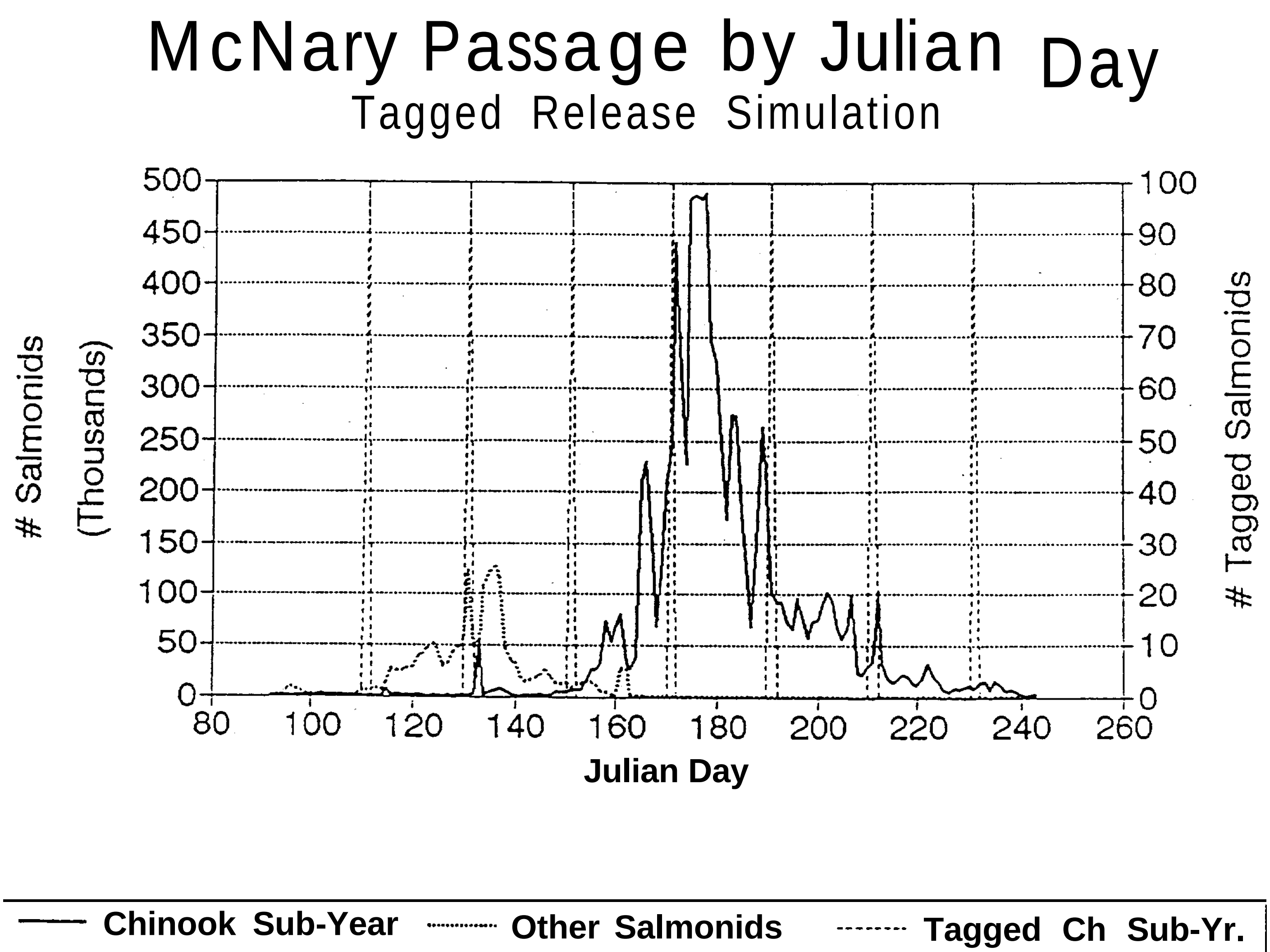


Figure 2. McNary passage by Julian Day - Tagged Release Simulation.

