Development of a Systemwide Program: Stepwise Implementation of a Predation Index, Predator Control Fisheries, and Evaluation Plan in the Columbia River Basin

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CONTENTS

I. IMPLEMENTATION

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EXECUTIVE SUMMARY

by Charles F. Willis

We report our results from the second year of a basinwide program to harvest northern squawfish (*Ptychocheilus* ***oregonensis)*** in an effort to reduce mortality due to squawfish predation on juvenile salmonids during their emigration from natal streams to the ocean. Earlier work in the Columbia River Basin suggested predation by northern squawfish on juvenile salmonids may account for most of the 10-20% mortality juvenile salmonids experience in each of eight Columbia and Snake River reservoirs. Modeling simulations based on work in the John Day Reservoir from 1982 through 1988 indicated it is not necessary to eradicate northern squawfish to substantially reduce predation-caused mortality of juvenile salmonids. Instead, if northern squawfish were exploited at a 10-20% rate, reductions in their numbers and restructuring of their populations could reduce their predation on juvenile salmonids by 50% or more.

Consequently, we designed and tested a sport-reward angling fishery and a commercial longline fishery in the John Day pool in 1990. Based on the success of these limited efforts, we implemented three test fisheries on a multi-pool or systemwide scale in 1991: a tribal longline fishery, a sport-reward fishery, and a dam-angling fishery. The sport-reward and dam-angling fisheries were continued in 1992 together with an investigation of the feasibility of implementing a commercial longline fishery in the Columbia River below Bonneville Dam.

In addition, we examined several alternative harvest techniques to determine their potential for use in systemwide test fisheries. Evaluation of the success of the two test fisheries conducted in 1992 in achieving a 20% exploitation rate on northern squawfish, together with information regarding the economic, social, and legal feasibility of sustaining each fishery, is presented in Section II of this report.

The implementation team consists of the Oregon Department of Fish and Wildlife Columbia River Coordination Section (ODFW), S.P. Cramer and Associates, Inc. (SPCA), the Washington Department of Wildlife (WDW), the Columbia River Inter-Tribal Fish Commission (CRITFC), the University of Washington (UW), the National Marine Fisheries Service (NMFS), and the Pacific States Marine Fisheries Commission (PSMFC). ODFW, with assistance from SPCA, is responsible for the coordination and administration of the entire program and has subcontracted various tasks and activities to WDW, CRITFC, UW, NMFS, and PSMFC based on expertise each brings to the tasks involved in implementing the program. Objectives of each cooperator related to fishery implementation are as follows.

1. ODFW (Report A): Investigate the feasibility of implementing a commercial longline fishery in the Columbia River below Bonneville Dam.

2. WDW (Report B): Implement a systemwide sport-reward fishery.

3. CRITFC (Report C): Implement a systemwide angling fishery at eight mainstem Snake and Columbia River dams.

4. UW (Report D): Examine and summarize information regarding alternative harvest techniques to determine their utility for harvesting northern squawfish in mainstem reservoirs of the Snake and Columbia rivers.

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

6. PSMFC (Report F): Process and provide accounting for reward payments and compensation payments to participants in the sport-reward and commercial longline fisheries, respectively.

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

Report A
Feasibility Investigation of a Commercial Longline Fishery for Northern Squawfish in the Columbia River Downstream from Bonneville Dam

1. A commercial longline fishery for northern squawfish was conducted in the Columbia River downstream from Bonneville Dam. The purpose of this test fishery was to improve gear effectiveness, to assess catch efficiency, and to evaluate the potential for a self-sustaining commercial longline fishery.

2. Commercial fishers used various longline, hook set, and bait types. The fishing season lasted from April 1 to August 14, 1992. A total of 1,755 longline sets were deployed and fished for a total of 2 1,997 hours. Commercial fishers caught a total of 6,035 fish.

3. Northern squawfish were caught at a rate of 36% (2,158 fish) or 0.1 northern squawfish per hour fished. Nearly all incidentally caught species were released alive. White sturgeon comprised 61% (3,660 fish) of the total catch.

4. Most longlines (1,015 lines, or 58%) were baited with fresh, frozen coho smolts and accounted for 70% (1,530 fish) of the total northern squawfish catch and 53 % (1,934 fish) of the white sturgeon catch.

5. When considering catch, effort, and cost collectively, we concluded that a commercial longline fishery was ineffective for harvesting large numbers of northern squawfish. It may, however, be useful for harvesting localized concentrations under special conditions.

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

1. Objectives for 1992 were to implement the sport-reward fishery for northern squawfish in the lower Snake and Columbia rivers, to conduct a survey to assess impacts of the fishery on non-target fish species, and to report on the inseason dynamics of the fishery.

2. The northern squawfish sport-reward fishery was conducted from May 18 through September 27, 1992. Twenty registration stations were located throughout the lower Snake and Columbia rivers. The area serviced by registration stations was increased by approximately 50% over that serviced in 1991, with the placement of five additional stations below Bonneville Dam.

3. A total of 186,904 northern squawfish 11 inches or longer were caught by 35,128 anglers, which represented 39.7% of the total number of registered anglers that participated in the fishery in 1992. Harvest of northern squawfish increased 15% over that observed in 1991 with an increase in participation of 24%. The catch per unit effort (CPUE) decreased 10.6% in comparison to 1991, yielding 2.11 fish per angler day in 1992.

4. Fork lengths of northern squawfish averaged 346 mm and 93% of those measured were over 250 mm (11 inches) total length.

5. A T-test indicated a statistically significant decrease in mean fork length of total northern squawfish catch from 1991 to 1992.

6. A total of 2,349 fish other than northern squawtish were returned to the registration sites comprising 1.24% of the total catch. Smallmouth bass, walleye, channel catfish, and peamouth comprised the majority of other fishes caught.

7. A portable computerized data collection station was tested during the last month of the season. Modifications to the software are in progress and evaluation will continue in 1993.

8. We recommend that the 1993 sport-reward fishery start in early May and extend through mid-September. Fish licenses should be required for residents of both Oregon and Washington. Regulations specific to the sport-reward fishery should be developed. Some registration stations should be relocated to areas where high predation index values indicate the potential for greater reduction of predator impacts on juvenile salmonid survival. Additional incentives and aggressive media coverage should be used to promote participation in the fishery. The use of computerized data collection stations should continue to be investigated.

Report C
Controlled Angling for Northern Squawfish at Selected Dams on the Columbia and Snake Rivers in 1992

1. Dam angling at eight dams on the lower Snake and Columbia rivers during 1992 resulted in 27,868 northern squawfish being caught during a 21-week season.

2. The total catch of northern squawfish in 1992 declined 30% from the 1991 catch. This was largely due to declines in catch at Snake River dams.

3. During 1992, incidental catch was roughly half of that observed in 1991. As in 1991, the majority of incidentally caught fish were taken at Snake River dams, with channel catfish comprising 79% of the incidentally caught fish. Salmonids comprised 1.41 % of the incidental catch and .08% of the total catch in 1992.

4. We recommend that angling at all eight dams be continued in 1993. Fishing effort will be shaped over time and location to increase harvest. A mobile crew will be used to augment resident crew efforts. We will continue to evaluate the contribution and feasibility of angling from boats in boat restricted zones at some dams. We will increase the use of controlled volunteer angling at high-catch dams. We will work with others to relocate bird wires to increase angler access and effectiveness. Biological sampling on incidentally caught channel catfish will be pursued at key dams.

Report D
Evaluation of Harvest Technology for Squawfish Control in Columbia River Reservoirs

1. We prepared a comprehensive report that summarizes information on harvest methods for squawfish removal. Each type of gear was evaluated with respect to squawfish catch rates, incidental catch rates, ease of deployment, and potential contribution to the overall northern squawfish management program. This report was presented to ODFW in October 1992 as a special issue paper and is available under separate cover from the University of Washington.

2. During 1992, the University of Washington developed and tested two methods for large-scale removal of northern squawfish on the Columbia River -- mobile floating trap nets and boat-based electrofishing. Additionally, potential restrictions and regulations for a large-scale floating trap net fishery were investigated.

3. Over 5,500 northern squawfish were captured during the 1992 season using a stationary Merwin trap. This accounted for 21.5% of the overall catch of all species. Salmonids comprised 3.63% of the total catch, a decrease of over 82.6% from 1991 catch levels, while northern squawfish catches increased by 31.9%.

4. The mean fork length of northern squawfish caught declined from 314 mm in 1991 to 295 mm. A 46% increase from 1991 in northern squawfish that were less that 250 mm long was due primarily to the large numbers of small squawfish captured during the month of August.

5. Mobile Merwin trapping occurred in a variety of locations throughout the Columbia River during the 1992 season. Mobile traps were fished a total of 79 days capturing 1,108 northern squawtish, comprising 21.2% of the total catch. Salmonids accounted for 14.3% of the total catch with nearly 75% of these fish caught in two sets near McNary Dam during the peak of the sockeye run.

6. Electrofishing on the Columbia and Snake rivers accounted for a total of 4,076 northern squawfish taken in 43.16 hours of unit on-time, yielding a CPUE of 94.44 northern squawfish per hour on-time. The overall CPUE for northern squawfish greater than 250 mm long was 18.9 northern squawfish per hour on-time.

Report E
Effectiveness of Predator Removal for Protecting Juvenile Fall Chinook Salmon Released from Bonneville Hatchery, 1992

1. Subyearling chinook salmon from Bonneville Hatchery released into the midstream Columbia River exhibited significantly higher survival rates than fish released into Tanner Creek at the hatchery. The difference in survival is in part related to predation by northern squawfish on fish released at the hatchery.

2. The predominance of coded-wire tags (CWTs) from Tanner Creek released juvenile salmon in digestive tracts of northern squawfish indicated that juvenile salmon released from the hatchery were more vulnerable to predation by northern squawfish located in the river region near Bonneville Hatchery than juveniles released midstream.

3. The survival difference between midstream Columbia River and Tanner Creek release groups appears to be inversely related to the movement rate of Tanner Creek release groups. Higher movement rates for fish were associated with high river flows and may also have been influenced by smoltification differences between years.

4. It was difficult to determine if the high numbers and catch rates of predators at the transects nearest Tanner Creek occurred in response to the hatchery release or to general high densities of northern .squawfish throughout the study area.

5. Electrofishing efforts to remove northern squawfish from the migration route of juvenile salmon released from Bonneville Hatchery did not significantly reduce the survival difference between midstream Columbia River and Tanner Creek release groups.

Report F
Northern Squawfish Sport Reward Payments

1. During 1992, a total of $537,066 was paid to anglers for 179,022 northern squawfish harvested in the sport-reward fishery. Also, $52,126.50 was paid as compensation to three individuals under contract to participate in the commercial longline fishery.

2. Payment activity for the sport-reward fishery was highest during June and July, accounting for about 74% of total dollars paid.

3. Vouchers that had missing or incomplete information were returned to anglers for completion, causing delay in payment. A total of 1,736 vouchers were returned.

4. There were several requests by various agencies to withhold payment on anglers suspected of wrongdoing. A total of 14 individuals had their payments withheld or delayed in accordance with these requests.

5. The commercial longline fishery was open for 14 weeks and PSMFC processed 144 vouchers totaling $52,126.50. Longliners were compensated $250 per day for a five-day work week or $3 12.50 for a four-day work week. Compensation for effort totaled $48,187.50 and reward payments for 1,313 ‘squawfish caught during the season totaled $3,939.

REPORT A

Feasibility Investigation of a Commercial Longline Fishery for Northern Squawfish in the Columbia River Downstream from Bonneville Dam

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1992 Annual Report

CONTENTS

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Matthew M. Marshall and John T. Skidmore, ODFW Columbia River Coordination Section, Commercial Longline project, assisted with overseeing field operations. Seven other seasonal employees monitored fishing activities, and recorded and summarized related data sets.

ABSTRACT

We are reporting progress on evaluating the feasibility of a commercial longline fishery for northern squawfish (*Ptychocheilus oregonensis*) in the Columbia River downstream from Bonneville Dam. The purpose of this test fishery is to improve gear effectiveness, to assess efficiency limitations, and to evaluate the probability of a self-sustained commercial longline fishery for northern squawfish in the lower Columbia River.

Pre-season fishing was conducted from April 1 to May 22 to (1) identify potential fishing locations with high northern squawfish abundance, (2) to determine early season susceptibility of northern squawfish to various longline gear configurations and bait types, and (3) to develop methods to reduce the incidental catch of white sturgeon (*Acipenser transmontanus*). The Oregon Department of Fish and Wildlife (ODFW) contracted with three commercial fishers to maximize catch rates for northern squawfish from May 18 to August 14. In addition, we evaluated the level of public interest in a longline fishery to be implemented in subsequent years for northern squawfish.

Contracted commercial fishers used various longline, hook set, and bait types. ODFW employees observed all fishing activities. From April 1 to August 14, a total of 1,755 longline sets were deployed and fished for 21,997 hours (soaking time). The total catch was 6,035 fish including 2,158 (36% of the catch) northern squawfish, or 0.1 northern squawfish per hour fished. Nearly all incidentally caught species were released alive. White sturgeon catch totaled 3,660 fish (61% of the total catch). Three adult and four juvenile salmonids were also caught. Most longlines (1,015 lines, or 58%) were baited with fresh, frozen coho smolts and accounted for 70% (1,530 fish) of the total northern squawfish catch and 53% (1,934 fish) of the white sturgeon catch.

INTRODUCTION

Water impoundments created by the development of the Columbia River Basin hydroelectric system delay downstream migration of juvenile salmonids and prolong their exposure to predators (Raymond 1988). Resulting habitat changes have enabled some resident, predaceous fish species, particularly northern squawfish (*Ptychocheilus oregonensis*), to increase in abundance (Beamesderfer and Rieman 1988). Predation is an important component of reservoir mortality in migrating juvenile salmonids, and could account for 80% of the reservoir losses (Rieman et al. 1988). Modeling results have suggested a potential 50% reduction in juvenile salmonid losses to predation when resident northern squawfish populations are exploited by sustained fisheries at a rate of 10-20% (Rieman and Beamesderfer 1990).

Previous predator control studies (Vigg and Burley 1989, Vigg et al. 1990) developed a stepwise process for systematic implementation and evaluation of various northern squawfish fisheries in the Columbia River Basin. Angling fisheries (sport-reward fishery and controlled angling at selected hydropower projects) were implemented. In 1989 the University of Washington evaluated longline gear for applicability to commercial harvest using small vessels and manual reels in the John Day Reservoir (Mathews et al. 1989). The use of monofilament groundlines, 3/0 hooks and salmonid smolts for bait was most effective. Catches averaged one northern squawfish per 12 baited hook sets. Total catch was comprised of 72% northern squawfish, 23 % white sturgeon and 5% other species. In 1990 a subsidized commercial, limited entry (three tribal vessels), longline test fishery was implemented in the John Day Reservoir (Vigg et al. 1990). Catches were lower than expected based on 1989 results and averaged one northern squawfish per 22.5 hook sets. Total catch was comprised of 73% northern squawfish, 15% white sturgeon and 12% other species.

Mathews and Iverson (1990) suggested that the effectiveness of longline gear as a predator removal method be tested when applied on a larger scale. Consequently, ODFW implemented a commercial longline fishery in three Columbia River reservoirs in 1991 (Mallette and Willis 1991). All members of the four treaty tribes were eligible for participation in the fishery; however, only four tribal crews fished with regularity (i.e., more than one week). We conducted a phone survey to determine reasons for low tribal participation. The survey revealed that unfamiliarity with locations of northern squawfish concentrations and unfamiliarity with longline gear resulted in low catch rates. Consequently, fishing trip expenses could not be covered by reimbursement of $4 per qualifying northern squawfish caught. Catches averaged one northern squawfish per 34.7 hook sets. Total catch was comprised of 66% northern squawfish, 22% white sturgeon and 12 % other species.

Due to very low tribal participation in the 1991 longline fishery, and resulting inadequate sample sizes, the effectiveness of a large scale, commercial longline fishery and its relative contribution to northern squawfish management program harvest could not be evaluated conclusively. Based on the 1991 results, we suggested additional subsidies to increase tribal interest and participation. In addition, we recommended to investigate the feasibility of a commercial longline fishery in the Columbia River downstream from Bonneville Dam. In 1992, this recommendation was addressed through the implementation of a limited entry (three vessels) test fishery.

METHODS

The Northern Squawfish Commercial Longline Fishery Investigation Project was implemented in the lower Columbia River from Multnomah Falls, River Mile (RM) 136, downstream to the west end of Puget Island, RM 38, We conducted pre-season fishing tests from April 1 to May 22 (Week 1 through Week 8) to (1) identify potential fishing locations with high northern squawfish abundance, (2) to determine early season susceptibility of northern squawfish to various configurations of longline gear, and (3) to develop methods to reduce the incidental catch of white sturgeon. The fishing season started on May 18 and lasted through August 14 (Week 8 through Week 20).

The ODFW crew fished from Week 1 through Week 17. We used a 1974 Clipper Craft 23-foot wooden dory (FV Grey Ghost) crewed by three ODFW seasonal employees. The crew used a manual reel with drag control and free spooling features, 250-pound test soft monofilament groundline with brass bead stops every three feet, ‘L-inch plastic gangion snaps, 12-inch gangion leaders with test strengths ranging from 6 to 30 pounds, 3/0 Eagle Claw nickel or bronze plated “up-eye” hooks, and numerous bait and lure types to target northern squawfish. During the pre-season, northern squawfish were marked with Floy spaghetti tags and the entire catch was released. The ODFW crew started to remove northern squawfish in Week 8 and continued to do so through the end of the fishing season.

We contacted the Columbia River Fishermen Protective Union in Astoria, Oregon, and the Northwest Gillnetters in Chinook, Washington, to solicit commercial fishers who could assist with harvesting northern squawfish at commercial rates using longline gear. We received a total of 37 responses from commercial fishers who expressed interest in the project. From these fishers, 22 applied (Appendix Figure A-l) for a total of three available personal services contracts. We graded all applications on a 42-point system (Appendix Figure A-2) and interviewed the 12 highest scoring applicants. We offered personal services contracts to the three highest scoring fishers, Wallace A. Nelson, Larry E. Ponn, and Brian Tarabochia.

These fishers and their crews joined the ODFW crew from May 18 to August 14 to maximize northern squawfish catch using longline gear. Fishing occurred Monday through Friday (except for holidays) for up to 40 hours per week. Contractors were required to (1) set and reset, (2) reset, or (3) reset and remove at least 7,200 feet of groundline and 720 baited hooks within an eight-hour period, or 9,000 feet of groundline and 900 baited hooks within a lo-hour period. Contractors used either 250-pound test soft monofilament groundline with brass bead stops every three feet and 2-inch plastic gangion snaps, or a combination of the monofilament groundline and 3/4-inch braided (halibut) groundline with steel wire gangion snaps. Also used were gangion leaders of 20-pound test strength and ranging from 9 inches to 24 inches in length, 3/0 Eagle Claw nickel or bronze plated "up-eye" hooks, and numerous bait and lure types.

The study area was initially divided into three regions to avoid competition for fishing areas among contractors. The area from the west end of Puget Island (RM 38) upstream to the east end of Cottonwood Island (RM 72) was defined as Region 1 and assigned to Tarabochia. He used a 1989 Modutech 32-foot fiberglass gillnet bow picker (FV OR 247 RZ). The area from the east end of Cottonwood Island (RM 72) upstream to the Interstate 5 (Vancouver) bridge (RM 107) was defined as Region 2 and assigned to Nelson. He used a 1978 Roberts 36-foot fiberglass gillnet/crab stern picker with power block (FV Casino). The area from the Interstate 5 (Vancouver) bridge (RM 107) upstream to Multnomah Falls (RM 136) was defined as Region 3 and assigned to Ponn. He used a 1988 Luhrz 30-foot gillnet bow picker (FV Gypsy). On July 20 all three regions were made equally available to the contracted fishers.

The contracted fishers fished from Week 8 through Week 20. An ODFW observer accompanied each crew during each trip. A fishing trip was defined as a calendar day, for a given vessel, during which longlines were set. Longlines were retrieved either on the same day they were set or on the following day.

The ODFW crew and observers recorded information regarding the longline sets in a logbook. Each logbook page (Appendix Figure B-l) contained information on one longline set including location, type of bait used, longline length, numbers of hooks, weights, and floats used, soaking time (the cumulative amount of time that the longline was in the water fishing), time spent working with the gear, and catch. In addition, daily information, including weather conditions, turbidity, water surface temperature, and fishing trip start and end times were recorded on an observation form (Appendix Figure B-2).

ODFW employees processed and released incidentally caught species quickly. Processing consisted of measuring the fork length, checking for tags, and assessing the physical condition of the fish. This information was recorded on a biological data form (Appendix Figure B-2).

At the end of each fishing trip, the fishers received a $3 voucher (Appendix Figure B-3) in exchange for each northern squawfish harvested that was at least 11 inches in total length. We transported the northern squawfish to local field stations and stored them in chest freezers until collection by Oregon State University personnel.

RESULTS

Effort

All fishing crews combined made a total of 216 fishing trips. The number of trips per boat remained fairly constant through the season, with totals for the season ranging from 52 trips by Tarabochia's crew to 57 trips by Ponn's crew. Table 1 lists the numbers of trips and related northern squawfish catch by week. The majority of the trips (148, or 68%) occurred from mid-May to mid-July.

The ODFW crew set a total of 300 longlines during 54 trips. Only one trip was made during the first and last weeks of fishing. The weekly average number of longlines set per trip ranged from three to 7.3, with an average for the season of 5.6 longlines per trip. An average of 55.2 hooks were set per longline, for a total of 16,551 hooks set during the season. Soaking time averaged 365.0 hours per week, with a season total of 6,205.3 hours.

Nelson set 445 lines with a total of 39,617 hooks during 53 trips, averaging 8.4 longlines per trip and 89 hooks per longline. Nelson's lines soaked for an average of 484.6 hours per week, for a season total of 6,299.9 hours. During 57 trips, Ponn set 405 longlines with a total of 49,776 hooks, averaging 7.1 longlines per trip and 122.9 hooks per longline. Ponn's lines soaked for an average of 384.5 hours per week, for a season total of 4,998.2 hours. During 52 trips, Tarabochia set 608 longlines with a total of 55,831 hooks, averaging 11.7 longlines per trip and 91.8 hooks per longline. Tarabochia's lines soaked for an average of 345.6 hours per week, for a season total of 4,493.3 hours. Appendix Figures D-1 through D-6 illustrate the number of trips, number of lines, number of hooks used, time spent setting gear, time spent retrieving gear, and soaking time, by week for each fisher.

The ODFW crew started longlining earlier in the season than the contracted fishers, and ended earlier. Therefore, the total fishing effort per week is variable. A very small proportion of the lines that were set by the four fishers (12 out of 1,767, or 0.7%) became snagged or lost, or were otherwise not retrievable.

The ODFW crew fished in all three regions of the study area, setting 11% (33 out of 300) of the longlines in Region 1, 37% (112 lines) in Region 2, and 52 % (155 lines) in Region 3. Nelson fished primarily in Region 2, setting 92% (411 out of 445) of the lines there, and the other 8% in Region 3. Ponn fished exclusively in Region 3, and Tarabochia set all but two lines (less than 1%) in Region 1.

Table 1. Number of trips and northern squawfish caught for all fishers combined, by week.

Week	Dates	Trips		Squawfish Caught	
		#	%	#	%
1	Mar 30 - Apr 03	1	<1	9	<1
2	Apr 06 - Apr 10	4	2	28	1
3	Apr 13 - Apr 17	4	2	31	1
4	Apr 20 - Apr 24	4	2	41	2
5	Apr 27 - May 01	4	2	41	2
6	May 04 - May 08	2	1	16	1
7	May 11 - May 15	2	1	11	1
8	May 18 - May 22	16	7	102	5
9	May 25 - May 29	14	6	117	5
10	Jun 01 - Jun 05	18	8	214	10
11	Jun 08 - Jun 12	17	8	153	7
12	Jun 15 - Jun 19	18	8	272	13
13	Jun 22 - Jun 26	17	8	137	6
14	Jun 29 - Jul 03	15	7	190	9
15	Jul 06 - Jul 10	16	7	296	14
16	Jul 13 - Jul 17	17	8	154	7
17	Jul 20 - Jul 24	12	6	82	4
18	Jul 27 - Jul 31	13	6	49	2
19	Aug 03 - Aug 07	11	5	84	4
20	Aug 10 - Aug 14	11	5	131	6
Total		216	100	2,158	100

Northern Squawfish Catch

During the 1992 northern squawfish longlining season, a total of 6,035 fish were caught. Northern squawfish comprised 36% (2,158 fish) of the total catch. This proportion is low compared to previous years. In 1991, northern squawfish comprised 66% of the total catch (Mallette and Willis 1991); in 1990, 73% (Mathews and Iverson 1990); and in 1989, 72% (Mathews et al. 1989).

The weekly northern squawfish catch reflects the number of fishing crews participating. Catch remained low through Week 7, increased in Week 8, stayed high through Week 16, and then dropped off through the end of the fishing season (Table 1). The majority (76%, or 1,635 fish) of the northern squawfish harvest occurred during Weeks 8 through 16, as did the majority of the effort (68% of the trips, 77% of the lines set, 69% of the hooks set, and 76 % of the soak time).

The numbers of northern squawfish caught, tagged, removed, and paid for are listed in Table 2 by fisher and type of groundline used.

Table 2. Numbers of northern squawfish caught, tagged, removed and paid for, by fisher and groundline type.

Fisher	Dates	Groundline Type[a]	# Caught	# Tagged	# Removed	# Paid
ODFW	03/30-07/31	M	409	164	230	NA
Nelson	05/18-06/12	B	185	NA	‘170	147
	06/15-08/14	M	557	NA	541	394
Ponn	05/18-06/19	B	147	NA	143	133
	06/22-08/14	M	190	NA	186	144
Taraboc.	05/18-08/14	M	670	NA	534	522
Total			2,158	NA	1,804	1,340

[a] B=braided, M=monofilament.

The ODFW crew caught 409 northern squawfish (19% of the total northern squawfish catch), averaging 24 northern squawfish per week of fishing. For the first part of the season, from April 2 to May 22, the majority (87%, or 164 out of 188) of the northern squawfish caught were tagged and then released. Starting in Week 9, all of the northern squawfish caught were kept, for a total of 230 (56% of the total ODFW catch) removed from the system.

Nelson's crew caught a total of 742 northern squawfish (34% of the total northern squawfish catch; Table 2.), averaging 57 per week. Partway through the season, on June 15, Nelson switched from using only braided groundline (Period 1: 4 weeks) to using monofilament groundline for some proportion of sets (Period 2: 9 weeks). During Period 1, Nelson caught 185 northern squawfish (25% of total Nelson catch), removed 170 (92% of the Nelson Period 1 catch, and received vouchers for 147 squawfish (79% of the Nelson Period 1 catch). For Period 1, Nelson's average catch was 46 northern squawfish per week; he removed an average of 42 per week and was paid for an average of 37 per week. During Period 2, Nelson caught 557 northern squawfish (75 % of total Nelson catch), removed 541 (97% of the Nelson Period 2 catch, and received vouchers for 394 squawfish (71% of the Nelson Period 2 catch). For Period 2, Nelson's average catch was 62 northern squawfish per week; he removed an average of 60 per week and was paid for an average of 44 per week.

Ponn's crew caught a total of 337 northern squawfish (16% of the total northern squawfish catch; Table 2), averaging 26 per week. Partway through the season, on June 22, Ponn switched from using only braided groundline (Period 1: 5 weeks) to using monofilament groundline for some proportion of sets (Period 2: 8 weeks). During Period 1, Ponn caught 147 northern squawfish (44% of total Ponn catch), removed 143 (97% of the Ponn Period 1 catch), and received vouchers for 133 squawfish (90% of the Ponn Period 1 catch). For Period 1, Ponn's average catch was 29 northern squawfish per week; he removed an average of 29 per week and was paid for an average of 27 per week. During Period 2, Ponn caught 190 northern squawfish (56% of total Ponn catch), removed 186 (98% of the Ponn Period 2 catch), and received vouchers for 144 squawfish (76% of the Ponn Period 2 catch). For Period 2, Ponn's average catch was 24 northern squawfish per week; he removed an average of 23 per week and was paid for an average of 18 per week.

Tarabochia's crew caught a total of 670 northern squawfish (3 1% of the total northern squawfish catch; Table 2), averaging 52 per week. Except for the first week of fishing, he used monofilament groundline exclusively. Tarabochia removed 534 (80%) squawfish and was paid for 522, 78% of the northern squawfish he caught. On average, Tarabochia removed 41 and was paid for 40 northern squawfish per week.

Incidental Catch

Table 3 illustrates the incidental catch of the 1992 northern squawfish commercial longline fishery. Most of the white sturgeon (2,179, or 60%) were caught in Weeks 8 through 12, the first five weeks of heaviest fishing effort. The average of 436 white sturgeon per week during this time period dropped to 236 white sturgeon per week for Weeks 13 through 16, although effort did not decrease significantly.

The majority of white sturgeon (3,416, or 93.3%) were released in good condition. Fifty-five white sturgeon (1.5%) were released in fair condition, 44 (1.2%) were in poor condition, and one was dead (Table 4).

Conditions of 144 white sturgeon (3.9%) were not recorded. Most of the white sturgeon (45%) that were in fair or poor condition, and the one dead, were caught in Week 8, the first week of fishing by the contracted boats.

The ODFW boat caught 3% of the total white sturgeon catch, averaging seven per week. Almost all (97%) of the white sturgeon caught by the ODFW boat were released in good condition.

During the first four weeks of fishing (using braided groundline exclusively), Nelson caught 24% of the total white sturgeon catch. The average per week for this period was 217 white sturgeon. Most (89%) were released in good condition, although 2% were in poor condition and one fish was dead (the conditions for 9% were not recorded). During the rest of the fishing season (using monofilament groundline to some degree), Nelson caught 35% of the total white sturgeon catch, averaging 142 fish per week. All of the white sturgeon for which conditions were recorded were released in good condition.

During the first five weeks of fishing (using braided groundline), Ponn's crew caught 26% of the total white sturgeon catch. The average per week was 188 white sturgeon. Most (93%) were released in good condition, although 5% were released as fair, and 2% as poor. During the rest of the fishing season (using monofilament groundline to some degree), Ponn caught 10% of the total white sturgeon catch, averaging 47 per week. Most (96%) were released in good condition, 2% in fair condition, and 1% in poor condition.

Tarabochia caught 2% of the total white sturgeon catch, averaging six per week. All of the white sturgeon caught by Tarabochia were released in good condition.

Fork lengths were measured for 3,636 (99%) of the white sturgeon caught. Almost 80% (2,868 fish) were in the range of 401-600 mm. Only one white sturgeon was less than 200 mm, and only two were greater than 900 mm in fork length. Condition at release does not appear to vary with length (Appendix Figure D-7).

Table 3. Incidental catch and percent of total catch by species.

Species	# Fish Caught	Percent of Total Catch
Sturgeon	3,660	60.6
Sculpin	50	0.8
Peamouth	48	0.8
Catfish	37	0.6
Sucker	37	0.6
Carp	15	0.2
Shad	6	0.1
Bullhead	5	0.1
Flounder	5	0.1
Salmon Smolt	4	0.1
Chiselmouth	3	<0.1
Yellow Perch	3	<0.1
Chinook	2	<0.1
Bass	1	<0.1
Steelhead	1	<0.1
Total	3,877	64.2

Table 4. Number of white sturgeon caught and condition at release, by fisher and groundline type.

Fisher	Dates	Groundline Type[a]	# Caught	# Good	# Fair	# Poor	# Dead
ODFW	03/30-07/31	M	121	118	2	1	0
Nelson	05/18-06/12	B	868[b]	772	0	20	1
	06/15-08/14	M	1,276'	1,207	0	0	0
Ponn	05/18-06/19	B	942	879	45	18	0
	06/22-08/14	M	374	361	8	5	0
Tarabochia	05/18-08/14	M	79	79	0	0	0
Total			3,660	3,416	55	44	1

[a] B=braided, M=monofilament.
[b] The disposition at release of 75 of these sturgeon is unknown.
[c] The disposition at release of 69 of these sturgeon is unknown.

For incidental species other than sturgeon, average catch per week by fisher ranged from 1.6 fish to 11.5 fish. The ODFW boat caught 14% of the total non-sturgeon incidental catch, averaging 1.8 fish per week. Nelson caught 37%, averaging 11.5 fish per week in Period 1, and 3.9 fish per week in Period 2. Ponn caught 39 % , averaging 11 fish per week in Period 1, and 3.6 fish per week in Period 2. Tarabochia had the smallest non-sturgeon incidental catch, with 10% of the total and an average of 1.6 fish per week. Of all the non-sturgeon incidental catch, 75% were released in good condition.

Catch per Unit of Effort

Northern Squawfish

Catch per unit effort (CPUE) was lower in the 1992 season than in 1991 or 1990. For the 1992 season, the overall catch rate was 0.098 northern squawfish per hour, compared to 0.124 fish per hour in 1991 (Mallette and Willis 1991). In the 1992 season, an average of 74.9 hooks were set to catch one northern squawfish, compared to 34.6 hook sets per northern squawfish in 1991 (Mallette and Willis 1991) and 22.5 hook sets per northern squawfish in 1990 (Mathews and Iverson 1990). The average number of northern squawfish caught on each line in 1992 was 1.23 fish.

The northern squawfish catch rate for the ODFW crew was 0.066 fish per hour. The ODFW crew caught an average of 1.36 northern squawfish per line, and set an average of 41 hooks per fish.

The northern squawfish catch rate for Nelson during Period 1 (using braided groundline) was 0.110 fish per hour. Nelson caught an average of 2.01 northern squawfish per line, and set 68 hooks per fish. During Period 2 (using monofilament groundline to some degree), Nelson's catch rate was 0.12 1. He caught an average of 1.58 fish per line, and set an average of 48 hooks per fish.

The northern squawfish catch rate for Ponn during Period 1 (using braided groundline) was 0.054 fish per hour. Ponn caught an average of 1.03 northern squawfish per line and set 122 hooks per fish. During Period 2 (using monofilament groundline to some degree), Ponn's catch rate was 0.082. He caught an average of 0.73 fish per line and set an average of 167 hooks per fish.

The northern squawfish catch rate for Tarabochia was 0.149 fish per hour. Tarabochia caught an average of 1.11 northern squawfish per line, and set an average of 83 hooks per fish.

Incidental Catch

The overall catch rate for white sturgeon was 0.814 fish per hour. The average number of white sturgeon caught on each line was 2.09 fish; an average of 44 hooks were set to catch each white sturgeon.

The white sturgeon catch rate for the ODFW crew was 0.019 fish per hour. The ODFW crew caught an average of 0.40 white sturgeon per line and set an average of 137 hooks per fish.

The white sturgeon catch rate for Nelson during Period 1 was 0.514 fish per hour. Nelson caught an average of 9.45 white sturgeon per line and set 15 hooks per fish. During Period 2, Nelson's catch rate was 0.277. He caught an average of 3.61 fish per line and set an average of 21 hooks per fish.

The white sturgeon catch rate for Ponn during Period 1 was 0.351 fish per hour. Ponn caught an average of 6.59 white sturgeon per line and set 19 hooks per fish. During Period 2, Ponn's catch rate was 0.161. He caught an average of 1.43 fish per line and set an average of 85 hooks per fish.

The white sturgeon catch rate for Tarabochia was 0.018 fish per hour. Tarabochia caught an average of 0.13 white sturgeon per line and set an average of 706 hooks per fish.

Gear Deployment and Evaluation

Information on the type of longline (monofilament or braided), longline length, gangion leader length, hook spacing, use of floats and weights, position of line relative to the shore, distance of the line from the shore, and water depth was collected for the majority of longlines that were set. In addition, types of baits used were recorded.

Two types of groundline were used, braided and monofilament. Two of the fishers (ODFW and Tarabochia) used monofilament line for the entire season; two (Nelson and Ponn) used braided for the first part of the season and then began using monofilament line for some proportion of the sets in the second part of the season. Overall, 52 % (905 out of 1,755) of the lines set had monofilament groundline, 13% (235 out of 1,755) had braided groundline, and the remaining 35% (615 out of 1,755) of the sets had some proportion of monofilament groundline.

Of the braided lines that were set, 99% (232 out of 235) were horizontal in the water and parallel to the shoreline. The longlines were set from 8-300 yards from the shore, with most of them (61%, 143 out of 233) between 25 yards and 74 yards from the shore. Most of the lines (65%, 152 out of 234) were set in water 10-19 feet deep. The majority of the lines (66%, 155 out of 235) were 1,200 feet long, although lengths varied from 200-4,200 feet. Groundlines were unbranched. The gangion leader length ranged from 10-24 inches, with 10 inches being the most frequent length (60%, 142 out of 235). Hook sets were placed from 8-20 feet apart, primarily at 10 feet apart (62%, 147 out of 235). None of the longline sets employed weights, although 76% (175 out of 229) did use floats spaced along the line to achieve buoyancy. For these lines, float spacing ranged from 50-750 feet. For 51% of the lines (89 out of 175), the float spacing was from 200-299 feet; for an additional 35% (62 out of 175), spacing was between 100 and 199 feet.

Of the longline sets that used monofilament groundline in some proportion, 77% (1,149 out of 1,496) were set horizontal in the water and parallel to the shoreline, and 22% (330 out of 1,496) were set "vertical" in the water column (with one end anchored and the other end floating, also called "Portuguese" longlines). Longlines were set 4-200 yards from the shore, with 47% (710 out of 1,509) between 25 and 49 yards. Most of the lines (60%, 913 out of 1,5 15) were set in water that was 10-19 feet deep, although water depth ranged 6-70 feet. The horizontal lines ranged 250-7,200 feet in length, with 25% (298 out of 1,183) at 600 feet, 22 % (259 out of 1,183) at 1,200 feet, 18 % (2 19 out of 1,183) at 250 feet, and 17% (199 out of 1,183) at 1,800 feet. The vertical lines ranged 20-40 feet, with the majority (88%) at 40 feet. All of the lines were unbranched.

The length of the gangion leaders ranged 9-24 inches, with 39% (585 out of 1,488) at 12 inches and 23% (348 out of 1,488) at 20 inches. On the horizontal lines, the hook sets were spaced 7-20 feet apart. The majority of the horizontal lines had hook sets spaced 10 feet (35 %; 413 out of 1,183) and 11 feet (32%; 380 out of 1,183) apart. On the vertical lines, the hook sets were placed l-4 feet apart, with the majority (56%; 188 out of 333) at 2 feet apart. Only a few of the horizontal longlines (96 out of 1,178, or 8%) had weights in addition to the anchors, and none of the vertical longlines did. Most of the horizontal lines (75 %, 865 out of 1,158) employed floats to achieve buoyancy. The number of floats used ranged from l-23 per line. The most frequent spacing between floats was from 100-199 feet (47%, or 409 out of 865), and an additional 32% of the lines (281 out of 865) had floats spaced 200-299 feet apart. All of the vertical lines employed at least one float, and 13% (44 out of 337) employed more than one.

The ODFW crew tested different types of hook sets. The contracted fishers consistently used 20-pound test line for gangion leaders, while ODFW used 6-, 10-, 20-, and 30-pound test (Appendix Figure D-8). The ODFW boat also set a very small proportion of lines using hose gear and suspension gear. The term "hose gear" is used to describe a hook set that has a gangion leader of minimal test strength (6 pounds in this case) encased within a piece of surgical tubing. The surgical tubing prevents the gangion leader from coiling and snagging. "Suspension gear" incorporates a piece of surgical tubing between the snap and the gangion leader, allowing for more flexibility than in the standard hook set (where the gangion leader is attached directly to the snap).

There is no apparent association between the gangion leader length and the number of northern squawfish or white sturgeon caught (Appendix Table C-l).

All of the longliners used a variety of baits. The ODFW boat used primarily steelhead chunks (62%, or 186 out of 300, of the line sets), but also tried coho (fresh and salted), worms and lures (Appendix Figure D-9). Fifty-six percent (229 out of 409) of the northern squawfish catch and 65% (79 out of 121) of the white sturgeon were caught using steelhead chunks for bait (Appendix Table C-2). Fresh coho smolts were used on 24 % (73 out of 300) of the line sets, catching 34% (139 out of 409) of the northern squawfish and 20% (24 out of 121) of the white sturgeon (Appendix Table C-2).

For all of the fishers combined, 58% of the lines (1,015 out of 1,755) were baited with fresh coho smolts or a combination of bait types including fresh coho smolts (Appendix Table C-3). These lines accounted for 70% of the total northern squawfish catch (1,530 out of 2,158) and 53 % of the white sturgeon catch (1,934 out of 3,660). Worms were used on 16% of the lines (28 1 out of 1,755), accounting for 5 % of the total northern squawfish catch (99 out of 2,158) and 4% of the total white sturgeon catch (151 out of 3,660). Steelhead chunks were used on 11% of the lines (196 out of 1,755), accounting for 12% of the total northern squawfish catch (255 out of 2,158) and 4% of the total white sturgeon catch (153 out of 3,660).

Weather and River Conditions

Weather, wind and river conditions were recorded for each fishing trip during the 1992 season (for this analysis, a "trip" is defined as a fishing day, for a given fisher, during which lines were pulled). Appendix Table C-4 summarizes the proportions of different conditions within these three categories. Since a trip may have been described by more than one type within a category (i.e., the weather may have been sunny for part of the trip and overcast for part of the trip), the proportions do not sum to 100%. The data indicate that most trips were made on sunny days, when the river was smooth and the wind was from the northwest or the southwest.

The ODFW crew recorded daily readings of water surface temperature. The weekly mean water surface temperature rose fairly steadily through the fishing season, from a low of 49” Fahrenheit in the second week of the season, to a high of 71” F in the 18th week (Appendix Figure D-10; temperature readings were not available for Weeks 17, 19 and 20). All four participating fishers measured turbidity once or twice each trip. The weekly mean turbidity ranged from approximately 125 cm to slightly more than 275 cm (Appendix Figure D-l 1).

DISCUSSION

Catch and Effort

Participating commercial fishers complied with contract conditions and cooperated at satisfactory levels. In general, effort obligations were exceeded by the contracted fishers, who were motivated by the monetary incentive offered per qualifying northern squawfish harvested. The overall number of northern squawfish that were removed from the system by the 1992 Commercial Longline Fishery Investigation Project was higher than the northern squawfish catch of previous longline fishery implementations (Vigg et al. 1990, Mallette and Willis 1991). However, catch per unit of effort (CPUE) was disappointingly low in 1992, as was the percentage of northern squawfish in the total catch. The average northern squawfish catch rate for all participating fishing crews and for all longline gear types and hook set assemblies used was lower than catch rates that were achieved in previous longline fisheries. Several reasons may have contributed to the low catch rate, as discussed in the following paragraphs.

The ODFW crew sought to improve longline gear effectiveness by testing numerous hook set assemblies, gangion leader lengths and test strengths, and bait types. Due to the experimental nature of this assignment, resulting northern squawfish catch and effort rates were expectedly lower than catch and effort rates for contracted commercial fishers and lower than catch rates achieved in previously conducted fisheries.

In mid-July, the ODFW vessel developed a leak in the hull. Necessary repairs, related dry dock time, and the unavailability of an alternative vessel prevented the crew from expending fishing effort and from conducting further meaningful gear tests through the last four weeks of the fishing season.

In addition to using the recommended 250-pound test monofilament groundline, two of the contracted commercial fishers deployed braided (halibut) groundline to some proportion. Monofilament groundline is best retrieved manually; braided groundline, on the other hand, is easily retrievable with commercial, hydraulic reel systems. Use of braided groundline resulted in significantly increased bycatch of white sturgeon and reduced catch rates for northern squawfish.

The availability of the most effective bait type (fresh, flash frozen salmonid smolts) was limited, especially during Weeks 8 to 12, the first month of maximized fishing effort. Although a total of 106 federal, state, and private fish culturists in Oregon and Washington were contacted several months prior to the start of the fishery, only two orders for relatively small quantities of adequately sized coho smolts could be placed. The availability of this bait type depends on the timely coordination of project needs with interested fish culturists no later than the preceding fall season. At that time hatchery managers identify production needs for the subsequent year. Without having specific orders for smolt bait in place, fish culturists are understandably hesitant to purchase large quantities of eyed eggs. The managers' decisions are especially critical if spatial accommodations of the hatchery facilities are limited; the option of rearing surplus fish beyond bait size to facilitate alternative end uses is not provided. Upon the start of the 1992 longline season, it was apparent that fishers would have to utilize secondary bait types, since the quantities of ordered coho smolts, delivery dates, and the volume of otherwise obtained salmonid bait (hatchery donations, surplus of cured smolts from previous longline fisheries, etc.) would only cover a fraction of the projected bait need for the 1992 longline fishery investigation.

The very high incidental catch of small sized white sturgeon constitutes the most limiting, single factor to a successful commercial longline fishery for northern squawfish in the Columbia River below Bonneville Dam. In addition to a higher susceptibility of white sturgeon to the gear type used, as opposed to other resident fish species, white sturgeon of these smaller size classes are distinctly more abundant in the study area than in other Columbia River reaches (Devore et al. 1992). Furthermore, low gear efficiency may be magnified by the considerable amount of time that fishing crews spent to (1) assess relative gear impact on, and physical condition of, incidentally caught white sturgeon, and to (2) release the captured specimens appropriately.

Gear Deployment and Evaluation

The contracted fishers were encouraged to test commercial (braided) longline gear and compare its effectiveness to the recommended monofilament groundline. Although fishing effort could have been maximized to a higher degree by using braided groundline, the related catch composition, comprised primarily of white sturgeon, was undesirable. It has not been determined whether the catch composition was solely a result of the type of groundline used or the type of bait used (smelt, worms, etc.) or a combination of both. However, unacceptably high bycatch rates for white sturgeon did not occur in catches of fishers who used monofilament groundline exclusively. Therefore, it appeared that the type of groundline used had a more significant impact on catch composition than the type of bait used. One possible explanation for the experienced low northern squawfish and high white sturgeon catch rates associated with braided groundline deployment might be that this groundline type is highly visible, even under marginal water clarity conditions. Northern squawfish have been described as visual feeders (Eggers et al. 1978). Therefore, foraging northern squawfish could easily detect and avoid this type of groundline regardless of the type of bait used. Consequently, available baited hooks attract more of the other resident fish, and in particular white sturgeon, who probably locate food by olfaction rather than vision (Brannon et al. 1987).

Comparisons between the two groundline types used and between related catch rates for northern squawfish and white sturgeon suggest that deployment of monofilament groundline generally yields comparable or higher northern squawfish catch and significantly lower incidental bycatch of white sturgeon. However, the decline in bycatch rates for white sturgeon that occurred as the season progressed may equally be a result of fishers' increasing levels of experience in avoiding white sturgeon by (1) adjusting the position of the groundline relative to the water column (lines were set to achieve buoyancy at a minimum of six feet off the river substrate), and (2) avoiding sites with known high abundance of white sturgeon, as well as increasing availability of preferred bait types.

The use of 40-foot long monofilament, Portuguese longline sets yielded desirable catch compositions in terms of depressed white sturgeon bycatch and elevated northern squawfish catch. The floating end of the groundline appears to provide additional movement to the hook set assemblies, which attracts northern squawfish, while bottom fish are less susceptible to this groundline type. However, deployment is more labor intensive and not as uniformly applicable to varying river conditions as groundlines that are set horizontally.

Analyses of hook set assembly test results suggest that the most efficient hook set assembly, with regard to highest catch rates for northern squawfish and minimal bycatch of white sturgeon, consists of 20-pound test gangion leader, spaced approximately 10 feet apart on monofilament groundline, and 3/0 eagle claw hooks baited with whole, fresh frozen, coho smolts that are 8-10 cm in total length.

The ODFW crew attempted to minimize the incidental bycatch of white sturgeon by testing the effectiveness of gangion leaders of less than 30-pound test strength (30-pound test leaders were used in previous northern squawfish longline fisheries). Gangion leaders of 10-pound test and less tended to coil around the groundline, resulting in additional labor expended in setting and retrieving longlines, and generally lower catch rates. Use of 20-pound test leaders, however, yielded comparable northern squawfish catch rates with a lesser likelihood of capturing white sturgeon (of 50-80 cm in total length) compared to catch rates that were achieved by using leaders of 30-pound test strength.

Various types of salmonid bait were made available to the longline fishers. Most effective were whole smolts of 8-10 cm in total length that were starved for three to five days prior to processing. Bait quality was preserved best by instant, postmortem flash freezing and packaging in small batches of not more than five pounds each. Bait processed in this fashion maintained its quality grade beyond thawing, however, the consistency of this bait type was fairly soft, resulting in losses from the hook set assemblies after prolonged exposure to regular river conditions. The effectiveness of bait types that did not comply with the above bait specifications decreased with the increasing number of bait and processing criteria that were not met. However, longlines that employed hook set assemblies with scented or unscented, white or fluorescent green lures alternating with high quality salmonid bait demonstrated comparable, high efficiency attributes.

CONCLUSIONS AND RECOMMENDATIONS

Deployment of longline gear could be effective in removing population concentrations of northern squawfish if the following gear and deployment specifications are met:

1. Selection of fishing locations should primarily depend on criteria regarding the avoidance of white sturgeon bycatch.
2. Monofilament, 250-pound test strength groundline should be deployed manually, and set vertical (Portuguese style) or horizontal to the water column.
3. Hook sets should be fished a minimum of six feet off the river substrate.
4. Hook set assemblies should consist of 20-pound test strength gangion leaders with 3/0 eagle claw hooks baited with fresh, starved, flash frozen salmonid smolts of 8-10 cm in total length; baited hook sets could be alternated with lures.

Although northern squawfish abundance is relatively high in the lower, free-flowing reach of the Columbia River compared to the impounded reaches above Bonneville Dam, large northern squawfish aggregations could not be identified. Therefore, longline fishing effort could not be focused on localized concentrations. Furthermore, capture and handling of abundant, small white sturgeon was cumbersome and time-consuming. Use of automated fishing techniques could yield economic harvest of northern squawfish in commercially valuable quantities. However, the most effective longline gear is too light to be set and retrieved hydraulically. Consequently, a self-sustaining commercial fishery with a monetary remuneration of fishing effort that is solely based on qualifying northern squawfish catch, is not feasible in the study area. Manually deployed longline gear could possibly be effective in removing localized northern squawfish population concentrations where they exist (i.e., in boat restricted areas of hydropower projects).

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APPENDIX A

Selection of Fishers

ODF&W

Northern Squawfish Management Program

Commercial Longline Test Fishery

Fishers Application Form

Your Name	Address
Daytime Phone #	

Boat Name	Are You the Boat Owner?
Type of Boat	# Years Fishina Experience
Model and Make	# Years Longline Experience
Length	What Fish Species?
Engine (hp)	
Type of Reel	Where?
Size of Fishlocker	
Other Fish Handling Facilities?	
	Crew Size

Preferred Fishing Areas

Are You Able To Fish Other Areas?

Are you interested in serving on a fishery design/oversight committee?

Date:

Signature:

Appendix Figure A-l. Commercial Fisher Application Form.

COMMERCIAL FISHER GRADING FORM

FISHER Name:
VESSEL Name:

CATEGORY	DESCRIPT.	POINTS	MAX. POINTS	CATEGORY	DESCRIPT.	POINTS	MAX. POINTS
VESSEL Type	Nonaccept.	0		OTHER Fac.			
	Accept.	1	1	Trailer	No	0	
Length	<20ft.	0			Yes	1	1
	20-30ft.	1		Subst. V.	None	0	
	>30ft.	2	2		Suit.Poor	0	
Engine	< 200hp.	0			Suit.Fair	1	
	< 300hp.	1			Suit.Good	2	2
	> 300hp.	2	2		Needs Reloc.	1	
Gen.Cond.	Poor	0			Needs Gear	1	
	Fair	1			Is Ready	2	2
	Good	2		EXPERIENCE			
	Excellent	3	3	Comm.	<4 years	0	
Safety	Poor	0			<9 years	1	
	Fair	1			>9 years	2	2
	Good	2		Col.Riv.	<4 years	0	
	Excellent	3	3		< 9 years	1	
Obs.Space	Poor	0			>9 years	2	2
	Fair	1		Longline	< 1 year	0	
	Good	2			< 5 years	1	
	Excellent	3	3		> 5 years	2	2
FACILITIES				LL Sturg.	No	0	
Reel	Non-Hydraul	0			Yes	1	1
	Hydraulic	1		REFERENCE			
	Single	0		ODFW	Poor	-1	
	Sing./Div.	1			No Op.	0	
	Twin	1			Good	1	
	Dual	2	2		Very Good	2	2
Fishlocker	<1000lbs.	0		Pers.Ref. 1	Poor	-1	
	< 2000lbs.	1			No Op.	0	
	> 2000lbs.	2	2		Good	1	
	No Insulat.	0			Very Good	2	2
	Insulation	1	1	Pers.Ref.2	Poor	-1	
Live Tank	No	0			No Op.	0	
	Yes	1	1		Good	1	
Hyd.Fi.pick.	No	0			Very Good	2	2
	Yes	1	1	LOCATION	Washington	0	
Roller	No	0			Oregon	0	
	Yes	1	1		Upper Riv.	0	
Davit/					Mid River	0	
Snatchblock	No	0			Lower Riv.	0	0
	Yes	1	1				
Powerblock	No	0					
	Yes	1	1	TOTAL			42

COMMENTS:

Appendix Figure A-2. Commercial Fisher Grading Form.

APPENDIX B

Data and Voucher Forms

Fisherman's Name:	**Long-line no. :**
Fisherman's ID no.:	**Location:**
Distance to nearest shore point [yards]:	
Line length [feet]:	**No. of hooks:**
Line depth [feet] min - max:	**Bait type:**

	Line set			**Line pulled**		
Date YY/MM/DD						
Gear work start		am	pm		am	pm
Gear work stop		am	pm		am	pm

ODFW Verification

Location ID:

Comments:

Clerk No.:

Species	**# caught**	**# lost**	**# kept**	# released and condition was good	poor	dead
Squawfish						
Sturgeon						
Catfish						
Bass						
Walleye						
SalmonEteelhead						
Other (specify)						

Fisherman's comments:

Appendix Figure B-1. Logbook Data Form.

1992 NSQF LONGLINE OBSERVATION FORM

Page of _

Fisherman's Name		Date(YY/MM/DD)	
Fisherman's ID no.		Boat Name	
_aunch Site		Start Time (military)	
Fishing Location	ID #	Stop Time (military)	
Distance to nearest shore point (yrds)		Time on Water (min)	

Weather/Wind:	☐N ☐NE	River:	Comments
☐Sun	☐S ☐NW	☐ Smooth	
☐ Overcast	☐E ☐SE	☐ Swells < 2"	
☐ Rain	☐ W OSW	☐ Swells > 2"	
☐ Fog	Temp. (F)	Turb.(cm)	

How many hooks were empty? ☐ < 30% ☐ < 50% ☐ > 50%

INCIDENTAL CATCH

Fish no	Species	Fork lgth. (mm)	Disp.	Tag No.	Color	Mark	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
0							

Observer's Comments

Appendix Figure B-2. Observation and Incidental Catch Form.

OREGON DEPT. OF FISH AND WILDLIFE

PACIFIC STATES MARINE FISHERIES COMMISSION

1992 NSQF LONGLINE VOUCHER

Date: ____________________

Fisherman's Name: ____

Last First Middle

Fisherman's ID No.: _______________

No. of NSQF: _______________ Amount $_______________

____________________________________ ____________________________________

Fisherman ODFW Clerk

Appendix Figure B-3. Voucher Form.

APPENDIX C

Result Tables

Appendix Table C-1. Gangion leader lengths and associated northern squawfish and white sturgeon catch.

Gangion Leader Length (in)	Longline Sets		Squawfish Catch		Sturgeon Catch	
	#	%	#	%	#	%
9	1	<1	0	0	1	<1
10	335	19	309	14	1,253	34
12	601	34	865	40	188	5
14	2	<1	2	<1	13	<1
15	280	16	133	6	11	<1
18	4	<1	4	<1	22	1
20	438	25	734	34	2,109	58
24	2	<1	2	<1	0	0
Unknown	92	5	109	5	63	2
Total	1,755	100	2,158	100	3,660	100

Appendix Table C-2. Bait types used on longlines set by the ODFW crew, and associated northern squawfish and white sturgeon catch

Bait	Longline Sets #	Longline Sets %	Squawfish Catch #	Squawfish Catch %	Sturgeon Catch #	Sturgeon Catch %
Steelhead Smolts	186	62	229	56	79	66
Fresh Coho Smolts-SF1[a]	67	22	137	33	23	19
Mixed-Smolts and Lures[b]	27	9	34	8	3	2
Fresh Coho Smolts-SF2[c]	6	2	2	<1	1	1
Mixed-Smolts[d]	5	2	7	2	6	5
Worms	5	2	0	0	9	7
Mixed-Lures'	3	1	0	0	0	0
Salted Coho Smolts	1	<1	0	0	0	0
Total	300	100	400	100	121	100

[a] From Sea Fresh Co.; used from May 19 through July 15.
[b] More than one type of bait, including smolts and lures.
[c] From Sea Fresh Co.; used after July 15.
[d] More than one type of bait, including smolts.
[e] More than one type of bait, including lures.

Appendix Table C-3. Bait types used on longlines set by all fishers combined, and associated northern squawfish and white sturgeon catch.

Bait	Longline Sets #	Longline Sets %	Squawfish Catch #	Squawfish Catch 8	Sturgeon Catch #	Sturgeon Catch %
Fresh Coho Smolts-SF1[a]	449	25	671	31	741	20
Worms	281	16	99	5	151	4
Steelhead Smolts	196	11	255	12	153	4
Fresh Coho Smolts-SF2[b]	192	11	242	11	189	5
Mixed-Smolts[c]	168	10	238	11	526	14
Other[d]	129	7	95	4	647	18
Fresh Coho Smolts-FP[e]	126	7	262	12	281	8
Mixed-Smolts and Lures'	80	5	117	5	197	5
Mixed	59	3	69	3	510	14
Salted Coho Smolts	49	3	79	4	176	5
Mixed-Lure+	16	1	15	1	44	1
Lures	1	<1	0	0	1	Cl
Unknown	9	1	16	1	44	1
Total	1,755	100	2,158	100	3,660	100

[a] From Sea Fresh Co.; used from May 19 through July 15.
[b] From Sea Fresh Co.; used after July 15.
[c] More than one type of bait, including smolts.
[d] Anchovies, apples, marshmallows, potatoes, sand shrimp, shrimp, smelt, and squid.
[e] From Fish Pro Co.
[f] More than one type of bait, including smolts and lures.
[g] More than one type of bait, including lures.

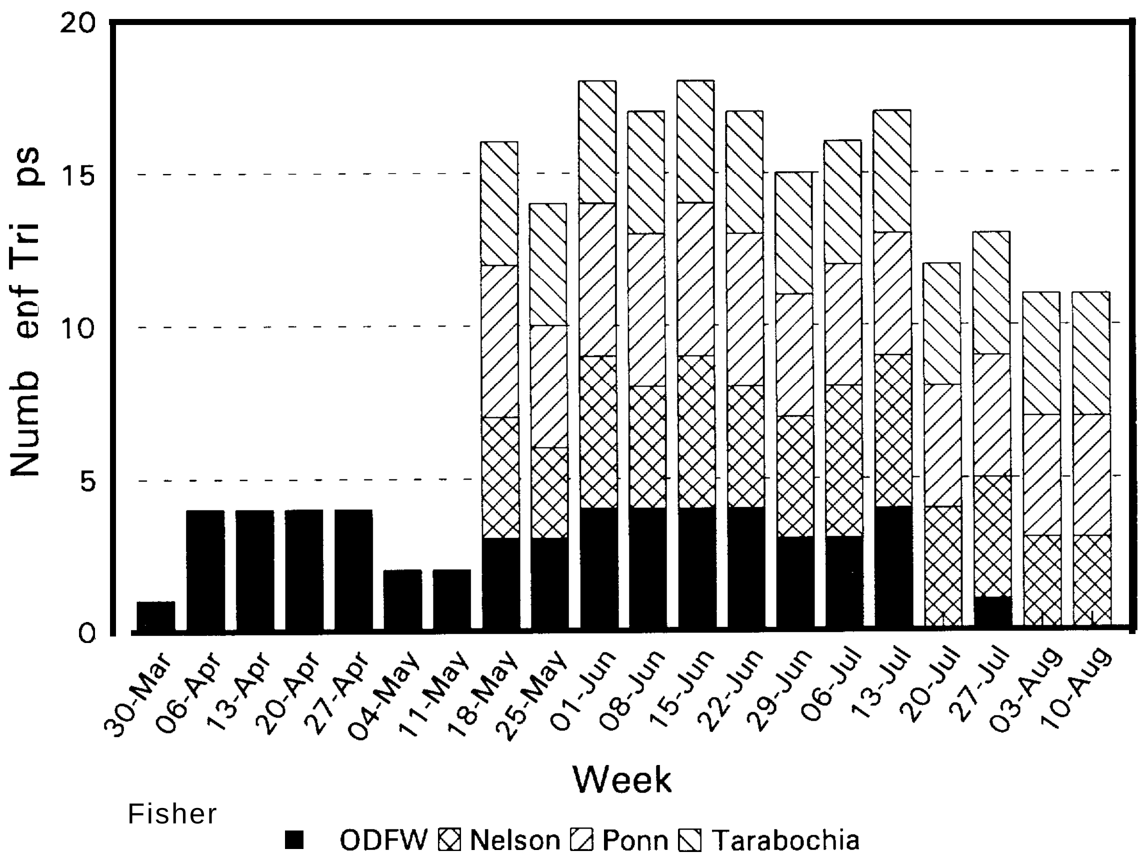
Appendix Table C-4. Categorized weather and river conditions by percent of total fishing trips[a].

Weather				Wind							River		
											Smooth	Swells	
Sun	Over-cast	Rain	Fog	NW	SW	N	S	NE	SE	W		<2ft	≥2ft
60	47	7	1	30	29	0	1	14	7	16	56	46	2

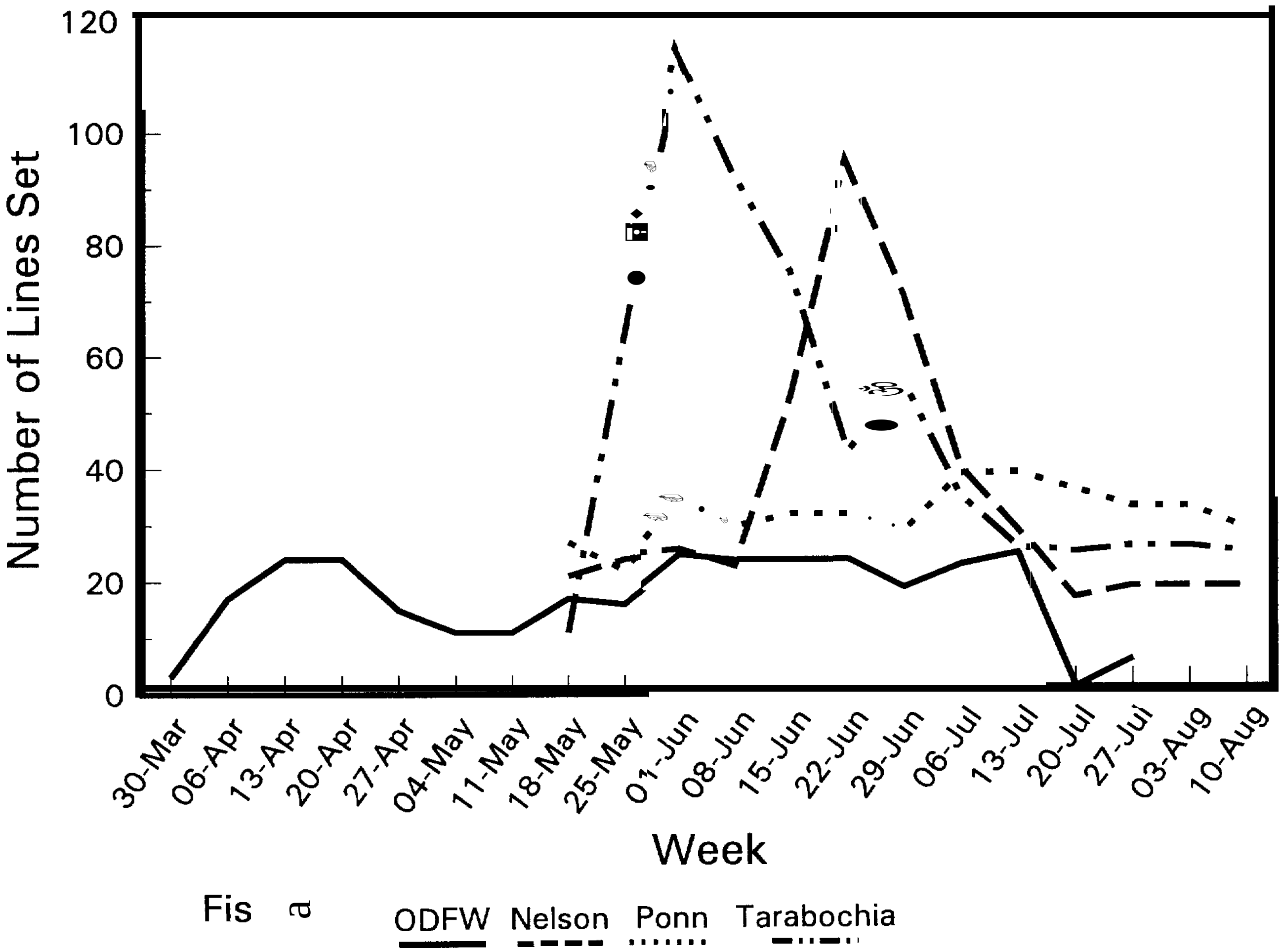
[a] The total percent for each category is greater than 100%, since more than one condition for a category was sometimes recorded on a given trip (i.e., weather during a trip may have been described as both sunny and overcast).

APPENDIX D

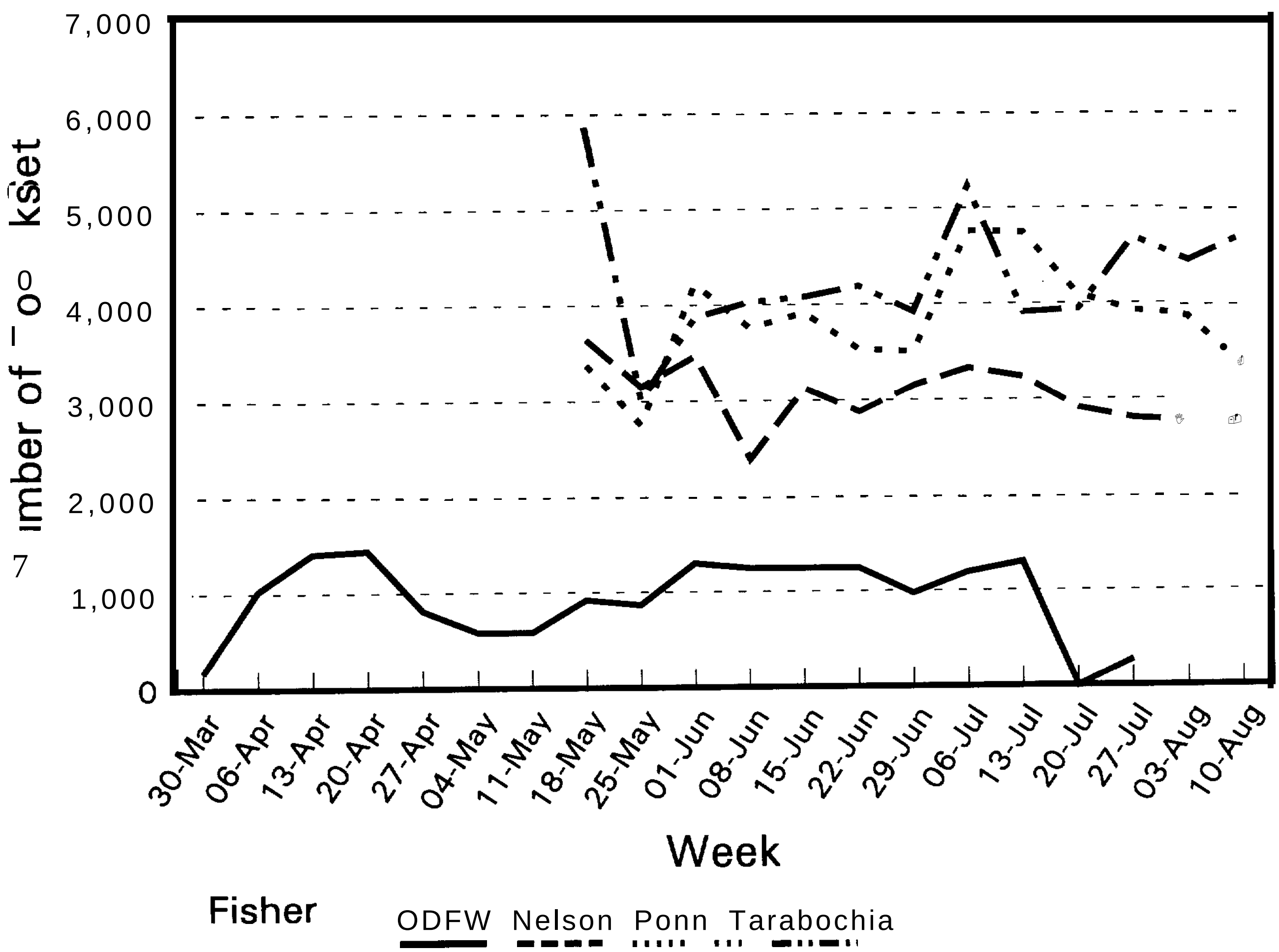
Result Figures



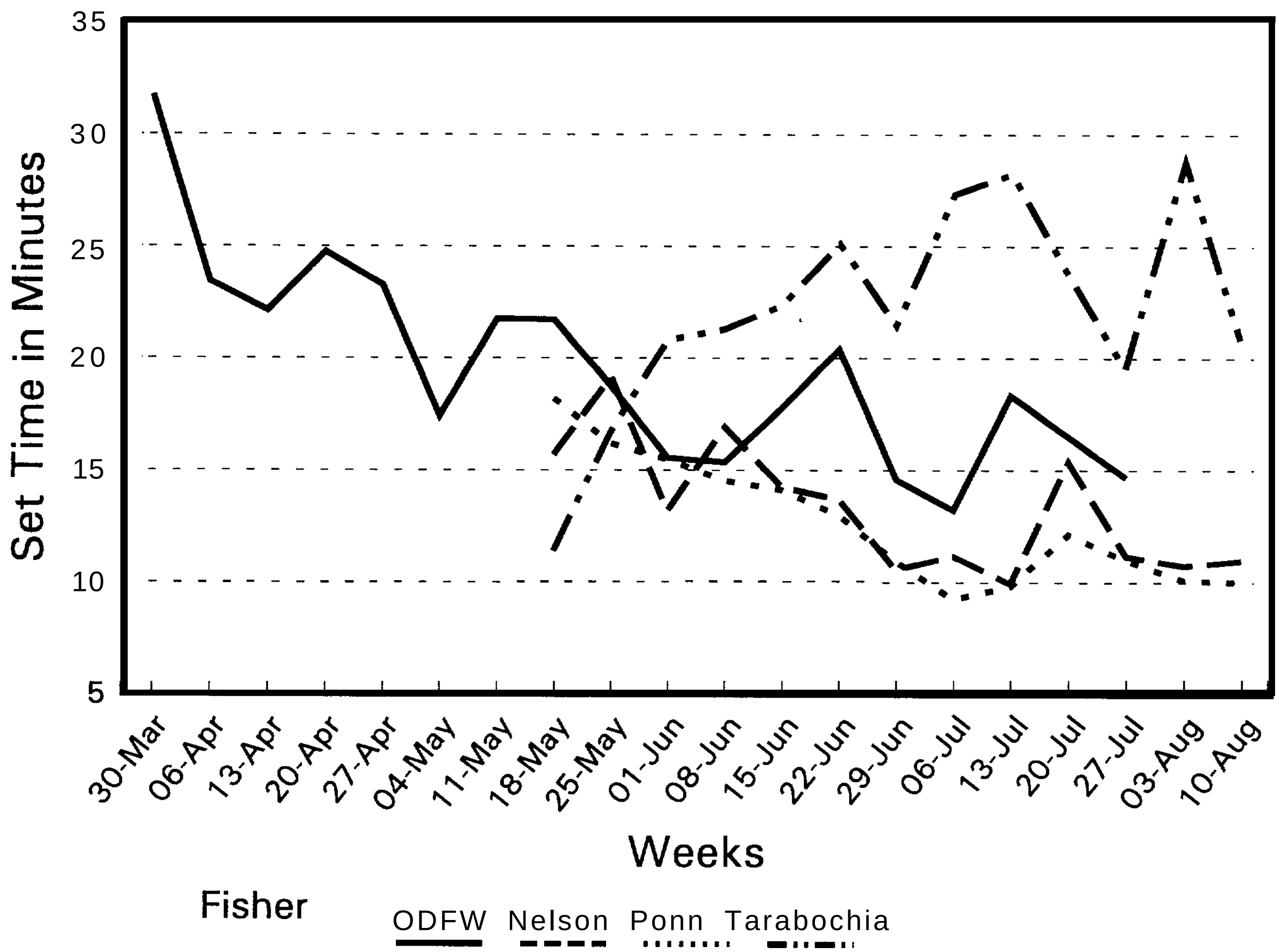
Appendix Figure D-I. Number of Trips per Week by Fisher.



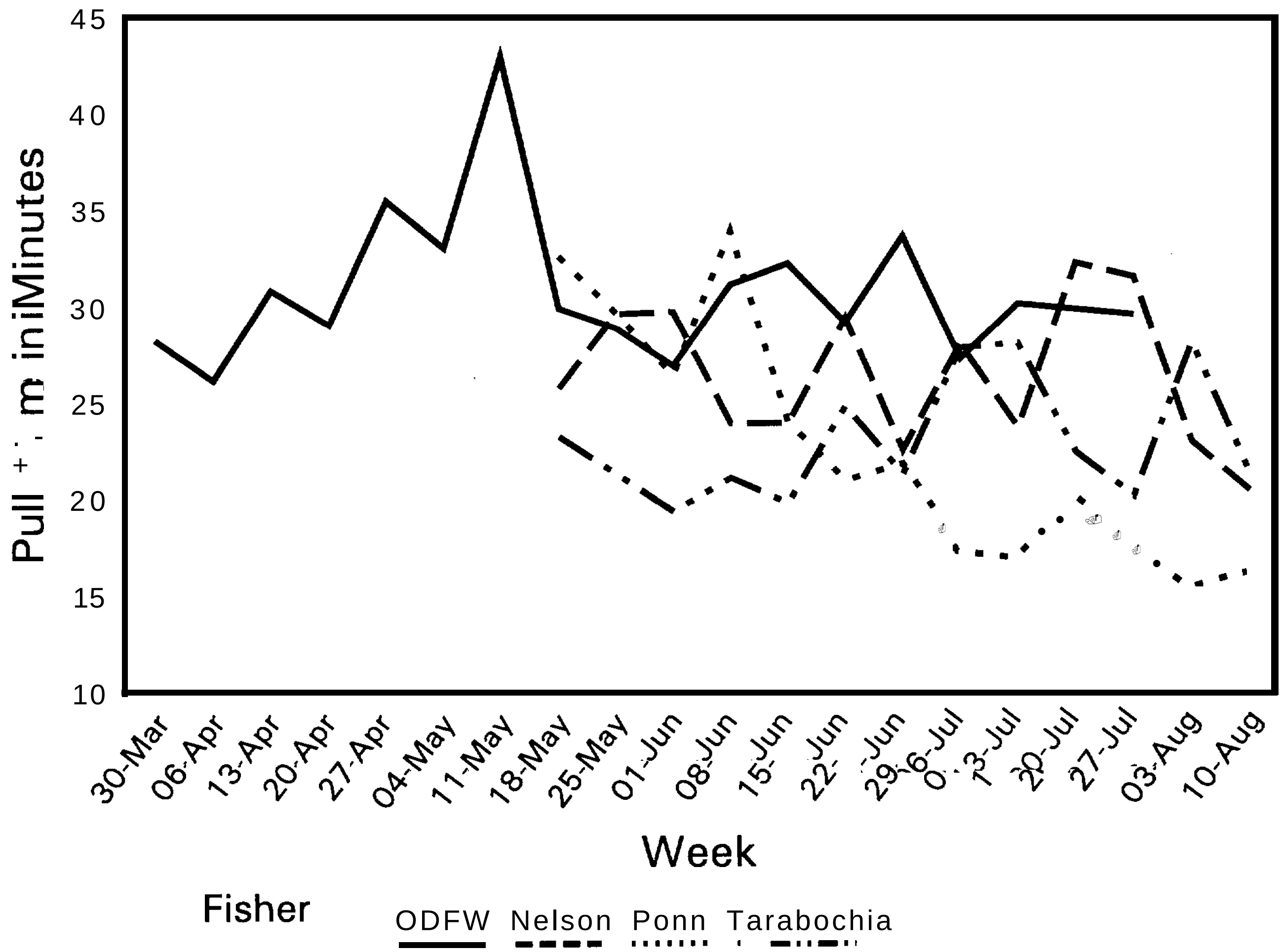
Appendix Figure D-2 Number of Lines Set per Week by Fisher



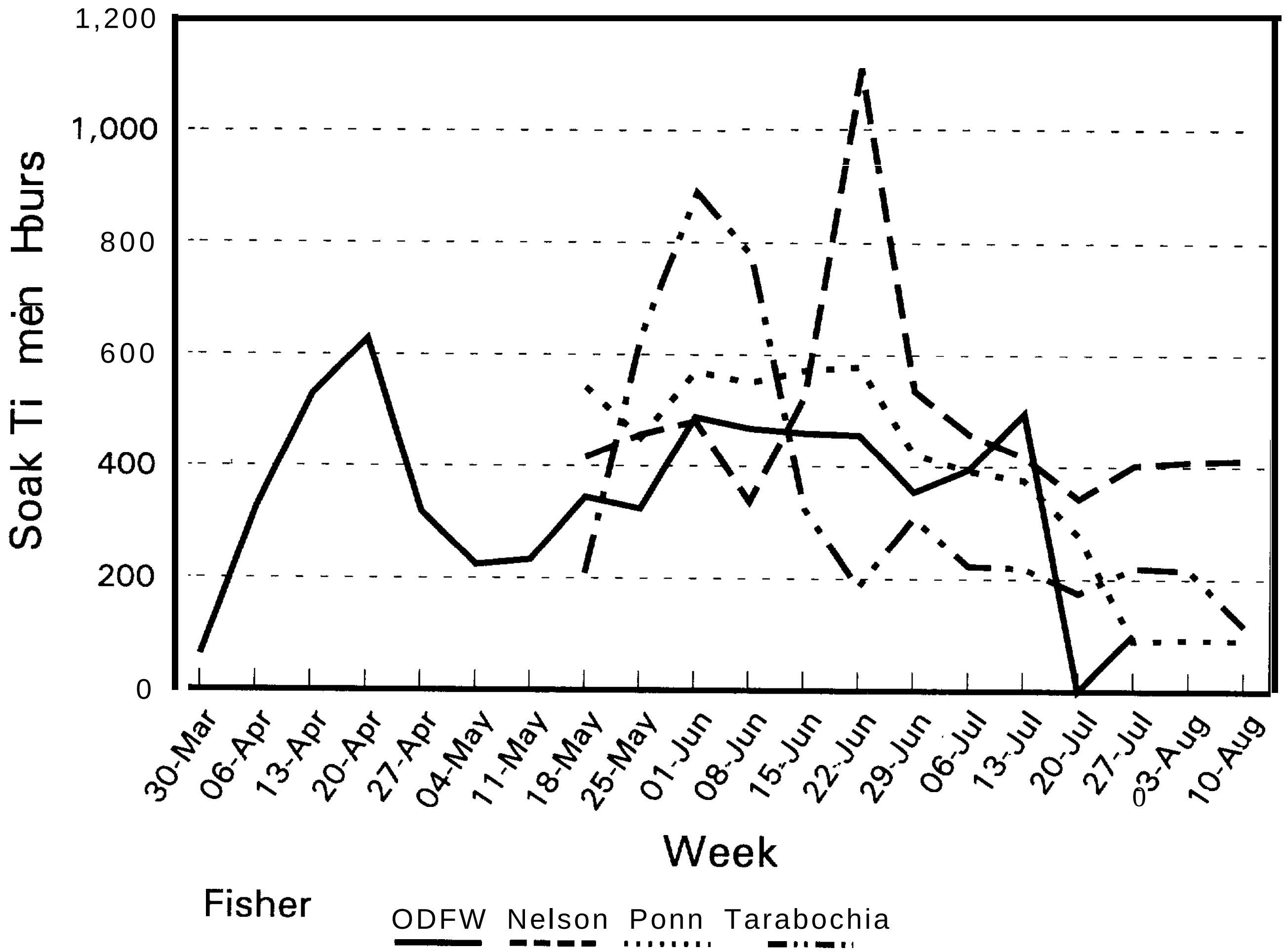
Appendix Figure D-3. Number of Hooks Set per Week by Fisher.



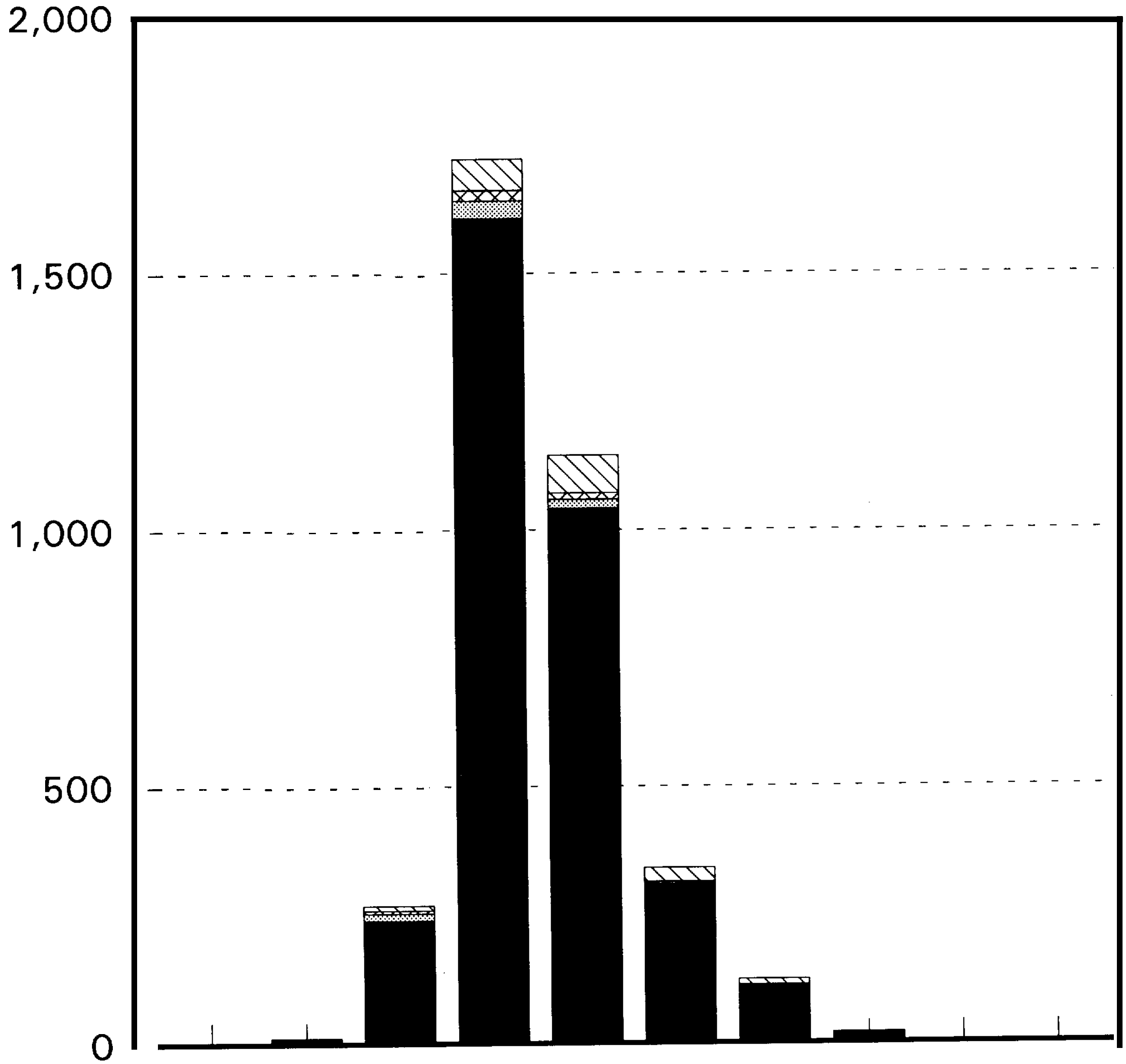
Appendix Figure D-4. Set Time per 120 Hooks by Week and Fisher.



Appendix Figure D-5. Pull Time per 120 Hooks by Week and Fisher.

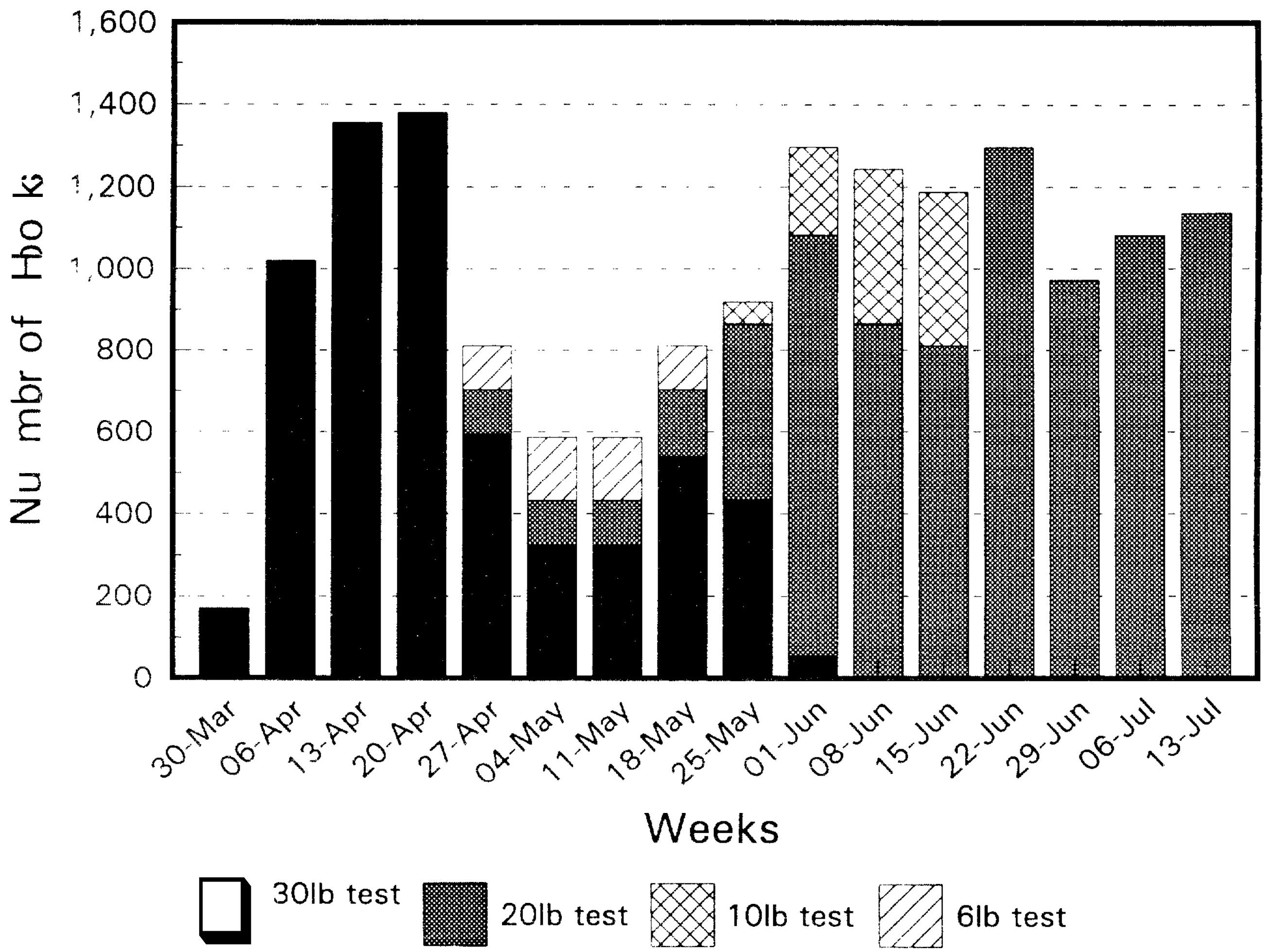


Appendix Figure D-6. Longline Soak Time per Week by Fisher.

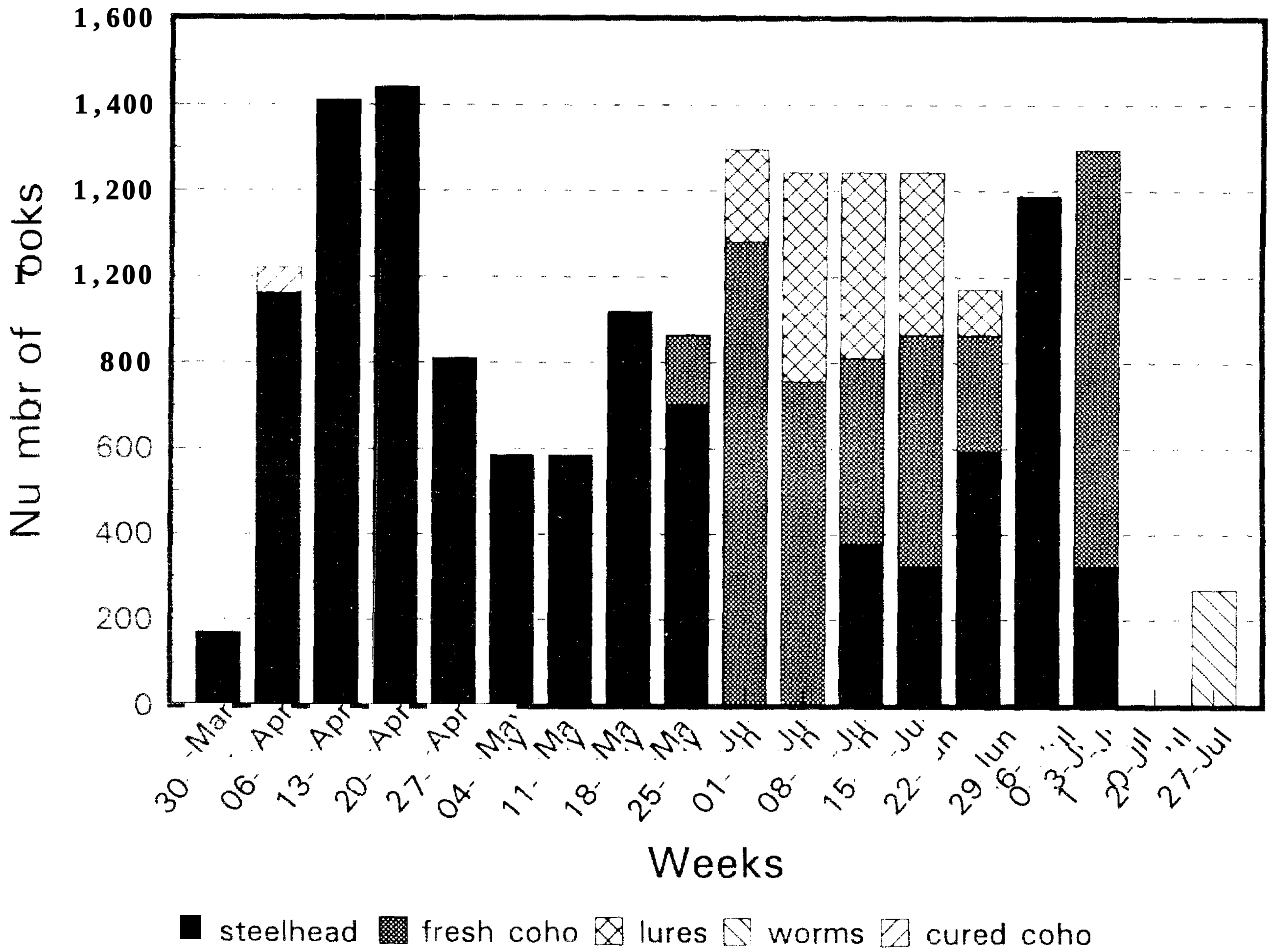


	101-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-1000	1001-1100
Good	1	12	239	1,606	1,042	307	108	18	1	1
Fair	0	0	14	34	18	2	3	0	0	0
Poor	0	0	6	20	13	4	2	0	0	0
Dead	0	0	0	1	0	1	0	0	0	0
Not recorded	0	0	9	61	73	27	11	2	0	0

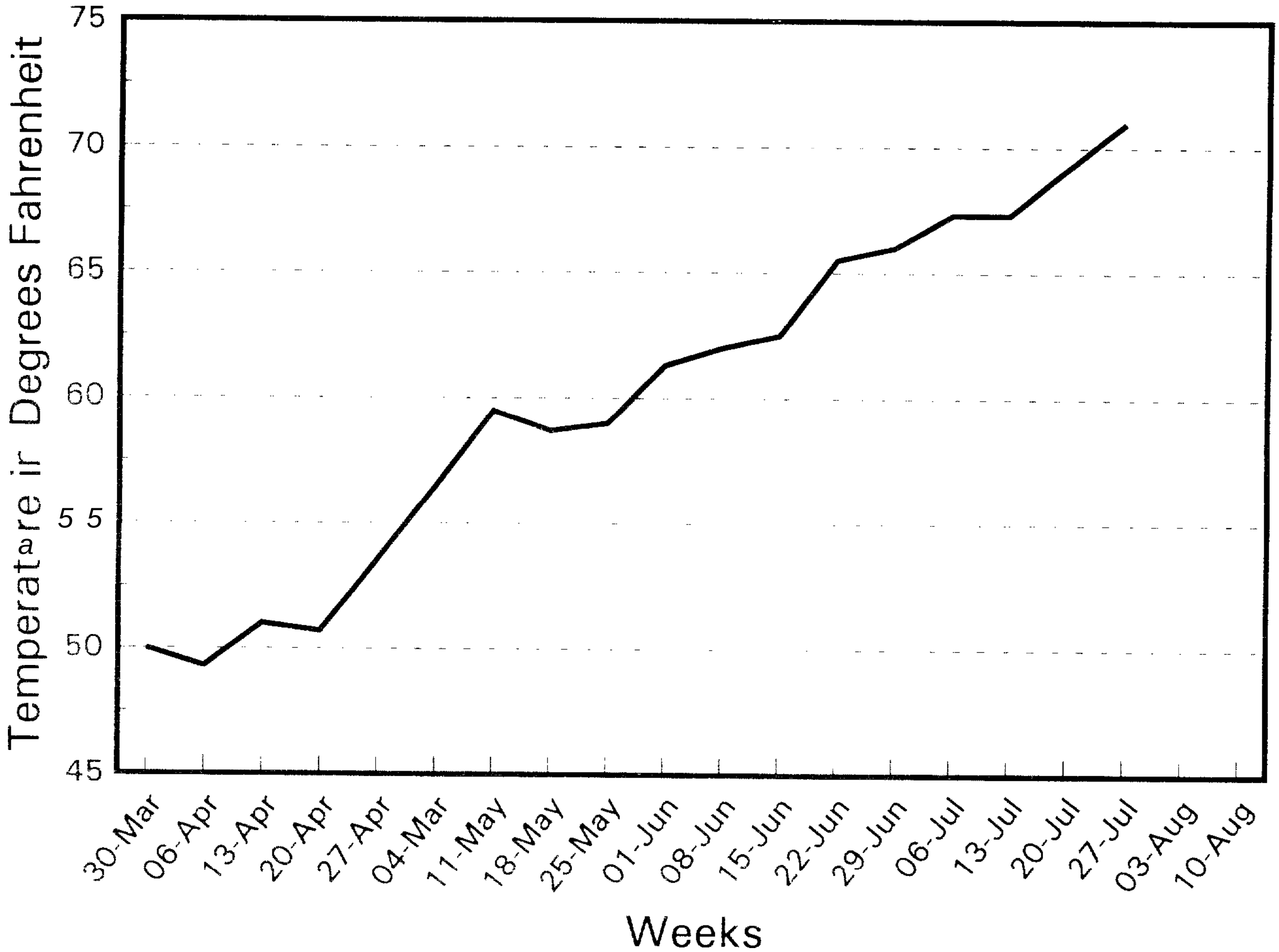
Appendix Figure D-7. Number of White Sturgeon by Length and Condition.