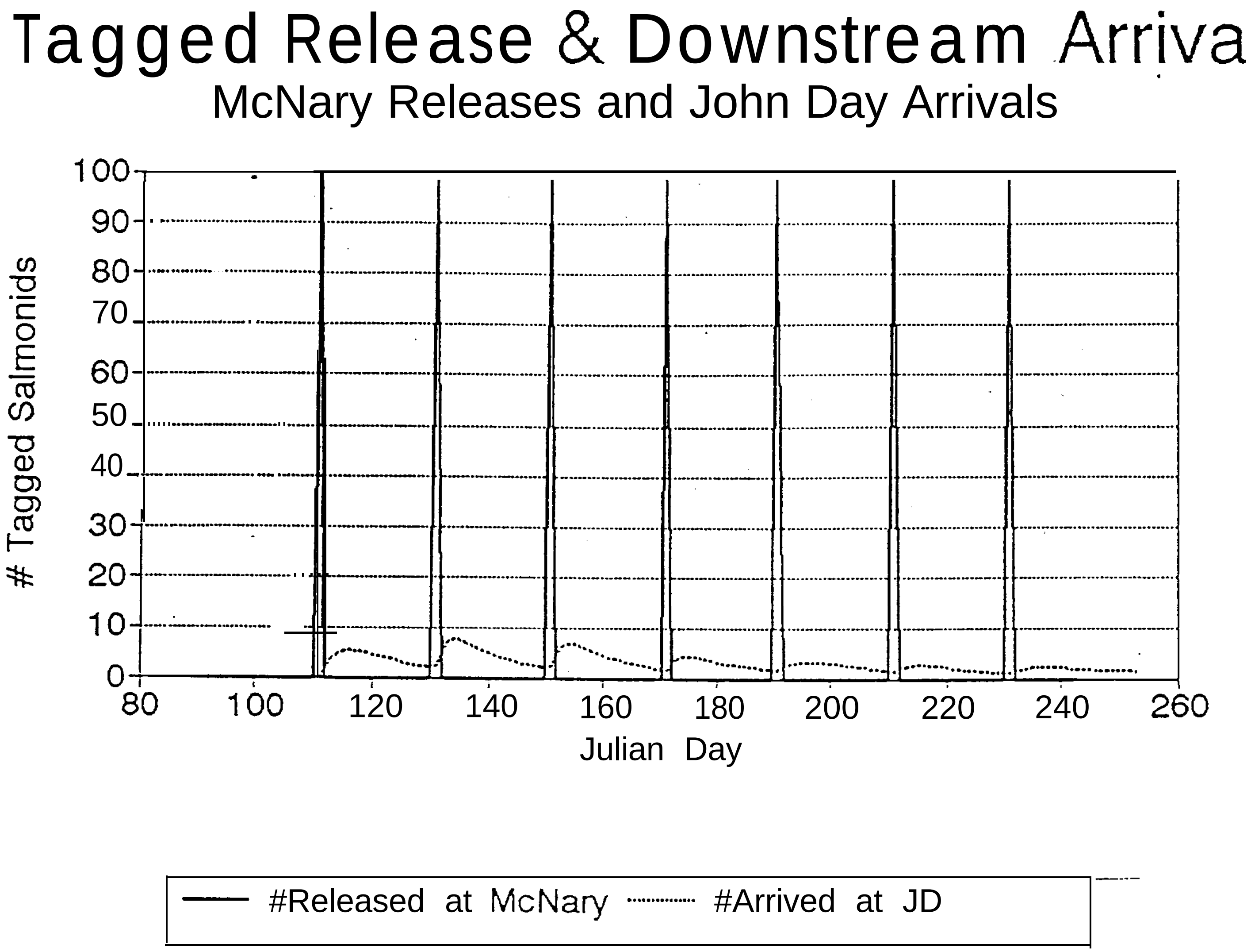


Figure 3. Tagged release and downstream arrival - McNary releases and John Day arrivals.

Long-Term Salmonid Mortality Projections

The results of the long-term mortality projections from Tables 4 and 5 are plotted in Figures 4 and 5, respectively. They clearly demonstrate the gradual decreasing of the 1992-2000 mortalities for Columbia and Snake River chinook 0s for both predator populations regrowth models described earlier. The projected mortalities of the other salmonid stock are also shown in the figures.

These results are to be expected in light of the current effort to control the predator population by various means (assuming these efforts continue at least at the current level). The higher total salmonid mortality in the case of the 10% predator population regrowth model compared to the no-regrowth one was not surprising either, since the increase in predator population would result in higher salmonid mortality in the absence of the proportionally increased predator catch.

The difference between predation mortality for Snake or Columbia River subyearling chinook and other salmonid groups appears very large. To understand this difference, consider only the mortality that occurs in a single reservoir, John Day, during a single year, 1992.

Figure 6 shows the passage time series for three salmonid groups, Snake River and Columbia River subyearlings and other salmonid groups (non-chinook species and yearling chinook). Also show are the water temperature and river flow time series. Table 6, below, shows the total mortality experienced by these three salmonid groups for 1992 in John Day Reservoir.

Table 6. Predation mortality (percent) predicted by CREM for three salmonid groups in John Day Reservoir during 1992. A) Normal daily passage into the reservoir; B) Artificial uniform daily passage into the reservoir, for test purposes (see text).

Group	Snake River chinook 0s	Columbia River chinook 0s	Other Salmonids
a) Predation Mortality	49.1	41.8	2.2
b) Predation Mortality (uni-form passage)	31.0	31.0	16.7