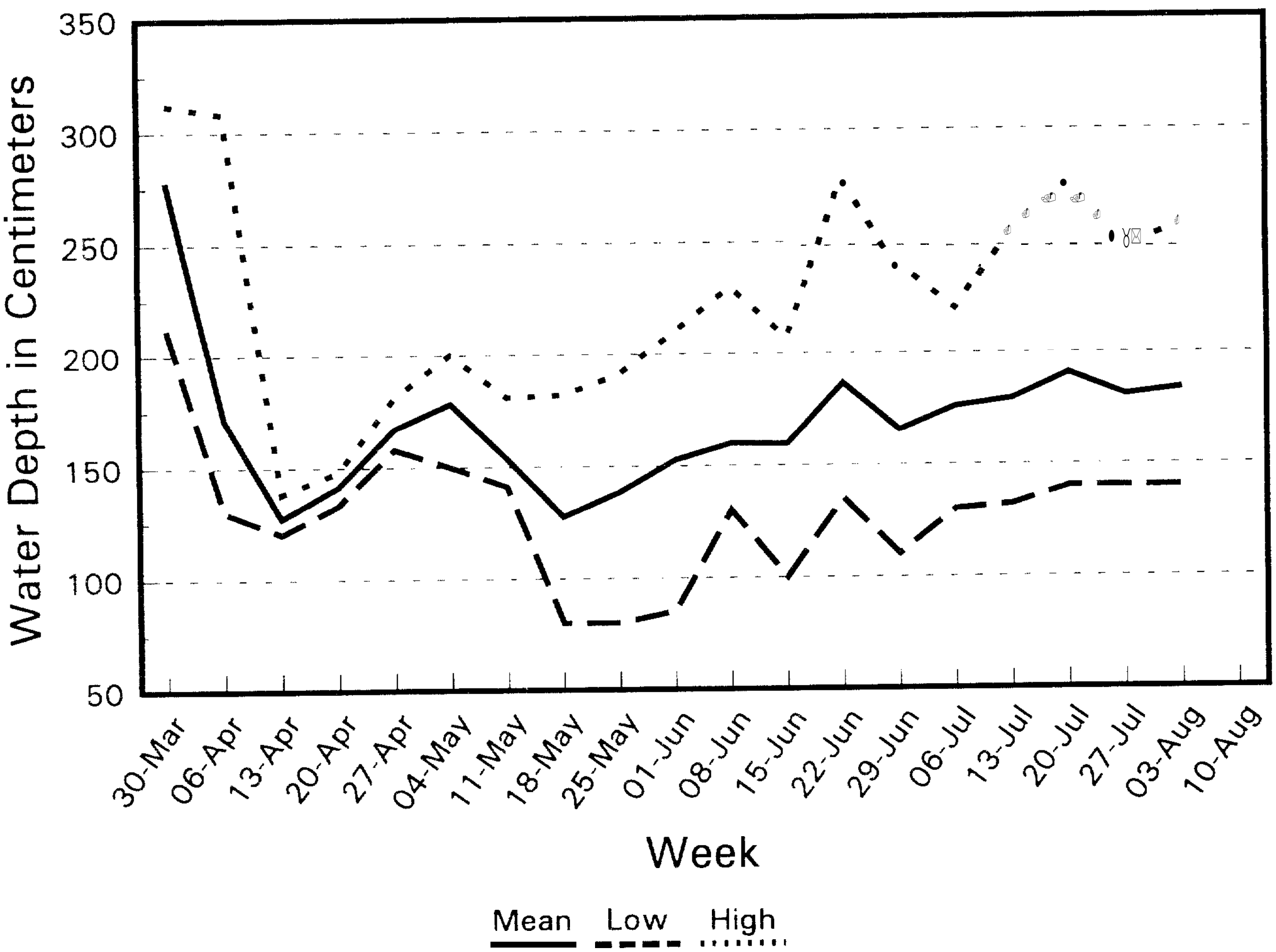
Appendix Figure D-8. Use of Gangion Leader Test Strengths by Number of Hooks per Week for ODFW Vessel.



Appendix Figure D-9. Use of Bait Types by Number of Hooks per Week for ODFW Vessel.



Appendix Figure D-10. Weekly Mean Water Surface Temperature.



Appendix Figure D-11. Weekly Turbidity.

REPORT B

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

Prepared by

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1992 Annual Report

CONTENTS

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ABSTRACT

We are reporting on the progress of the Northern Squawfish (*Ptychocheilus oregonensis*) Sport-Reward Fishery in the Columbia River Basin for April 1 through September 30, 1992. The objectives of this project were (1) to implement the Sport-Reward Fishery for northern squawfish at 20 registration stations on the Washington and Oregon shores in the lower Columbia River and Snake River; (2) to register anglers to participate in the program; (3) to collect biological data on northern squawfish and other fish species caught and turned in to the registration stations; (4) to conduct a roving creel survey to assess impacts of the fishery on other fish species; and (5) to report on the inseason dynamics of the fishery.

The Northern Squawfish Sport-Reward Fishery was conducted during May 18 through September 27, 1992. A total of 88,494 angler days were spent fishing for northern squawfish. A total of 35,128 (39.7%) anglers returned to the registration stations and turned in 186,904 northern squawfish 11 inches or longer for the $3 reward. An additional 13,892 northern squawfish less than 11 inches were turned into the stations (no reward was issued for northern squawfish less than 11 inches). The catch per unit effort (CPUE) for the season was 2.11 fish per angler day (northern squawfish 11 inches or longer).

The harvest of reward-size northern squawfish was 15% greater in 1992 than in 1991, with an increase in participation of about 24 % . From 199 1 to 1992, the CPUE decreased (10.6%) from 2.36 fish per angler day in 1991 to 2.11 fish per angler day in 1992.

Fork lengths were collected from 128,510 northern squawfish, 119,437 were from northern squawfish with a fork length of 250 mm or longer (approximately 11 inches total length). The overall mean fork length of the northern squawfish greater than 250 mm was 346 mm (SD = 59.7 mm). We used a t-test to compare the mean fork length of northern squawfish between 1991 and 1992. We found a statistically significant decrease in mean fork length for all reservoirs combined.

Fish species other than northern squawtish turned into the registration stations totaled 2,349 fish (1.24% of all fish species returned). Smallmouth bass (*Micropterus dolomieui*) had the highest reported harvest of 693 fish. A total of 231 walleye (*Stizostedion vitreum*) and 141 channel catfish (*Ictalurus punctatus*) were observed in the catch. Peamouth

(*Mylocheilus caurinus*) had the highest harvest of 588 fish for unclassified species (non-game or non-food).

The portable computerized data collection station was field tested during the last month of the field season at the Hamilton Island boat ramp. Modification of the software is in progress and the unit will continue to be evaluated in 1993.

The roving creel survey interviewed a total of 6,754 angling parties in nine reservoirs during the 1992 fishery. The percent harvest by registered anglers encountered in the creel survey by reservoir ranged from 2.3 % in the Lower Monumental Reservoir to 42.8 % in The Dalles Reservoir. A positive correlation was observed between the harvest of northern squawfish calculated by reservoir turned into the registration stations and the estimated harvest of northern squawfish calculated by the roving creel survey.

INTRODUCTION

Predation on outmigrating juvenile salmonids (*Oncorhynchus spp.*) by northern squawfish (*Ptychocheilus oregonensis*) in the Columbia River Basin has been identified as a major concern of the Columbia River Basin Fish and Wildlife Program (NPPC 1987). Predator control of northern squawfish on the Columbia and Snake rivers has developed in recent years to the extent that multiple fisheries now exist that target northern squawfish (Nigro 1990). The goal of the predator control program is to achieve a sustained harvest of 10-20% of the larger northern squawfish in the population (250 mm or longer). This could restructure the population and reduce the impacts of predation on the outmigrating juvenile salmonids by as much as 50% (Rieman and Beamesderfer 1990).

One component of the program is a test fishery, paying the public a reward of $3 each for northern squawfish 11 inches or longer (Burley et al. 1992). The sport-reward test fishery began in 1990 in the John Day Reservoir (Vigg et al. 1990) and expanded to include multiple reservoirs in the Columbia and Snake rivers in 1991 (Burley et al. 1992).

The objective of this project was to implement the sport-reward fishery for northern squawfish at 20 registration stations on the Washington and Oregon shores in the lower Columbia and Snake rivers from May 18 through September 27, 1992. Specifically, the project called for registering anglers to participate in the fishery, issuing vouchers for payment to successful anglers, collecting biological data on northern squawfish and other fish species caught and turned into the registration stations, and reporting on the inseason dynamics of the fishery. The feasibility of using a roving creel survey to assess the impact of the sport-reward fishery on game, food, and other unclassified fish species, was also tested.

METHODS

Study Area

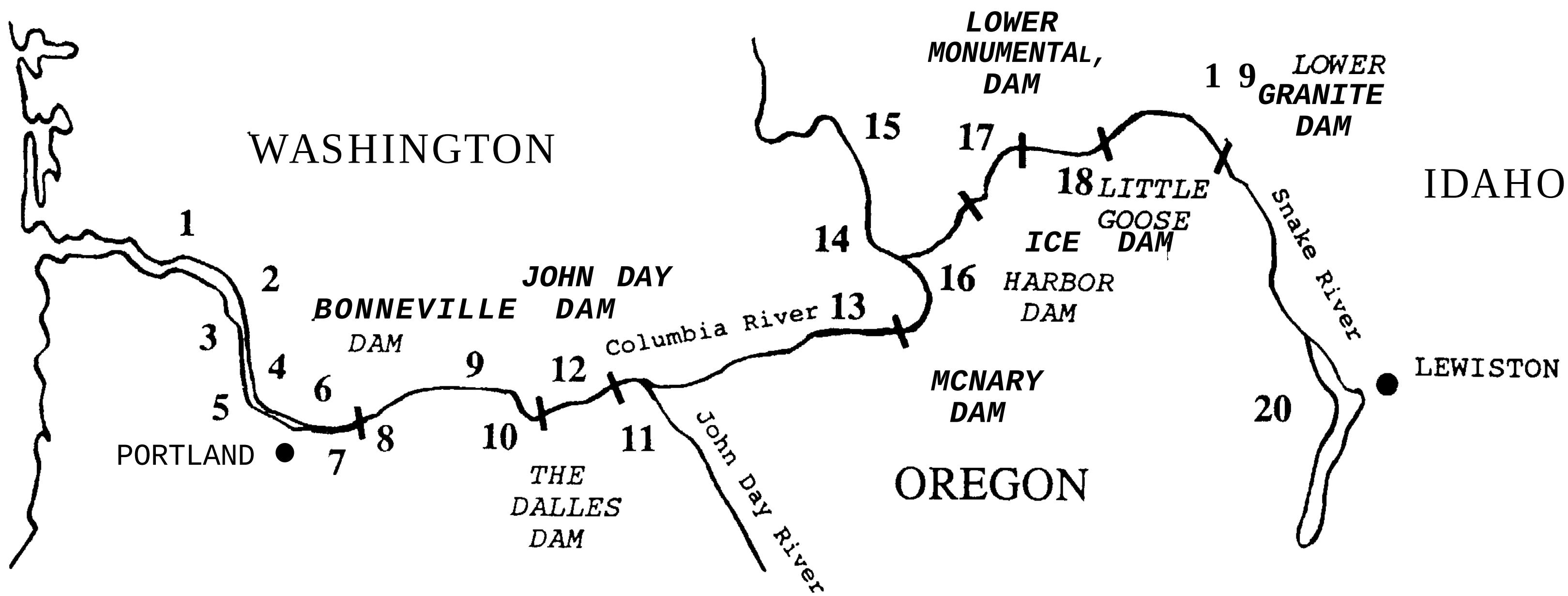
The sport-reward fishery for northern squawfish was conducted from the mouth to the tailrace of Priest Rapids Dam on the Columbia River, and from the mouth to the Hells Canyon Dam on the Snake River. Backwaters, sloughs, and up to 400 feet inside the mouth of tributaries along the above mentioned reaches of the Columbia and Snake rivers were also open for harvest of northern squawfish for payment.

Twenty registration stations were located on the lower Columbia and Snake rivers (Figure 1). The stations on the Columbia River were located below Bonneville Dam at Willow Grove Park, Wash.; Bayport Marina, Ore.; Kalama Marina, Wash.; M.J. Gleason Park, Ore.; Portco Park Marina, Wash.; The Fishery at Convert's Landing, Ore.; and Hamilton Island Ft. Rains Outlook, Wash.. In the Bonneville Reservoir, stations were at Cascade Locks Marina, Ore.; Bingen Marina, Wash.; and The Dalles Boat Basin, Ore.. Stations were located in The Dalles Reservoir at Maryhill State Park, Wash., and in the John Day Reservoir at LePage Park, Ore., and Plymouth Park, Wash.. In McNary Reservoir, stations were at Columbia Point Park, Wash., and Ringold Boat Ramp, Wash.. On the lower Snake River, registration stations were located in McNary Reservoir at Hood Park, Wash., and in the Ice Harbor Reservoir at Windust Park, Wash. In the Lower Monumental Reservoir, a station was located at Lyons Ferry Marina, Wash. In the Little Goose Reservoir, the station was at Boyer State Park, Wash. The station in the Lower Granite Reservoir was located at the Greenbelt Boat Ramp, Wash.

Field Procedures

Registration Interview

Washington Department of Wildlife (WDW) technicians were present to register anglers from 9 a.m. to 9 p.m. Anglers could self-register at a registration box near the site between 9:01 p.m. and 8:59 a.m. A short interview was conducted to record information pertinent to the anglers fishing day and tiled by last name.



1. Willow Grove
2. Kalama Marina
3. Bayport Marina
4. Marine Park
5. M.James Gleason
6. Hamilton Island Boat Ramp
7. The Fishery
8. Cascade Locks Marina
9. Bingen Marina
10. The Dalles Boat Basin
11. LePage Park
12. Maryhill State Park
13. Plymouth Boat Ramp
14. Columbia Point
15. Ringold Access Site
16. Hood Park
17. Windust Park
18. Lyons Ferry Marina
19. Boyer Park
20. Greenbelt Boat Ramp

Figure 1. Location of the northern squawfish sport-reward fishery check stations on the Columbia and Snake rivers during May 18-September 27, 1992.

Exit Interview

Upon completion of fishing, anglers were requested to return to the same station that they registered. A WDW technician then retrieved the anglers registration form and conducted the exit interview. All fish turned in were inspected and counted by technicians. This included the number of northern squawfish 11 inches or greater ($3 reward per fish) and their total weight (± 0.2 lbs), the number of northern squawfish turned in less than 11 inches, and the number of northern squawfish lost or released. Other fish species harvested were also recorded.

The qualifying northern squawfish were totaled and the angler was issued a pay voucher. The technician and angler each signed the pay voucher to verify the number of northern squawfish eligible for the reward. The angler was required to complete the inside questionnaire on his or her own and mail to the Pacific States Marine Fisheries Commission (PSMFC). Sport-reward payment was funded by the Bonneville Power Administration.

Biological Data Collection

Fish brought to the registration station by registered anglers were sampled for biological data by a scientific technician. These data were recorded on the back portion of the original angler registration form. During periods when large numbers of fish were being turned in or people were in line to register or exit, a subsampling regime was conducted.

Complete biological data was collected for northern squawfish catches numbering 30 or less. Catches greater than 30 fish were subsampled (fish species and fork length). Complete biological data was collected on every fifth fish. All qualifying northern squawfish returned to the check station were tail-clipped to indicate a voucher had been issued for these fish. Other fish species brought to the site were processed for biological data then returned to the angler. If time allowed during the shift, technicians would process any fish not previously sampled for a more complete biological profile.

Northern Squawfish Processing

After WDW technicians collected the biological data, each northern squawfish was graded according to guidelines provided by Oregon State University (OSU). These guidelines outlined specific instructions for technicians to determine whether a fish would be processed as "food-grade" or "fertilizer-grade" fish. Food-grade fish were placed on ice in red insulated coolers while fertilizer-grade fish were placed on ice in blue insulated coolers. At the end of each shift, technicians delivered the iced fish to a designated facility for fish processing or storage. Empty coolers and ice were picked up by technicians for the next day. This routine was repeated daily at each site for the duration of the Northern Squawfish Sport-Reward Fishery.

Computerized Data Collection

During September 10-27, 1992, a computerized data collection station was tested at the Hamilton Island registration site. This water-resistant work station incorporated an electronic balance, metric length measurement scale, a digitizer, multiplexer, an external computer keyboard, a laptop computer, and a 12-VDC power source. A customized software package developed by the work station manufacturer, Biomark Inc.[1], enabled WDW technicians to enter registration, exit interview, and biological data directly onto a computer diskette in lieu of hand recording this information. This data was audited by the software upon entry, alerting the technicians to errors or omissions in the data while the registrant and specimens were still at hand. At the end of the evening shift, WDW technicians would remove the labeled computer diskette that included all data from both shifts. A new diskette was used to record the data for each day.

Roving Creel Survey

A roving creel survey was conducted concurrently with the Northern Squawfish Sport-Reward Fishery from May 18-September 27, 1992, to assess the impact of the sport-reward fishery on fish species other than northern squawfish. The creel survey was conducted on about 500 miles of the Columbia and Snake rivers (Figure 1). The area encompassed the free-flowing section of the Columbia River (Puget Island to Bonneville Dam) and several reservoirs on the Columbia and Snake rivers (Columbia River -- Bonneville, The Dalles, John Day, and McNary reservoirs; Snake River -- Ice Harbor, Lower Monumental, Little Goose, and the Lower Granite reservoir to the mouth of the Grande Ronde River).

The design was based on an adaptation of Malvestuto et al. (1978) and Von Geldern and Tomlinson (1973) using a roving creel survey to estimate harvest on large impoundments with multiple access points, and structured around a lo-hour work day.

The study area was divided into approximately lo-mile sections and each section assigned a unique code. The field season consisted of 19 weeks with 95 weekdays and 43 weekend days (including holidays) for a total of 138 days. Every weekend and holiday was sampled as well as two randomly selected weekdays each week, This resulted in 38 weekdays and 43 weekend days for a total of 79 sampling days. The sample day was defined as a lo-hour period from 8 a. m. to 6 p. m. The sample day was further divided into two time periods, early and late. Angler counts and angler interviews were assigned using a stratified random design without replacement. Each cell (geographic section, day type, and time period) was given equal weight.

Through the randomization process some cells were not represented at a satisfactory sample size to determine probability of angler encounter for future sample design

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

refinements. Supplemental sampling were randomly assigned within a strata to meet the predetermined minimum sample size per cell.

Angler Counts

Counts were stratified by anglers fishing from shore and anglers fishing from boats. Only people actually in the process of fishing were included in the counts. An angler count was conducted once at the beginning and once at the end of the sampling period by traveling the entire section at a constant rate and observing anglers at strategic vantage points using binoculars (10 X 70). The direction traveled was randomly determined and angler counts were completed in less than one hour. The data collected were river section, date, start time, number of anglers fishing from shore, number of fishing boats, and number of anglers in the fishing boats.

Angler Interviews

Angler interviews were conducted in the assigned section giving equal time to all access points where anglers could be encountered. Angler interview data were recorded using the "Angler Fish Data Base" form and associated codes. All anglers encountered were interviewed as time permitted, however, at heavy use areas a subsampling regime was used. In this case, every fourth angler was interviewed and catch cohort data collected (fork length and weight from every fourth fish). The angler interview data collected were river section, date, number of anglers in fishing party, time fished (start and stop time), complete or incomplete effort, registered in sport-reward fishery or not, angler type, gear type, target species, and catch cohort data [species, origin, marks, fork length ($\pm$ 1 mm), and weight ($\pm$ 1 g)].

Data Analysis

Sport-Reward Fishery

Computer programs were written using SAS Version 6.04 statistical software to retrieve subsets of data for analysis of the Northern Squawfish Sport-Reward Fishery.

Roving Creel Survey

The roving creel survey data was calculated using methodologies similar to Malvestuto et al. (1978). Daily calculations were made. They were combined by strata and expanded for a reservoir.

Daily Calculations

The fishing effort was calculated from angler count data. The effort in angler hours was determined by multiplying the mean number of anglers per count by the total number of fishing hours for each day (Neuhold and Lu 1957; Malvestuto et al. 1978):

$$F_i = h_i X_i \qquad (1)$$

where

F_i = fishing effort (hours) for the i^{th} day,
h_i = number of total possible fishing hours for the i^{th} day, and
X_i = mean number of anglers per count for the i^{th} day.

The daily fishing effort was kept separate by strata (reservoir section, angler type, and day type).

The harvest per unit of effort (fish * angler $hour^{-1}$) was calculated for each day using the equation:

$$r_i = \frac{\sum h_{ij}}{\sum t_{ij}} \qquad (2)$$

where

r_i = Harvest per unit of effort (HPUE) for the i^{th} day,
h_{ij} = harvest of all species for the j^{th} angler, and
t_{ij} = the fishing time for the j^{th} angler.

The daily HPUE were kept separate by strata.

The harvest for each day (by strata) was calculated using fishing effort (F_i, angler hours) from Equation 1 multiplied by the HPUE (r_i, fish * angler hour-‘) from Equation 2:

$$H_i = r_i F_i \qquad (3)$$

Calculations By Strata

A mean daily angler effort was calculated for each stratum:

$$\overline{F}_h = \frac{\sum F_{hi}}{n_h} \tag{4}$$

where n_h is the number of days surveyed.

The total effort for the stratum was calculated by multiplying the total possible fishing days (N_h) in the season by the mean daily fishing effort:

$$F_h = N_h \overline{F}_h \tag{5}$$

The variance of the angler counts for each stratum was calculated using Equations 6 and 7 (Zar 1974; Malvestuto et al. 1978):

$$VAR(\overline{F}_h) = \frac{\sum F_{hi}^2 - \frac{(\sum F_{hi})^2}{n_h}}{n_h - 1} \tag{6}$$

$$VAR(F_h) = N_h^2(VAR(\overline{F}_h))(1 - \frac{n_h}{N_h}) \tag{7}$$

where

$VAR(\overline{F}_h)$	=	the variance of the mean daily effort,
$VAR(F_h)$	=	the variance of total effort for the h^{th} stratum,
n_h	=	the number of days surveyed in the stratum,
N_h	=	the total available days in the stratum, and
$(1-(n_h/N_h))$	=	the finite population correction (applied when $n/N > 0.05$).

The HPUE for each stratum was calculated by averaging the daily HPUE similar to Equation 4 (Malvestuto et al. 1978). The variance of the HPUE for each strata was calculated using Equation 8:

$$VAR(r_h) = \frac{\sum r_{hi}^2 - \frac{(\sum r_{hi})^2}{n_h}}{n_h - 1} \qquad (8)$$

The harvest for each stratum was calculated by multiplying the total possible fishing days (N_h) in the season by the mean daily harvest estimates similar to Equation 5. The variance of harvest for each stratum was calculated.

Season Calculations

The total fishing effort for the season was calculated by summing the fishing effort of all the strata. The variance for the total fishing effort was calculated using the following equation:

$$VAR(F_T) = VAR(F_1) + VAR(F_2) + . + VAR(F_k) \qquad (9)$$

where

k = the number of groups in the stratification, and

$VAR(F_1)$ = the variance of the h^{th} stratum, assuming that the fishing effort for each h^{th} strata were independent and that the covariance terms were zero due to random sampling.

The standard error (SE) of the total fishing effort was determined by calculating the square root of $VAR(F_T)$ in Equation 10:

$$SE(F_T) = \sqrt{VAR(F_T)}. \qquad (10)$$

The 95% confidence interval for the total fishing effort was determined using Equation 11:

$$95\,\%C.I. = F_T \pm t_{(0.05(2),v)}\, SE(F_T) \qquad (11)$$

where

v = the degrees of freedom (approximated by a number midway between the smallest n_h and the sum of the individual strata degrees of freedom), and

$SE(F_T)$ = standard error of the total fishing effort.

The HPUE for the season was calculated by dividing the total harvest by the total effort. The variance of the HPUE for the season was calculated using Equation 11 (assuming zero covariance, from Hansen et al. (1953) and standard error using Equation 13:

$$VAR(r_T) = \frac{H_T^2}{F_T^2} * \left(\frac{VAR(H_T)}{H_T^2} + \frac{VAR(F_T)}{F_T^2} \right) \qquad (12)$$

$$SE = \sqrt{VAR(r_T)} \qquad (13)$$

The equation used for calculating the 95% confidence intervals for the HPUE was:

$$C.I.r_h = r_h \pm t_{(0.05(2),v)} \, SE(r_h) \qquad (14)$$

We assumed the H_js were independent and calculated total harvest and the variance of the total harvest as follows:

$$H_T = H_1 + H_2 + . + H_k \qquad (15)$$

$$VAR(H_T) = VAR(H_1) + VAR(H_2) + . + VAR(H_k) \qquad (16)$$

where k is the number of stratifications.

The standard error and confidence intervals were calculated as follows:

$$SE = \sqrt{VAR(H_T)} \qquad (17)$$

$$95\ \%\ C.I.H_T = H_T \pm t_{(0.05(2),v)}\ SE(H_T) \tag{18}$$

RESULTS

Sport-Reward Fishery

Northern Squawfish Harvest Data

The sport-reward fishery had a total participation (effort) of 88,494 angler days. A total of 35,128 (39.7%) anglers returned to the registration stations. Those anglers harvested, and turned in for payment, a total of 186,904 northern squawfish 11 inches or longer. An additional 13,892 northern squawfish less than 11 inches were turned into the registration stations (no payment was issued for northern squawfish less than 11 inches). The overall CPUE for northern squawfish eligible for payment was 2.11 fish per angler day.

The harvest of northern squawfish and effort varied by week during the season (Figure 2). The weekly totals of harvest and effort were calculated showing fairly constant harvest for the first five weeks with a gradual decrease through the rest of the season. The participation showed a gradual decrease during the season. The weekly harvest ranged from 1,802 to 20,572 northern squawfish. The effort ranged from 992 to 10,813 angler days. The average CPUE by week was 1.99 fish per angler day and ranged from 1.48 to 2.59 fish per angler day (Figure 3).

Harvest and effort of northern squawfish varied by reservoir (Figure 4). Harvest ranged from 3,045 fish in Lower Monumental Reservoir to 79,822 fish in the Bonneville tailrace (defined as the reach of the river from Bonneville Dam to the mouth of the Columbia River, and for ease of presenting the results is termed a reservoir). Effort in returning angler days (only anglers returning to the registration stations were asked where they fished) ranged from 779 in the Lower Monumental Reservoir to 16,620 returning anglers in the Bonneville tailrace. The average CPUE by reservoir was 5.34 fish per returning angler day. CPUE ranged from 3.43 to 7.36 fish per returning angler day (Figure 5).

The harvest and effort of northern squawfish varied by registration location (Figure 6). The average catch of northern squawfish was 9,345 fish and ranged from 1,456 fish at Windust Park to 23,851 fish at The Fishery at Covert's Landing. The average effort in angler days was 4,425 and ranged from 1,164 to 10,672 angler days. The average CPUE by registration location was 2.07 fish per angler day and ranged from 0.49 at Bayport Marina to 4.16 fish per angler day at Columbia Point Park (Figure 7).

Fishing location No. 10 (Bonneville tailrace) exhibited the highest harvest of northern squawfish at 42,760 fish (Figure 8A) and effort at 7,834 angler days (Figure 11A). Fishing location No. 25 (McNary Reservoir) and fishing location No. 37 (Ice Harbor Reservoir) showed no harvest (Figure 9B-C) or effort (Figure 12B-C). The CPUE (36 fish per angler day) was highest in McNary Reservoir's fishing location No. 26 (Figure 15B). The majority of harvest and effort appear to be concentrated at the tailrace sections below the hydropower facilities (Figures 8-13). CPUE varied by fishing location (Figures 14- 16).

Fork length measurements were taken from a total of 128,466 northern squawfish. The average length for all locations combined was 337 mm (SD = 66.1; Figure 17). Length frequency distributions were also analyzed by reservoir for the entire season. Mean lengths ranged from 306 mm (SD = 40.8) in Lower Monumental Reservoir to 368 mm (SD = 58.8) in John Day Reservoir (Figures 18-20).

Game, Food, and Unclassified Fish Species Catch Data

Of the game fish turned into the registration stations, smallmouth bass (*Micropterus dolomieui*), channel catfish (*Ictalurus punctatus*), and walleye (*Stizistedion vitreum*) were most often seen. A total of 693 smallmouth bass were harvested and observed in returning anglers' catch. This number was higher than all other species excluding northern squawfish. A total of 141 channel catfish and 231 walleye were also turned into the registration stations (Table 1). Besides northern squawfish, there were more peamouth (*Mylocheilus caurinus*) caught (588) than any other unclassified fish species. We also continued to see individual specimens (125) that appear to be a hybridization between the northern squawfish and chiselmouth, and are referred to as Columbia River chub for reporting purposes in this report (Table 1). Efforts continue to determine whether these fish are hybridized.

Fish species caught by participants in the Northern Squawfish Sport-Reward Fishery were also looked at relative to whether the angler was targeting those species. Of the 693 smallmouth bass that were caught, 50% of those were caught by anglers targeting smallmouth bass (Figure 21). Seventy-one percent of the 23 1 walleye caught and 57% of the 14 1 channel cattish were also targeted. All peamouth caught were incidental to the program.

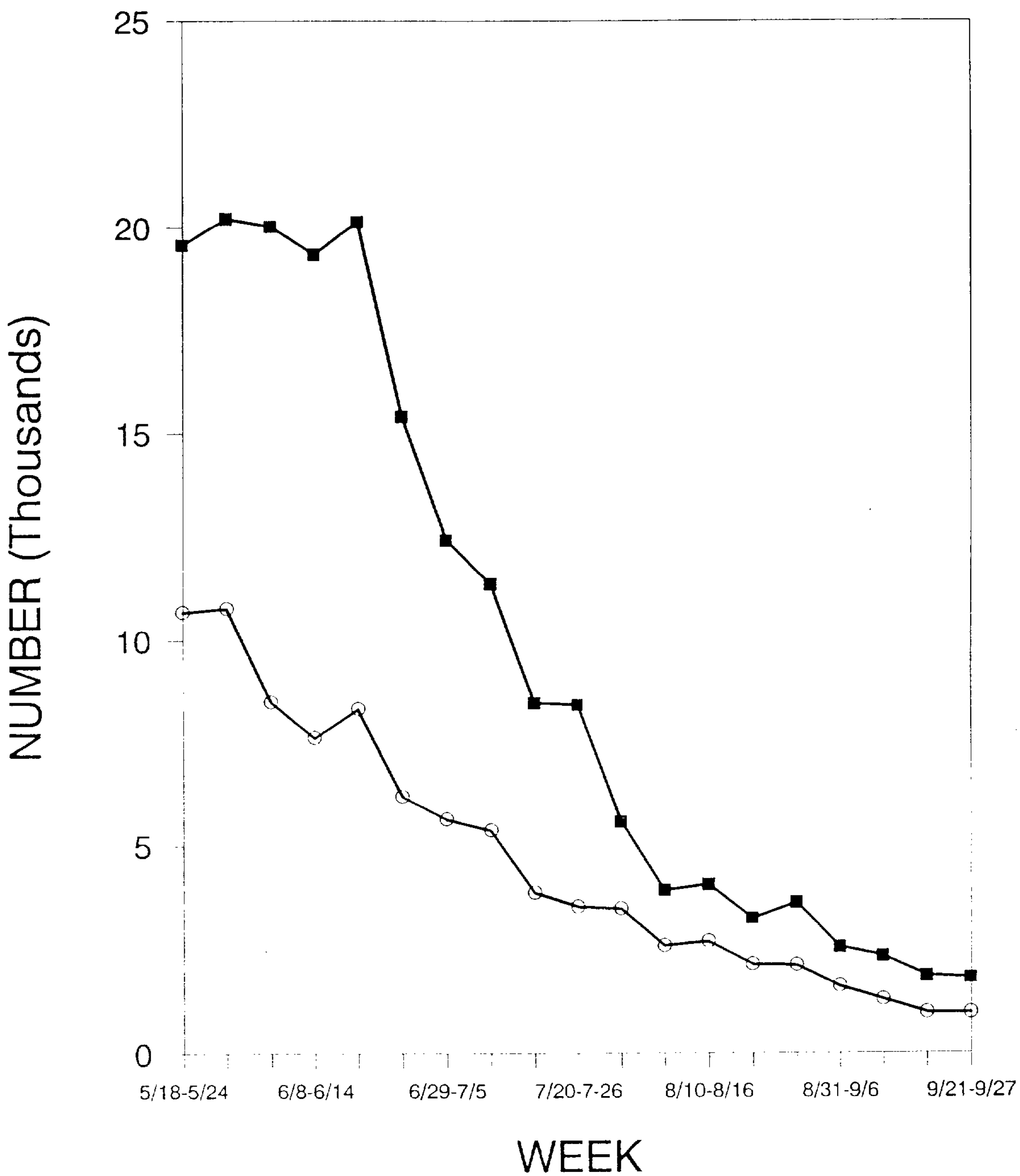

Figure 2. Northern squawfish effort (angler days) and harvest by week (O= angler days and ■= northern squawfish catch), May 18-September 27, 1992.

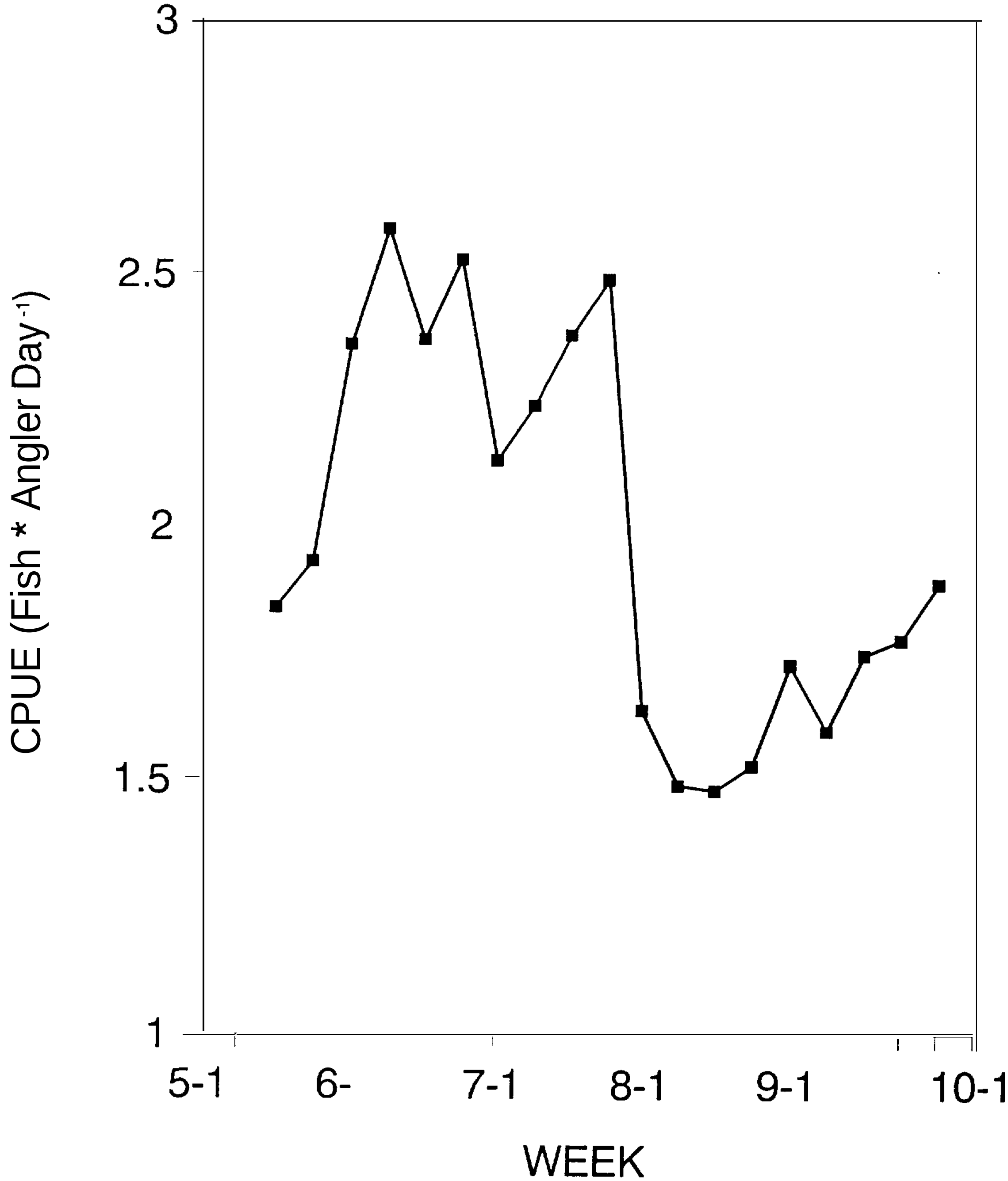

Figure 3. CPUE (fish * angler day^{-1} for northern squawfish by week, May 18-September 27, 1992.
Figure 3.

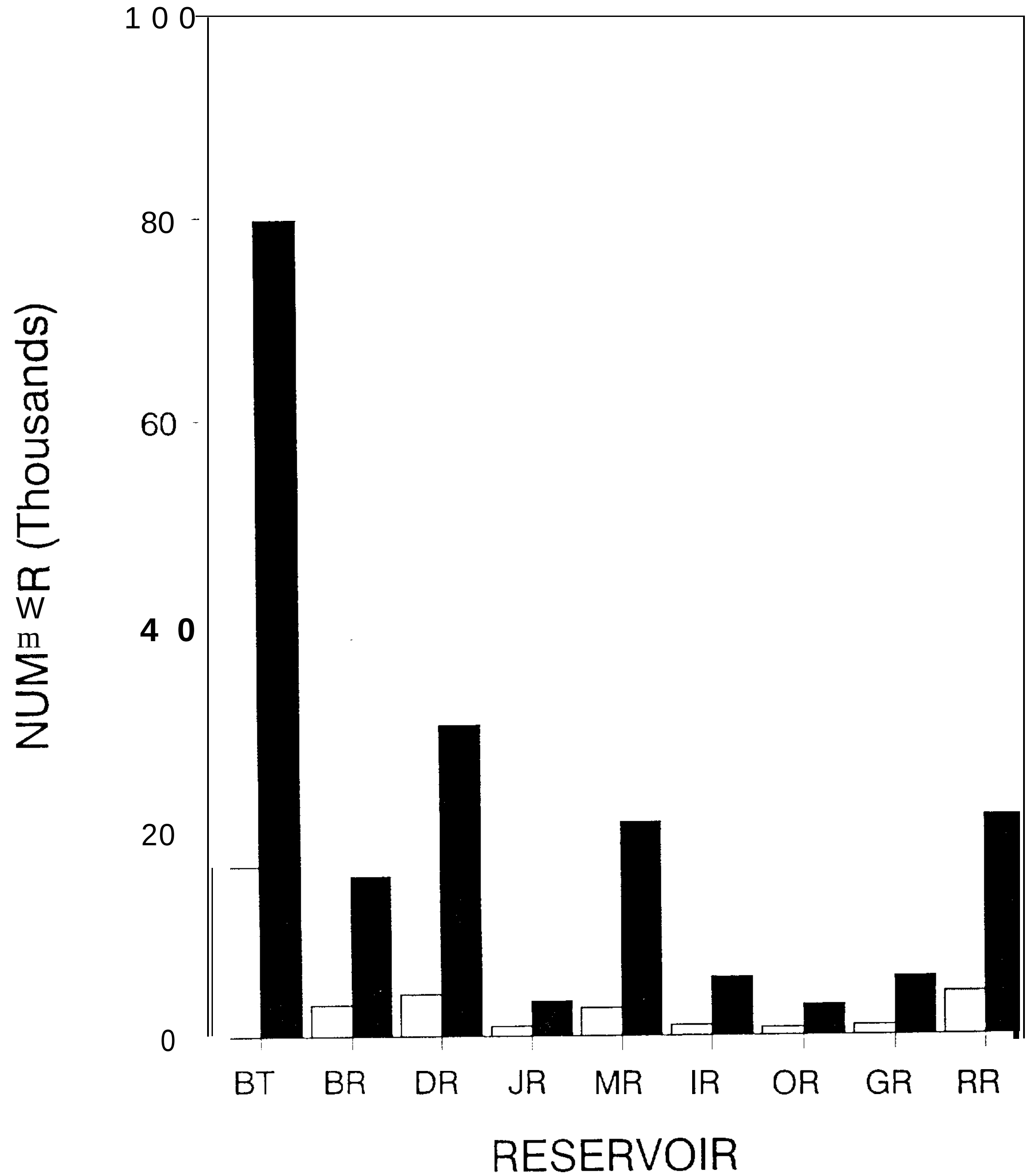

Figure 4. Northern squawfish harvest and effort (returning angler days) by reservoir (only anglers returning to the registration station had location fished recorded); (shaded bar= returning angler days, black bar= northern squawfish harvest); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

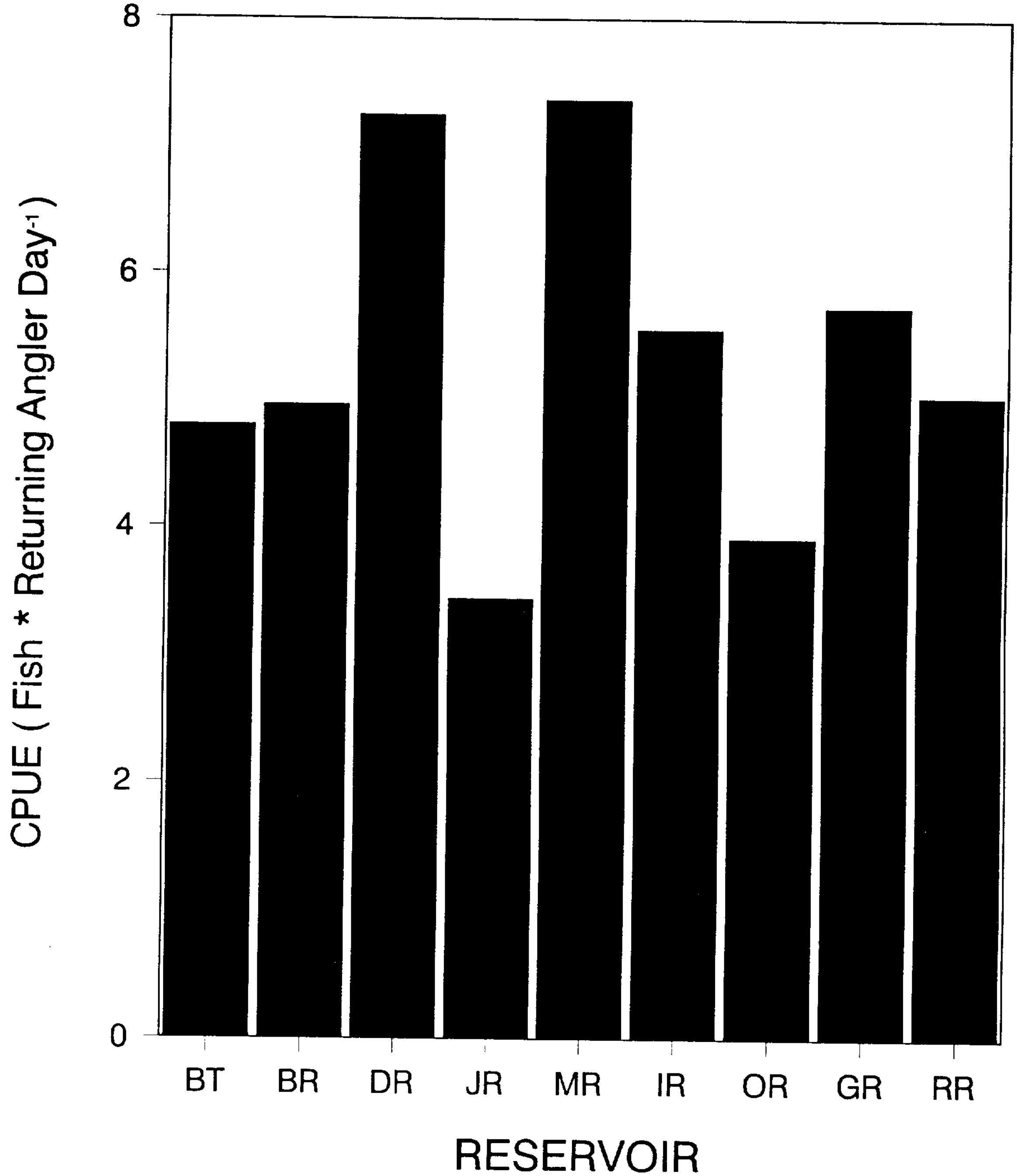

Figure 5. CPUE (fish * returning angler day^{-1}) for northern squawfish by reservoir (only anglers returning to registration stations had location fished recorded); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

Figure 5.