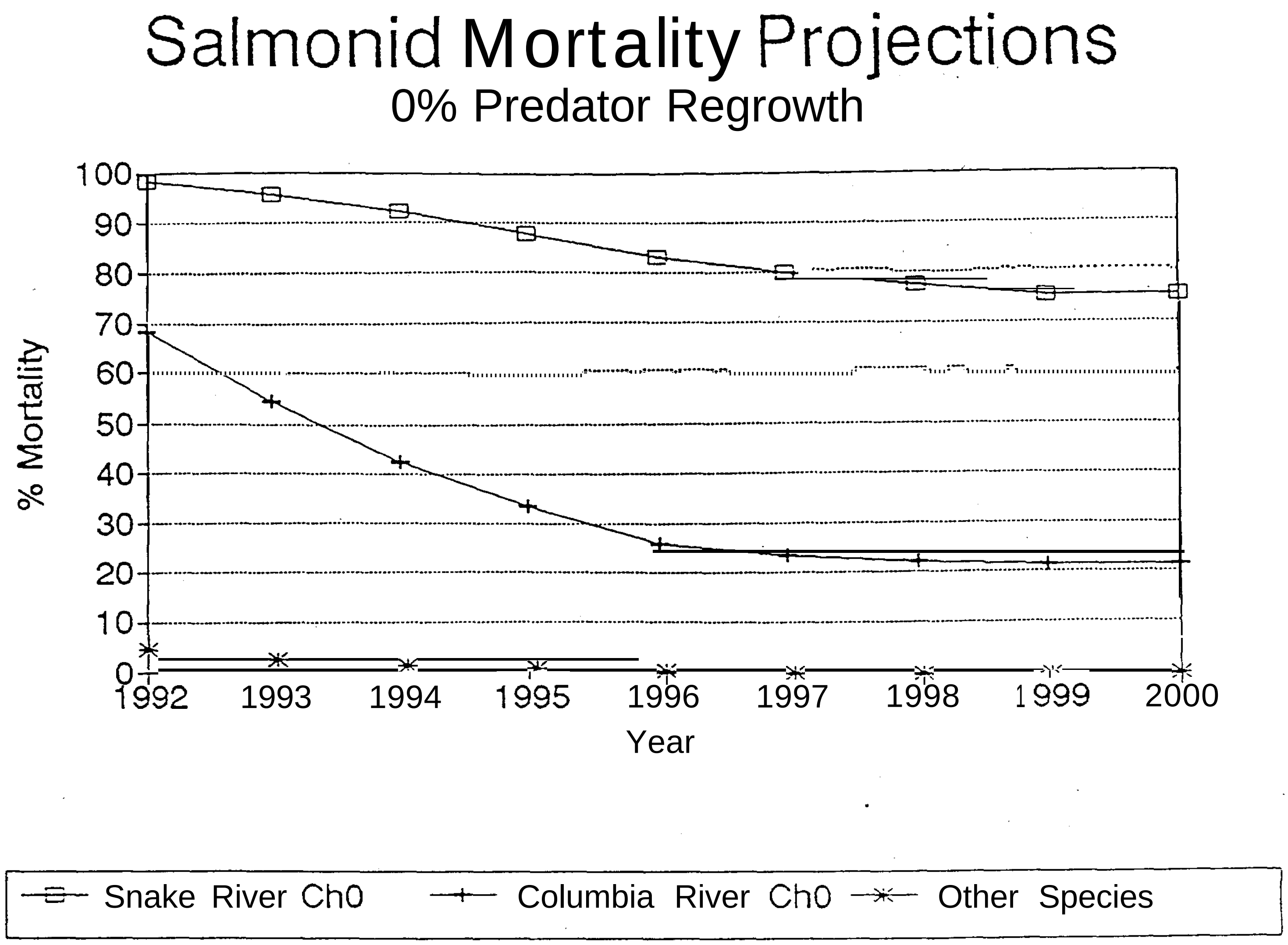


Figure 4. Salmonid mortality projections - 0% predator regrowth

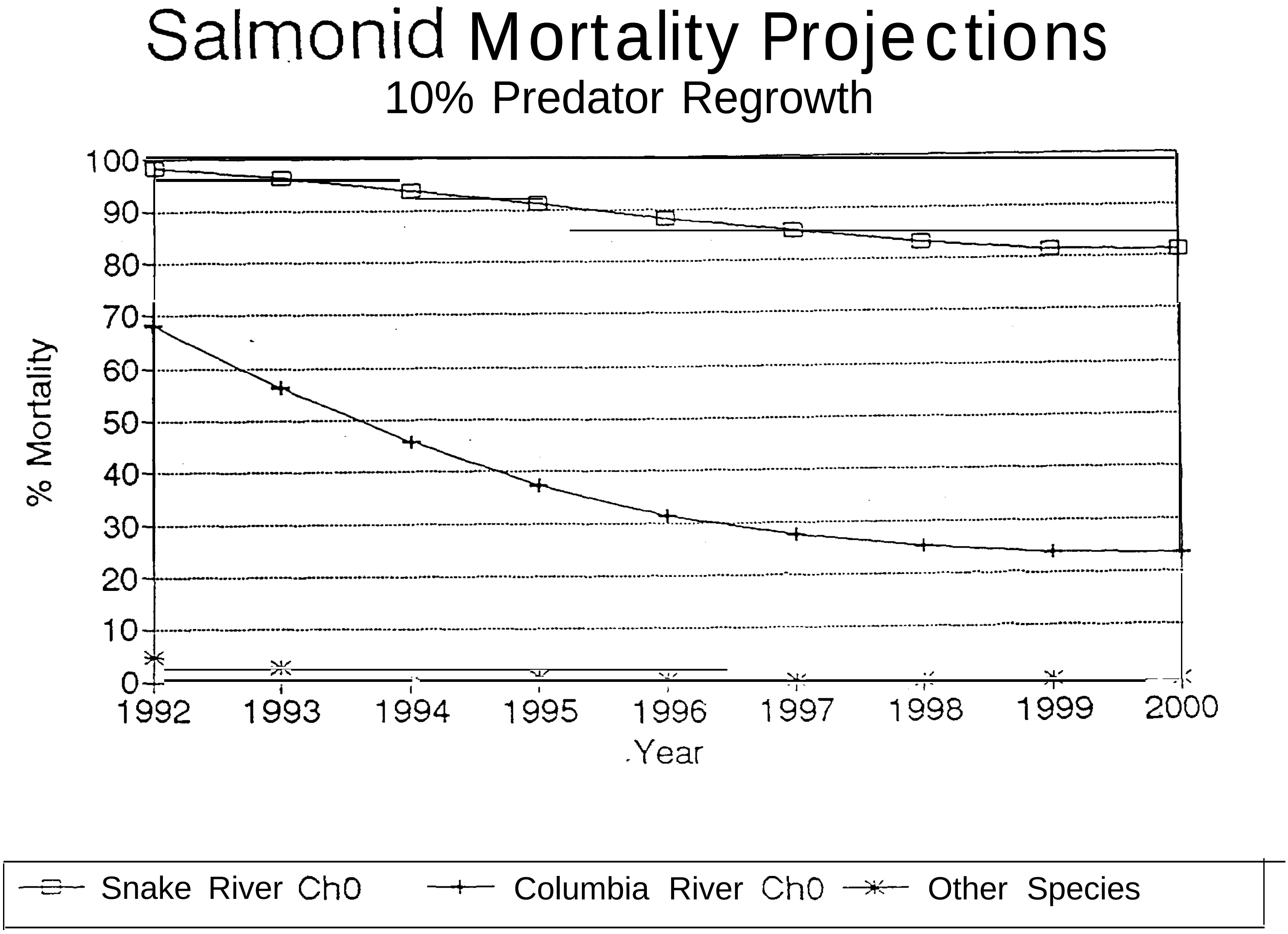