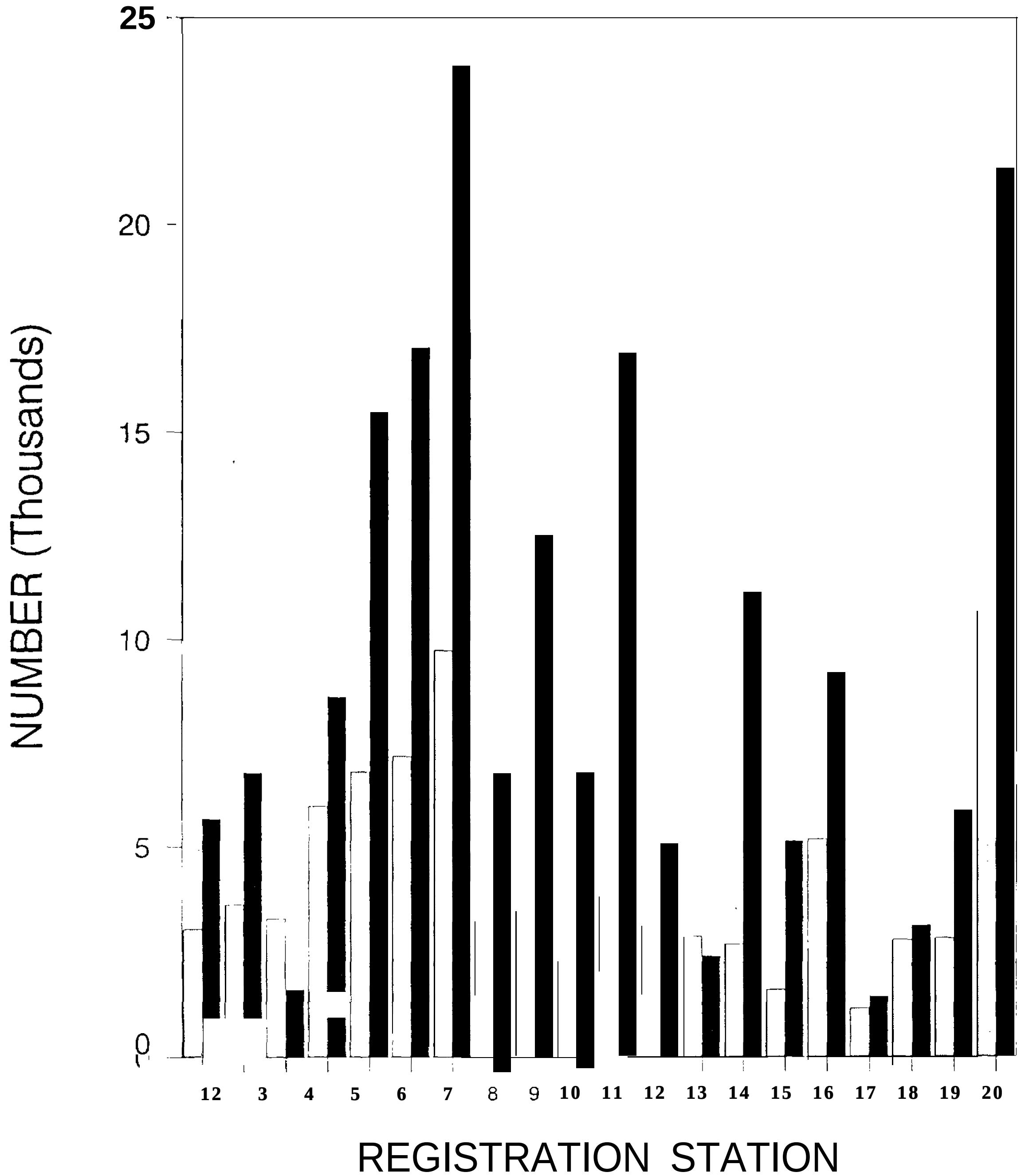

Figure 6. Northern squawfish harvest (dark bar) and effort (shaded bar = angler day) by registration station; 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Point, 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

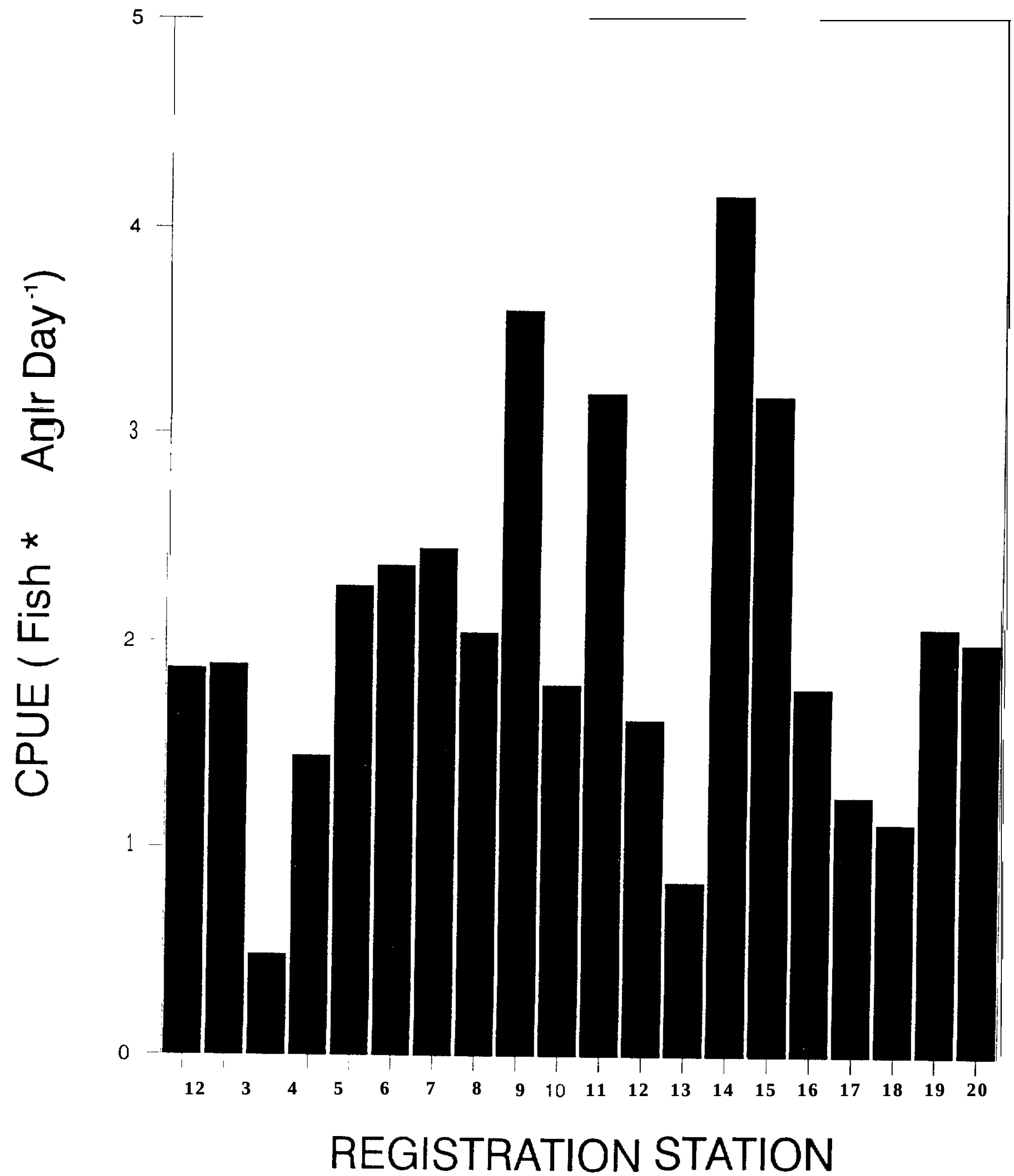

Figure 7. CPUE (fish * angler day^{-1}) for northern squawfish by registration station; 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= M. James Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Point, 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

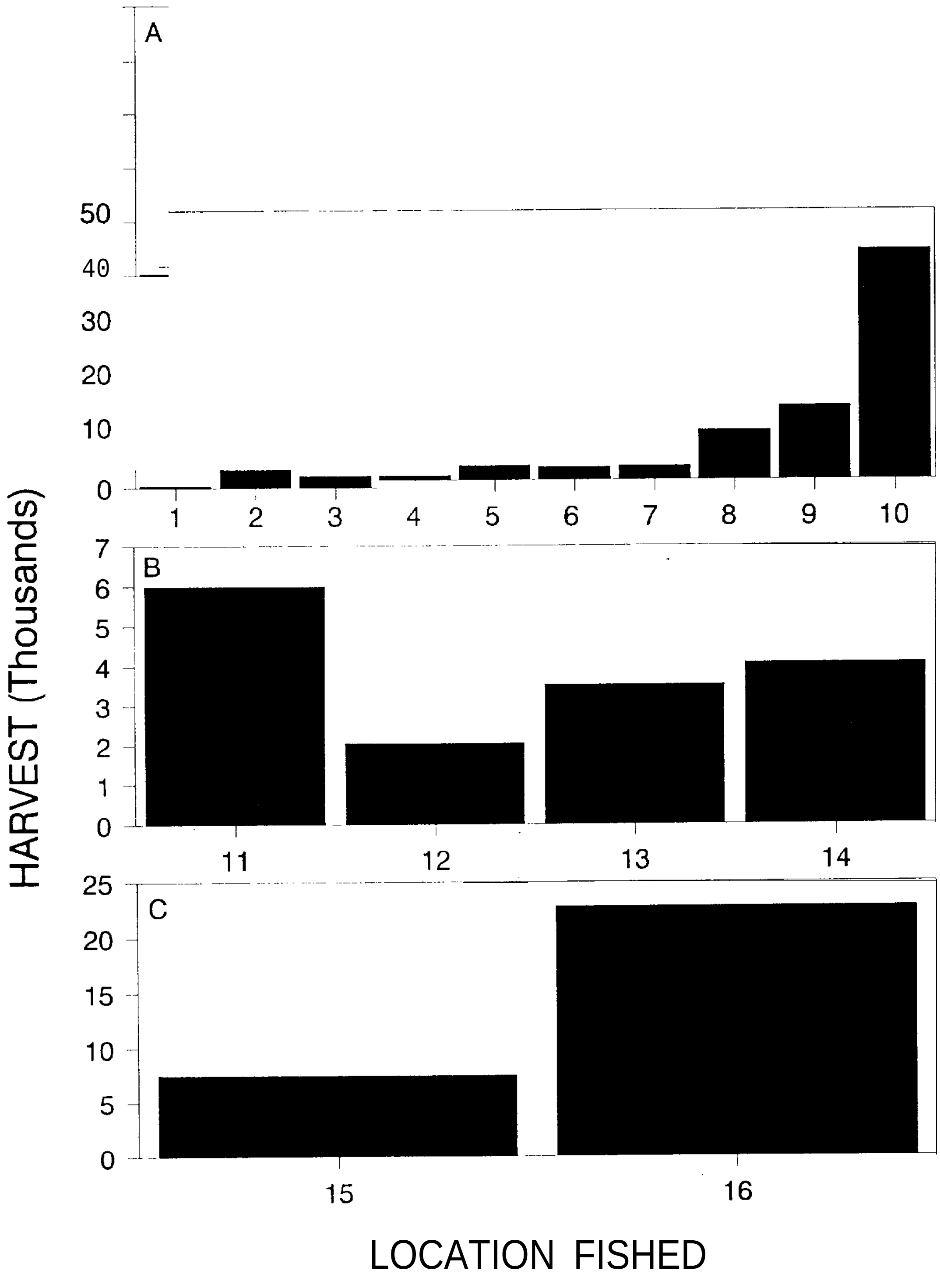

Figure 8. Northern squawfish harvest by reservoir and location fished; (A)= Bonneville Tailrace, (B)= Bonneville Res., (C)= The Dalles Res.

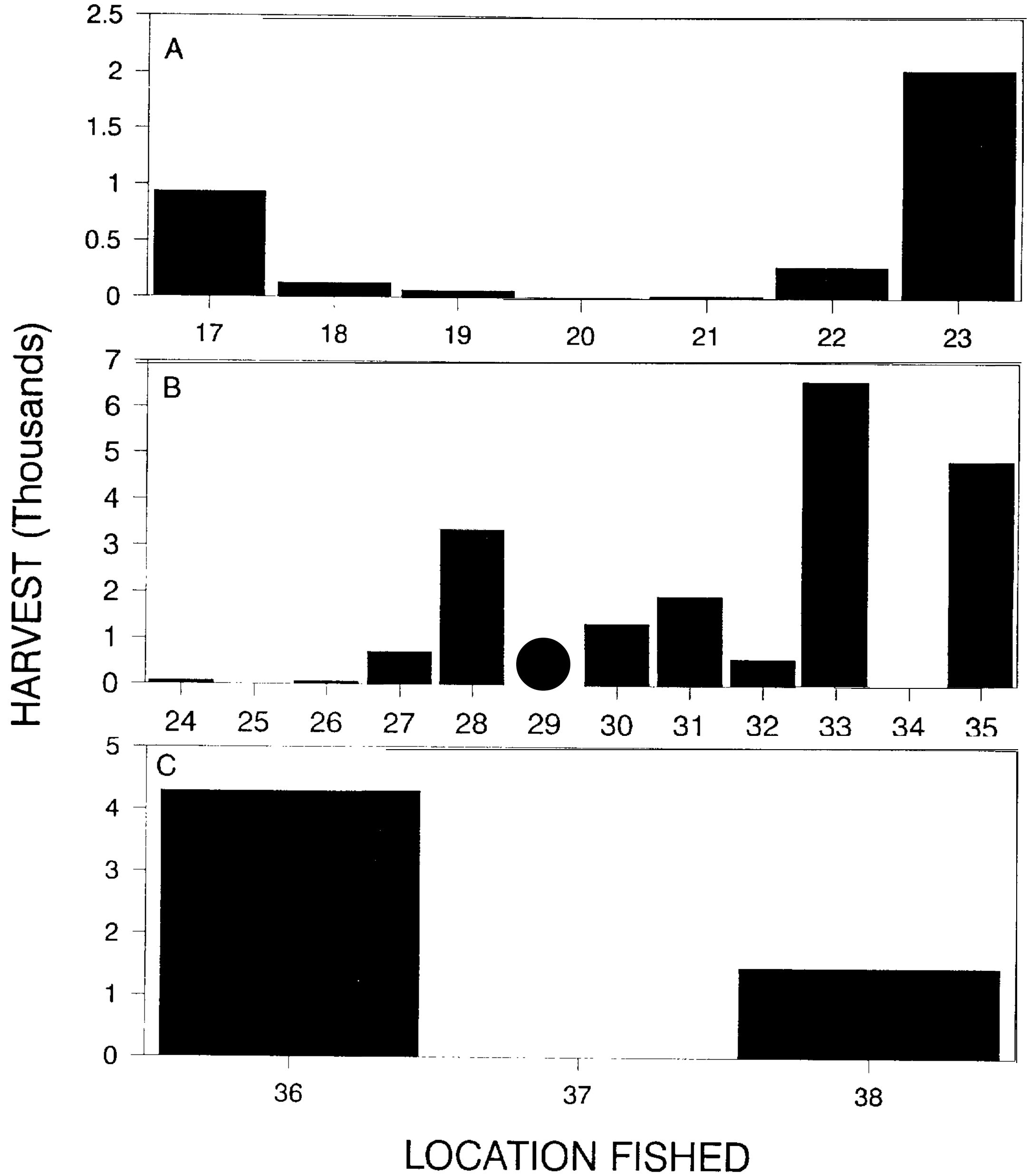

Figure 9. Northern squawfish harvest by reservoir and location fished; (A)= John Day Res.. (B)= McNary Res., (C)= Ice Harbor Res.

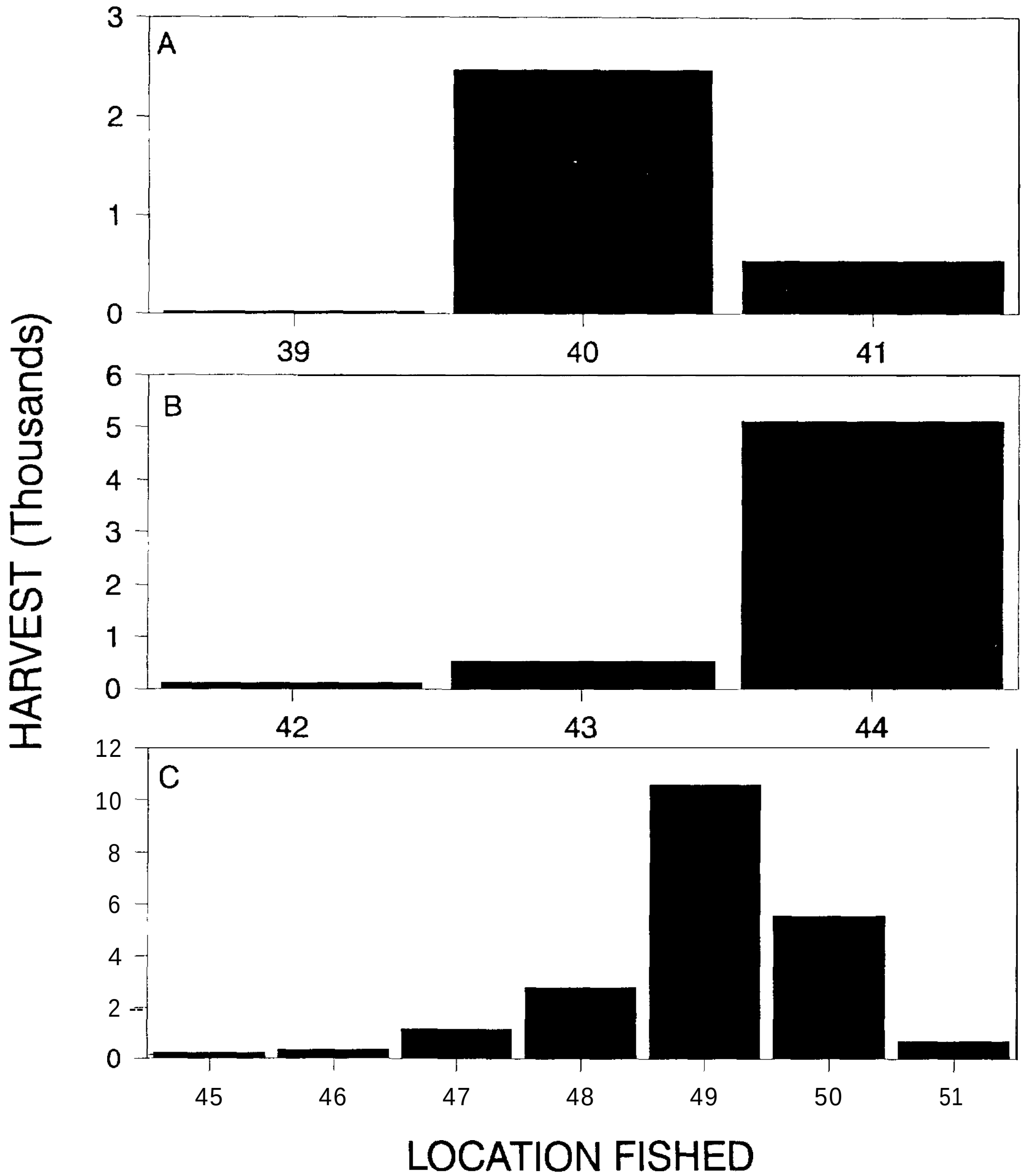

Figure 10. Northern squawfish harvest by reservoir and location fished; (A)= Lower Monumental Res., (B)= Little Goose Res., (C)= Lower Granite Res.

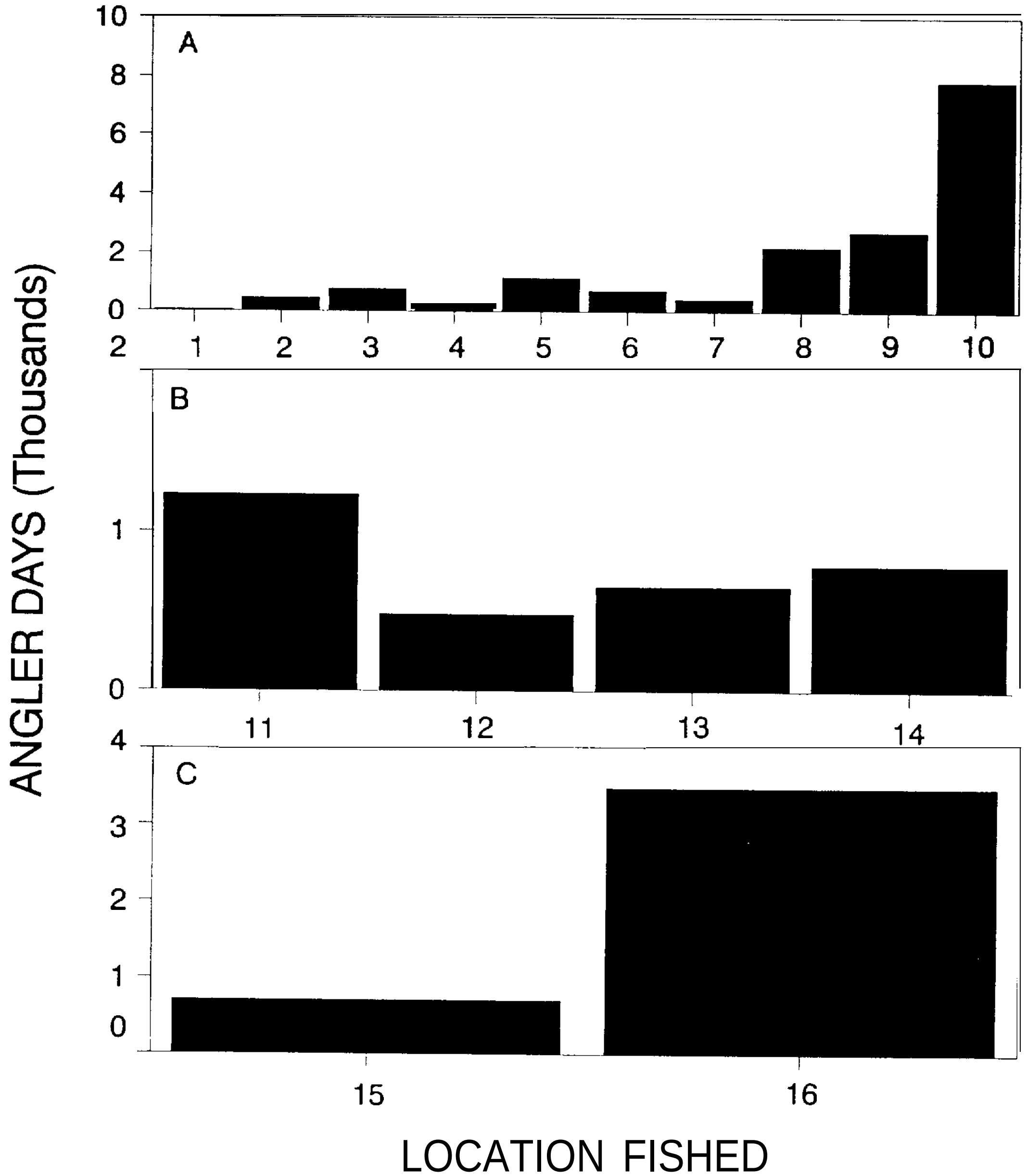

Figure 11. Effort (angler days) by reservoir and location fished; (A)= Bonneville Tailrace, (B)= Bonneville Res., (C)= The Dalles Res.

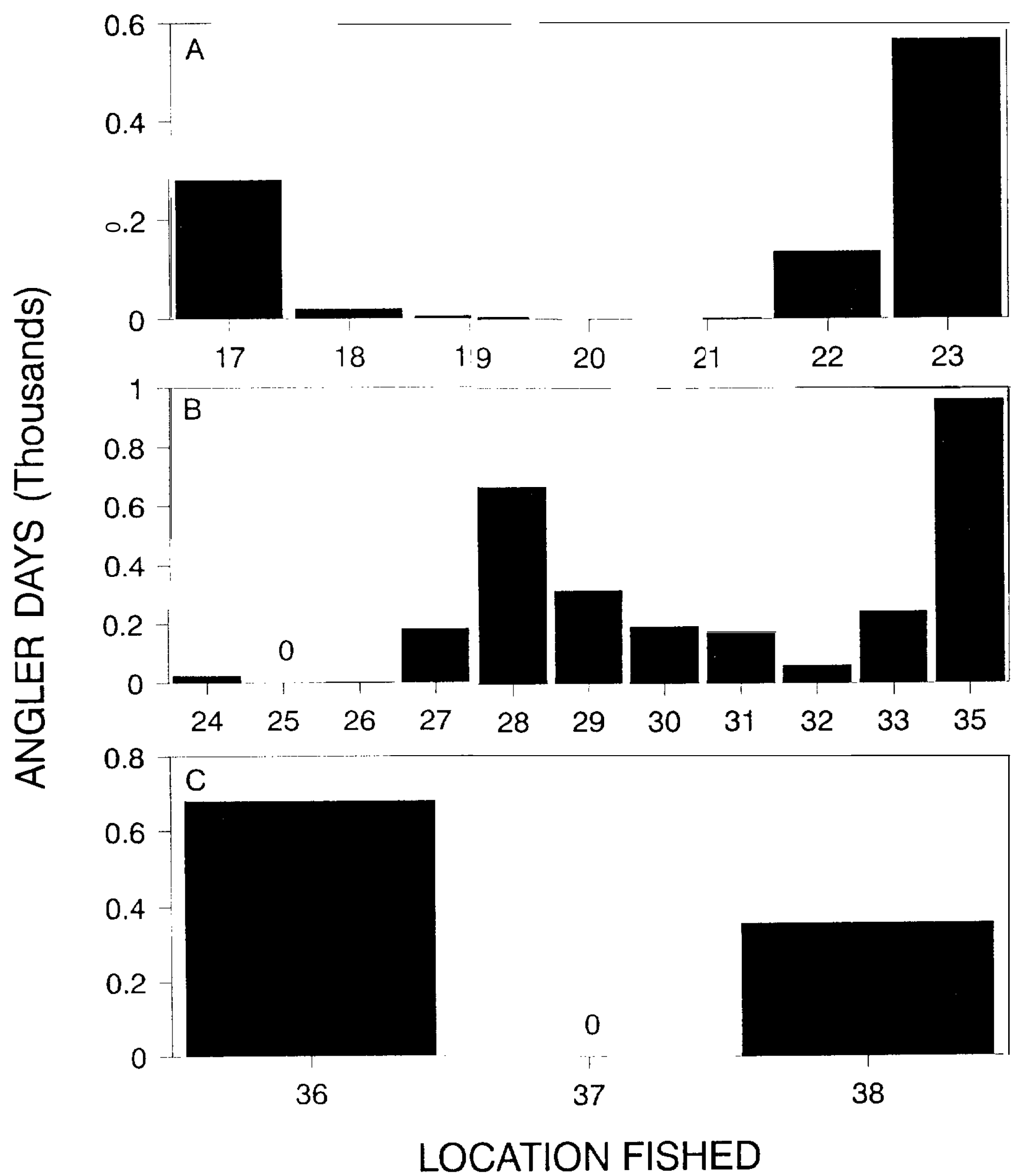

Figure 12. Effort (angler days) by reservoir and location fished; (A)= John Day Res., (B)= McNary Res., (C)= Ice Harbor Res.

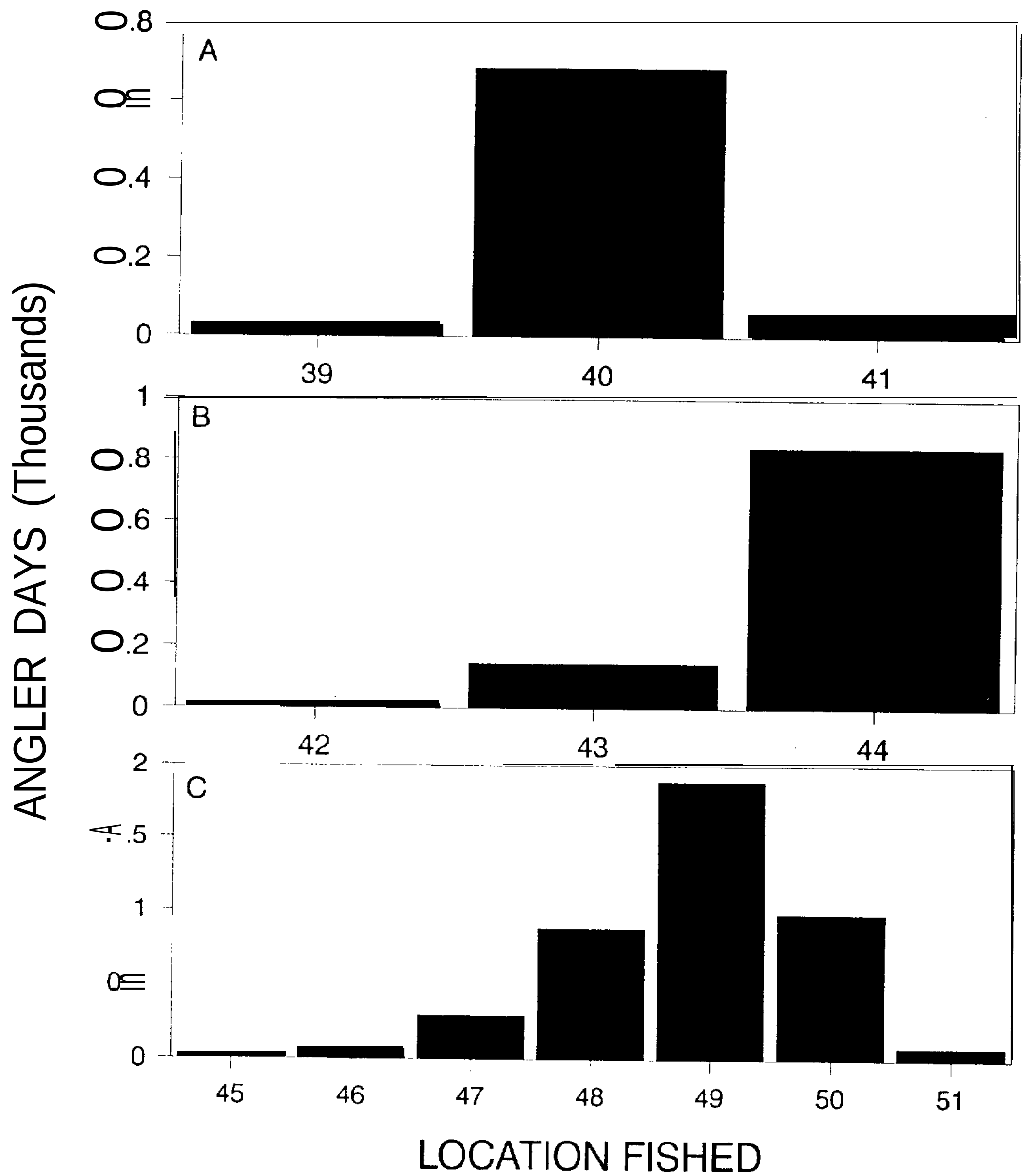

Figure 13. Effort (angler days) by reservoir and location fished; (A)= Lower Monumental Res., (B)= Little Goose Res. (C)= Lower Granite Res.

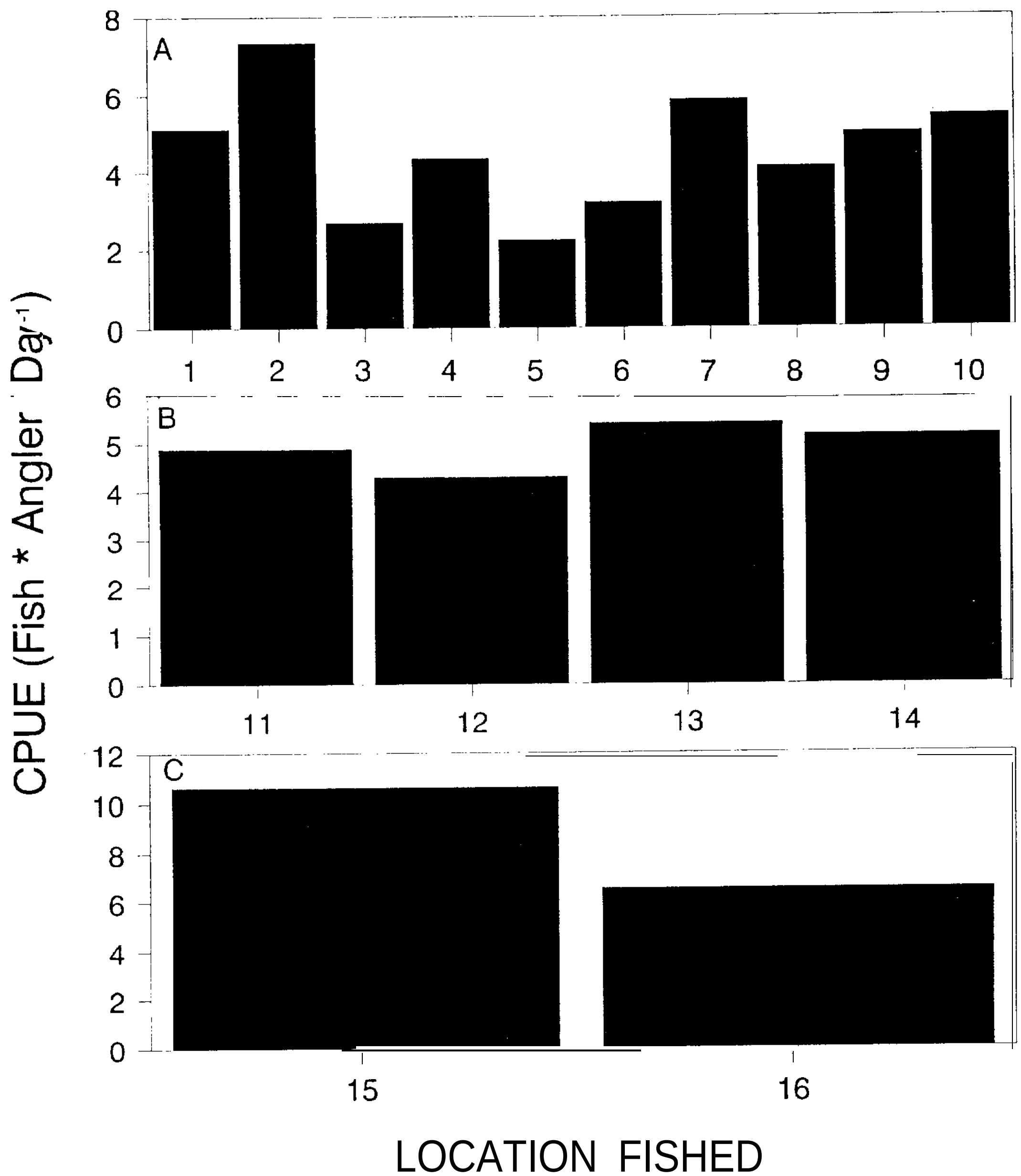

Figure 14. CPUE (Fish * Angler Day-') by reservoir and location fished; (A)= Bonneville Tailrace, (B)= Bonneville Res., (C)= The Dalles Res.

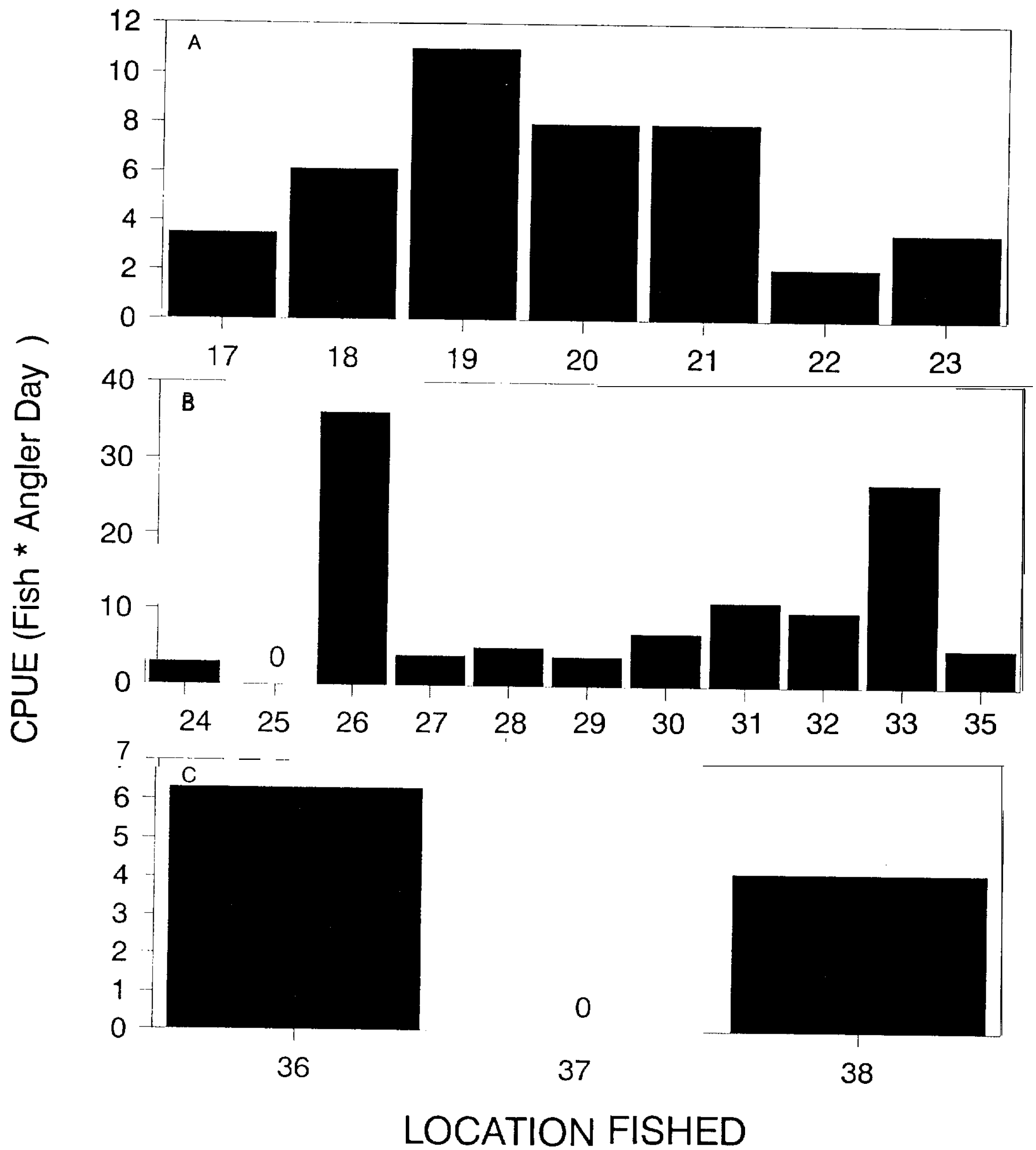

Figure 15. CPUE (Fish * Angler Day^{-1}) by reservoir and location fished; (A) = John Day Res., (B)= McNary Res., (C)= Ice Harbor Res.

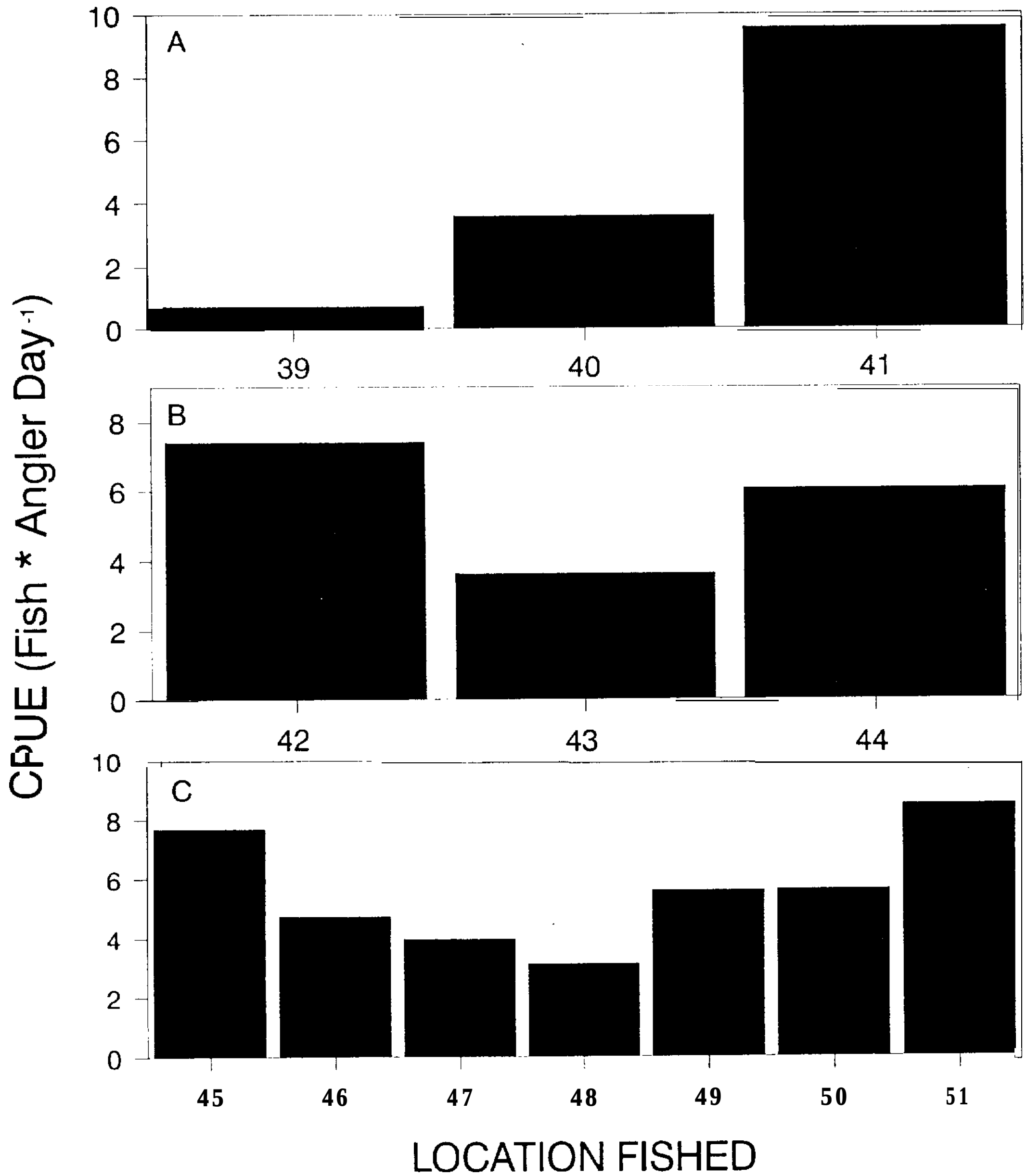

Figure 16. CPUE (Fish * Angler Day-') by reservoir and location fished; (A)= Lower Monumental Res., (B)= Little Goose Res., (C)= Lower Granite Res.

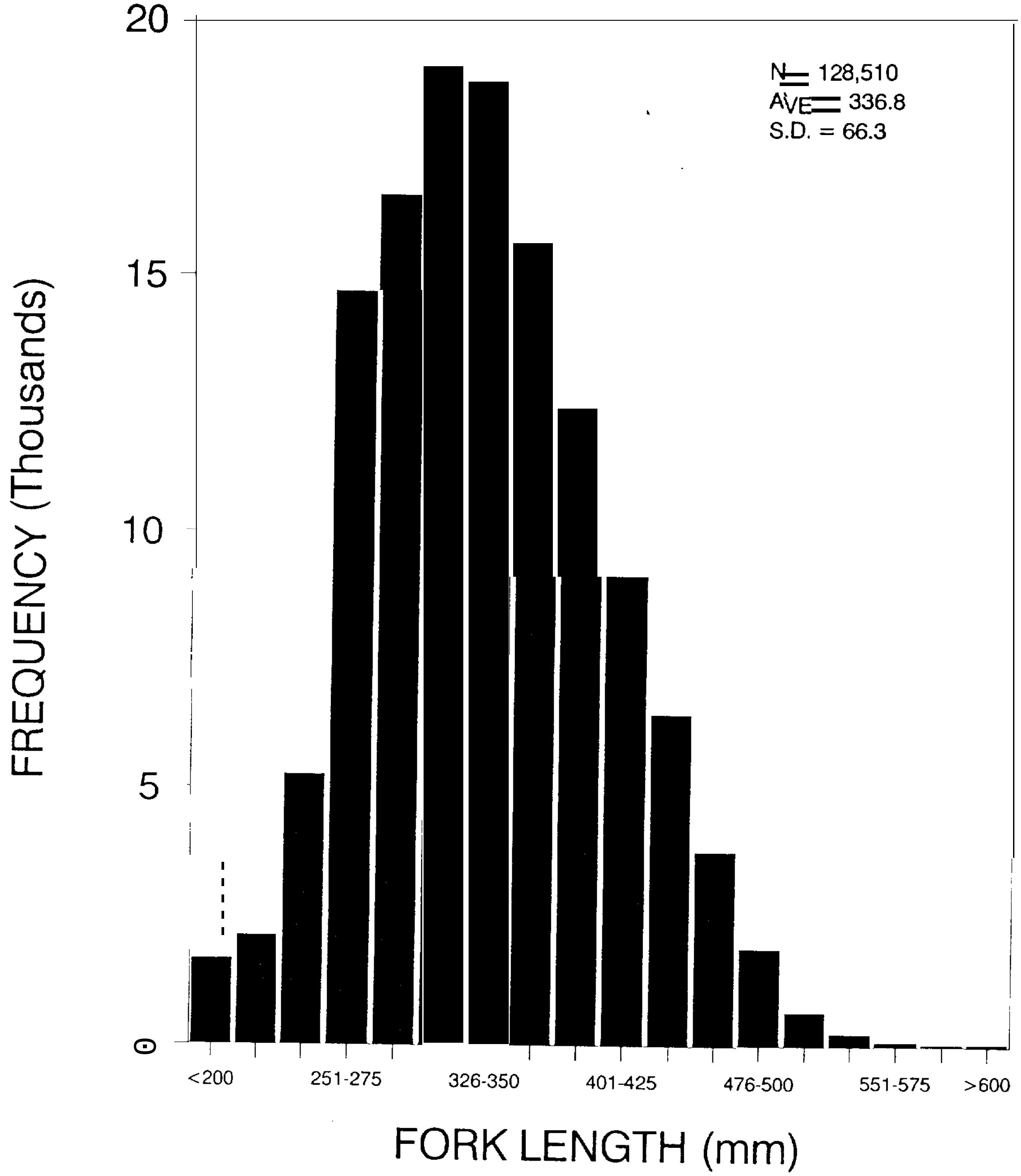

Figure 17. Overall length frequency distribution of northern squawfish caught in the sport-reward fishery.

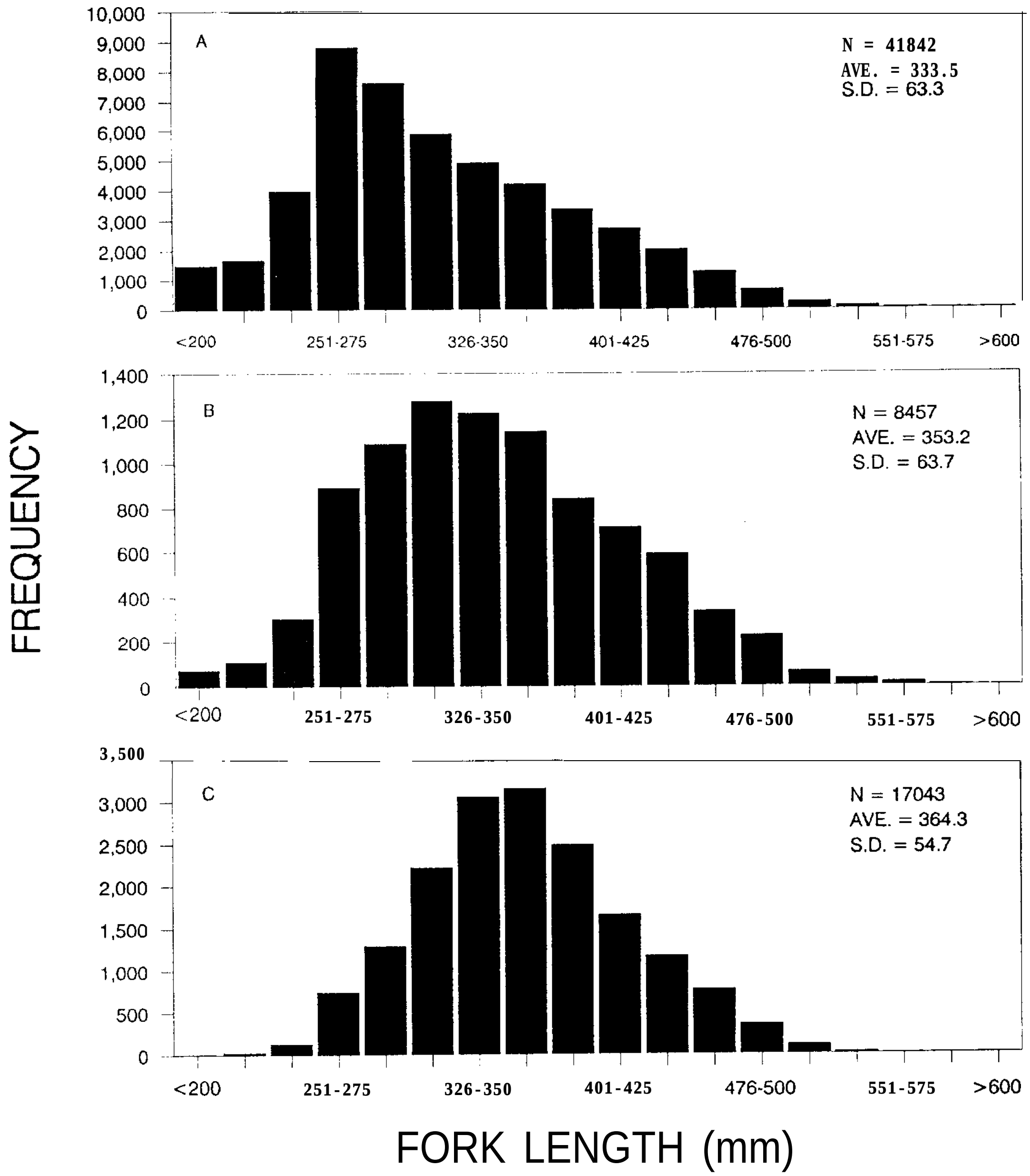

Figure 18. Length frequency distribution of northern squawfish by reservoir; (A)= Bonneville Talirace, (B)= Bonneville Res., (C)= The Dalles Res.

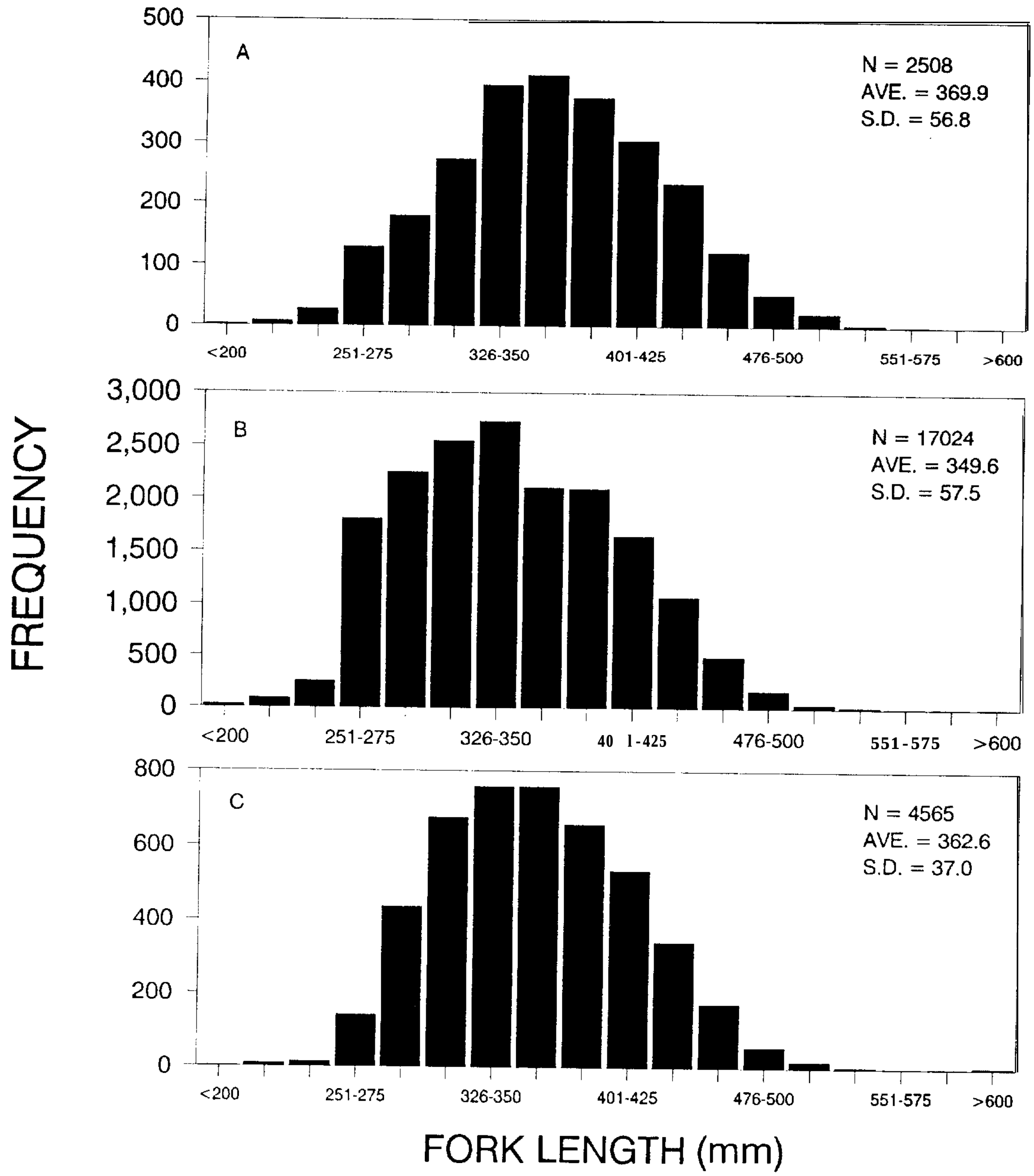

Figure 19. Length frequency distribution of northern squawfish by reservoir; (A)= John Day Res., (B)= McNary Res., (C)= Ice Harbor Res.

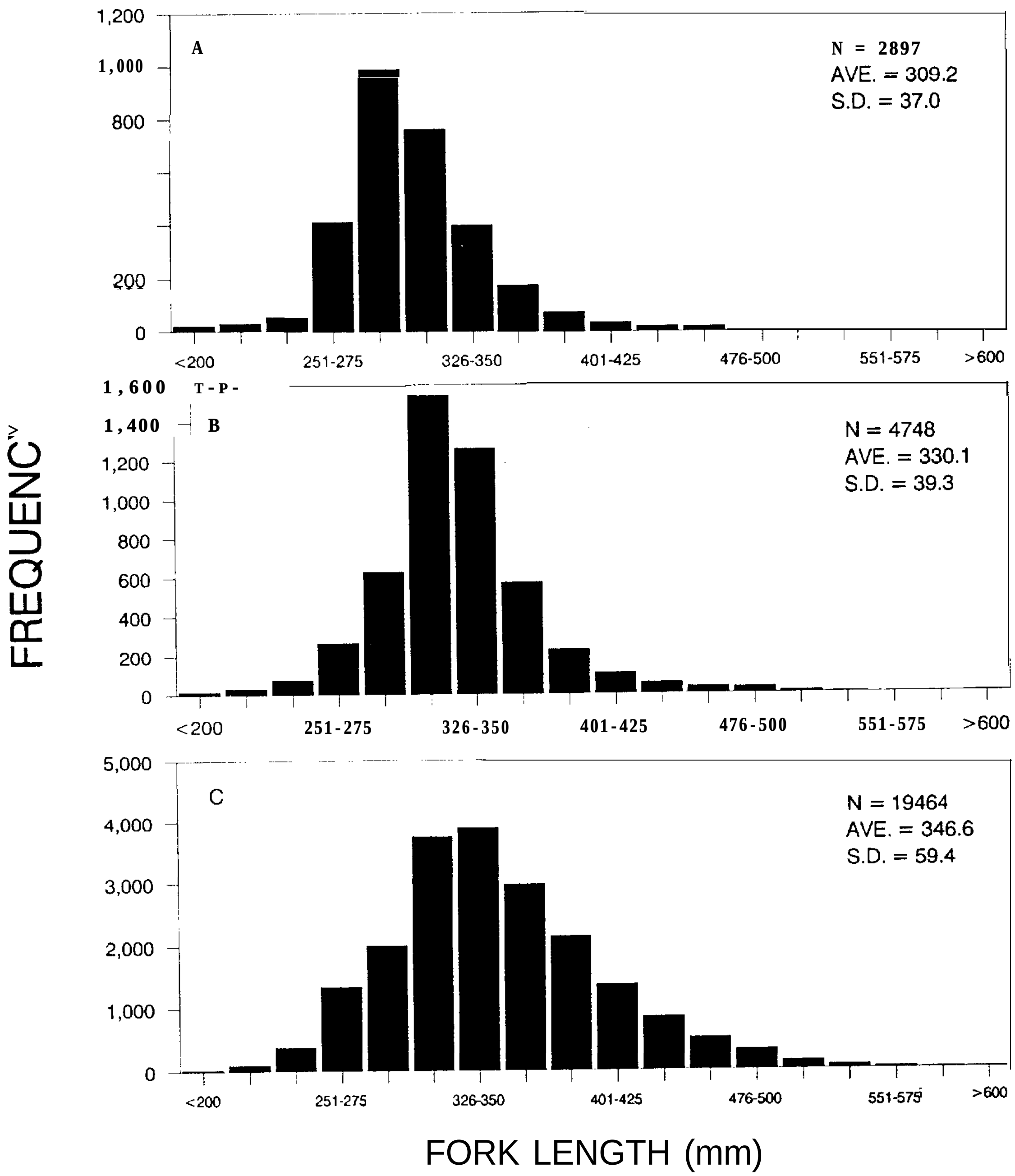

Figure 20. Length frequency distribution of northern squawfish by reservoir; (A)= Lower Monumental Res., (B)= Little Goose Res., (C)= Lower Granite Res.

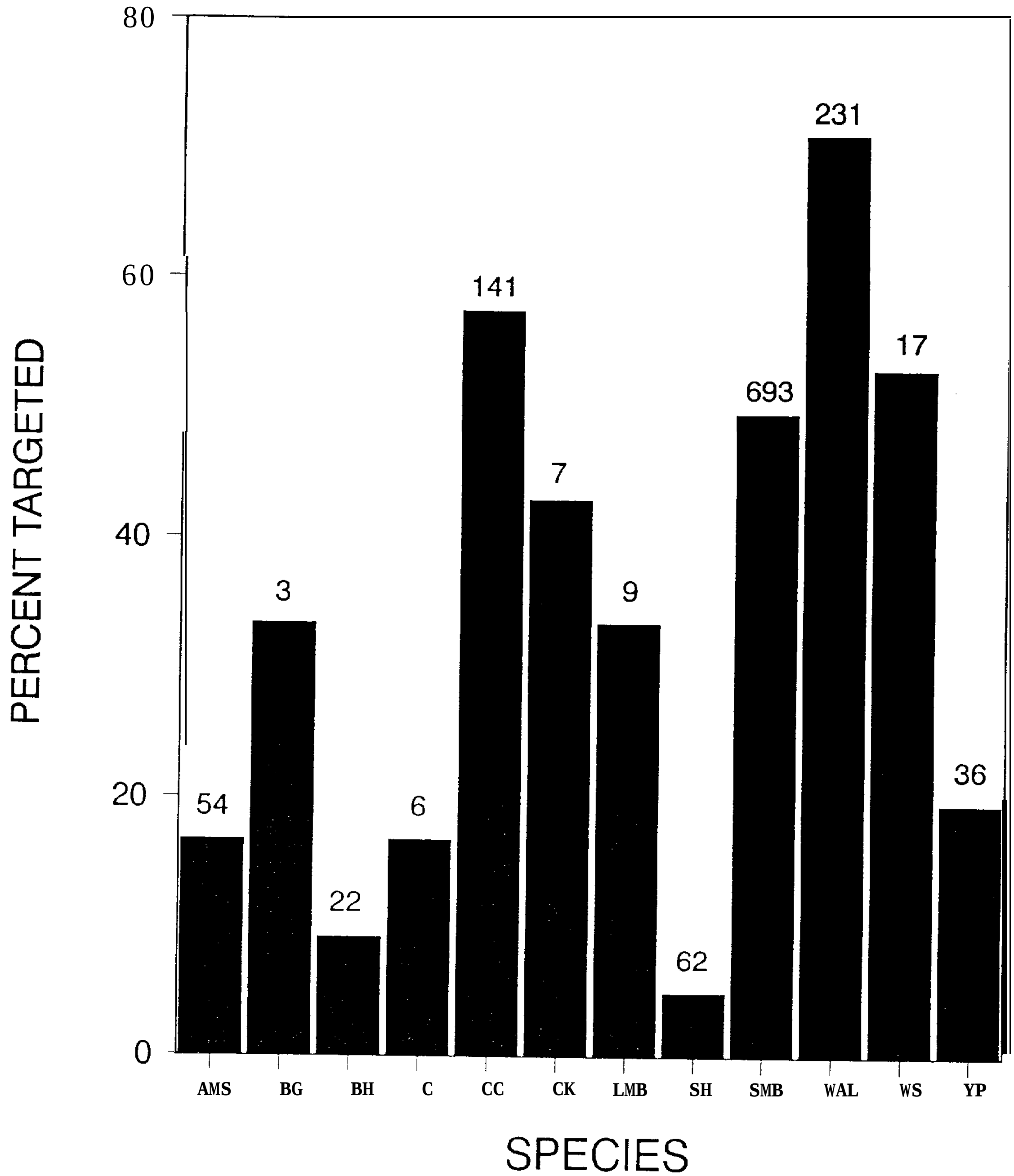

Figure 21. Percent targeted and number of other species turned in to registration stations; AMS= american shad, BG= bluegill, BH= bullhead (general), C= crappie (general), CC= channel catfish, CK= chinook salmon, LMB= largemouth bass, SH= steelhead, SMB= smallmouth bass, WAL= walleye, WS= white sturgeon, YP= yellow perch.

Roving Creel Survey

A total of 6,754 angling parties were interviewed and 1,739 random effort counts were conducted during the 1992 field season. There were a total of 12,110 anglers encountered of which 775 (6%) were registered and 11,335 (94%) were unregistered. The catch, all species combined, kept and released was 14,634 fish (Table 2). Of the total, 1,460 fish (10%) were caught by registered anglers and 13,174 fish (90%) by unregistered anglers.

The number of registered and unregistered anglers varied by reservoir and location fished (Figures 22-24), however, the majority of angling activity was by unregistered anglers. The overall percent harvest by registered and unregistered anglers also varied in this manner, again with the majority of total harvest by the unregistered angler (Figure 25).

The lowest overall catch was in Ice Harbor Reservoir (614 fish); the highest catch was in Little Goose Reservoir (2,912 fish; Appendix A). Total catch for Snake River reservoirs were higher than Columbia River reservoirs.

The overall catch composition for registered and unregistered anglers in all reservoirs show smallmouth bass as the most prevalent fish species (4,256 fish) with lesser catches of rainbow trout (1,392 fish), channel catfish (1,249 fish), northern squawfish (1,222 fish), and white sturgeon (1,22 1 fish), respectively (Table 2).

When examining the percent harvest of smallmouth bass by registered anglers, we see that Ice Harbor Reservoir was the highest at 2 1.2 1%. Registered anglers accounted for 75% of the channel catfish harvested in The Dalles Reservoir; 100% of the observed harvest of walleye were by registered anglers in this reservoir (Figure 26).

High numbers of fish were released by registered (598 fish) and unregistered anglers (7,760 fish) for a combined total of 8,358 fish (Table 1). Smallmouth bass were the dominant fish species released (3,401 fish) followed in ranking order by white sturgeon (1,081 fish), rainbow trout (1,040 fish), channel catfish (327), and steelhead (309 fish).

Expanded harvest estimates (all fish species kept) for registered anglers ranged from 802 (CI= ±684) fish in Ice Harbor Reservoir to 17,167 (CI= ±12,214) fish in Lower Granite Reservoir. The range for unregistered anglers was 3,420 (CI= ± 1,756) fish in Bonneville Reservoir and 42,951 (CI= ±27,958) fish in the Bonneville Dam tailrace (Figure **27).**

The comparison of northern squawfish harvested by reservoir in the sport-reward fishery and the estimated harvest of northern squawfish by registered anglers from the roving creel survey (Figure 28) showed a positive correlation using the Spearman Correlation Coefficient (SAS Institute Inc. 1988); r= 0.733 (P= 0.025).

Table 1. Total of all species of fish turned into the registration stations excluding northern squawfish.

Common Name	Scientific Name	Code	Total 1992
American shad	*Alosa sapidissima*	AMS	54
Brown bullhead	*Ictalurus nebulosus*	BBH	18
Black crappie	*Pomoxis nigromaculatus*	BC	3
Bluegill	*Lepomis macrochirus*	BG	3
Bullhead (general)	*Ameiurus spp.*	BH	4
Bull trout	*Salvelinius malma*	BLC	0
Bridgelip sucker	*Catostomus columbianus*	BRS	8
Brown trout	*Salmo trutta*	BT	0
Crappie (general)	*Pomoxis spp.*	C	3
Channel catfish	*Ictalurus punctatus*	c c	141
Chum salmon	*Oncorhynchus keta*	CH	1
Chinook salmon	*Oncorhynchus tshawytscha*	CK	7
Chiselmouth	*Acrocheilus alutaceus*	CMO	139
Sculpin (general)	*Cottus spp.*	COT	10
Carp	*Cyprinus carpio*	CP	19
Columbia River chub”		CRC	125
Cutthroat trout	*Oncorhynchus clarki*	CT	0
Largemouth bass	*Micropterus salmoides*	LMB	9
Longnose sucker	*Catostomus catostomus*	LNS	1
Largescale sucker	*Catostomus macrocheilus*	LRS	11
Mountain whitefish	*Prosopium williamsoni*	MW	5
Peamouth	*Mylocheilus caurinus*	PMO	588
Pumpkinseed	*Lepomis gibbosus*	PS	2
Rainbow trout (res.)	*Oncorhynchus mykiss*	RB	9
Redside shiner	*Richardsonius balteatus*	RS	2
Rainbow trout (unk.)	*Oncorhynch us mykiss*	RU	113
Sculpin, prickly	*Cottus asper*	PRS	
Searun cutthroat	*Oncorhynchus clarki*	SCT	1
Starry flounder	*Platichthys stellatus*	SF	9
Steelhead (unk.)	*Oncorhynchus mykiss*	SH	9

Table 1. Continued.

Common Name	Scientific Name	Code	Total 1992
Sucker (general)	*Catostomus spp.*	SK	21
Smallmouth bass	*Micropterus dolomieui*	SMB	693
Sockeye salmon	*Oncorhynchus nerka*	SO	2
Steelhead (summer)	*Oncorhynchus mykiss*	SS	40
Steelhead (winter)	*Oncorhynchus mykiss*	SW	13
Tench	*Tinca tinca*	TNC	0
Walleye	*Stizostedion vitreum*	WAL	231
White crappie	*Pomoxis annularis*	WC	0
Warmouth	*Chaenobryttus gulosus*	WM	0
White sturgeon	*Acipenser transmoutanus*	WS	17
Yellow perch	*Per-ca flavescens*	YP	36
Total			2,349

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

Table 2. Catch composition from the roving creel survey for all reservoirs, 1992 (species codes are listed in Table 1).

	Registered Anglers			Unregistered Anglers			
Species	Kept	Released	Total	Kept	Released	Total	Total
AMS	28	2	30	955	169	1124	1154
B	1	34	35	43	212	255	290
BC	2	7	9	296	22	517	526
BCF	--	--	--	1		1	1
BG	1	10	11	64	83	147	158
BH		3	3	49	88	137	140
BBH	--	--	--	29	--	29	29
BRS	1	--	1	50	11	61	62
C	--	1	1	118	193	311	312
c c	20	27	47	902	300	1202	1249
CMO	1	1	2	8	44	52	54
CYP		3	3		3	3	6
CK	1	--	1	118	24	142	143
c o	--	--		13	--	13	13
COT	--	9	9	1	6	7	16
CP		--		8	15	23	23
GS	--	--		--	20	20	20
LMB		1	1	3	15	18	19
LRS	--	2	2	4	3	7	9
NSF	751	43	794	201	227	428	1222
PK	1	--	1	54	36	90	91
PMO	1	3	4	17	2	19	23
PS	I		1	15	12	27	28
RU		48	48	186	194	380	428
S	3		3	25	35	60	63
SAL	--			13	17	30	30
SCT		--		3	--	3	3
SF	--	--		1	--	1	1
SH	4	45	49	291	310	601	650
SK	--	26	26	13	64	77	103

Table 2. Continued.

Species	Registered Anglers			Unregistered Anglers			
	Kept	Released	Total	Kept	Released	Total	Total
SMB	32	219	251	823	3182	4005	4256
s o	--	--	--	--	2	2	2
s s				227	30	257	257
TR	3	68	71	349	972	1321	1392
TCH	--	--		--	1	1	1
WC	--		--	96	15	111	111
WAL	7	11	18	26	10	36	54
w s	2	29	31	138	1052	1190	1221
YBH	--	--	--	39	15	54	54
YP	2	6	8	235	177	412	420
Totals	862	598	1460	5414	7760	13174	14634

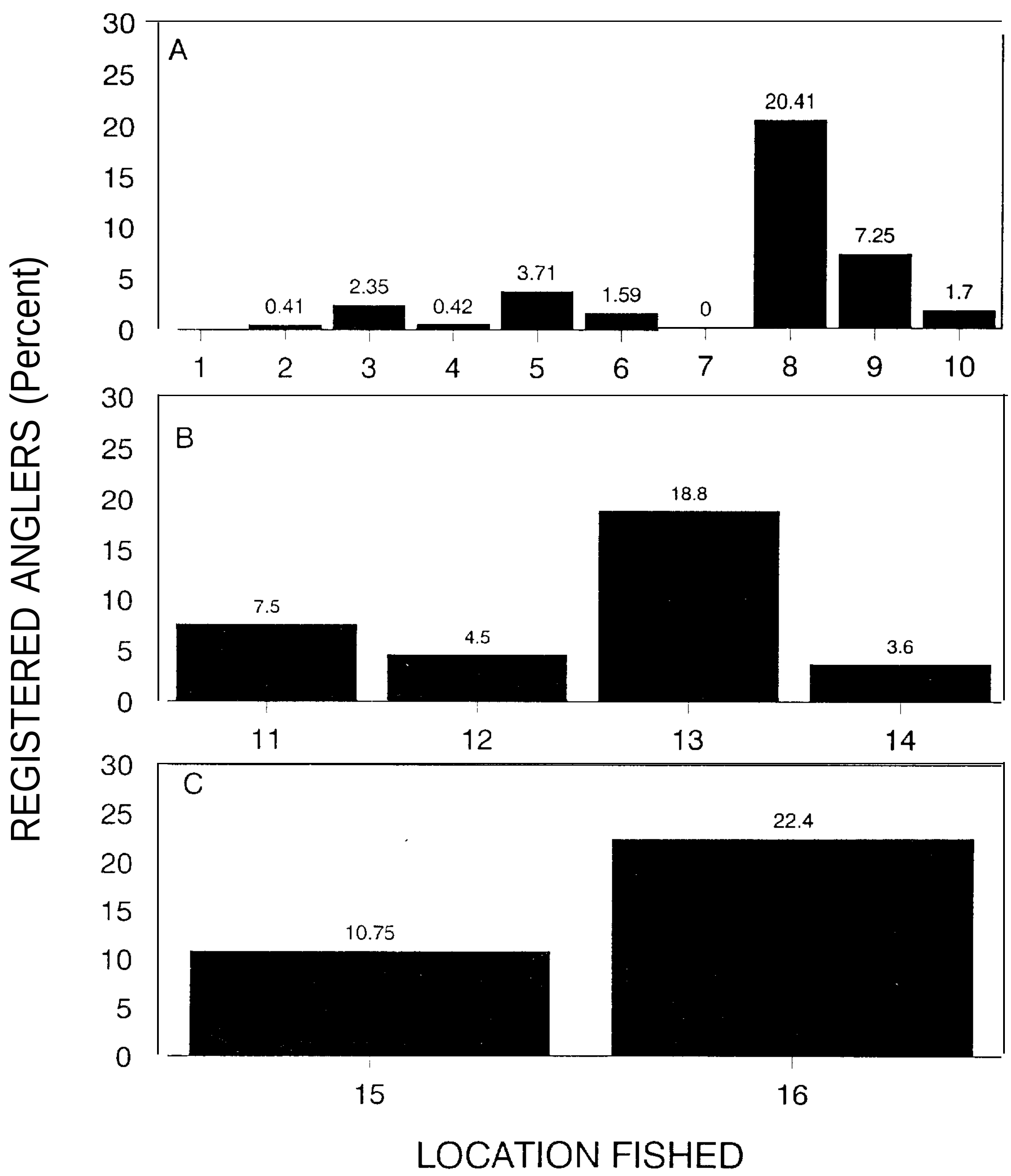

Figure 22. Creel survey percent registered anglers by reservoir and location fished; (A)= Bonneville Tailrace. (B)= Bonneville Res., (C)= Dalles Res.

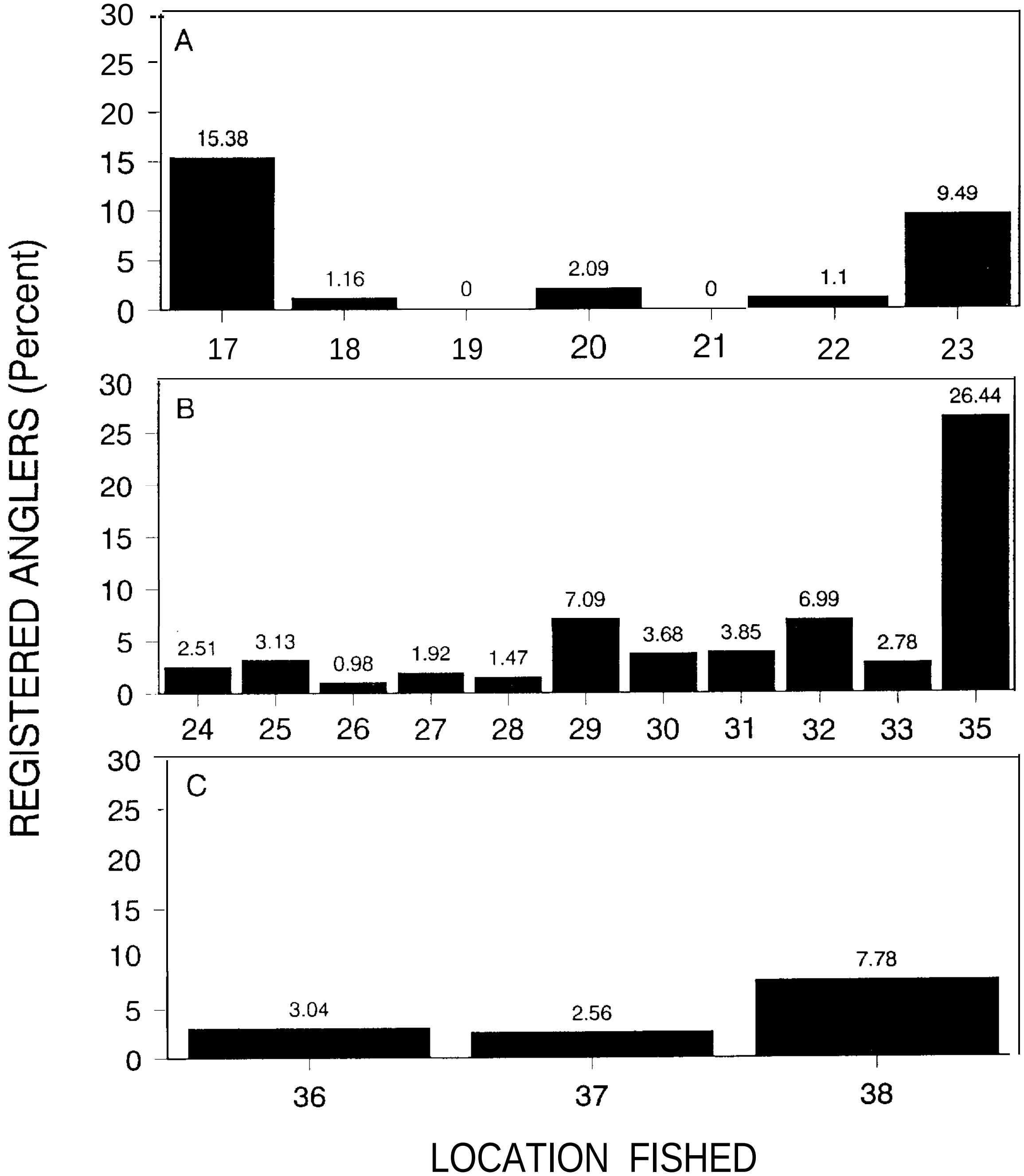

Figure 23. Creel survey percent registered anglers by reservoir and location fished; (A)= John Day Res., (B)= McNary Res., (C)= Ice Harbor Res.

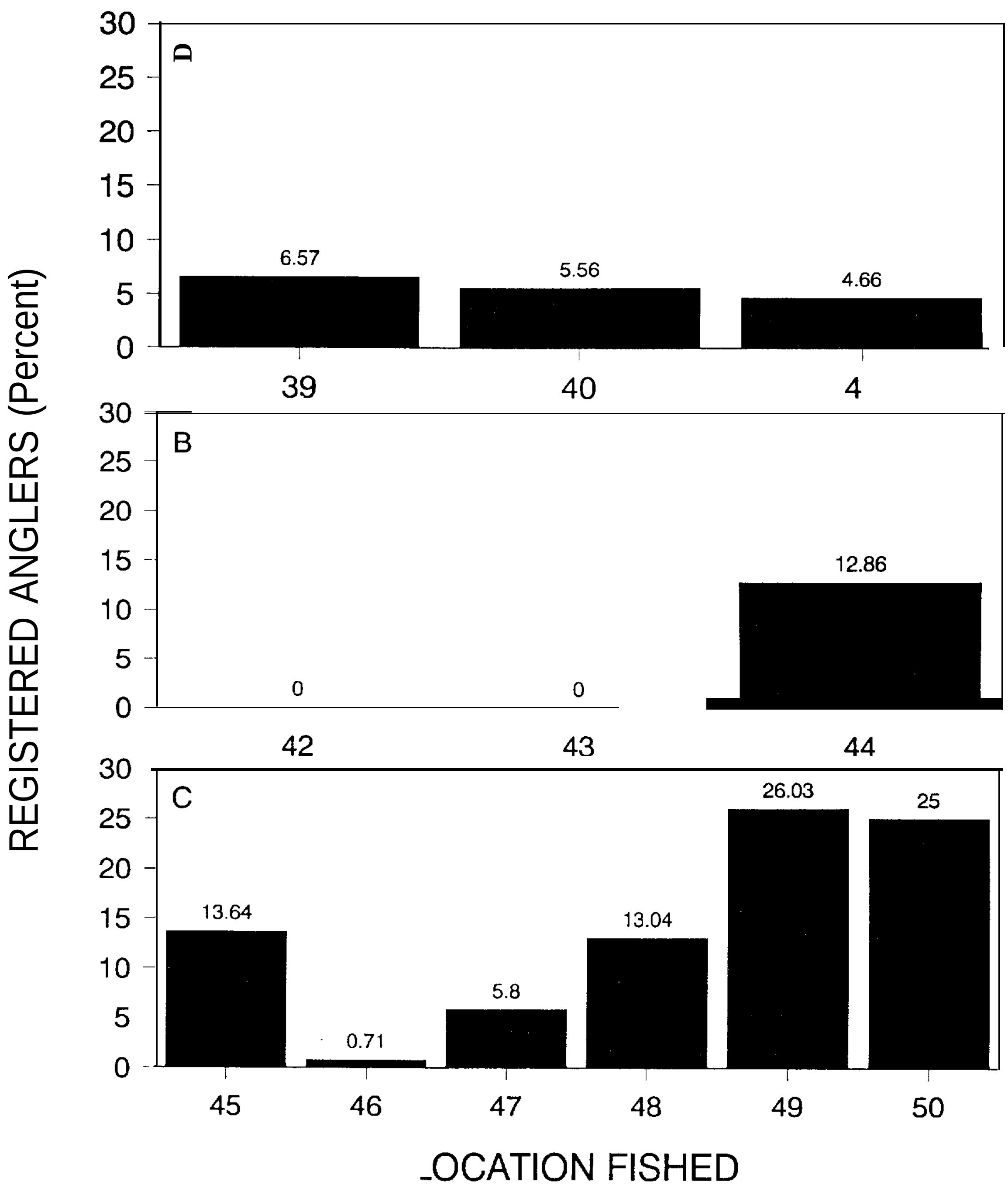

Figure 24. Creel survey percent registered anglers by reservoir and location fished; (A)= Lower Monumental Res., (B)= Little Goose Res., (C)= Lower Granite Res.

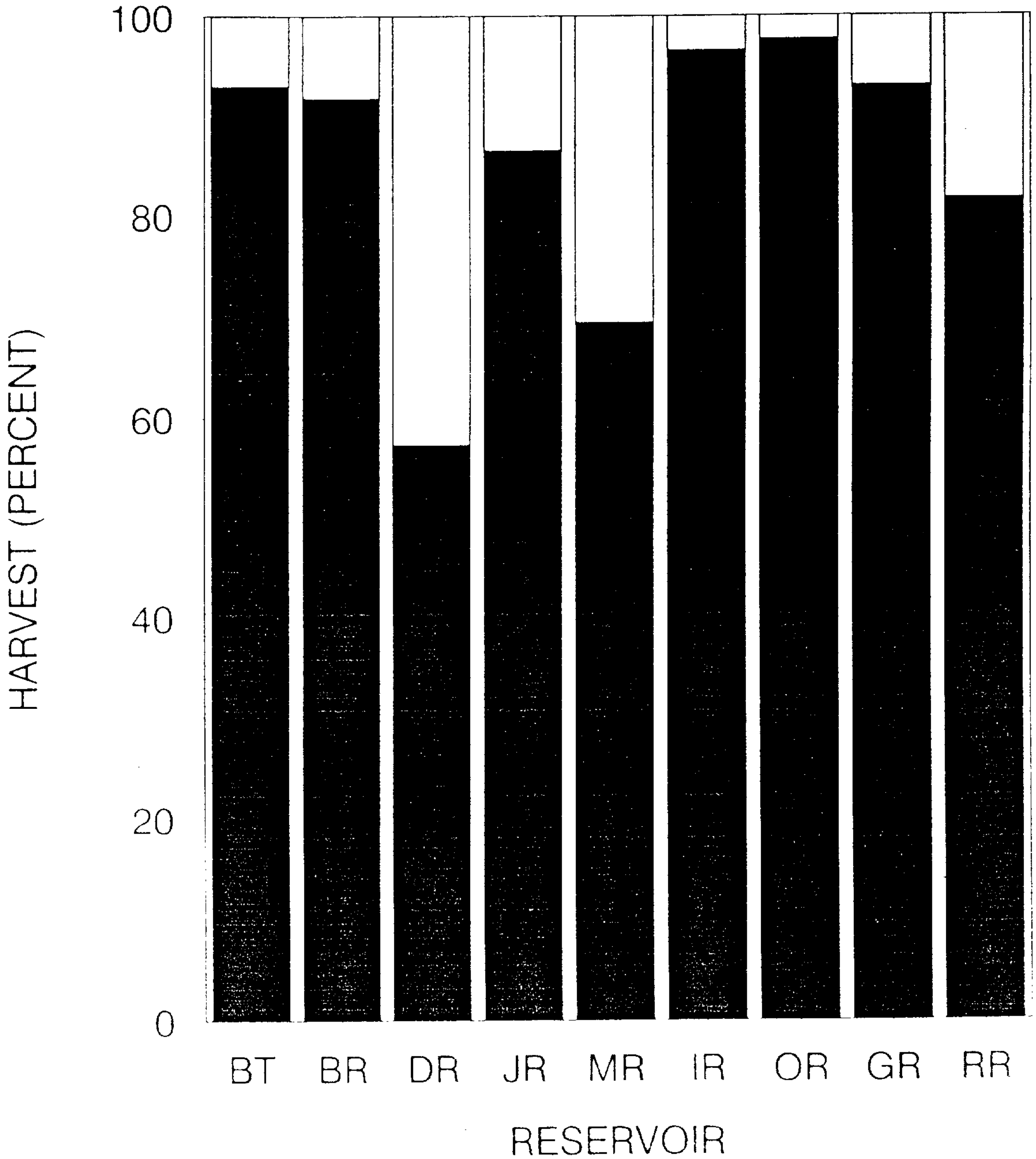

Figure 25. Creel survey percent harvest by reservoir for all species combined; (shaded bar= registered anglers, black bar= unregistered anglers). BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

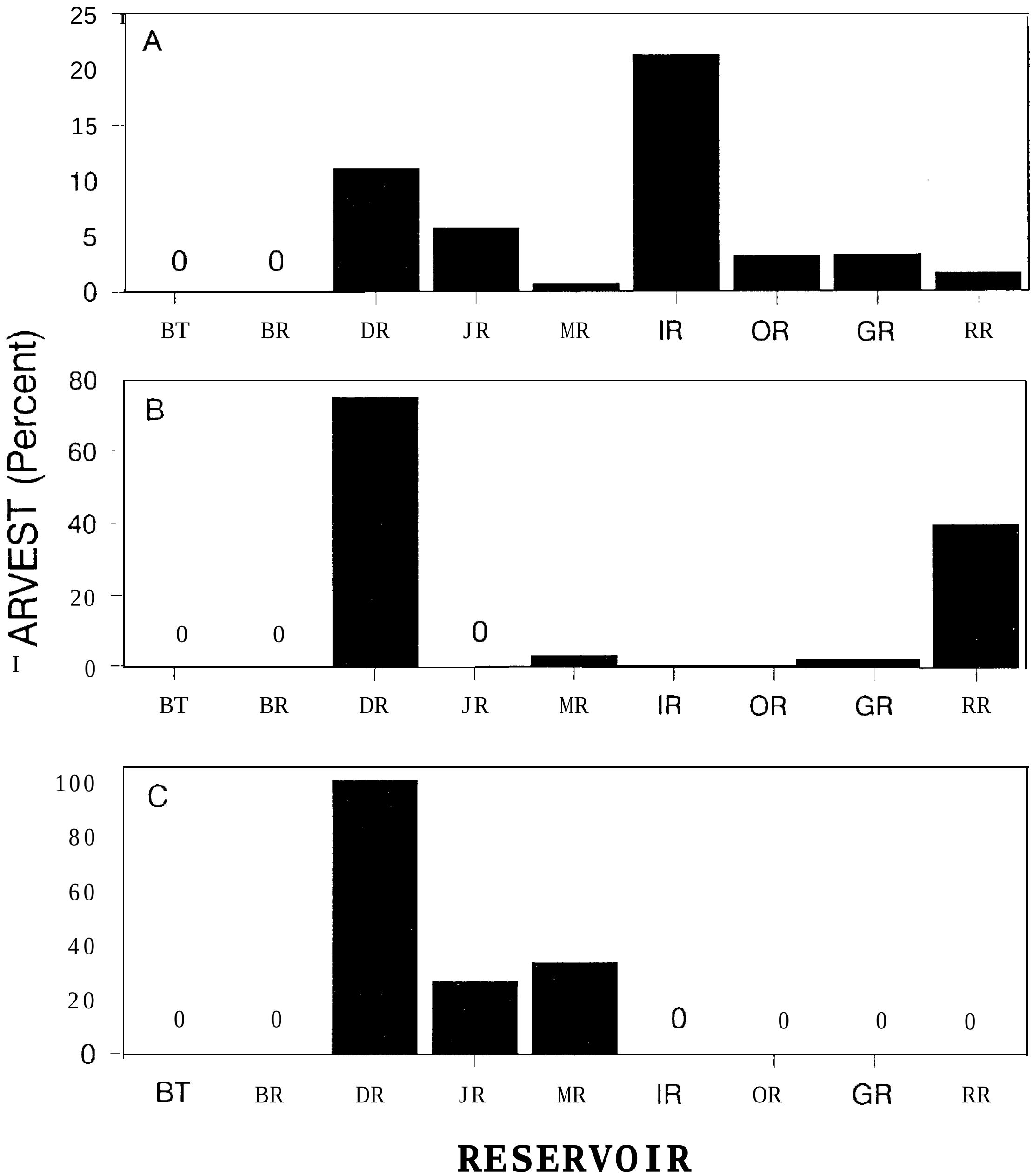

Figure 26. Creel survey percent harvest by registered angler by reservoir; (A)= smallmouth Bass, (B)= channel catfish, (C)= walleye; BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

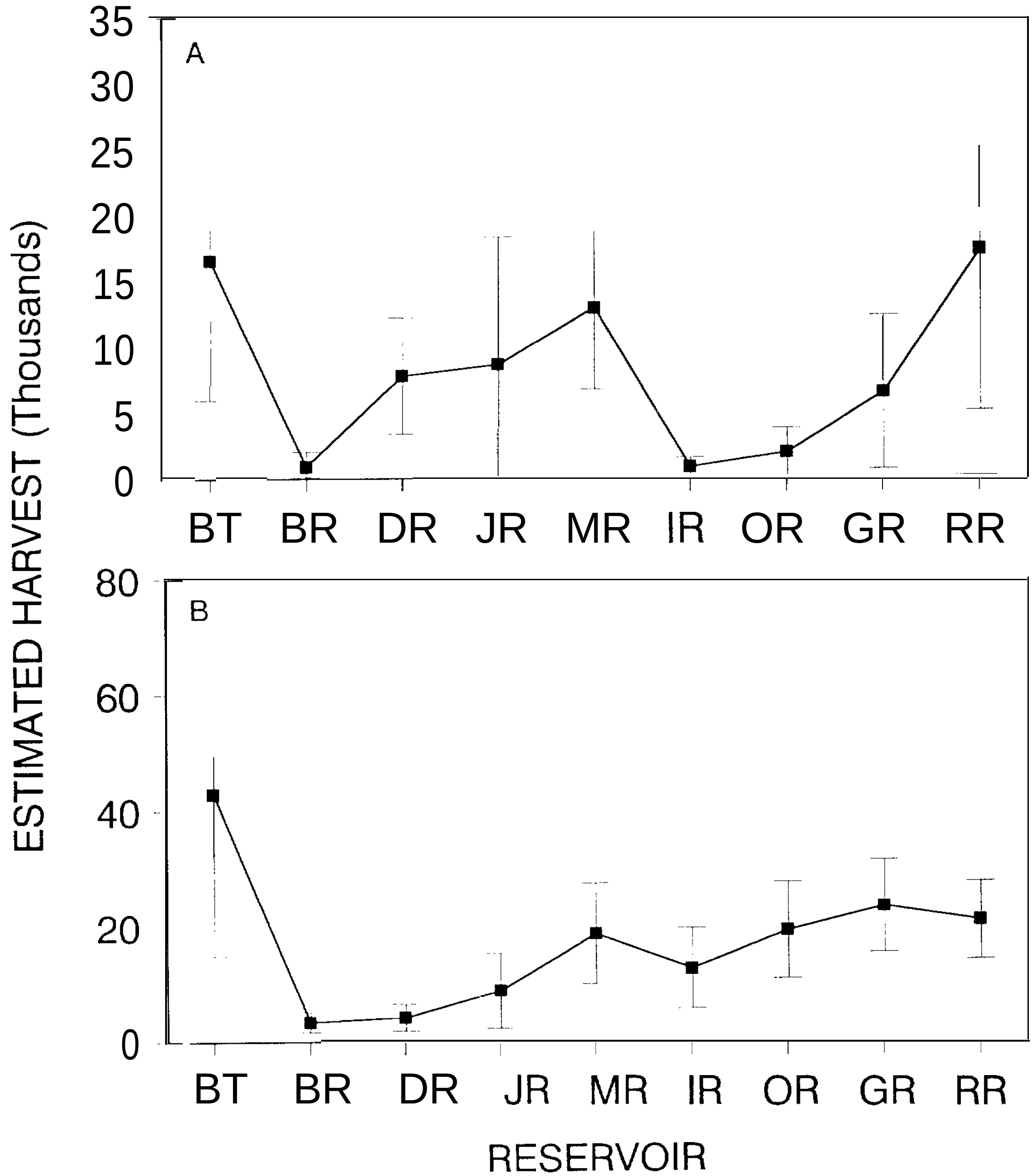

Figure 27. Creel survey estimated harvest for all species combined by reservoir with 95% confidence intervals; (A)= registered anglers, (B)= unregistered anglers; BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

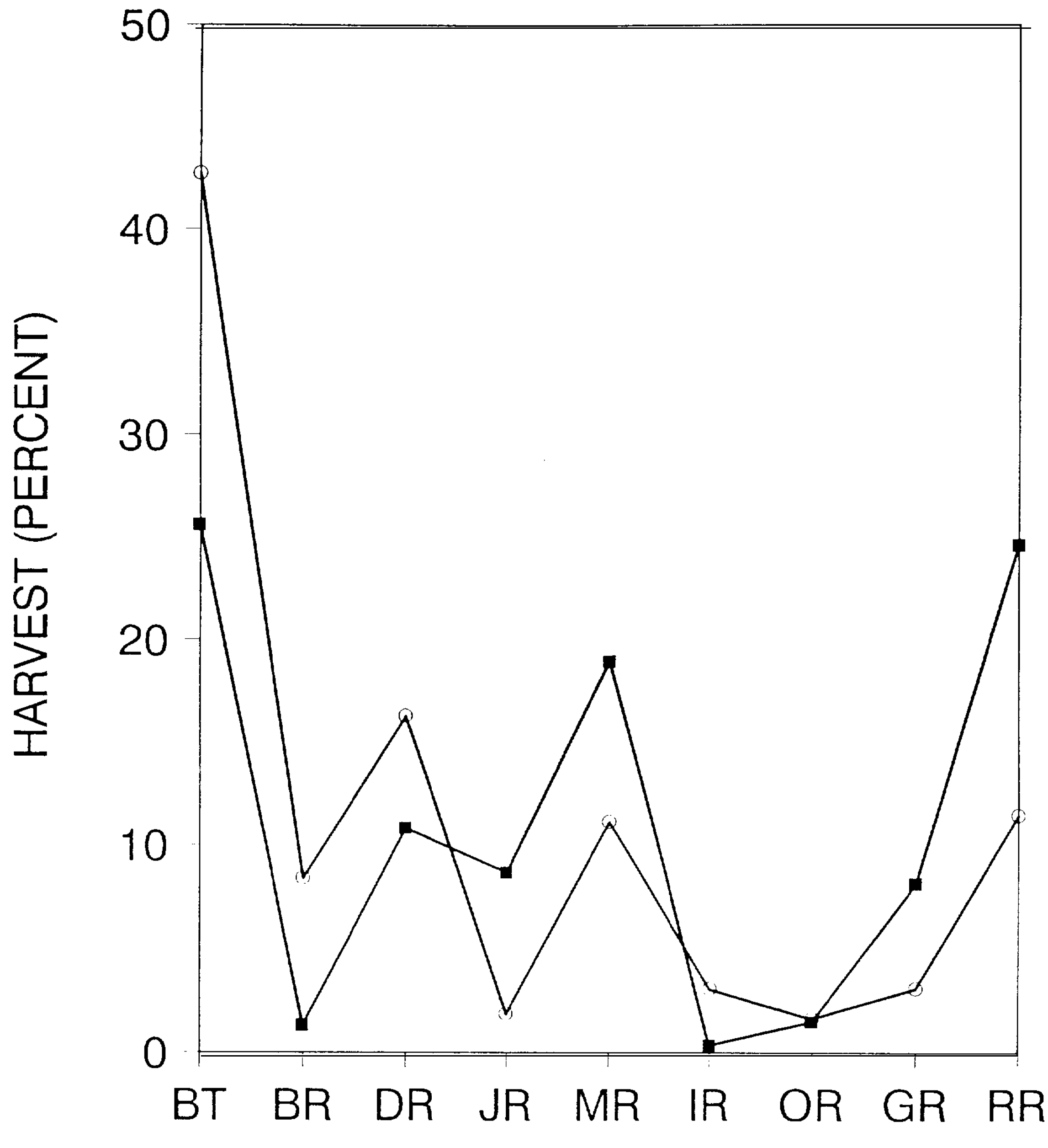

Figure 28. Northern squawfish harvest by reservoir (O= sport-reward fishery-actual, ■= creel survey-registered angler-estimated); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

1991-1992 Comparisons

The overall harvest in 1992 was approximately 15% higher than the sport fishery harvest of 159,162 northern squawfish in 1991. Participation also increased by about 24% from an estimated 67,384 angler days in 1991 to 88,494 angler days in 1992. The CPUE showed a decrease from 2.36 fish per angler day in 1991 to 2.11 fish per angler day in 1992.