Figure 5. **Salmonid** mortality projections - 10% predator regrowth.

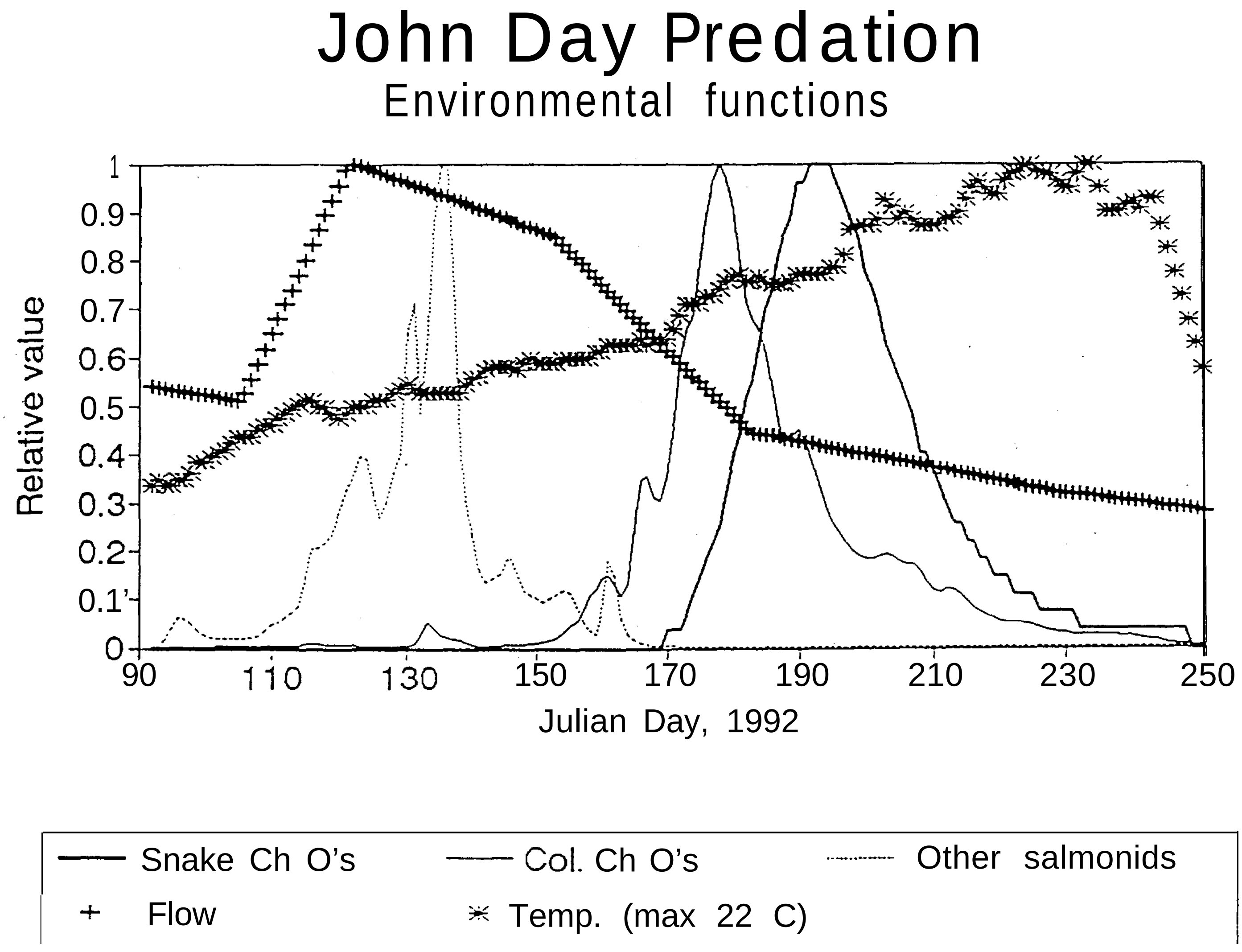


Figure 6. John Day predation - Environmental functions.