A comparison of the harvest data and effort by week for 1991 and 1992 shows a marked difference between years in the early weeks of the season. The two years had similar trends in harvest in the later weeks of the season, however, the 1992 data was shifted approximately three weeks earlier (Figure 29). The comparison of effort data by week between the two fishing seasons showed trends similar to the harvest data (Figure 30). The CPUE values varied more in 1991 than in 1992 (Figure 31). Both years had fairly similar and level CPUE values in the later weeks of the season.

The catch and effort (returning anglers only) data by reservoir between the two seasons showed differences. Five of the nine reservoirs had increased harvests of northern squawfish from 1991 to 1992 (Bonneville tailrace; McNary, Ice Harbor, Little Goose, and Lower Granite reservoirs). The largest increase in numbers of fish harvested was from 58,235 to 79,822 in the Bonneville tailrace. The other four reservoirs (Bonneville, The Dalles, John Day, and Lower Monumental reservoirs) had reduced harvest between the two years (Figure 32). Six of the nine reservoirs had increased effort in 1992 (Bonneville tailrace; The Dalles, McNary, Ice Harbor, Lower Monumental, and Little Goose reservoirs). The other three reservoirs (Bonneville, John Day, and Lower Granite) had reduced effort in 1992 (Figure 33). Five of the nine reservoirs had increased CPUE (fish per returning angler day) values from 1991 to 1992 (Bonneville, John Day, McNary, Ice Harbor, and Lower Granite reservoirs). The other four had reduced CPUE values from 1991 to 1992 (Figure 34).

Catch, effort (angler days), and CPUE (fish per angler day) varied by registration station between the two years. Thirteen of the 20 registration sites were open in both 1991 and 1992. Of the 13 registration stations that were open in both years, six (The Dalles Boat Basin, Maryhill State Park, Columbia Point, Hood Park, Windust Park, and Greenbelt Boat Ramp) had greater catches (Figure 35). Seven (The Dalles Boat Basin, Maryhill State Park, Columbia Point, Hood Park, Windust Park, Lyons Ferry Marina, and Greenbelt Boat Ramp) of the 13 stations had higher participation (Figure 36). Eight of the 13 stations (Cascade Locks, Bingen Marina, The Dalles Boat Basin, Maryhill State Park, Columbia Point, Hood Park, Windust Park, and Greenbelt Boat Ramp) had higher CPUE values in 1992 than in 1991 (Figure 37).

Length measurements were taken from a total of 119,437 northern squawfish with fork lengths greater than or equal to 250 mm (11 inches total length) during the 1992 season and 59,650 northern squawfish during the 1991 season. The average length for all locations combined was 346 mm (SD = 59.7 mm) in 1992, and 350 mm (SD = 59.6) in 1991. We used a t-test to compare mean fork lengths by reservoir to determine whether there was a statistically significant change in mean fork lengths between 1991 and 1992. We found that the John Day and Ice harbor reservoirs did not show a statistically significant difference in mean fork lengths ($P = 0.05$) while all other reservoirs did show a statistically significant difference. One possible reason for this could be attributed to between-season variability (Table 3).

DISCUSSION

Sport-Reward Fishery

Northern Squawfish Harvest Data

The 186,604 northern squawfish removed systemwide in 1992 accounted for a significant portion of the systemwide exploitation of about 9.8-14.4% (Parker et al. 1992). The upper range of this estimate met the minimum targeted exploitation rate of 10%.

The increase in harvest by 15 % and participation by 24% from the 1991 fishery can partially be attributed to the addition of five registration stations and increased public awareness of the program. However, with CPUE being lower in 1992 than in 1991, our ability to increase the level of northern squawfish harvest will depend primarily on our ability to increase participation in 1993.

When analyzing the sport-reward fishery data to determine how many and where registration stations should be located to achieve the targeted systemwide exploitation rate of 10-20%, we need to focus on three factors: (1) the reservoir specific predation index values, (2) the current annual exploitation of northern squawfish in that reservoir, and (3) the size composition of the northern squawfish being turned in. The reservoir specific predation index values, associated exploitation rates, and size composition indicated that we should increase effort in some reservoirs and reduce effort in others. Specifically, additional registration stations should be opened below Bonneville Dam where there are some of the highest predation index values and exploitation rates (Parker et al. 1992).

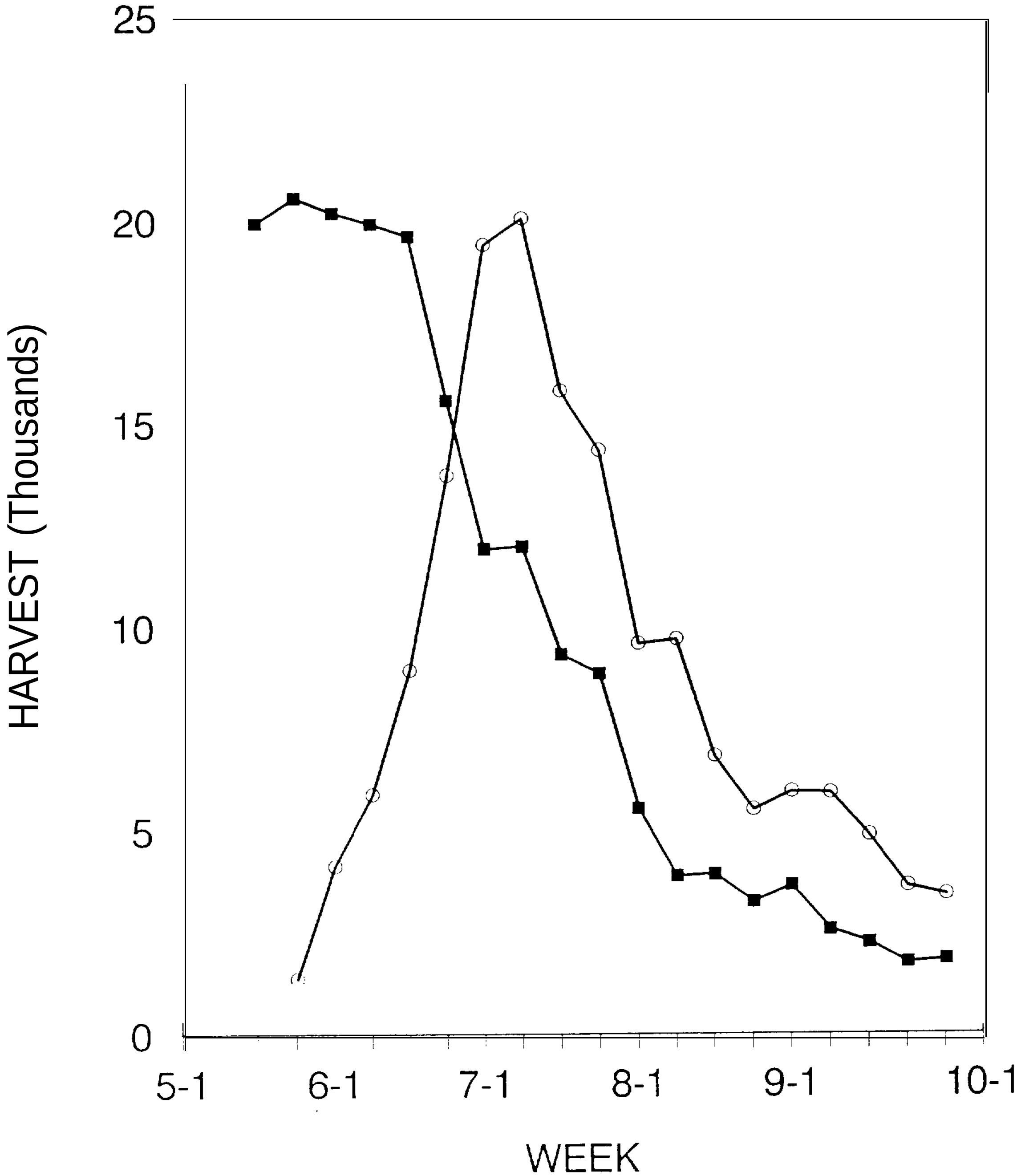

Figure 2≥. Northern squawfish harvest by week between 1991 and 19≥2 (○= 1991, ■= 1≥92).

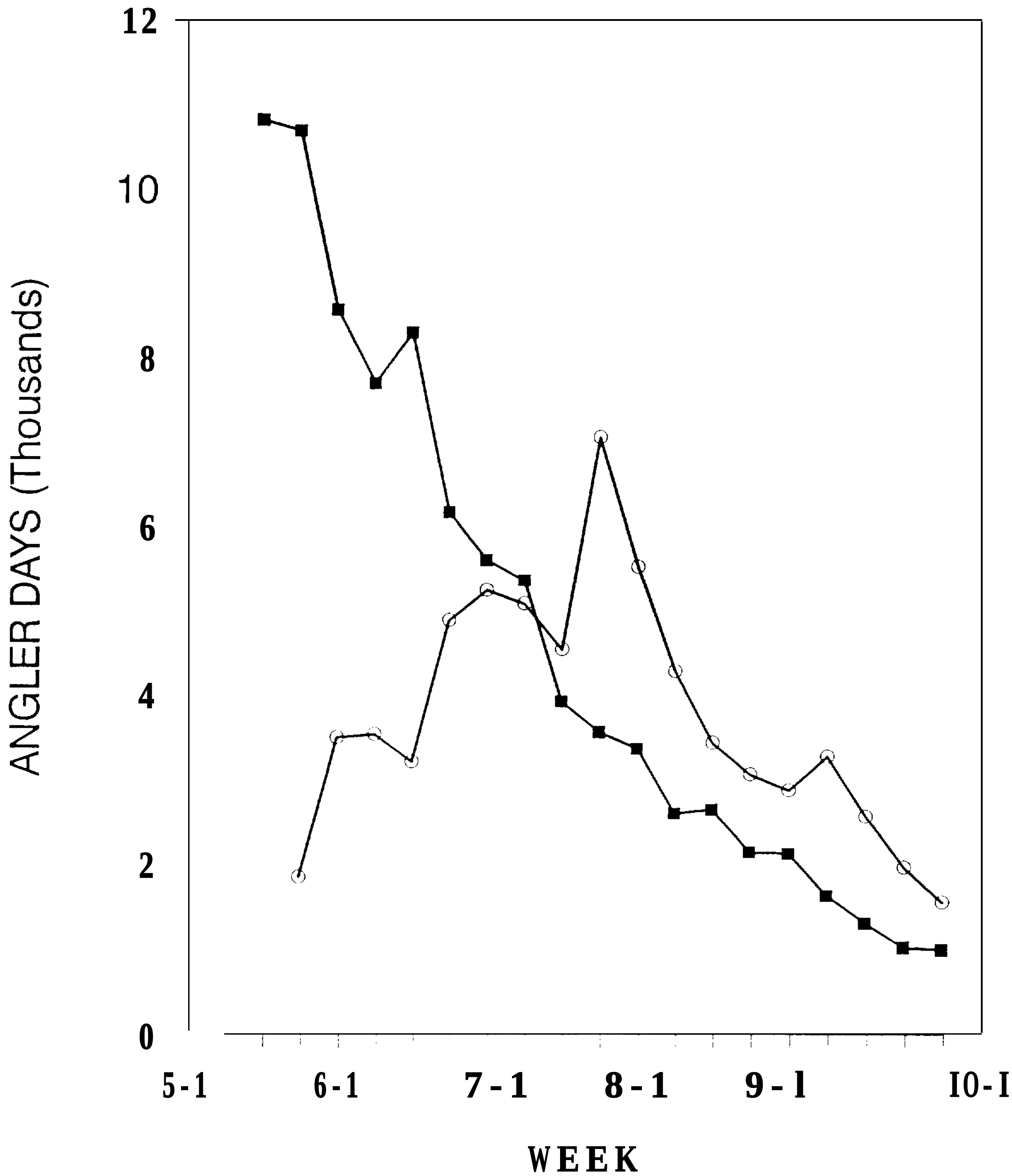

Figure 30. Effort (angler days) by week between 1991 and 1992 (o= 1991, ■= 1992).

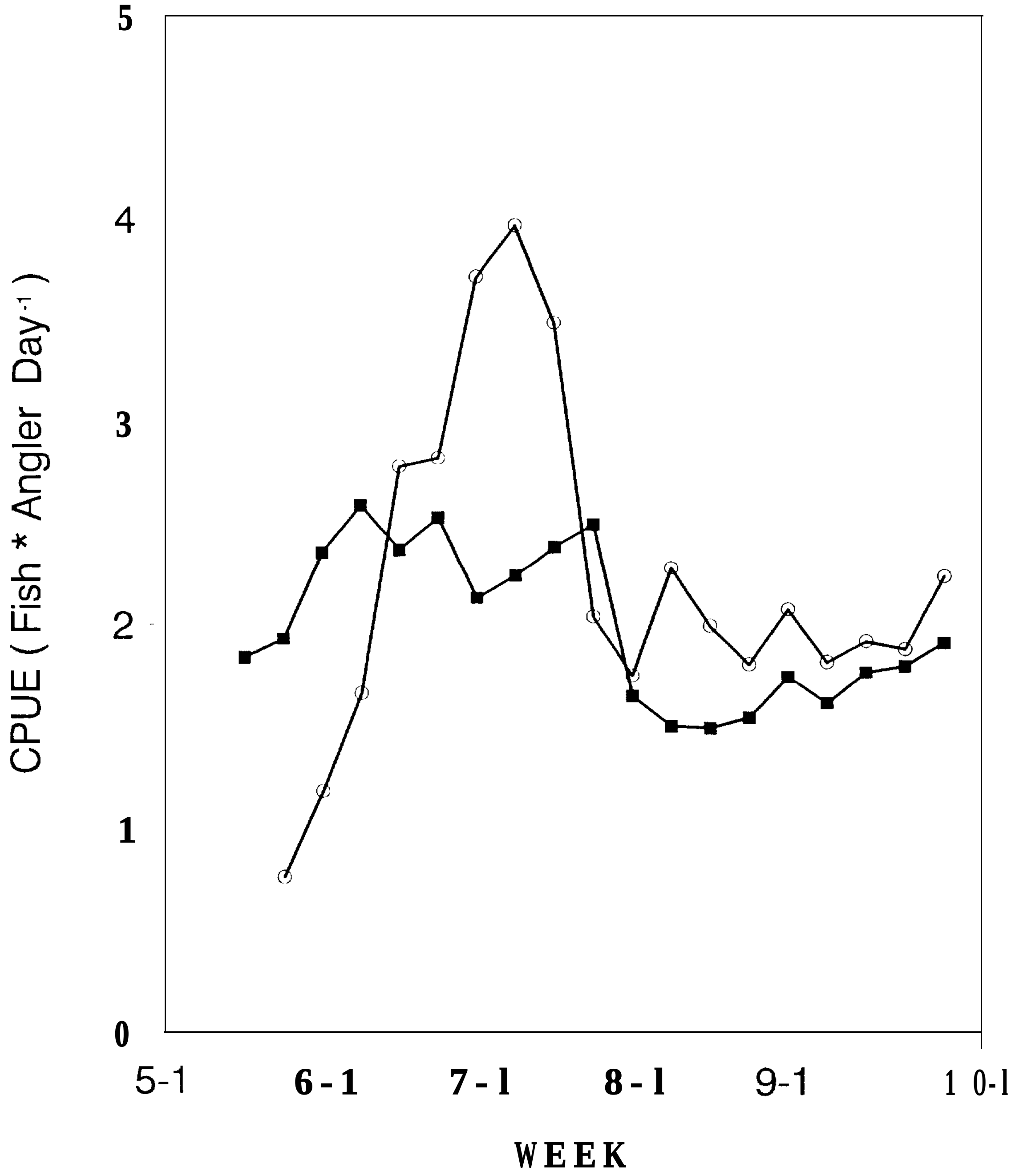

Figure 31. CPUE (fish * angler day-') of northern squawfish by week between 1991 and 1992 (○= 1991, ■= 1992).

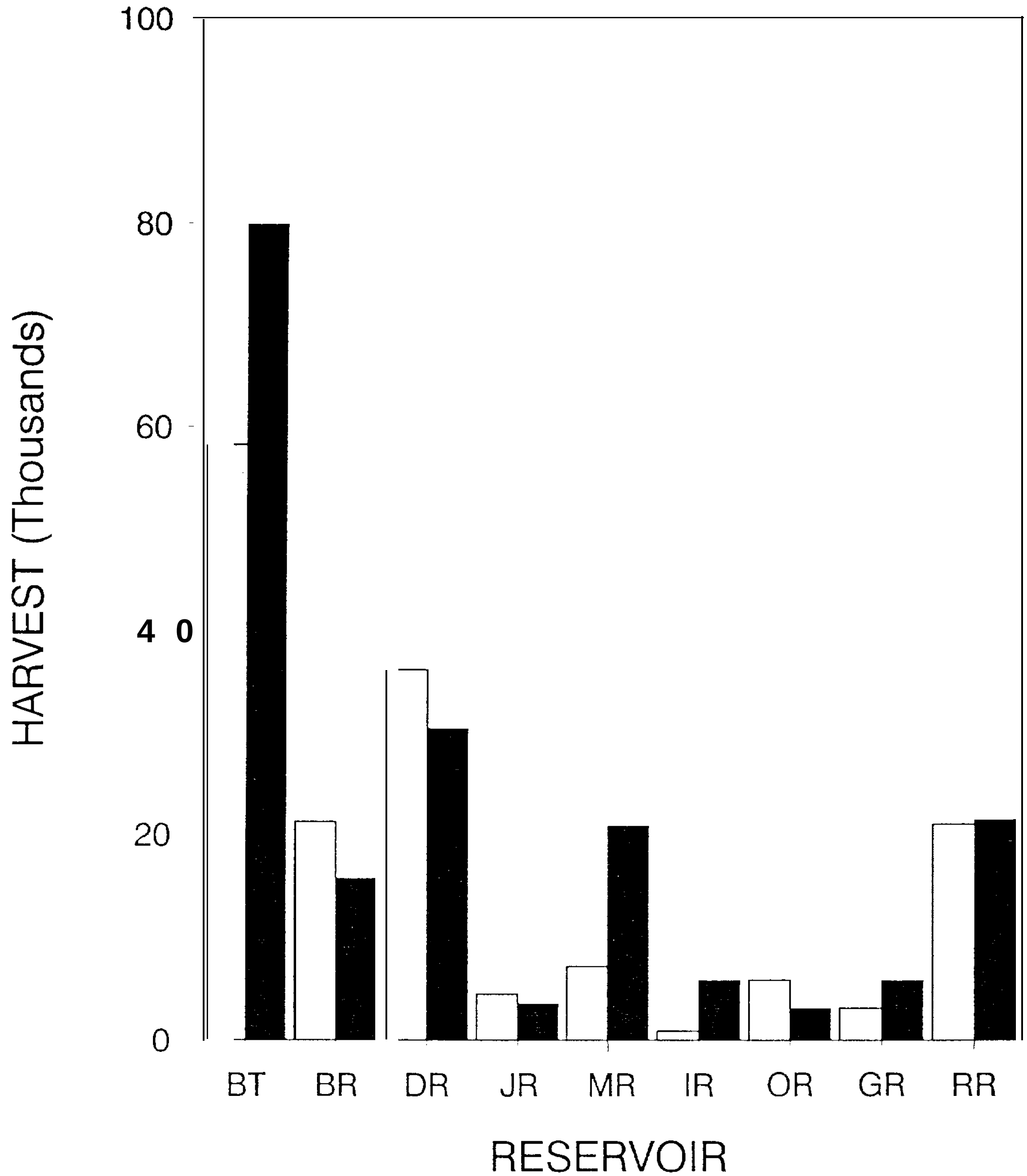

Figure 32. Northern squawfish harvest by reservoir between 1991 (shaded bar) and 1992 (dark bar); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

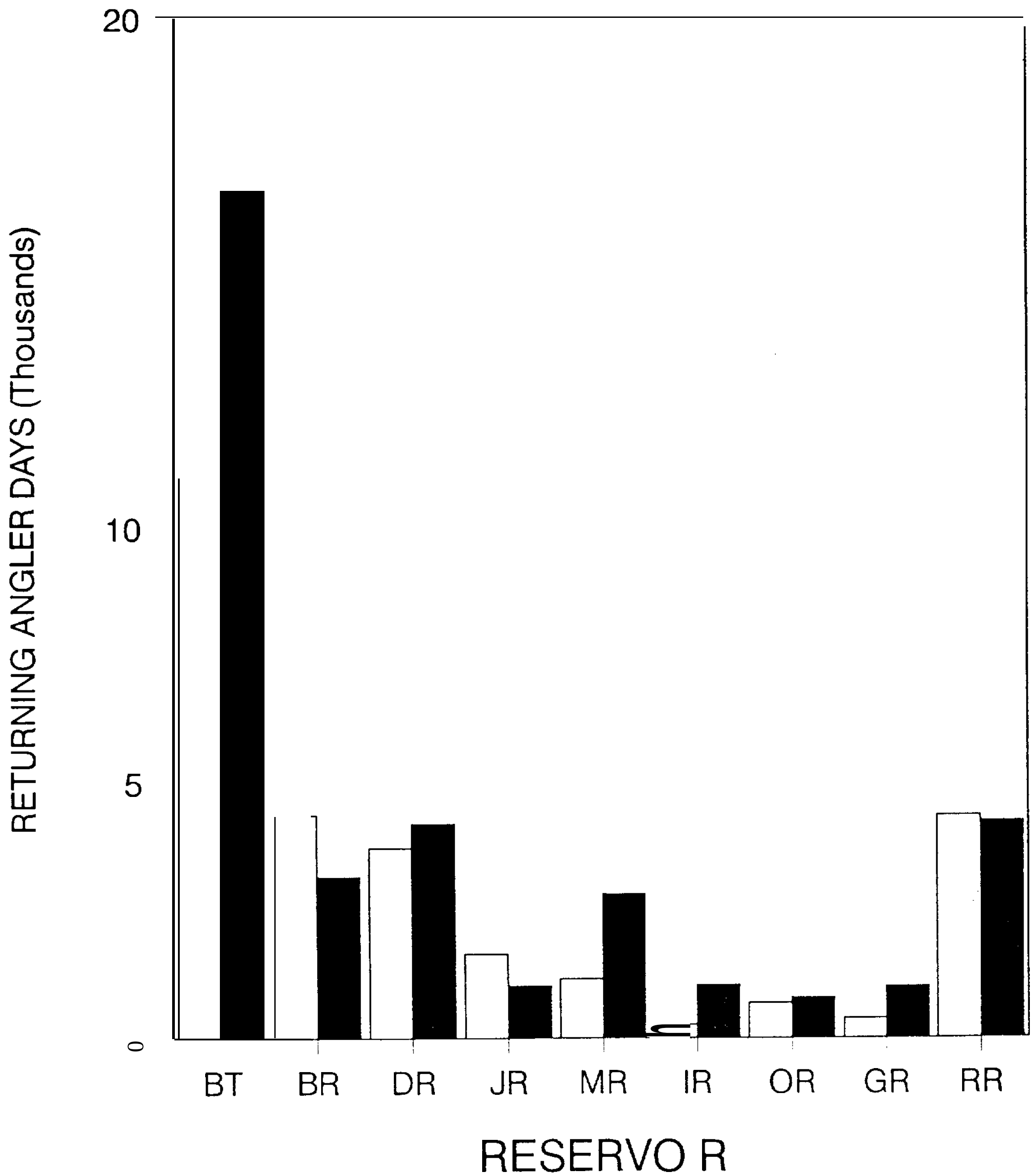

Figure 33. Effort (returning angler days) by reservoir between 1991 (shaded bar) and 1992 (dark bar); (only anglers returning to registration station had location fished recorded); BT= Bonneville Tailrace, BR= Bonneville Res., DR= The Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Lower Monumental Res.. GR= Little Goose Res., RR= Lower Granite Res.

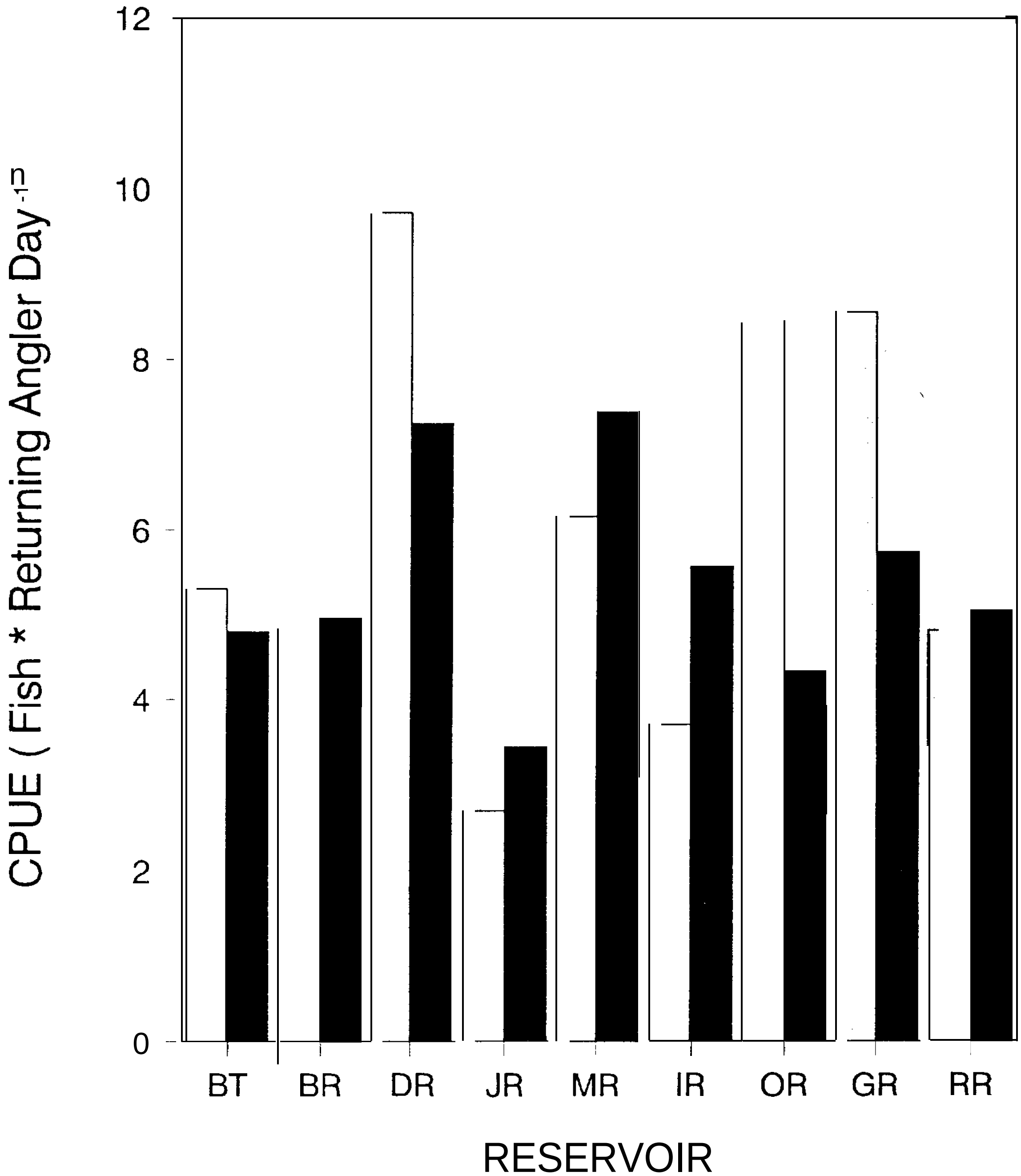

Figure 34. CPUE (fish * angler day-') of northern squawfish by reservoir between 1991 (shaded bar) and 1992 (dark bar); (only anglers returning to registration station had location fished recorded); BT= Bonneville Tailrace, BR= Bonneville Res., DR= Dalles Res., JR= John Day Res., MR= McNary Res., IR= Ice Harbor Res., OR= Low. Monumental Res., GR= Little Goose Res., RR= Lower Granite Res.

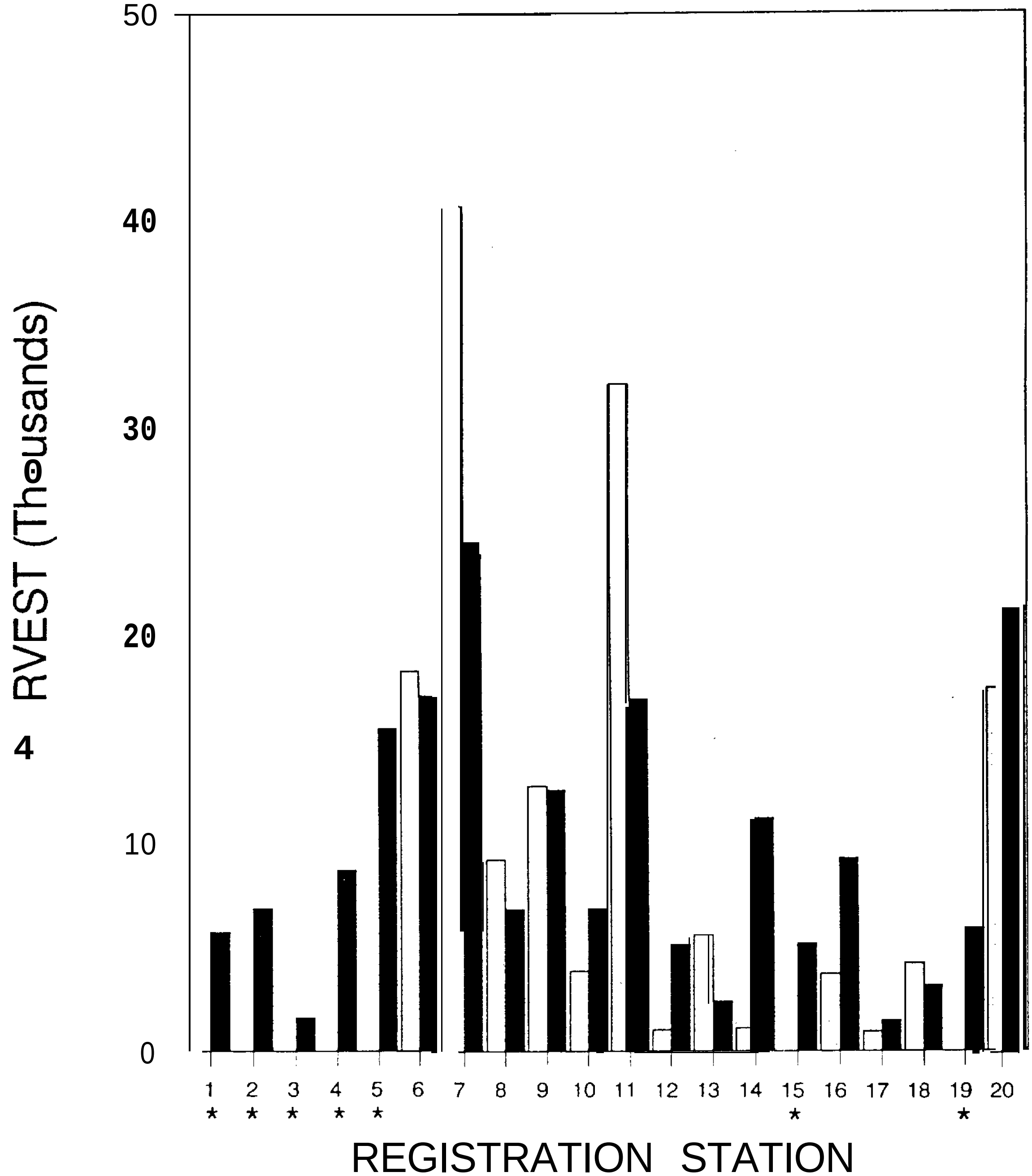

Figure 35. Northern squawfish harvest by registration station between 1991 (shaded bar) and 1992 (dark bar); (*= new stations in 1992, eliminated stations from 1991 not shown); 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Pt., 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

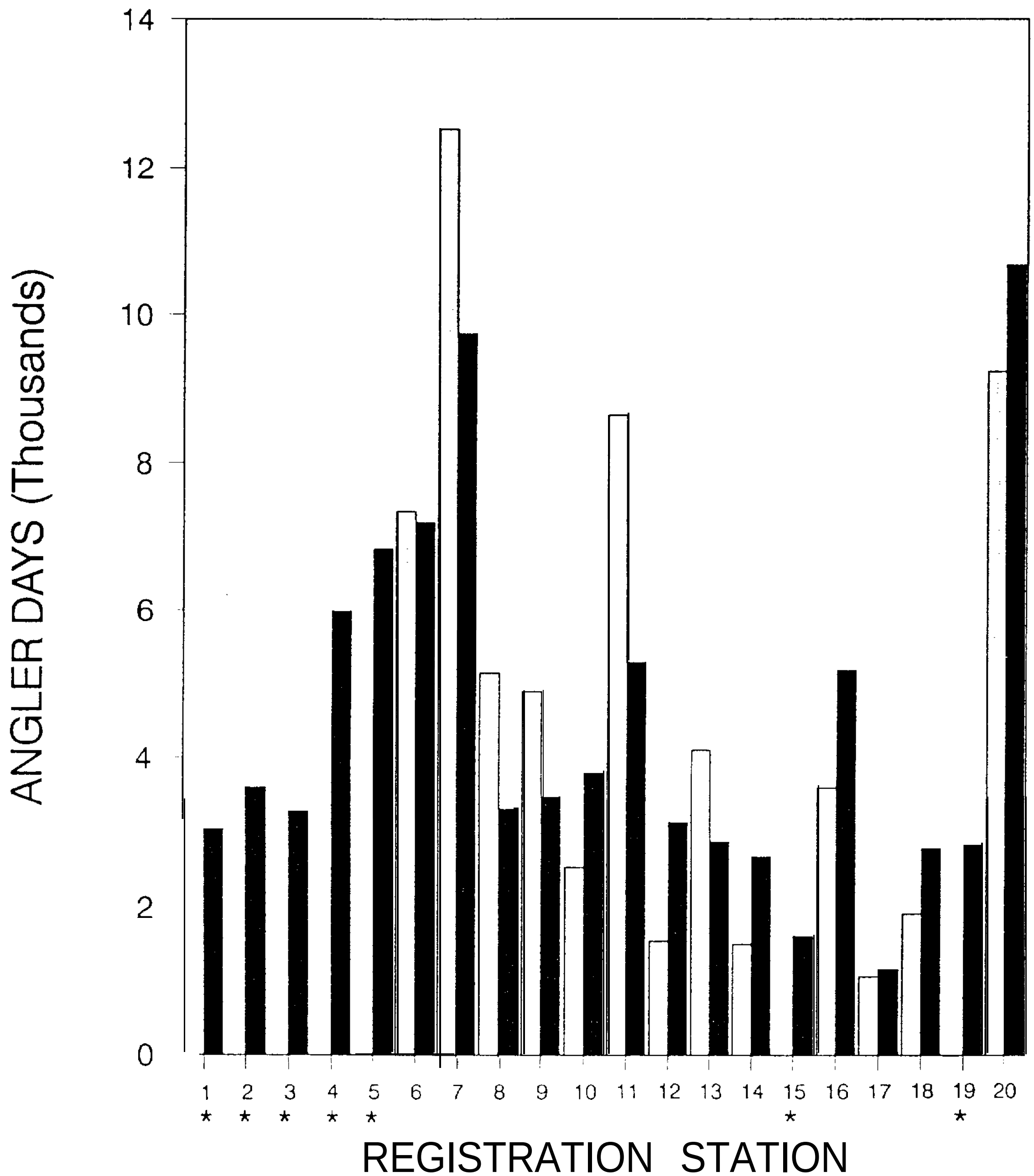

Figure 36. Effort (angler days) by registration station between 1991 (shaded bar) and 1992 (dark bar); (*= new stations in 1992, eliminated stations from 1991 not shown); 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= M. James Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Pt., 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

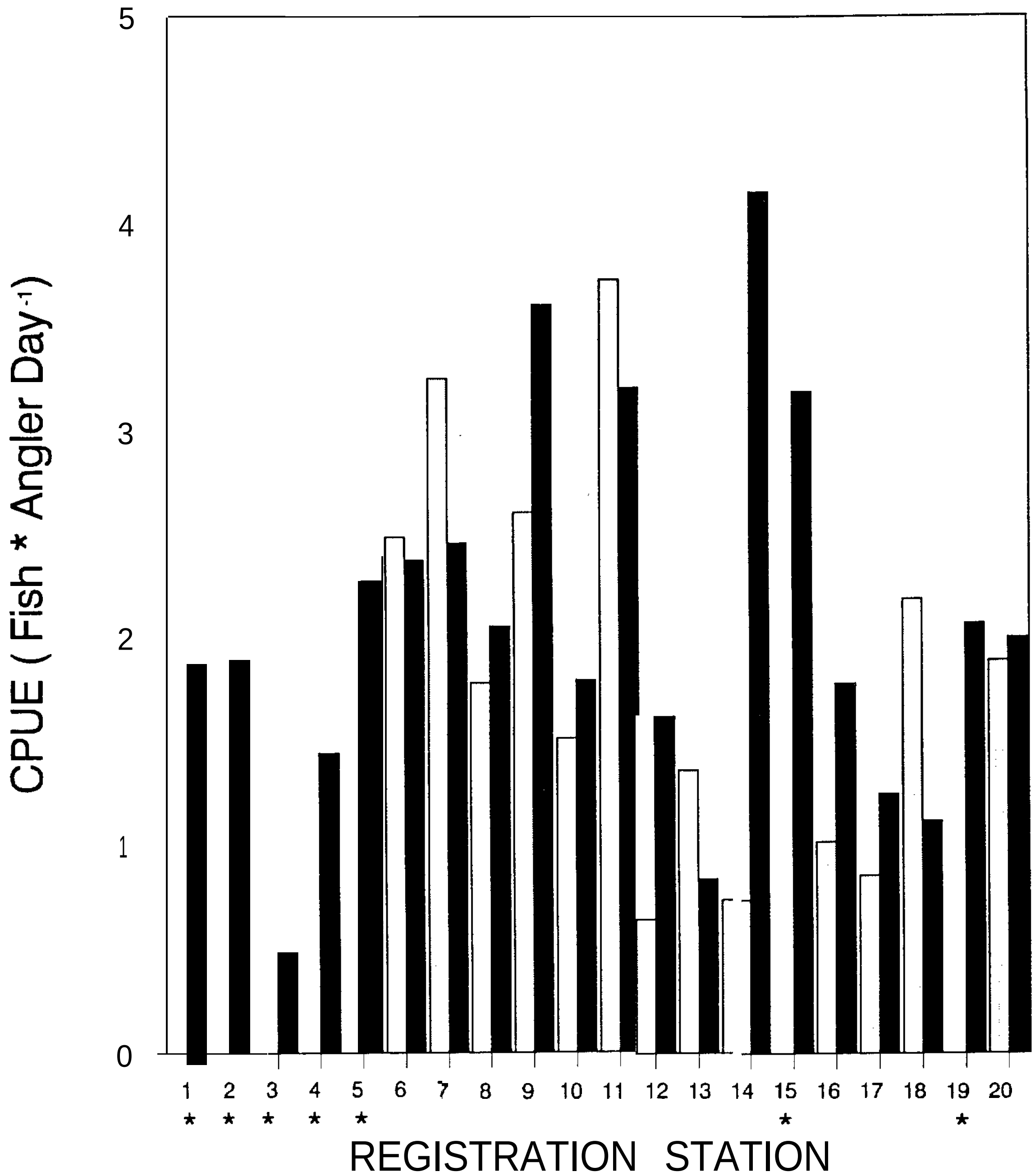

Figure 37. CPUE (Fish * Angler Day^{-1}) of northern squawfish by registration station between 1991 (shaded bar) and 1992 (dark bar); (*= new stations in 1992); 1= Willow Grove, 2= Kalama, 3= Bayport, 4= Marine Park, 5= M. James Gleason, 6= Hamilton, 7= The Fishery, 8= Cascade Locks, 9= Bingen, 10= Dalles, 11= Lepage, 12= Maryhill, 13= Plymouth, 14= Columbia Pt., 15= Ringold, 16= Hood Park, 17= Windust, 18= Lyons Ferry, 19= Boyer, 20= Greenbelt.

Table 3. Mean fork length comparison of 1991 and 1992.

Reservoir	Year	n	Mean	SD	Prob
(1) Below Bonneville	1991	9698	341	64.6	0.0001
	1992	41842	334	63.3	
(2) Bonneville	1991	7550	349	63.9	0.0002
	1992	8457	353	63.7	
(3) The Dalles	1991	8563	371	57.4	0.0001
	1992	7043	364	54.7	
(4) John Day	1991	2821	371	61.6	0.3785
	1992	2508	370	56.8	
(5) McNary	1991	4701	356	53.0	0.0001
	1992	17024	350	57.5	
(6) Ice Harbor	1991	890	361	58.2	0.3069
	1992	4565	363	52.9	
(7) Lower Monumental	1991	3642	319	48.7	0.0001
	1992	2897	309	37.0	
(8) Little Goose	1991	1902	337	50.6	0.0001
	1992	4748	330	39.3	
(9) Lower Granite	1991	19122	348	55.9	0.0001
	1992	19464	350	55.6	
Combined Totals	1991	59650	350	59.6	0.0001
	1992	119437	346	59.7	

The station at Bayport Marina in St. Helens, Ore., should be relocated below St. Helens, Ore., at a higher use site. The predation index value was low in Ice Harbor and the estimate of exploitation was not calculated due to lack of marked fish recovered (Parker et al. 1992); the size distribution of the northern squawfish population showed no change from 1991 to 1992. The registration station at Windust Park should be moved to an area with' higher predation (e.g., below Bonneville Dam). The Plymouth boat ramp should be relocated in the John Day Reservoir to a higher use access site to increase the exploitation rate in the John Day Reservoir, where we see a high predation index value, a low exploitation rate, and no significant change in mean length of the northern squawfish. All other registration stations open in 1992 should remain as is to ensure that target exploitation rates are maintained systemwide. The conclusions made to alter registration station sites based on the exploitation rate, the predation index values, and changes in mean length of the northern squawfish between years agree well with each other.

The issue of increasing participation should also be addressed by incorporating an aggressive media campaign as well as with increased incentives to focus harvest effort in areas and times when participation is low. Additional incentives could include organized derbies, tournaments, lottery incentives from the pool of registered anglers, and prizes for recovery of tagged northern squawfish.

There were documented instances of anglers fishing outside the geographic boundary of the program as well as fish being turned in for payment from other components of the predator control program . The Washington Department of Wildlife, in coordination with the Oregon Department of Fish and Wildlife, is taking steps to codify rules and regulations in both states to reduce these types of activities for the 1993 sport-reward fishery.

Game, Food, and Unclassified Fish Species Catch Data

The harvest of other fish species by registered anglers in 1991 and 1992 is similar and accounts for a small percentage of the overall harvest. Warmwater species account for the majority of this harvest. While these fish species are currently being impacted at low levels, monitoring of the impacts of the sport-reward fishery should continue to ensure that this trend continues in future years.

Roving Creel Survey

One concern with the introduction of a new sport fishery is the impacts it could have on other fish species in the system. Specifically, in 1991 there was an estimated 60,000 angler days spent fishing for northern squawfish systemwide. Approximately 60% of the registered participants failed to return to the registration stations to have their catch inspected.

In 1992 we addressed the question of incidental harvest of other fish species by registered anglers (returning and non-returning) using a roving creel survey, and expressed this impact as a percent of the total harvest by species. This approach had several advantages over other methods; it allowed inspection of the catch in the field, it provided accurate catch and effort information, and it reduced biases associated with angler memory (Malvestuto 1983). This method allowed a quantifiable comparison between the total estimated harvest of other fish species and the percent of that harvest by anglers registered to participate in the Northern Squawfish Sport-Reward Fishery. One disadvantage was its relative cost to other methods, such as telephone surveys. The analysis of the data indicated that the sport-reward fishery did not significantly impact populations of other fish species in 1992.

Monitoring of the sport-reward fishery and the impacts it has on other fish species should continue through data collection at the registration stations and with follow-up phone surveys to ensure that the impacts on other fish species continue to be minimal. If in the future evidence suggests that these impacts are increasing, we recommend implementing a roving creel survey.

Computerized Portable Data Collection Station

The computerized portable data collection station appears to be an efficient way to collect registration and biological data at the registration stations, however, additional software modifications need to be made to the programs and field tested before final recommendations are made.

Although the initial capitol costs of the units would be high, the reduction in labor costs associated with entering the registration and biological data, and associated quality control costs, could be greatly reduced with the implementation of these units at all registration stations.

Recommendations for 1993 Sport-Reward Fishing Season

1. Adjust the timing of the fishery to begin in early May and extend through mid-September.

2. Classify the northern squawfish as a game fish in Washington, and codify regulation in Washington and Oregon to increase compliance with program objectives.

3. Add and/or move registration stations to areas with high predation index values (e.g., below Bonneville Dam, McNary Reservoir, etc.).

4. Eliminate and/or move registration stations from areas with low predation index values and exploitation rates (i.e., in Ice Harbor Reservoir, keep the reservoir open to the program, but relocate the registration station to an area with higher predation).

APPENDIX A

Catch Composition for Each Reservoir from the Roving Creel Survey

Appendix Table A-l. Catch composition from the roving creel survey for the Bonneville tailrace, 1992.

	Registered Anglers			Unregistered Anglers			
Species	Kept	Released	Total	Kept	Released	Total	Total
AMS		2	2	724	146	870	872
BBH		--	--	7	--	7	7
BRS			--	1	--	1	1
CK			--	48	6	54	54
CO		--	--	13		13	13
CP		--	--	--	2	2	2
LMB			--	--	5	5	5
LRS			--	1	--	1	1
NSF	93	4	97	37	15	52	149
PK	1	--	1		--	--	1
PMO	--		--	9	--	9	9
PS		--	--	1	--	1	1
SCT			--	3	--	3	3
SF	--		--	1	--	1	1
SH	--	--	--	4	--	4	4
SK	--		--	4	--	4	4
SMB		8	8	13	42	55	63
SO	--	--	--	--	2	2	2
SS		--	--	227	30	257	257
WAL	--	--	--	13	2	15	15
WS	1	5	6	101	481	582	588
YBH		--	--	28	4	32	32
YP	--	--	--	28	5	33	33
Total	95	19	114	1263	740	2003	2117

Appendix Table A-2. Catch composition from the roving creel survey for Bonneville Reservoir, 1992.