Snake and Columbia subyearlings both experience nearly 50% mortality, according to Table 5, however other salmonids experience only 2% mortality. Subyearling mortality is about 22 times as great. There are two differences in the simulated conditions under which these two groups experience predation pressure. The first is that the subyearlings travel more slowly through the reservoir by a factor of 2.5 than the other groups, which migrate in proportion to water velocity. This makes them subject to predation pressure for about 2.5 times as long as the others. The second difference is in the timing of the passage into the reservoir. As can be seen in Figure 6, subyearlings migrate predominantly during the latter part of the year whereas other groups migrate earlier in the season. There are also differences in the sizes of the groups, which result in differences in salmonid densities in the reservoir and, consequently, predation rate due to the non-linear functional curve. However, it is possible to explain the mortality difference solely in terms of the passage duration and seasonal timing differences.

The effect of passage duration would make an obvious difference in mortality, but only on the order of magnitude of the size of the timing difference, about 2.5 times. To investigate the effect of seasonal timing of the migration runs, a simulation was performed in which passage into the reservoir was replaced with a uniform rate of entry during the simulated season, Julian Day 92 through 253. The total number of fish passing into the reservoir was the same for the test simulation as for the normal simulation. However, in the test simulation, the number of fish per day that enter the reservoir was constant for each group.

Figure 7 graphs the time series of cumulative predation mortality for the normal and the test simulation. Under conditions of uniform daily passage, the subyearling mortality is reduced to about 60% to 75% of the mortality under the actual passage histogram. However, for the other salmonid groups, predation increases by a factor of about 7.6. The test simulation under conditions of uniform daily passage eliminates the variability in the mortality graphs that is due to varying salmonid densities and leaves only the effect of time in the season to vary the rate of mortality. Figure 7 shows that the uniform passage mortality curve rises much more rapidly late in the season. Figure 6 shows that this is the time when flow is lowest and, therefore, passage time, which is inversely proportional to flow, is longest, causing greater mortality due to time of exposure to predators. Figure 6 also shows that temperature is much higher, peaking at 22° C. Temperature also causes much faster rates of predation, according to U.S. Fish and Wildlife Service research results. In the Columbia River Ecosystem Model, predation increases due to temperature alone by a factor of more than 3 from Day 134, when "other" salmonids are at peak passage rate (water temperature 12° C), to Day 190, when Snake River subyearlings are at peak passage (water temperature 17° C).

The combined effect of all factors results in about a factor of 18 increase in mortality:

Inherently slower passage (2.5) X
Higher temperatures (3.1) X
Lower late season flows (2.2) = 17.6