	Registered Anglers			Unregistered Anglers			
Species	Kept	Released	Total	Kept	Released	Total	Total
B	--	--	--	--	3	3	3
C	--	--	--	--	1	1	1
CC	--	3	3	--	--	--	3
CK	--	--	--	14	2	16	16
NSF	9	--	9	4	--	4	13
SH	--	--	--	67	18	85	85
SMB	--	4	4	--	9	9	13
TR	--	--	--	18	1	19	19
WS	1	21	22	9	95	104	126
Total	10	28	38	112	129	241	279

Appendix Table A-3. Catch composition from the roving creel survey for The Dalles Reservoir, 1992.

	Registered Anglers			Unregistered Anglers			
Species	Kept	Released	Total	Kept	Released	Total	Total
AMS	20	--	20	157	13	170	190
B	--	--	--	4	12	16	16
CC	3	--	3	1	--	1	4
CK	--	--	--	5	3	8	8
NSF	201	--	201	62	1	63	264
SH	--	--	--	39	14	53	53
SMB	3	3	6	24	25	49	55
WAL	2	8	10	--	--	--	10
WS	--	1	1	12	201	213	214
YP	--	--	--	2	--	2	2
Total	229	12	241	306	269	575	816

Appendix Table A-4. Catch composition from the roving creel survey for John Day Reservoir, 1992.

	Registered Anglers			Unregistered Anglers			
Species	Kept	Released	Total	Kept	Released	Total	Total
AMS	2	--	2	41	2	43	45
B	--	--		27	74	101	101
BC	--	--	--	1	--	1	1
BH		--	--	--	1	1	1
BRS		--	--	--	1	1	1
C	--		--	--	1	1	1
CC	--		--	6	1	7	7
CMO	--	--	--	1	24	25	25
COT	--	9	9		--	--	9
CP	--	--	--		10	10	10
LMB	--		--	1	1	2	2
LRS	--	--	--	2	3	5	5
NSF	26	5	31	24	11	35	66
PS	--	--	--		1	1	1
S	3	--	3	21	10	31	34
SAL	--	--		1	14	15	15
SH	--	--		2	4	6	6
SK	--	--		1	5	6	6
SMB	6	11	17	97	369	466	483
WAL	4	3	7	11	6	17	24
WS	--	--	--	3	119	122	122
YBH	--	--	--	3	8	11	11
YP		--	--	18	21	39	39
Total	41	28	69	260	686	946	1015

Appendix Table A-5. Catch composition from the roving creel survey for McNary Reservoir, 1992.

	Resistered Anqlers			Unregistered Anglers			
Species	Kept	Released	Total	Kept	Released	Total	Total
AMS	6	--	6	33	8	41	47
B	1	32	33	12	112	124	157
BC	--	--		4	6	10	10
BCF	--	--		1		1	1
BG	--	--		3	13	16	16
BH	--	--	--	--	37	37	37
BRS	1	--	1	41	6	47	48
C	--	--		--	6	6	6
CC	3	5	8	90	59	149	157
CMO	1	1	2	6	17	23	25
CYP	--	--	--	--	2	2	2
CK	1	--	1	51	13	64	65
COT	--	--		--	5	5	5
GS	--	--		--	20	20	20
LMB	--	1	1	2	6	8	9
LRS	--	2	2	1		1	3
NSF	248	10	258	41	138	179	437
PMO	1	--	1	2		2	3
PS	--	--		2	10	12	12
RU	--	--		--	3	3	3
S	--	--	--	4	25	29	29
SAL	--	--		12	3	15	15
SH	3	10	13	111	254	365	378
SK	--	22	22	1	47	48	70
SMB	1	34	35	139	417	556	591
TR	--	--	--	10	86	96	96
TCH	--	--	--	--	1	1	1
WAL	1	--	1	2	2	4	5
WS	--	2	2	7	144	151	153
YBH	--	--		--	1	1	1
YP	--	--		16	19	35	35
Total	267	119	386	597	1458	2055	2441

Appendix Table A-6. Catch composition from the roving creel survey for Ice Harbor Reservoir, 1992.

	Registered Anglers			Unregistered Anglers			
Species	Kept	Released	Total	Kept	Released	Total	Total
BC	--	--	--	1	--	1	1
BG	--	--	--	3	1	4	4
BBH	--	--	--	1	--	1	1
BRS	--	--	--	5	1	6	6
CC	2	14	16	234	117	351	367
CMO	--	--	--	1	--	1	1
NSF	3	--	3	3	3	6	9
PMO	--	--	--	--	2	2	2
PS	--	--	--	--	2	2	2
RU	--	--	--	31	17	48	48
SH	--	--	--	17	6	23	23
SK	--	3	3	--	--	--	3
SMB	7	13	20	26	78	104	124
WS	--	--	--	2	1	3	3
YBH	--	--	--	1	--	1	1
YP	--	--	--	12	5	17	17
Total	12	30	42	337	233	570	612

Appendix Table A-7. Catch composition from the roving creel survey for Lower Monumental, 1992.

	Reqistered Anslers			Unresistered Anslers			
Species	Kept	Released	Total	Kept	Released	Total	Total
B	--	2	2	--	11	11	13
BC	2	7	9	167	200	367	376
BG	1	--	1	10	3	13	14
BBH	--	--	--	20	--	20	20
BRS	--	--	--	3	3	6	6
C	--	--	--	45	28	73	73
c c	2	3	5	237	73	310	315
CMO	--	--	--	--	2	2	2
CYP	--	3	3	--	1	1	4
CP	--	--	--	--	2	2	2
NSF	11	12	23	18	11	29	52
PMO	--	--	--	1	--	1	1
PS	1	--	1	5	1	6	7
RU	--	33	33	155	162	317	350
SH	--	--	--	42	10	52	52
SMB	3	65	68	89	300	389	457
TR	--	--	--	9	16	25	25
WC	--	--	--	1	--	1	1
WS	--	--	--	1	6	7	7
YBH	--	--	--	4	1	5	5
YP	2	6	8	132	104	236	244
Total	22	131	153	939	934	1873	2026

Appendix Table A-8. Catch composition from the roving creel survey for Little Goose Reservoir, 1992.

	Registered Anglers			Unregistered Anglers			
Species	Kept	Released	Total	Kept	Released	Total	Total
BC	--	--		95	15	110	110
BG	--	--		46	55	101	101
BH	--	--	--	48	47	95	95
BBH		--	--	1	--	1	1
C		1	1	46	126	172	173
CC	8	2	10	331	47	378	388
CMO		--	--	--	1	1	1
COT		--	--	1	1	2	2
CP	--	--	--	1	--	1	1
LMB	--	--	--	--	3	3	3
NSF	71	--	71	7	11	18	89
PK	--	--	--	45	26	71	71
PMO	--	3	3	3	--	3	6
SH	--	--	--	8	2	10	10
SK	--	--		1	8	9	9
SMB	9	28	37	258	873	1131	1168
TR	--	6	6	181	373	554	560
WC		--	--	80	15	95	95
WS	--	--	--	3	5	8	8
YBH	--	--	--	3	1	4	4
YP	--	--	--	8	9	17	17
Total	88	40	128	1166	1618	2784	2912

Appendix Table A-9. Catch composition from the roving creel survey for Lower Granite Reservoir, 1992.

	Registered Anglers			Unregistered Anglers			
Species	Kept	Released	Total	Kept	Released	Total	Total
BC		--	--	28	--	28	28
BG	--	10	10	2	11	13	23
BH	--	3	3	1	3	4	7
C	--	--	--	27	31	58	58
CC	2	--	2	3	3	6	8
CP	--	--	--	7	1	8	8
NSF	89	12	101	5	37	42	143
PK	--	--	--	9	10	19	19
PMO	--	--	--	2	--	2	2
PS		--	--	1	--	1	1
RU	--	15	15		12	12	27
SH	1	35	36	1	2	3	39
SK	--	1	1	6	4	10	11
SMB	3	53	56	177	1069	1246	1302
TR	3	62	65	131	496	627	692
WC			--	15	--	15	15
YP			--	19	14	33	33
Total	98	191	289	434	1693	2127	2416

REPORT C

Controlled Angling for Northern Squawfish at Selected Dams on the Columbia and Snake Rivers in 1992

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1992 Annual Report

CONTENTS

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ABSTRACT

The dam angling efforts reported here are part of an ongoing predator control program targeting northern squawfish (*Ptychocheilus oregonensis*), a major predator of juvenile salmonids (*Oncorhynchus sp.*) in the Columbia River Basin. In 1992, technicians stationed at eight U.S. Army Corps of Engineers dams on the lower Columbia and Snake rivers caught 27,868 northern squawfish in a 21-week season, from late April through early September.

The total catch of northern squawfish in 1992 declined 30% from 199 1, largely due to declines in catches at Snake River dams. Possible reasons for the overall decline in catch include (1) substantial removals of northern squawfish since program implementation, (2) an early spring combined with a late start on the Columbia River, (3) a reduction in effort at some dams to increase cost effectiveness, (4) reservoir drawdown activities on the Snake River, and (5) reduced access to tailrace angling sites due to newly installed bird wires.

The incidental catch in 1992 was roughly half that of 1991. As in 1991, the majority of incidentally caught fish were caught at Snake River dams, and most of these fish [79.1% (80.2% in 1991)] were ictalurids (primarily channel catfish, *Ictalurus* ***punctatus).*** Salmonids (adults and juveniles) composed 1.41% of the incidental catch and 0.08% of the total catch in 1992, down from 1991 (3.29% of incidental catch, 0.26% of total catch). Fewer white sturgeon (*Acipenser transmontanus*) were caught in 1992 (217) than in 1991 (384). The decline in incidental catch was in part due to preventive measures implemented in 1992.

INTRODUCTION

Impoundments created by the construction of hydroelectric dams on the Columbia and Snake rivers have severely impacted anadromous salmonids (*Oncorhynchus sp.* ; Raymond 1988). Migrating juvenile salmonids face an increased risk of predation around dams where predators concentrate (Beamesderfer and Rieman 1988, Faler et al. 1988, Raymond 1988). Predation rates adjacent to dams are high, particularly in tailrace areas (Brown and Moyle 1981, Poe et al. 1988). To address this problem, controlled angling from dams was adopted as part of a systemwide predator control program to decrease predation by northern squawfish (*Ptychocheilus oregonensis*) on juvenile salmonids (Nigro 1990).

Previous studies have shown that hook-and-line angling can remove large numbers of northern squawfish (Vigg et al. 1990, Beaty et al. 1991). In 1990, dam angling was among three test fisheries that were investigated to harvest northern squawfish in the Columbia River Basin. Dam angling was conducted at five dams from May through late September, harvesting approximately 11,000 northern squawfish (Vigg et al. 1990). In 1991, the Columbia River Inter-Tribal Fish Commission (CRITFC) and its subcontractors conducted angling operations at eight dams on the Columbia and Snake rivers, catching 39,351 northern squawfish (Beaty et al. 1991).

Results from the 1992 dam-angling season are presented in this report. Our main objectives in 1992 were to (1) remove northern squawfish from areas adjacent to dams where squawfish are abundant and predation rates on juvenile salmonids are high; (2) reduce the incidental catch; and (3) work with the cooperating agencies to develop, implement, and evaluate the program's fisheries.

This report includes preliminary catch and effort data for northern squawfish in 1992; incidental catch data are also presented. Comparisons are made throughout this report to results in 1991, and possible reasons for differences in catch between years are discussed. We also make recommendations for improvements in 1993.

METHODS

In 1992, angling crews worked at eight U.S. Corps of Engineers dams on the lower reaches of the Columbia and Snake rivers (Figure C-l). Crew size and season length were tailored among dams (Table 1) based on results from 1991 (Beaty et al. 1991) and the current year.

Table 1. Distribution of angling effort at Columbia and Snake river dams in 1992.

Dam (river km)	Average crew size[a]	Weeks worked	Season	Supervised by
Columbia River				
Bonneville (233)	4	15	May 28-Sept 3	CTWS[b], CRITFC
The Dalles (310)	6	18	May 11-Sept 10	CRITFC
John Day (348)	5	19	May 6-Sept 10	YIN
McNary (470)	8	13	June 2-Aug 27	CTUIR[d]
Snake River				
Ice Harbor (16)	3	13	June 3-Aug 27	CTUIR, CRITFC
Lower Monumental (68)	3	16	May 5-Aug 27	CRITFC
Little Goose (113)	5	21	April 21-Sept 10	NPT[e]
Lower Granite (172)	5	20	April 20-Sept 3	NPT

[a] Average crew size varied according to differences in the initial size of resident crews, attrition, and a tailoring of effort within the season in response to catch rates.
[b] Confederated Tribes of the Warm Springs Reservation.
[c] Confederated Tribes and Bands of the Yakima Indian Nation.
[d] Confederated Tribes of the Umatilla Indian Reservation.
[e] Nez Perce Tribe.

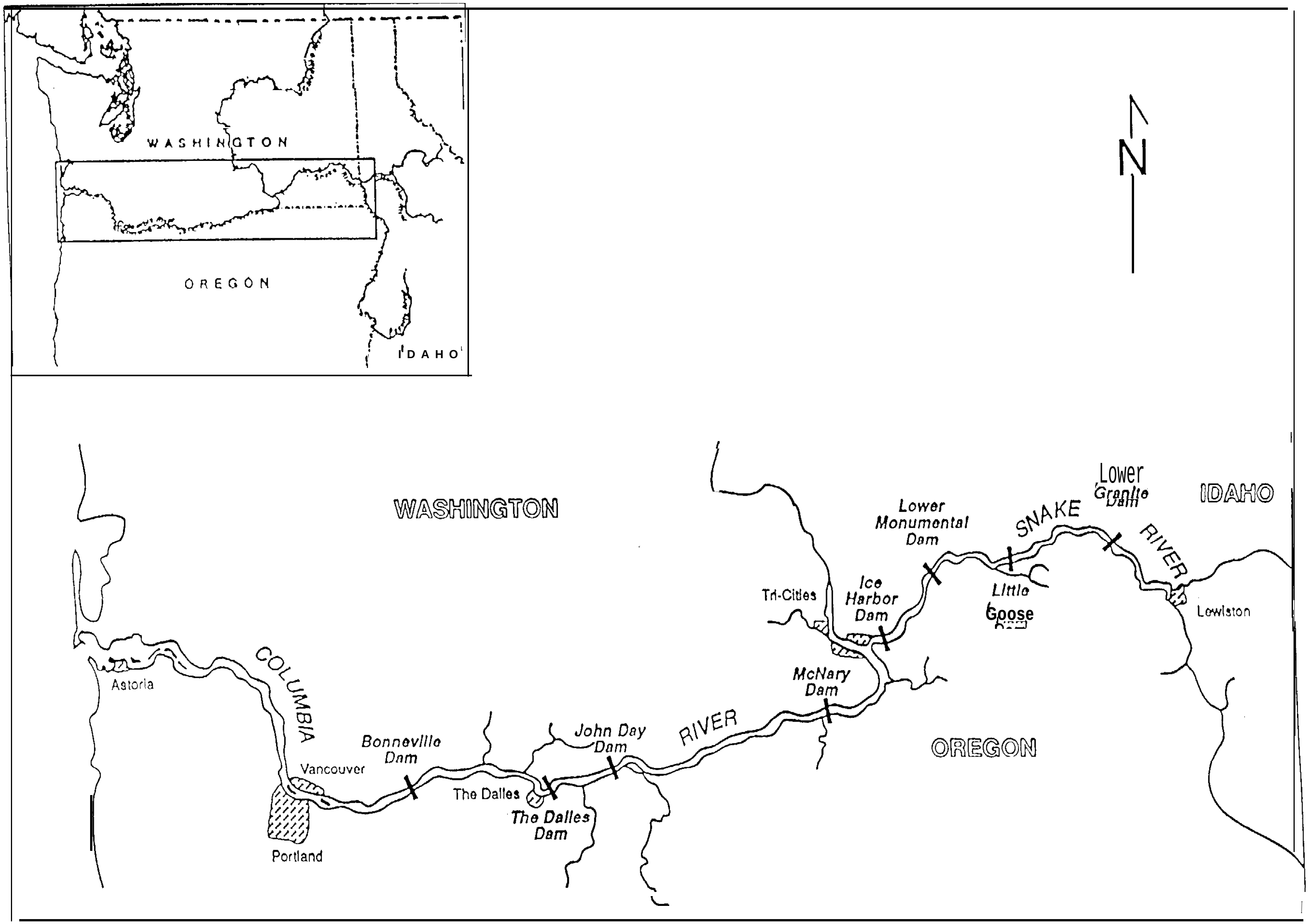

Figure C-l. Dams where controlled angling operations were conducted in 1992.

Resident crew efforts on the dam were supplemented by other angling activities -- a mobile crew, volunteer anglers, and boat anglers -- to improve catches (Table 2). The mobile crew consisted of 4-5 anglers and worked at Snake River dams early in the season and at Columbia River dams from mid- to late-season. The location and dates worked by the mobile crew depended upon the relative catch rates on each river and dam in the previous and current year. However, there were practical limitations to this crew's mobility. For example, travel costs and other constraints precluded moving the crew too frequently and with little advance notice to distant areas, such as between the Snake and Columbia rivers from day-to-day. Therefore, we planned to station the crew on one river for periods of at least one month and to assign it to work at specific dams on that river each day or week depending on where catch rates were best for resident crews.

In 1991, catch rates were higher at Snake versus Columbia river dams early in the season. Based on these data, the mobile crew was first deployed to Snake River dams in 1992. Thereafter, the mobile crew moved between rivers and among dams according to (1) relative catch rates among dams through the season and (2) costs and logistical difficulties involved with moving the crew.

Volunteer anglers, members of The Dalles Rod and Gun Club, supplemented the efforts at Bonneville Dam when catch rates were high later in the season (Table 2). Boat angling was tested by the regular crew at John Day Dam as a way to target concentrations of northern squawfish in the boat restricted zone (BRZ) outside the reach of land-based anglers (Table 2).

Field Procedures

In general, angling techniques used in 1992 were similar to those used in 1991 (see Beaty et al. 1991). Most of the changes in 1992 were made to reduce the impacts of the dam angling fishery on other species, particularly salmonids and white sturgeon (*Acipenser transmontanus*). Additional changes were made to increase catches of northern squawfish and increase overall efficiency.

Several measures were implemented to increase northern squawfish catch in 1992: (1) utilizing a mobile crew and volunteer anglers to supplement angling efforts at dams with high catch rates (Table 2); (2) utilizing boat angling in the BRZ at John Day Dam to target concentrations of fish inaccessible to anglers on the dam and shore (Table 2); (3) scheduling one crew to work two dams on alternate days to allow recruitment of northern squawfish into recently fished areas; and (4) continued testing and use of additional baits and lures (see Appendix Table A-l for list of baits and lures used in 1992).

Table 2. Supplemental angling activities used in 1992.

Supplemental angling activity	Average crew size	Location (dam)	Dates worked
Mobile crew	4	Snake River" (Little Goose & Lower Granite dams)	May 3-June 4
Mobile crew	4	Columbia River[b] (Bonneville, The Dalles, & McNary dams)	June S-July 31
Volunteer angling	4	Bonneville Dam'	June 28, July 31, Aug 16
Boat angling	4	John Day Dam[d]	June 22-25, July 1, July 7-9

[a] The mobile crew was stationed in Pomeroy, WA, while working at Snake River dams.
[b] The mobile crew was stationed in The Dalles, OR, while working at Columbia River dams.
[c] Volunteer anglers generally fished the forebay of Powerhouse I at Bonneville Dam from 6 p.m. - 10 p.m. on these dates.
[d] Boat angling was carried out by the resident crew in the boat restricted zone in the tailrace of John Day Dam.

Two measures were implemented to reduce the number of fish incidentally caught in 1992. First, fishing was restricted in areas where these fish were known to be abundant, such as near fishway entrances (also in 1991), in forebays when hold-over steelhead smolts were present, and near the river bottom. Second, once either one salmonid or three white sturgeon were caught at a particular site, that site was not fished by any angler for the remainder of the shift.

Barbless hooks were used to minimize injuries suffered by incidentally hooked fish. In most cases, barbless hooks allowed adult salmonids and white sturgeon to shake free when given slack line by the angler. Those adult salmonids and sturgeon unable to free themselves were released by cutting the line prior to landing the fish, to reduce some handling-caused stress and injury. Hooks used were bronze, rather than stainless steel, which facilitated the disintegration of hooks left in adult fish. Salmonids $\geq$ 0.50 m (approx. 1.5 ft) in length and sturgeon $\geq$ 0.75 m (approx. 2.5 ft) in length were considered adults. Smaller salmonids and sturgeon, as well as all other fish incidentally caught, were reeled in, unhooked, and released.

As part of the predator control program, some northern squawfish caught at dams have been tagged and released by other agencies in previous years. However, in 1992 all northern squawfish caught at dams were sacrificed, and those bearing tags were kept in freezers for the agencies responsible for those fish. Any tagged catfish (*Ictalurus sp.*), bass (*Micropterus sp.*), or walleye (*Stizostedion vitreum*) caught at dams was released immediately after the tag number and location of capture were recorded.

Data Collection

With a few exceptions, data were collected using the same method used in the previous year (see Beaty et al. 1991). In 1992, adult salmonids and large sturgeon were not handled and were assigned the condition code "Lost" in the data. Detailed notes on the condition of each salmonid caught were taken by the angler when possible, including where the hook was imbedded in the fish, how much line was attached to the hook (if the line was broken or cut), whether the fish was bleeding, and the general behavior of the fish upon release. This information, along with catch and effort data, was provided in weekly summaries to the Oregon Department of Fish and Wildlife (ODFW), the contracting agency.

Early in the season, data were written on data forms and sent to Portland on a daily basis using facsimile machines. Midway through the 1992 field season we implemented an electronic data system that enabled field crews to enter data directly into a hand-held computer (CMT MC-V with custom software developed by Corvallis MicroTechnology, Inc.) and transfer the data daily to a host computer in our Portland office via modem. As a backup, each day's data file was printed out at each field location and mailed to Portland weekly. The electronic data system greatly reduced data-handling time and increased data accuracy.

Data Summary and Analysis

Preliminary data were summarized by dam and river for comparison with other results, particularly those from 1991. Sums of catch and effort were used to calculate average catch per angler hour (CPAH), which was the basis for comparing success within and between years, among dams, and among management alternatives.

Incidental catch data were summarized, and we compared the species composition (percent of total and incidental catch) among dams and between years. In addition, information regarding the disposition of incidentally caught fish at release was summarized.

To manage the mobile crew well, we had to assign it to the more productive river in the longer term and to the best dam(s) on that river in the shorter term. We evaluated the mobile crew by comparing its CPAH to averages for the long- and short-term management alternatives. Specifically, we compared (1) the CPAH of the mobile crew to the average and maximum CPAH on the more productive river each month (long-term) and (2) the CPAH of the mobile crew to the average and maximum CPAH recorded at dams on the river that the mobile crew worked each week (short-term).

Our minimum standard was the average CPAH for all alternatives, which is equivalent to the result expected if we simply assigned the mobile crew randomly between rivers and among dams. The ideal standard was the maximum CPAH among alternatives, which would mean that we always chose the most productive alternative for the mobile crew. Even if the mobile crew was managed optimally, its productivity would not necessarily reach the ideal standard if resident crews in general were more effective, which seems to have been the case. Other factors, such as cost, must also be considered before we can fully evaluate whether the concept of the mobile crew and our management of it were successful.

The CPAH for volunteer and boat angling was calculated and compared with the average CPAH of the resident crew at the same dam during the same weeks. We did not consider factors other than CPAH (e.g., social considerations and cost) that would be necessary for a comprehensive evaluation of these supplemental methods.

RESULTS

Northern Squawf'ish Catch

From mid-April through mid-September, 27,868 northern squawfish were caught in 16,758.8 hours of angling at all dams, for a seasonal catch-per-angler-hour (CPAH) of 1.7. The total catch, effort, and CPAH for all dams combined in 1992 was below that of 1991 (Table 3), largely due to reduced catch rates at Snake River dams. In both years, effort, total numbers of fish caught, and catch rates were higher at Columbia River dams than Snake River dams (Table 3). Catch was distributed differently over time between the Columbia and Snake river dams in 1992 and 1991 (Figures C-2 and C-3).

Columbia River Dams

From early May through mid-September, 23,099 northern squawfish were caught in 9,575.3 hours of angling at Columbia River dams, for a seasonal CPAH of 2.4 (Table 3). The highest catches occurred in June and July (Figure C-2), and the highest CPAH was recorded in June (Figure C-3). The highest seasonal catch rates in 1992 were recorded at The Dalles Dam (3.0) and McNary Dam (2.9). In 1992, the total catch, effort, and seasonal catch rate were similar to 199 1 (Table 3).

Bonneville Dam

From late May through early September, 4,814 northern squawfish were caught in 1,781.3 hours of angling at Bonneville Dam, for a seasonal CPAH of 2.7 (Table 3). The mobile crew supplemented the efforts of the resident crew from mid-June through late July (see ***RESULTS, Mobile*** *Crew*). From early August through early September, the mobile crew replaced the resident crew at Bonneville Dam. Volunteer anglers were used at Bonneville Dam on three dates in June, July, and August to supplement the efforts of the resident crew ***(see RESULTS, Volunteer Angling).*** In general, weekly catch rates increased from the beginning of the season and reached a distinct peak in early August, declining sharply over the next month (Appendix Table A-2). A similar peak in catch was observed in 1991, but it occurred a month earlier (Figure C-4). Forty percent fewer fish were caught at Bonneville Dam in 1992 than in 1991, although effort only declined approximately one-third from 1991 (Table 3). The seasonal CPAH fell slightly from 3.1 in 1991 to 2.7 in 1992.

The *Dalles Dam*

From mid-May through mid-September, 7,561 northern squawfish were caught in 2,496.2 hours of angling at The Dalles Dam, for a seasonal CPAH of 3.0 (Table 3). The mobile crew supplemented the efforts of the resident crew from early June through late July ***(see RESULTS, Mobile Crew).*** The highest CPAH values of the season were observed in the first three weeks of angling, May 10 through May 30. Beginning in June, weekly catch rates declined gradually, with three distinct peaks of lesser value (Appendix Table A-3). A similar periodicity in catch rates occurred in 199 1 (Figure C-4). In 1992, greater than twice the number of fish were caught than in 1991, with a little less than twice the effort. The seasonal catch rate in 1992 (3.0) was higher than in 1991 (2.8).

John. Day Dam

From early May through mid-September, 3,427 northern squawfish were caught in 2774.7 hours of angling at John Day Dam, for a seasonal CPAH of 1.2 (Table 3). In June and July, boat angling was tested in the BRZ at John Day Dam ***(see RESIJLTS, Boat*** *Angling).* Weekly catch rates in 1992 were highest from late June through mid-July (Appendix Table A-4). The highest catch rates in 1991 were recorded from early August through mid-September (Figure C-4). Thirty-two percent fewer fish were caught in 1992, compared to 1991, with virtually the same amount of effort (Table 3). Consequently, the seasonal catch rate in 1992 was lower than in 1991: 1.2 versus 1.8, respectively.

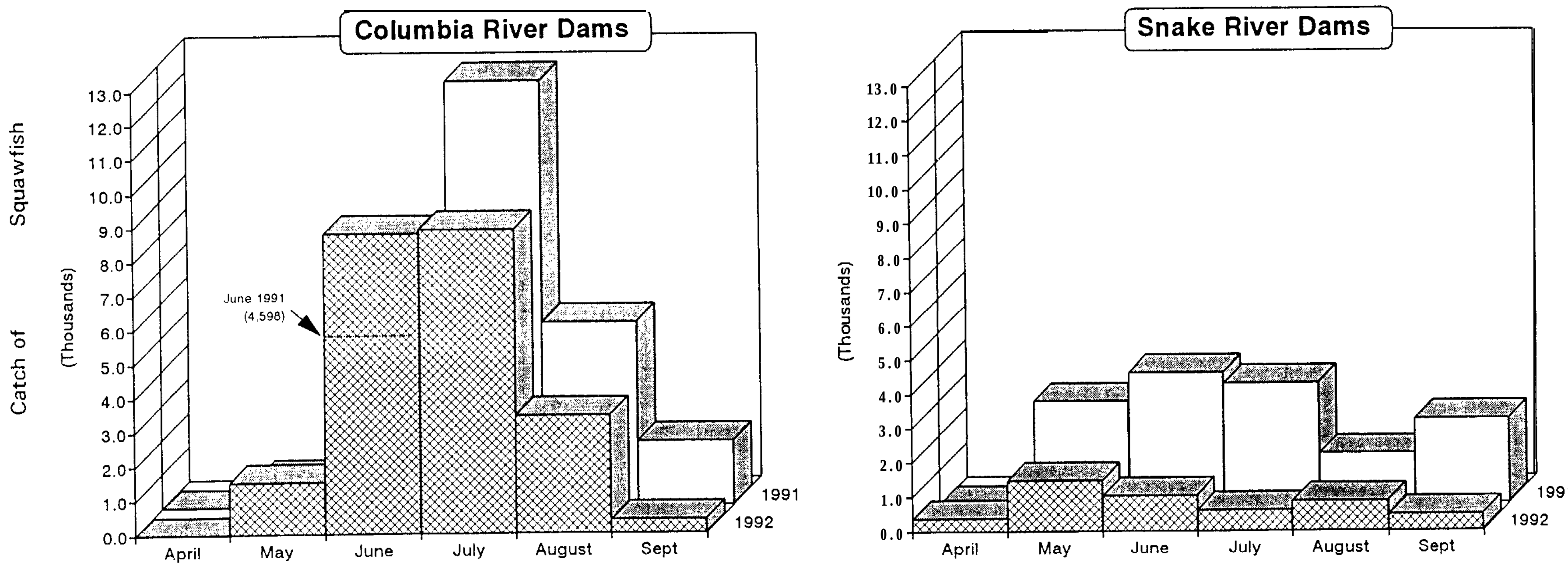

Figure C-2. Monthly catch of northern squawfish at Columbia and Snake river dams, 1991 and 1992.

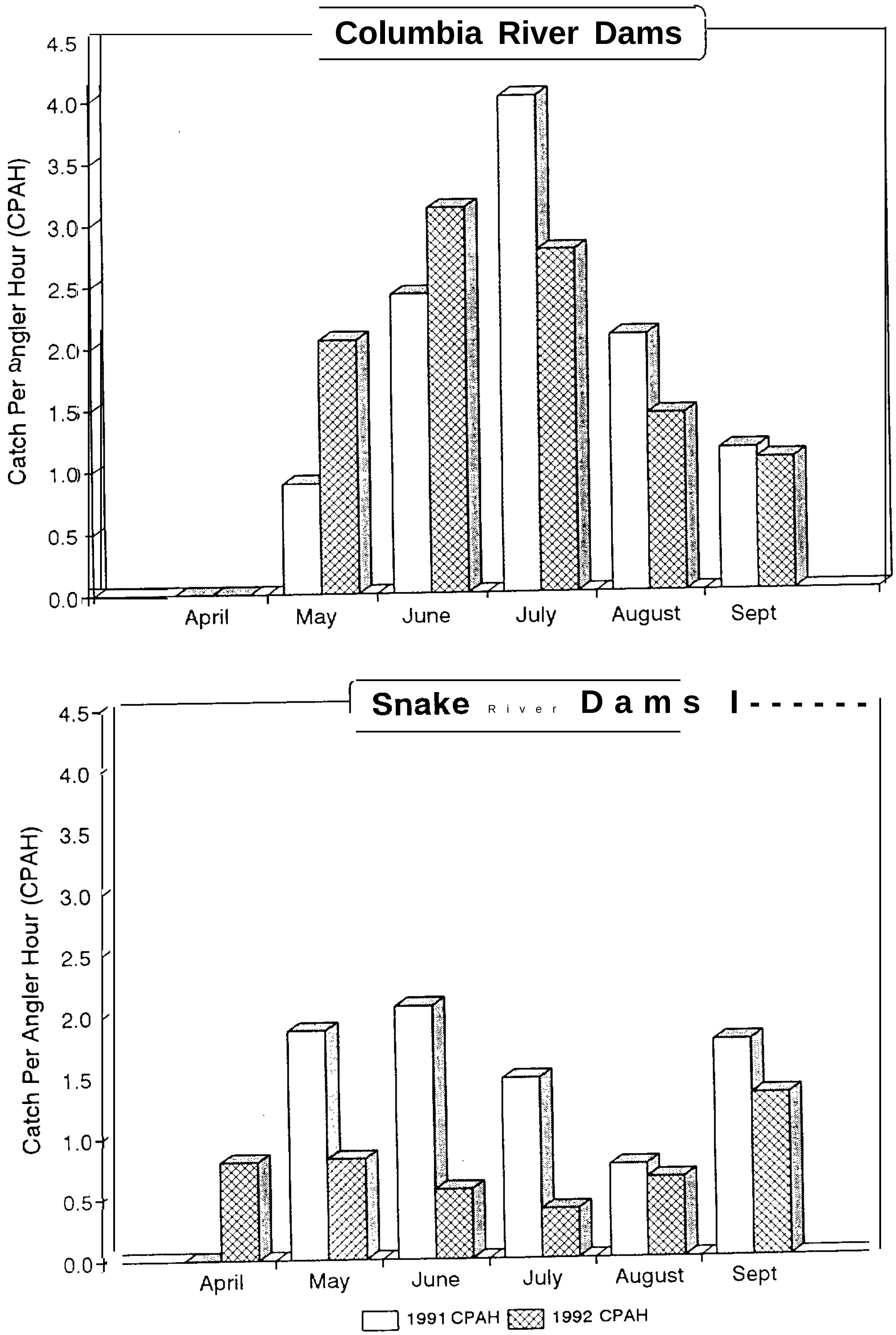

Figure C-3. Monthly catch per angler hour (CPAH) at Columbia and Snake river dams, 1991 and 1992.

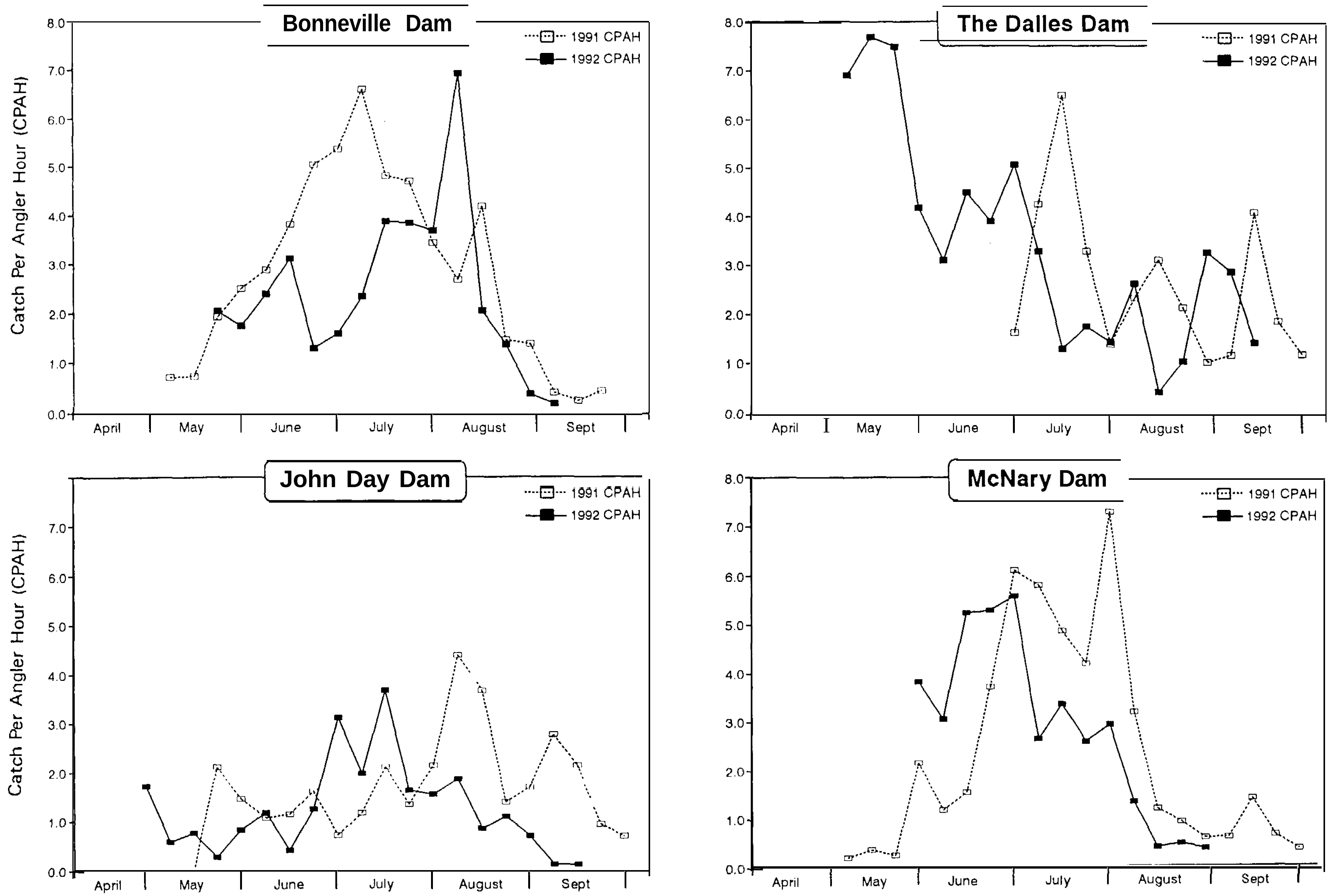

Figure C-4. Weekly average catch per angler hour (CPAH) at Columbia River dams, 1991 and 1992. Effort varied substantially within and between seasons.

Table 3. Angling effort and northern squawfish catch by dam, 199 1 and 1992.

	1991			1992				
	Seasonal totals			Seasonal totals			% of 1991 total	
Dam	Hours fished	Northern squaw-fish	CPAH	Hours fished	Northern squaw-fish	CPAH	Hours fished	Northern squaw-fish
Columbia River								
Bonneville	2,621.3	8,131	3.1	1,781.3	4,814	2.7	68.0	59.2
The Dalles	1.333.0	3,674	2.8	2,496.2	7,561	3.0	187.7	205.8
John Day	2,816.3	5,004	1.8	2,774.7	3,427	1.2	98.5	68.5
McNary	3,415.9	8,348	2.4	2,523.1	7.297	2.9	73.9	87.4
Columbia Total	10,186.5	25, 157	2.5	9.575.3	23,099	2.4	94.0	91.8
Snake River								
Ice Harbor	2,052.4	1.486	0.7	298.1	278	0.9	14.5	18.7
Lower Monumental	2.47 1.5	3,313	1.3	943.1	475	0.5	38.2	14.3
Little Goose	2,139.8	4.915	2.3	3,061 .8	1,664	0.5	143.1	33.9
Lower Granite	2,448.1	4,480	1.8	2.880.5	2,352	0.8	117.7	52.5
Snake Total	9.111.8	14.194	1.6	7.183.5	4,769	0.7	78.8	33.6
GRAND TOTALS	19,298.3	39,351	2.0	16.758.8	27,868	1.7	86.8	70.8

McNary Dam

From early June through late August, 7,297 northern squawfish were caught in 2,523.1 hours of angling at McNary Dam, for a seasonal CPAH of 2.9 (Table 3). The mobile crew supplemented the efforts of the resident crew from late June through mid-July ***(see RESULTS, Mobile Crew).*** The highest catch rates at McNary Dam occurred from mid-June through early July. Weekly catch rates declined rapidly following this peak (Appendix Table A-5). A similar peak in weekly catch was observed in 1991, but it occurred later in the season, from early July through early August (Figure C-4). Thirteen percent fewer fish were caught at McNary Dam in 1992, although less effort was expended than in 1991 (Table 3). The seasonal CPAH was higher in 1992 than in 1991: 2.9 versus 2.4, respectively.

Snake River Dams

From mid-April through mid-September, 4,769 northern squawtish were caught in 7,183.5 hours of angling at Snake River dams, for a seasonal CPAH of 0.7 (Table 3). The highest combined catch for all dams was observed in May (Figure C-2), while the highest combined CPAH was observed in September (Figure C-3). Lower Granite Dam had the highest total catch (2,352 northern squawfish) -and Ice Harbor Dam had the highest seasonal CPAH (0.9) of all the Snake River dams. Sixty-six percent fewer northern squawtish were caught at Snake River dams in 1992 with 21% less effort than in 1991 (Table 3). The seasonal catch rate for Snake River dams in 1992 (0.7) was less than half of that recorded in 1991 (1.6; Table 3).

Ice Hurbor Dam

From early June through late August, 278 northern squawfish were caught in 298.1 hours of angling at Ice Harbor Datn, for a seasonal CPAH of 0.9 (Table 3). In general, weekly CPAH values increased from the beginning of the season in late May to a peak in early July. The catch rate dropped dramatically the following week and rates remained low ($<$ 1.0 fish/h) for the remainder of the season (Appendix Table A-6). Weekly CPAH values in 1992 were more variable than those in 1991 (Figure C-5). The total catch of northern squawfish in 1992 was only 19% of the 1991 catch; however, effort in 1992 was only 15% of the effort expended in 1991. The seasonal CPAH was greater in 1992 than in 1991: 0.9 versus 0.7, respectively (Table 3).

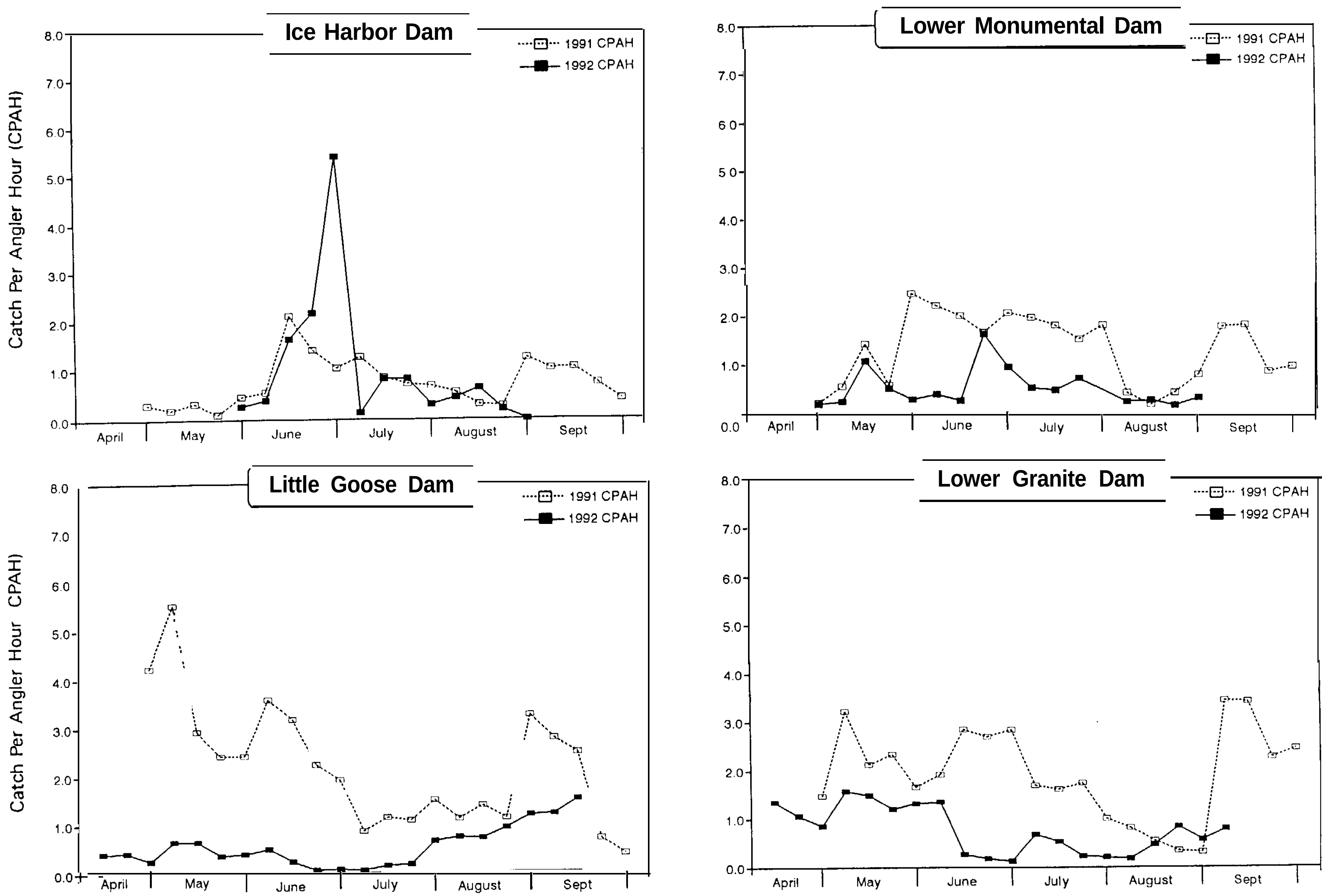

Figure C-5. Weekly average catch per angler hour (CPAH) at Snake River dams, 1991 and 1992. Effort varied substantially within and between seasons.

Lower Monumental Dam

From early May through late August, 475 northern squawfish were caught in 943.1 hours of angling at Lower Monumental Dam, for a seasonal CPAH of 0.5 (Table 3). In general, weekly CPAH fluctuated only slightly, with two small peaks in early to mid-May and in mid-June (Appendix Table A-7). In comparison to 1991, catch rates in 1992 were similar during the first few weeks of the season. However, from late May through the remainder of the season, catch rates in 1992 were substantially lower than in 1991 (Figure C-5). Total catch in 1992 was 14% of the catch in 1991, and the seasonal CPAH in 1992 (0.5) was less than in the previous year (1.3; Table 3).

Little Goose Dam

From mid-April through mid-September, 1,664 northern squawfish were caught in 3,061.8 hours of angling at Little Goose Dam, for a seasonal CPAH of 0.5 (Table 3). The mobile crew supplemented the efforts of the resident crew for the month of May (see ***RESULTS,*** *Mobile Crew*). Weekly catch rates were < 1 .O fish/h until the last three weeks of the season (Appendix Table A-8). There was a modest upswing in catch rates toward the end of the 1992 season, compared with 1991 when peaks in catch occurred early and late in the season. Weekly catch rates in 1992 were much lower and less variable than in 1991 (Figure C-5). The catch of northern squawfish in 1992 was only one-third of the 1991 catch, despite a 43% increase in effort in 1992. Consequently, the seasonal catch rate in 1992 (0.5) was lower than that of the previous year (2.3; Table 3).

Lower Granite Dam

From mid-April through early September, 2,352 northern squawfish were caught in 2,880.5 hours of angling at Lower Granite Dam, for a seasonal CPAH of 0.8 (Table 3). The mobile crew supplemented the efforts of the resident crew from early May through early June (see ***RESULTS, Mobile Crew).*** Weekly catch rates were highest early in the season in 1992 (Appendix Table A-9) and were lower overall than in 1991. Catch rates increased toward the end of the season in both years; however, the increase in 1992 was much less than in the previous year (Figure C-5). Total catch in 1992 was only 52 % of that in 199 1. The seasonal catch rate was much lower in 1992 (0.8) than in 1991 (1.8; Table 3).