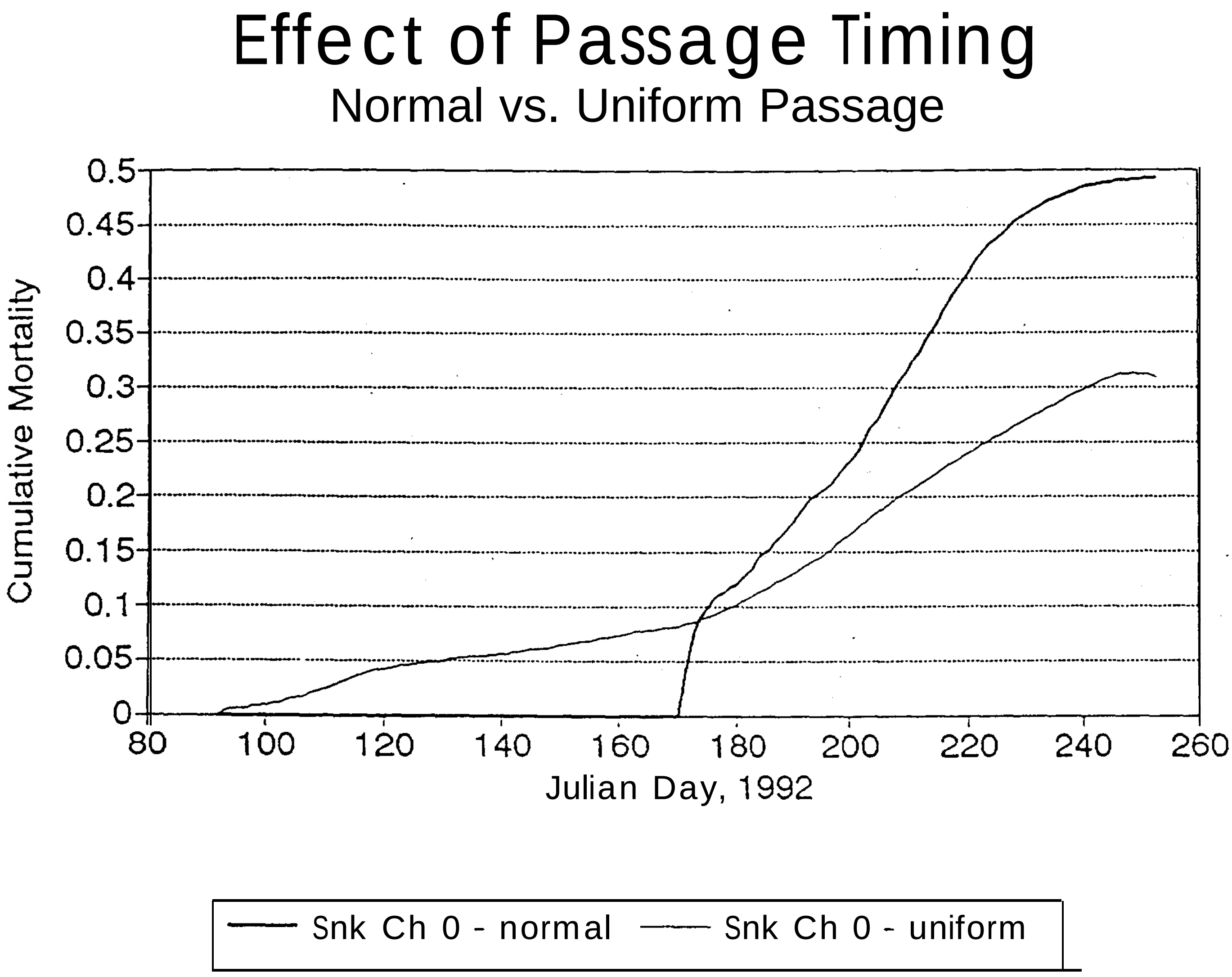


Figure 7. Effect of passage timing - Normal vs. Uniform passage into John Day reservoir.

Subyearling mortality was about 22 times higher than the other species. However, the remaining **22/17.6** = 1.25 factor that is unaccounted for above can be explained in terms of the non-linear increase in per capita consumption rate of predators with increase in prey density. Prey density is between six and 10 times higher during the late season when the Snake River subyearlings are migrating than during the early season when other groups are in the reservoir (Figure 8). The functional response curve increase from about 0.5 for low prey densities to a maximum of 4.0 prey per **squawfish** for these prey density increases.

Conclusions of the Mortality Sensitivity Study

The "tornado" diagram shown in Figure 9 displays the results of a study of Columbia River system **salmonid** mortality sensitivity to certain parameters used by **LONGCREM,** using Snake River chinook subyearlings as an example.

The baseline mortality was estimated at 95% with all the modeling parameters at their standard values. According to this diagram, **salmonid** mortality is most sensitive to the changes in the flow-dependent resident time parameter, **prt2.** When that parameter value was doubled, the **salmonid** mortality at the end of the simulated river system increased by 5 % . At half the standard parameter value, **salmonid** mortality dropped by 25 % . Other parameters were demonstrated to have less of an influence on the mortality -- parameters responsible for the maximum water temperature effect and the spawning effect. The **salmonid** mortality showed no apparent sensitivity to other tested parameters, the catchability coefficients, and the velocity threshold.

This study led to the conclusion that the presently used parameters are sufficiently accurate for our simulation studies and there is no need for their additional optimization.

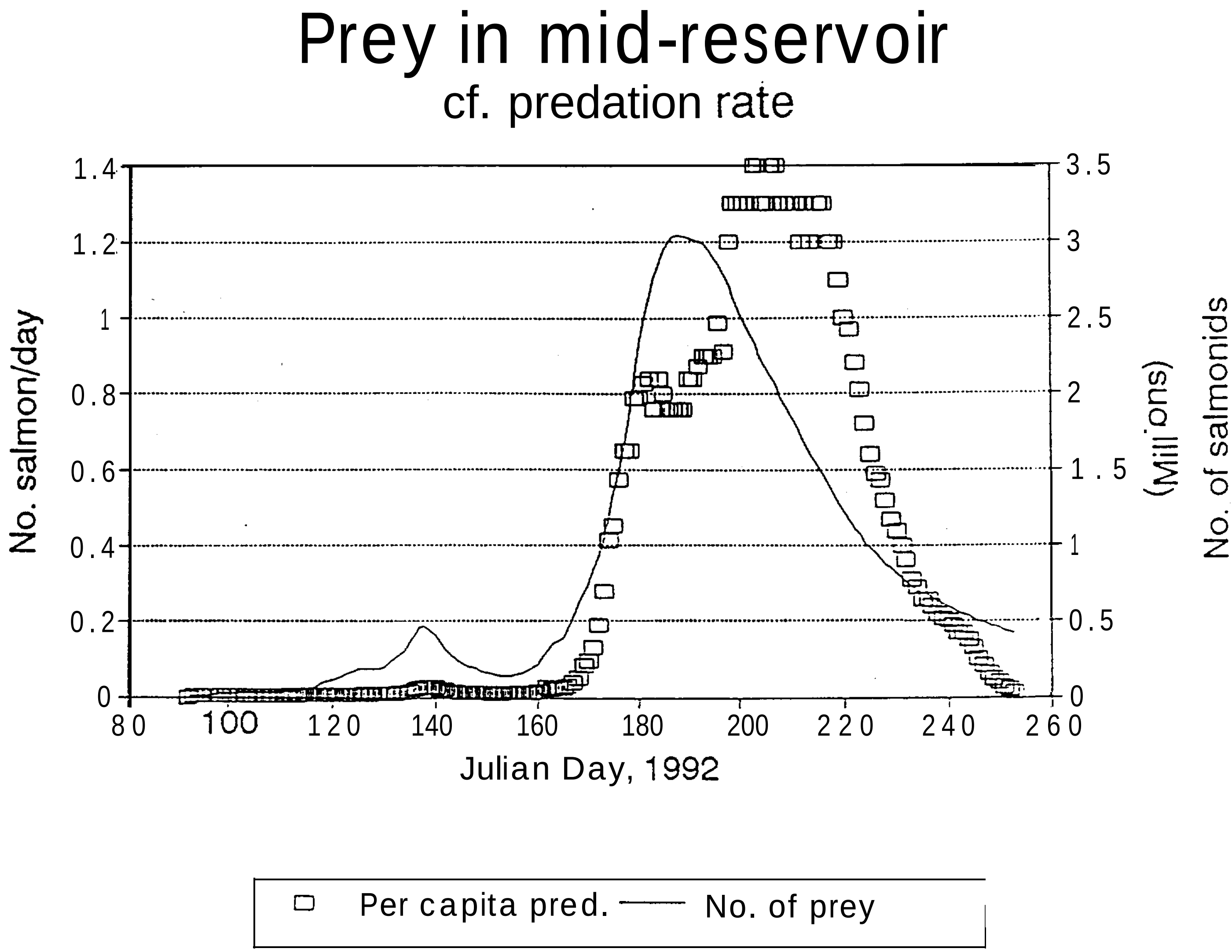
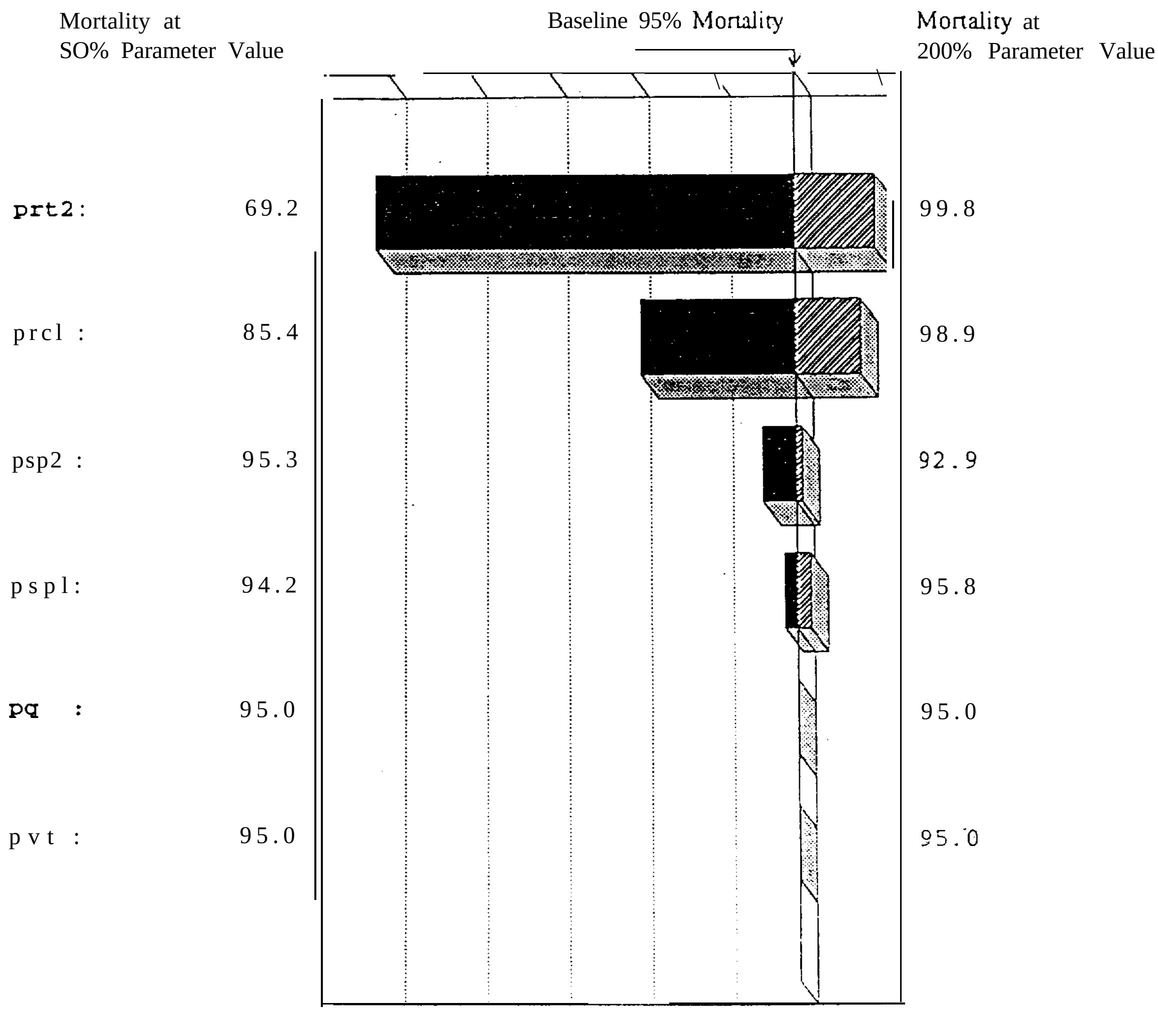


Figure 8. Prey in John Day Mid-Reservoir cf. Predation rate

Salmonid Mortality Sensitivity Analysis Using CREM



PARAMETERS:

prt2	flow-dependent residence time
prc1	- maximum temperature effect
psp1, psp2	- spawning effect
pq	catchability coefficient
pvt	- velocity threshold

Figure 9. **Salmonid** mortality sensitivity analysis using CREM.

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Bledsoe, L.J., A.F. Johnston, and H. Rudd. 1992. Columbia River Ecosystem Model (CREM) -- modeling approach for evaluation of control of northern squawfish populations using fisheries exploitation. In C.F. Willis and A.A. Nigro, editors. Development of a system-wide predator control program: stepwise implementation of a predation index, predator control fisheries and evaluation plan in the Columbia River basin. 1991 Annual Report. BPA Project 90-077, Bonneville Power Administration, Portland, Oregon.

Bledsoe, L.J., S. Vigg and J.H. Petersen. 1990. Simulation estimates of salmonid predation loss to northern squawfish in a Columbia River reservoir. Pages 22 l-254 in A. A. Nigro, editor. 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. 1990 Annual Report. Bonneville Power Administration, Portland, Oregon..

Miller, D.R., and C.W. Sims. 1984. Effects of flow on the migratory behavior and survival of juvenile fall and summer chinook salmon in John Day Reservoir. Annual Report (Contract DE-A179-83BP39645) to the Bonneville Power Administration, Portland, Oregon.

APPENDIX A

EZ-CREM User's Guide

The EZ-CREM utility is executed by entering EZ-CREM from the directory in which the program is located. The example presented below uses 1990 data for the John Day Reservoir.

Once **in EZ-CREM, the ENTER key is used to confirm a user choice. Pressing the ESCAPE key at any time will return the user to the previous menu.**

The first panel to appear is shown in Figure Al. Using the arrow keys, the user may choose a differentsimulation parameter file, or allow it to use the default.

```
        Simulation  Parameters
              Control  File:
Old Value: simpar.dat
New Value:
```

Figure Al.

The driving menu will now 'appear on the screen (Figure A2). The user may opt to change parameters, continue and immediately execute the program with the default parameters, or to quit EZ-CREM.

```
Change  Parameter
 Continue
 Quit
```

Figure A2.

Choosing the CHANGE PARAMETERS option brings up a new menu (Figure A3).

Predator Dist.
Catchability Coeffs.

Figure A3.

Pressing the ESCAPE key at this time will return the user to the previous menu. The CONTINUE option immediately begins execution of CREM, displaying tabular output for each time step, as in Figure A4:

Julian Day: 253.0

Predator Distribution by Area

	Trailrace	Mid-Res.	Forebay	Total
Initial Catch	2798	.8107E+05	898.9	.8477E+05
Current Catch	2464	.7114E+05	799.2	.7441E+05
US Elec.	243.5	13.50	53.04	310.1
%Exp. Rate	8.703	.1665E-01	5.900	.3658
Or Elec.	61.76	12.98	35.30	110.0
%Exp. Rate	2.207	.1601E-01	3.928	.1298
Commercial	611.7	822.9	.oooo	1435
%Exp. Rate	21.86	1.015	.oooo	1.692
Sport	1548	1.031	3070	4619
%Exp. Rate	55.32	.1272E-02	341.5	5.449
Dam Ang	3863	.oooo	30.71	3893
%Exp. Rate	138.0	.oooo	3.416	4.593
Total	6328	850.4	3189	.1037E+05
%Exp. Rate	226.1	1.049	354.8	12.23

Figure A4.

Upon selecting PREDATOR DIST, the user may use the arrow keys to choose any of the three parameters in the box, followed by pressing ENTER. The selection in Figure A5 will appear on the screen to allow the user to make a change.

Predator Distribution Percent by Area

	Tailrace	Mid-Res.	Forebay	Total
Squawfish	3.300	95.60	1.060	99.96

Old Value: 1.060
New Value:

Figure **A5.**

Pressing ENTER returns the updated value if entered. Pressing the ESCAPE key will return the user to the Figure 'A3 menu. The other option in this menu, CATCHABILITY COEFFS, will bring up the table shown in Fiugre A6, and any changes can be made in the same manner as described above.

Catchability Coefficients

	Tailrace	Mid-Res.	Forebav	unused	unused
us Es	4430	67.90	2510	.0000	.0000
ODFW ES	1410	85.40	2260	.0000	.0000
Commercial	1550	419.0	.0000	.0000	.0000
Sport	211.0	1.520	2210	.0000	.0000
Dam Ang.	3960	.0000	263.0	.0000	.0000

Old Value: 4430
New Value:

Figure A6.

Once all changes are implemented, the user may ESCAPE back through the previous menus to the driving menu (Figure A2) and execute the program.