Supplemental Angling Activities

Mobile Crew

In the long-term comparison (i.e., was the crew stationed on the better river each month?), the crew had mixed results (Table 4). In May, when the mobile crew was stationed on the Snake River, its CPAH (1.1) was less than the average CPAH for all dams combined (1.2). However, in June and July, while primarily on the Columbia River, its CPAH was intermediate between the average and the maximum (i.e., the better average for the two rivers) in both months. The overall results for the season (2.2) were also intermediate between the average (0.7) and the maximum (2.6). In August and September, the mobile crew became the resident crew at Bonneville Dam, and those results have been presented above ***(see RESULTS, Northern** Squawfish Catch, **Bonneville** Dam*).

In the short-term comparison (i.e., did the crew work at the right dams while stationed on one or the other river?), the crew's CPAH equalled the maximum while stationed on the Snake River (Table 5). However, its overall CPAH while on the Columbia River (2.8) was below the average (3.0).

Bout Angling

Angling for northern squawfish from a boat in the BRZ was conducted at John Day Dam by members of the resident crew during June (6/22-6/25) and July (7/ 1, 7/7-7/9). In June, boat anglers caught a total of 19 squawfish in 50.9 hours, for a CPAH of 0.4. In comparison, the CPAH of anglers fishing from the dam during the same week was 1.6. In July, boat anglers caught a total of 36 squawfish in 28.8 hours of fishing, with a CPAH of 1.2. In comparison, the CPAH of anglers fishing from the dam during these same weeks was 2.5.

Table C-4. Comparison of monthly CPAH values for the mobile crew with the maximum (of the combined average for either the Columbia or Snake river dams) average CPAH and the average CPAH (all resident crews combined on both the Snake and Columbia rivers).

	Mobile crew		Resident Crews	
Month	River	CPAH	Maximum CPAH[a]	Average CPAH
May	Snake	1.1	2.0	1.2
June	Snake/Columbia	2.9	3.1	2.0
July	Columbia	2.5	2.8	1.9
Average		2.2	2.6	1.7

[a] The maximum CPAH for all three months was at all Columbia River dams combined.

Table 5. Comparisons of weekly CPAH values for the mobile crew with the maximum CPAH and the average CPAH for all resident crews at Snake and Columbia river dams separately.

SNAKE RIVER DAMS

	Mobile Crew		Resident Crews	
Week[a]	Dam[b]	CPAH	Maximum CPAH	Average CPAH
3	GO/GR	0.4	0.9 (at GR)	0.4
4	GO/GR	1.5	1.5 (at GR)	0.8
5	GO/GR	1.2	1.4 (at GR)	1.1
6	GO/GR	1.0	1.1 (at GR)	0.6
7	GR	1.6	1.1 (at GR)	0.5
Average		1.2	1.2	0.7

COLUMBIA RIVER DAMS

	Mobile Crew		Resident Crews	
Week	Dam[b]	CPAH	Maximum CPAH	Average CPAH
8	TD	3.3	3.0 (at MC)	2.4
9	BO	3.9	5.2 (at MC)	3.1
10	TD/MC	2.1	6.3 (at MC)	3.3
11	TD/MC	2.3	7.3 (at TD)	4.5
12	TD/MC	1.7	4.1 (at TD)	2.8
13	BO/TD	1.8	4.4 (at BO)	3.2
14	BO/TD	2.9	3.6 (at BO)	2.4
15	BO	4.4	2.9 (at MC)	2.1
Average		2.8	4.5	3.0

[a] The mobile crew worked at Snake River dams from May 3-June 4 and at Columbia River dams from June 8-July 31.
[b] BO=Bonneville Dam, TD=The Dalles Dam, MC=McNary Dam. GO=Little Goose Dam, GR=Lower Granite Dam.

Volunteer Angling

Volunteer anglers from The Dalles Rod and Gun Club supplemented effort at Bonneville Dam by fishing in the forebay of the first powerhouse during evening hours on June 28, July 31, and August 16. Volunteer anglers caught 100 northern squawfish in 22.8 hours of fishing, for a seasonal CPAH of 4.4.

To evaluate the effectiveness of volunteer angling, we compared the daily CPAH for the volunteer anglers to the corresponding weekly CPAH for the resident crew at Bonneville Dam. The CPAH for the volunteer anglers was greater than the resident crew CPAH in two of three comparisons (Table 6).

Incidental Catch

At all dams combined, 1,706 fish were incidentally caught, which was 5.77% of the total catch in 1992 (see Appendix Tables A-10 and A-l 1) and roughly half the number caught in 1991 (3,401). As in 1991, the majority of the incidental catch was catfish caught at Snake River dams (Figure C-6). Salmonids (4 adults and 20 juveniles) composed 1.41% of the incidental catch and 0.08% of the total catch in 1992, which was down from 1991 (Figure C-7). The catch of sturgeon (297) also declined in 1992 from the total in the previous year (384).

Table 6. Comparison of daily CPAH values for the volunteer anglers with the corresponding weekly CPAH for the resident crew at Bonneville Dam.

Volunteer anglers		Resident crew	
Date	CPAH	Week	CPAH
6/28	5.9	6/28-7/4	1.6
7/31	3.4	7/26-8/1	3.7
8/16	5.0	8/16-8/22	1.4

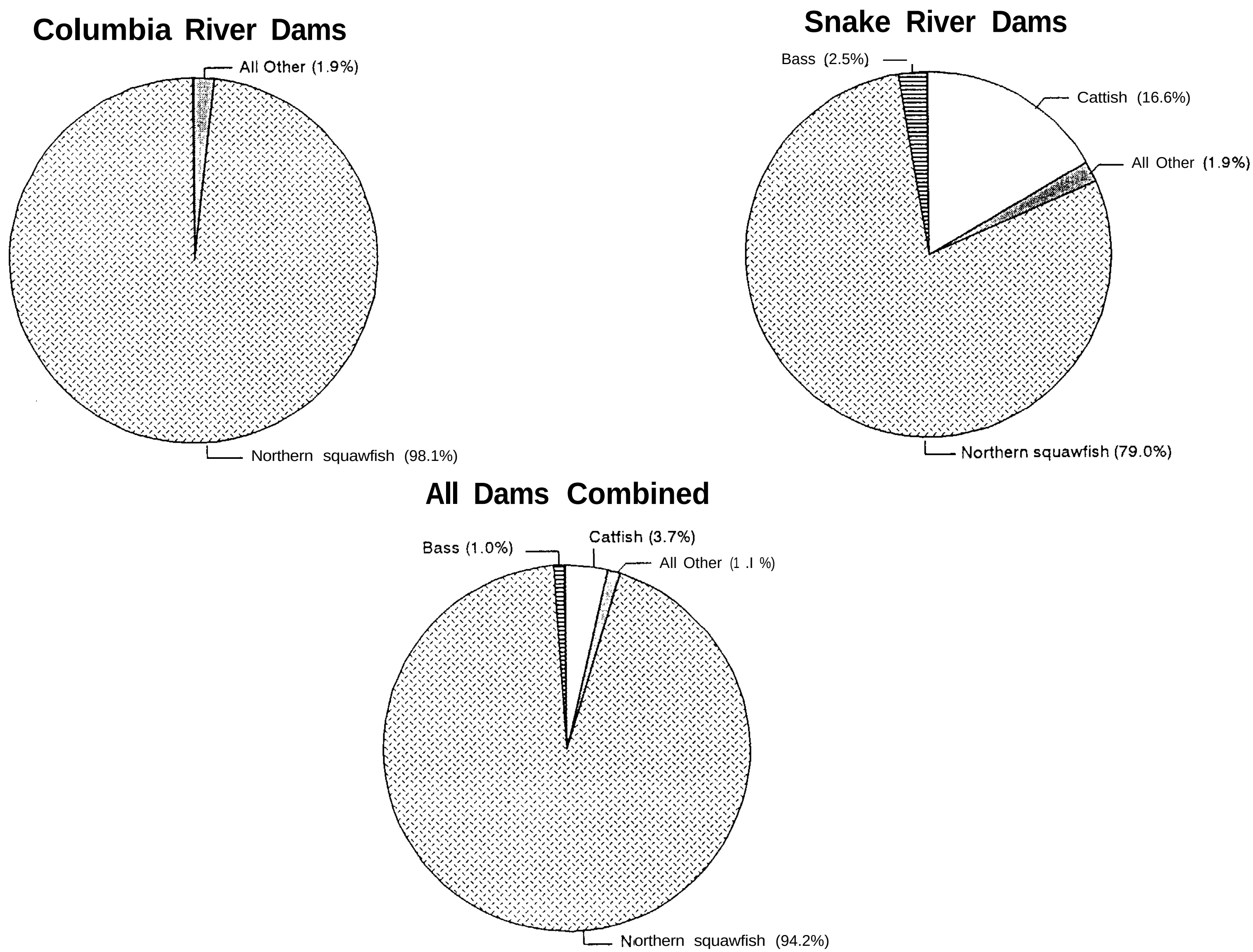

Figure C-6. Total catch percentages in 1992 at Columbia River dams, Snake River dams, and all dams combined. Individual species are displayed when they constitute 1 percent or more of the total catch; otherwise, they are combined with "All other.'!

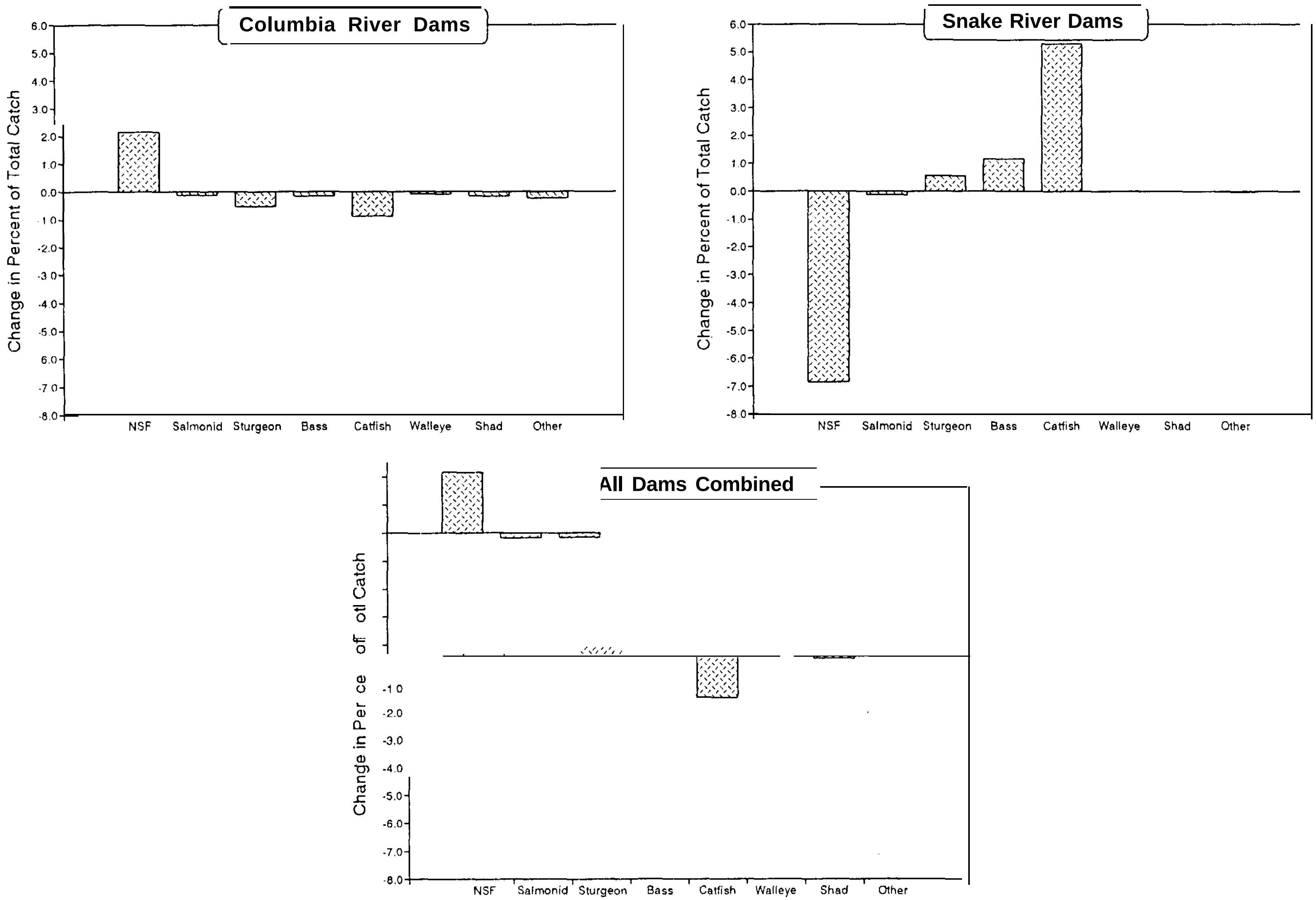

Figure C-7. Difference in percent of total catch of northern squawfish (NSF) and incidentally caught species between 1991 and 1992. Values were obtained by subtracting percent of total catch in 1991 from percent of total catch in 1992.

Columbia River Dams

At Columbia River dams, 439 fish were incidentally caught, which was 1.87% of the total catch in 1992 (see Appendix Tables A-10 and A-11). Fifty-eight percent fewer fish were incidentally caught in 1992 than in 1991 (1,055). Sturgeon and bass composed the highest proportions of the incidental catch in 1992, although each represented less than 1 .O% of the total catch (Appendix Table A-l 1). Two juvenile and no adult salmonids (0.45% of incidental catch and 0.01% of total catch) were caught at dams on the Columbia River in 1992, down from 22 adult and 11 juvenile salmonids (3.13% of incidental catch and 0.12% of total catch) caught in 1991 (Figure C-7). Sturgeon composed 0.68% of the total catch at Columbia River dams in 1992, also down from 1991 (1.18%). All species caught incidentally constituted smaller proportions of the total catch in 1992 than in 1991 (Figure C-T .

Bonneville Dam

At Bonneville Dam, 13 fish (0.27% of total catch; Figure C-8) were incidentally caught in 1992 (Appendix Table A-12 and A-13), which was down from 58 fish (0.70% of total catch) the previous year. As in 1991, American shad (*Alosa sapidissima*) was the most commonly caught incidental species in 1992, composing 76.9% of the incidental catch and 0.21% of the total catch. The remaining incidental catch (three fish) consisted of one juvenile salmonid and two sturgeon, 0.02% and 0.04% of the total catch, respectively. All three fish were released in good condition. The incidental catch of salmonids and sturgeon in 1992 was down from 199 1 (Figure C-9).

The Dalles ***Dam***

At The Dalles Dam, 154 fish (2.00% of total catch) were incidentally caught in 1992 (Appendix Tables A-12 and A-13), which was down from 196 fish (5.04% of total catch) the previous year. Bass composed 73.4% of the incidental catch and 1.46% of the total catch in 1992 (Figure C-8), down from the previous year (Figure C-9). No salmonids were caught in 1992 at The Dalles Dam, compared to one juvenile salmonid caught in 1991. Compared to 1991, the total number of incidentally caught sturgeon increased slightly in 1992; however, the proportion of sturgeon in the total catch declined in 1992 (Figure C-9).

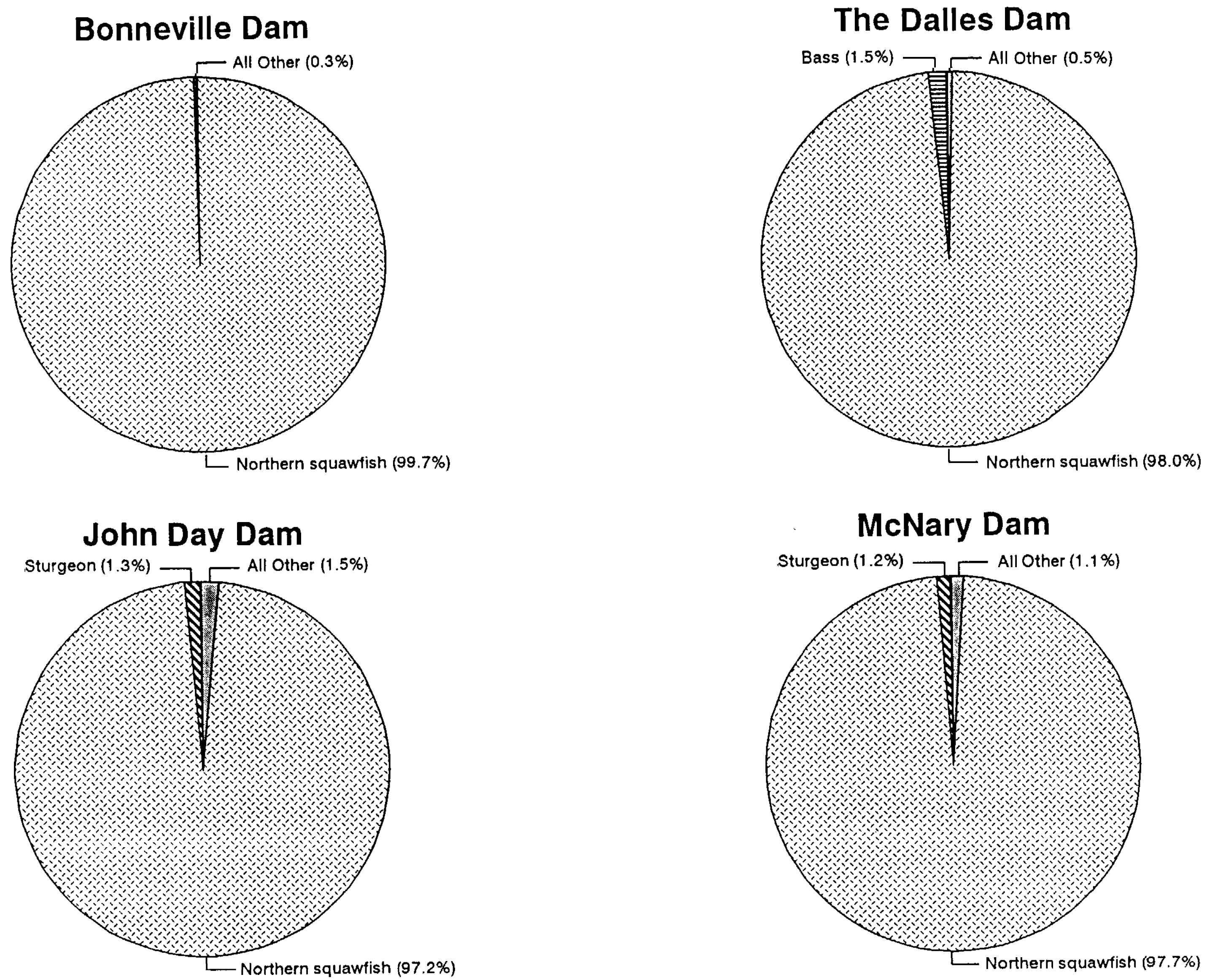

Figure C-8. Total catch percentages in 1992 for individual dams on the Columbia River. Individual species are displayed when they constitute 1 percent or more of the total catch; otherwise, they are combined with "All Other".

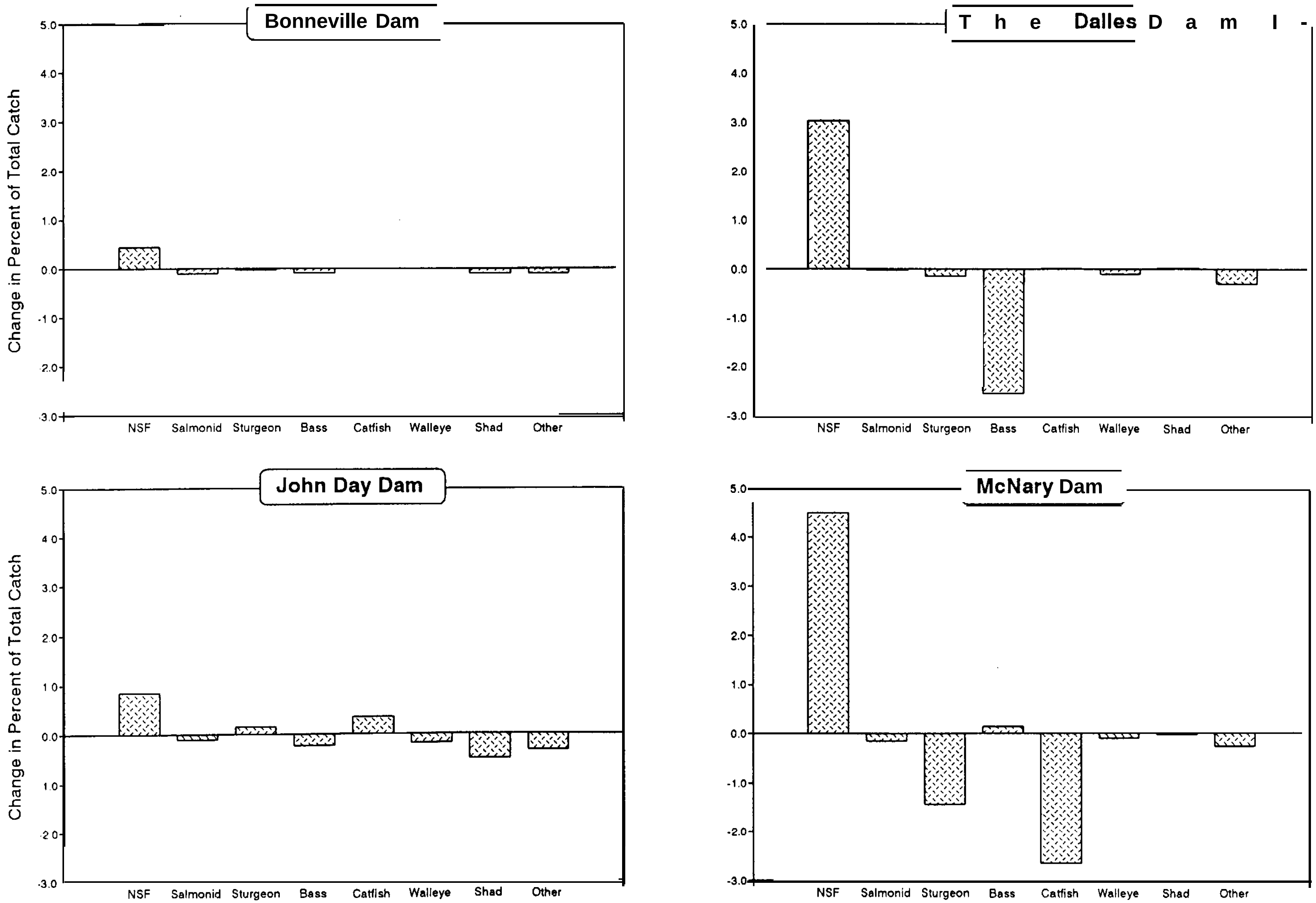

Figure C-9. Difference in percent of total catch of northern squawfish (NSF) and incidentally caught species between 1991 and 1992 at individual Columbia River dams. Values were obtained by subtracting percent of total catch in 1991 from percent of total catch in 1992.

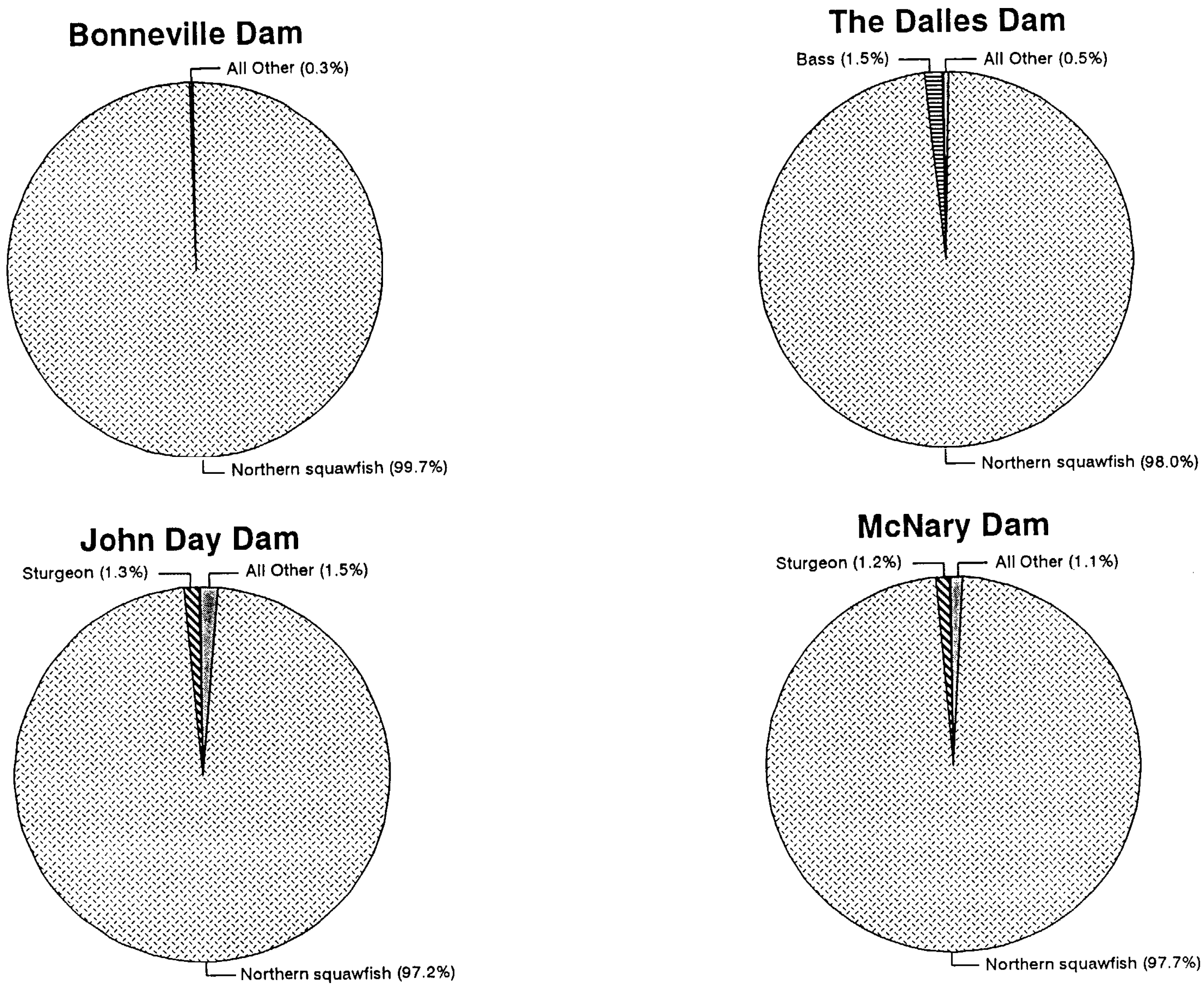

Figure C-8. Total catch percentages in 1992 for ipdividual dams on the Columbia River. Individual species are displayed when they constitute 1 percent or more of the total catch; otherwise, they are combined with "All other."

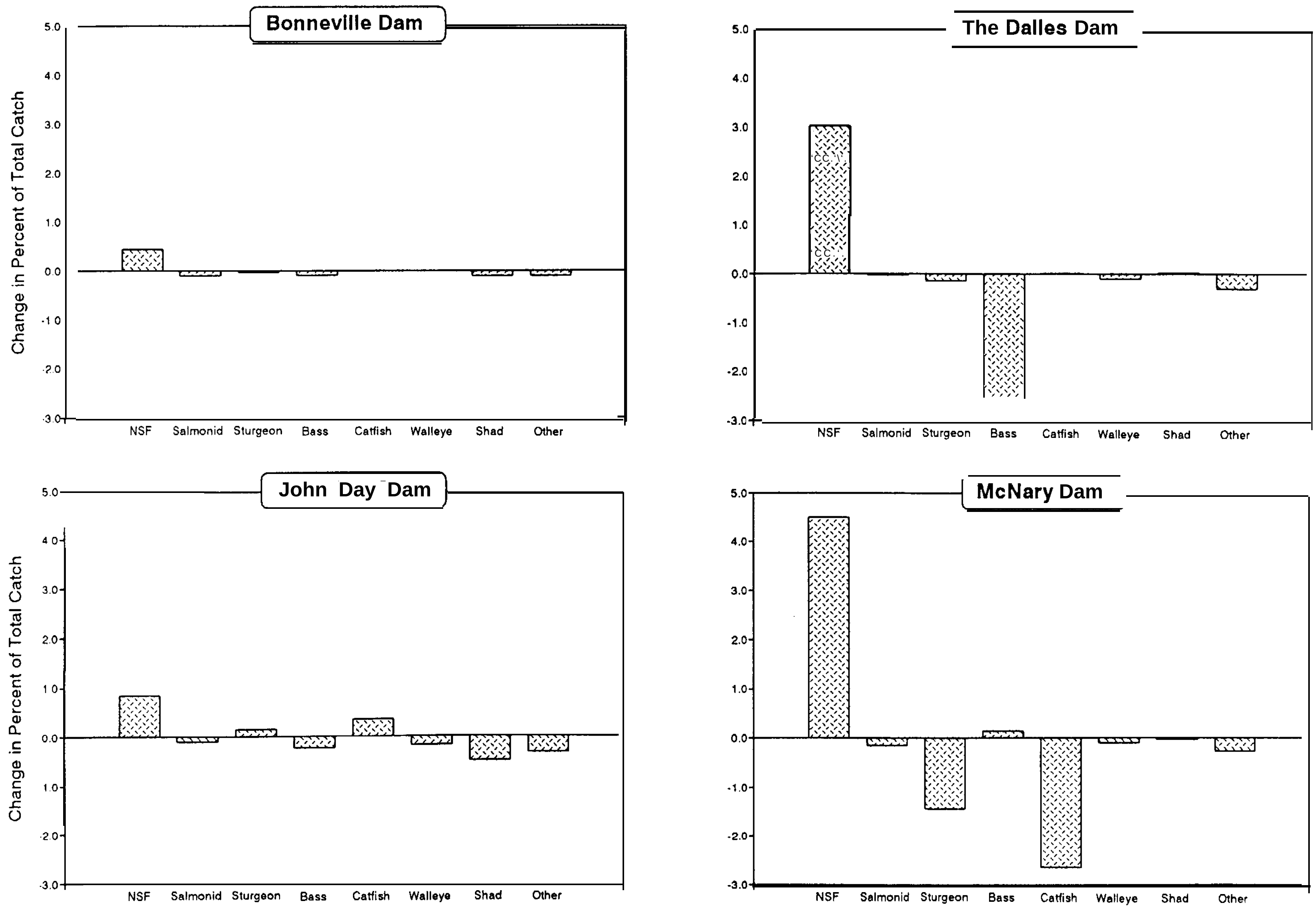

Figure C-9. Difference in percent of total catch of northern squawfish (NSF) and incidentally caught species between 1991 and 1992 at individual Columbia River dams, Values were obtained by subtracting percent of total catch in 1991 from percent of total catch in 1992.

John Day Dam

At John Day Dam, 99 fish (2.81% of total catch) were incidentally caught in 1992 (Appendix Tables A- 12 and A-13), down from 190 fish (3.65 % of total catch) in 199 1. Sturgeon accounted for the largest proportion of the incidental catch (45.4%) and composed 1.28% of total catch in 1992 (Figure C-8), up from the previous year (Figure C-9). A greater proportion of catfish was caught in 1992 (0.85% of total catch) than in 1991 (0.50% of total catch). One juvenile salmonid (0.03% of total catch) and no adults were caught at John Day Dam in 1992, compared to seven adults and no juveniles the previous year. Walleye, bass, shad, and "other" species constituted smaller proportions of the total catch in 1992 than in 1991 (Figure C-9).

McNary ***Dam***

At McNary Dam, 173 fish (2.32% of total catch) were incidentally caught in 1992 (Appendix Tables A-12 and A-13), down from 611 fish (6.56% of total catch) in 1991. Sturgeon accounted for half of the incidental catch and composed 1.16% of the total catch in 1992 (Figure C-8), which was down from 1991 (Figure C-9). Fewer catfish were caught in 1992 (48) than in 1991 (295). No salmonids were caught in 1992 at McNary Dam, compared to 14 salmonids (five juveniles and nine adults) caught in 1991 (Figure C-9). A slightly larger proportion of bass was caught in 1992 than in 1991 (Figure C-9).

Snake River Dams

At Snake River dams, 1,267 fish were incidentally caught, which was 21.0% of the total catch in 1992 (Appendix Tables A-10 and A-l 1, which contain data presented in this paragraph). Forty-six percent fewer fish were incidentally caught in 1992 than in 1991 (2,346). Catfish (79.1%) and bass (11.9%) composed the highest proportions of the incidental catch. Salmonids (four adults and 18 juveniles) composed 0.36% of the total catch at Snake River dams in 1992, down from 17 adult and 62 juvenile salmonids (0.47% of total catch) in 199 1. In 1992, a larger proportion of the total catch consisted of sturgeon, bass, and cattish than in 1991, due primarily to the decline in northern squawfish catch in 1992 (Figure C-7).

Ice Harbor Dam

At Ice Harbor Dam, 143 fish (34.0% of total catch) were incidentally caught in 1992 (Appendix Tables A-14 and A-15), down from 924 fish (38.3% of total catch) the previous year. Catfish accounted for the largest proportion of the incidental catch (94.4%) and 32.1% of the total catch in 1992 (Figure C-10), which was down from 1991 (Figure C-l 1). No salmonids were caught in 1992 at Ice Harbor Dam, compared to three salmonids (two adults and one juvenile) caught in 1991 (Figure C-l 1). All species caught incidentally constituted smaller proportions of the total catch in 1992 than in 1991 (Figure C-l 1).

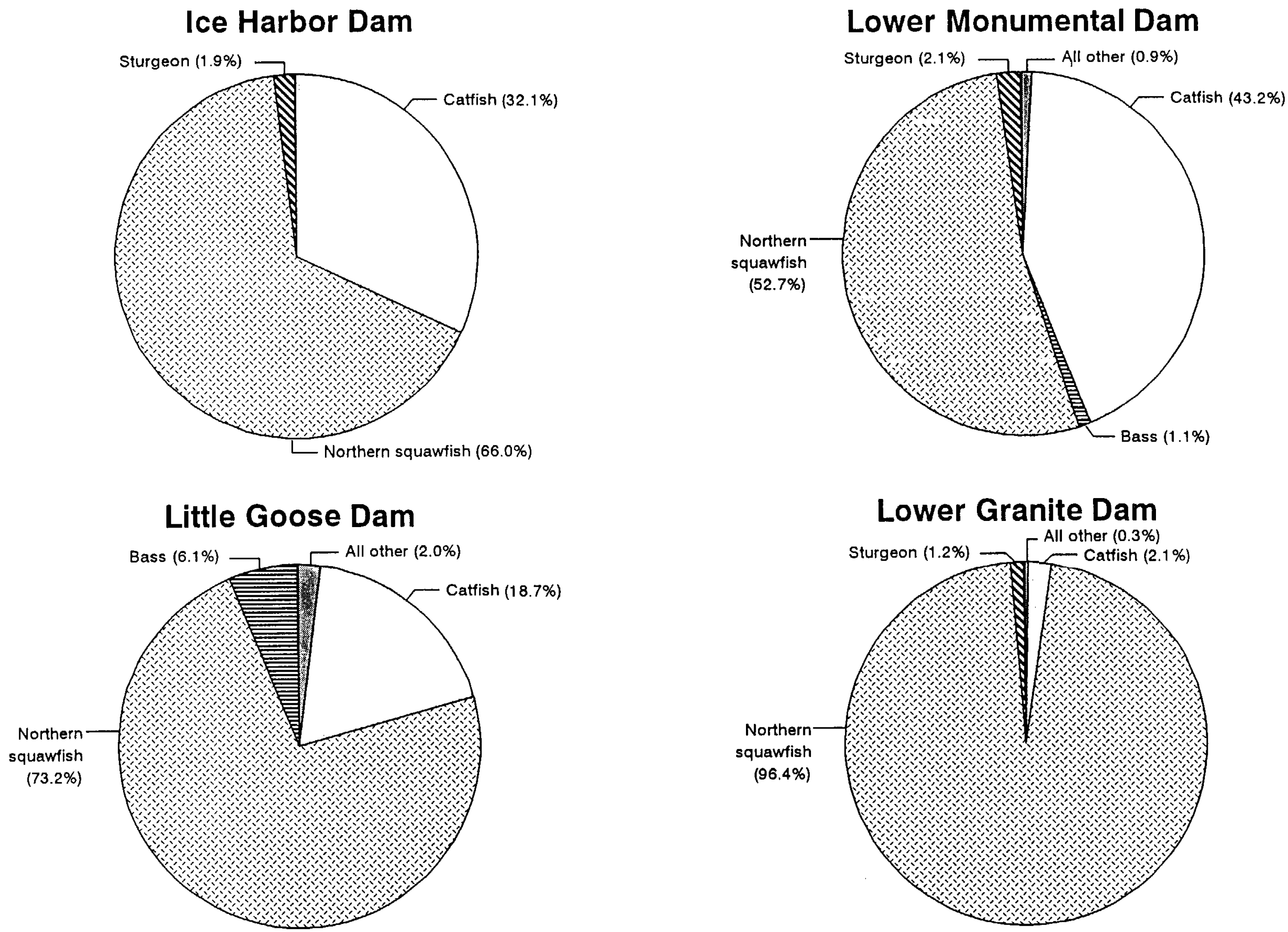

Figure C-10. Total catch percentages in 1992 for individual dams on the Snake River. Individual species are displayed when they constitute 1 percent or more of the total catch; otherwise, they are combined with "All other."

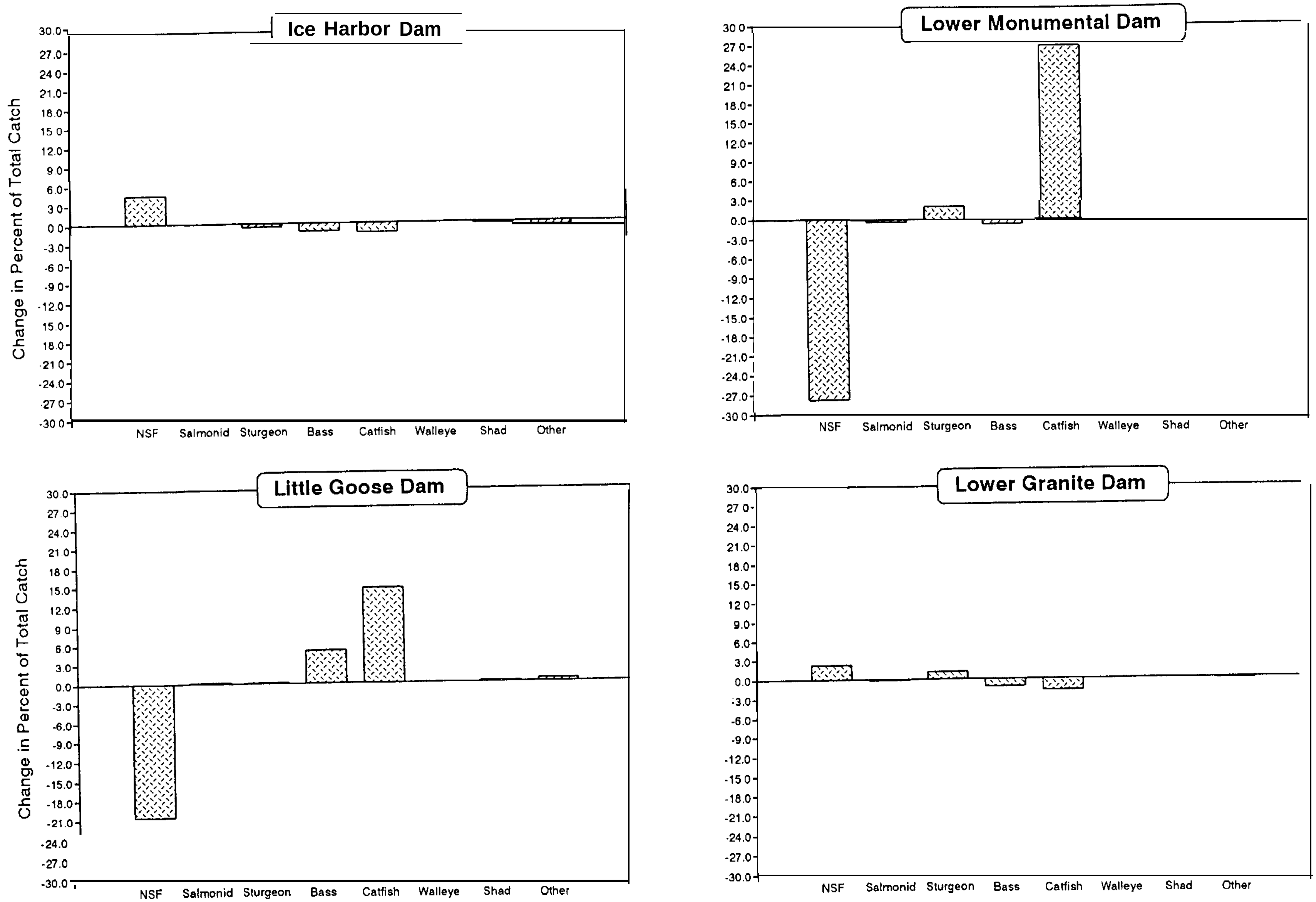

Figure C-11. Difference in percent of total catch of northern squawfish (NSF) and incidentally caught species between 1991 and 1992 at individual Snake River dams. Values were obtained by subtracting percent of total catch in 1991 from percent of total catch in 1992.

Lower Monumental Dam

At Lower Monumental Dam, 427 fish (47.3% of total catch) were incidentally caught in 1992 (Appendix Tables A-14 and A-15), down from 817 fish (19.7% of total catch) in 1991. Catfish were the largest component of the incidental catch, followed by sturgeon and bass (Figure C-10). Four salmonids (three adults and one juvenile) were caught at Lower Monumental Dam in 1992, compared to eight adult and 27 juvenile salmonids caught in 199 1. Compared to 199 1, proportions of catfish and sturgeon caught increased in 1992, while the proportions of salmonids and bass declined (Figure C-l 1).

Little Goose Dam

At Little Goose Dam, 610 fish (26.8% of total catch) were incidentally caught in 1992 (Appendix Tables A-14 and A-15), up from 329 fish (6.27% of total catch) in 1991. As in 1991, catfish and bass constituted the largest proportions of the incidental catch in 1992 (Figure C-10). One adult and 14 juvenile salmonids (0.66% of total catch) were caught at Little Goose Dam in 1992, down from five adult and 23 juvenile salmonids (0.54% of total catch) caught in 1991 (Figure C-l 1). Three sturgeon (0.13 % of total catch) were caught in 1992, compared to one the previous year.

Lower Granite Dam

At Lower Granite Dam, 87 fish (3.57% of total catch) were incidentally caught in 1992 (Appendix Tables A- 14 and A- 15), down from 276 fish (5.80 % of total catch) the previous year. Catfish and sturgeon composed the largest proportions of the incidental catch in 1992 (Figure C-10) and in 1991. Three juvenile salmonids (0.12% of total catch) were caught in 1992, down from two adult and 11 juvenile salmonids (0.27% of total catch) the previous year. In 1992, catches of bass, catfish, and "other" species also decreased relative to 1991 (Figure C-11). The catch of sturgeon increased slightly in 1992 (Figure C-11).

DISCUSSION

Northern Squawfish Catch

The changes in CPAH observed within and between years at Columbia and Snake river dams reflect changes in population size and/or catchability of fish near dams. This relationship is expressed symbolically as:

$$C/f = qN$$

where

C/f	=	(catch/effort) or catch per unit effort, in our case CPAH;
qN	=	(catchability coefficient * population size) or availability (for review see Ricker 1975).

There are many factors that might affect availability of fish and as a result cause differences in catch-rates among locations and over time.

Here we discuss some factors that potentially affect our catch rates at Columbia and Snake river dams. We recognize that other factors not addressed here -- expertise of anglers and weather conditions, for example -- may also be influential. Considerably more research would be required to fully explain the factors affecting northern squawfish abundance, their catchability, and, therefore, our catch rates. References to changes in catches and catch rates between 1991 and 1992 do not imply that those changes necessarily define a trend, particularly in the abundance of predaceous northern squawfish.

Columbia River Dams

The combined seasonal catch rate at Columbia River dams decreased slightly from 1991 to 1992, although seasonal catch rates at two of the four dams (The Dalles and McNary) increased (Table 3). Some factors that may have influenced changes in catch rates are described below.

Adjustments of Effort

Effort in 1992 was concentrated in months and at dams that were most productive in 1991. In 1992, a greater proportion of total effort was shifted to Columbia River dams and concentrated during mid-season, which successfully anticipated the high catch rates that recurred at those dams and times in 1992 (Table 3). Effort at Columbia River dams in 1992 was also augmented with supplemental angling activities (e.g., mobile crew, volunteer angling, boat angling). However, because of the relatively early and warm spring in 1992, we may have missed some productive weeks before the crews started working at Columbia River dams. Start dates that can be adjusted (by a couple weeks) depending on whether the spring is cool (as in 1991) or warm (as in 1992) could help us adapt to differences among years.

As we concentrate effort more in space and time, we expect that catch rates will decline. Rates of predator removal in the relatively small areas near the dams may exceed migration (or "recruitment") into those areas (see following section, ***Previous Removals).*** Catch ***rates*** (e.g., CPAH) at Columbia River dams may have been higher in 1992 if effort had been lower, but *catches* would have been lower.

Previous Removals

In 1990 and 1991, roughly 175,000 northern squawfish were reportedly removed from the lower Columbia River (from the tailrace of McNary Dam to the tailrace of Bonneville Dam) by predator control program fisheries (Nigro 1990, Willis and Nigro 1991). In 1992, approximately 145,000 northern squawfish were reportedly removed from this same area (field activity reports 1992). Previous removals, however, will reduce population size within a given area only if recruitment is less than the exploitation rate (Ricker 1975).

"Recruitment" here applies both to growth of new individuals into the vulnerable population and immigration. Preliminary analysis of 1991 dam angling data has shown that catch rates at dams decrease over the days within each week that crews work (D. Neeley, unpublished data), suggesting that the rate of migration into areas near dams is not high in the short-term (i.e., day-to-day). However, an analogous decline across years has *not* been observed (Table 3), perhaps because recruitment (i.e., growth *and* immigration) has compensated for previous removals. Also, previous removals may not have been sufficient to cause a ***detectable*** reduction in our catch rates. Regardless, the collective efforts of the predator control program fisheries over the past three years have removed large numbers of predators from the lower Columbia River. Continued removals throughout this reach in coming years will probably decrease the number of fish available (in adjacent river areas) to migrate into areas near Columbia River dams. Not until this time are we likely to see appreciable and sustained decreases in both catch and catch rates at these dams.

Bird Wires

Recently installed bird wires used to protect out-migrating smolts from bird predation at John Day, The Dalles, and McNary dams have restricted angler access to good fishing areas and reduced the catchability of fish. The location of these wires in tailrace areas has caused crews to change angling techniques that were used successfully before the wires were installed. For example, at John Day Dam, anglers had great success letting baits drift across the face of the powerhouse and casting out far away from the dam. The location of wires across the front of the powerhouse deck prohibited the use of these techniques in 1992. Bird wires caused similar problems at McNary Dam. Because bird wires at The Dalles Dam were located above the heads of anglers, they did not significantly restrict anglers at that dam.

Snake River Dams

In 1992, catch rates decreased substantially at all Snake River dams from the previous year with the exception of Ice Harbor Dam (Table 3). At this point, we do not know the reason for the decline or whether it is the start of a trend. Several factors may have been responsible for the changes in catch rates at these dams.

Adjustments of Effort

On average, catch rates at Snake River dams were lower than catch rates at Columbia River dams in 1991. Therefore, in 1992, we decreased the average crew size at Snake River dams so that proportionately more effort could be spent at Columbia River dams (Table 3). In 1992, crews at Snake River dams started earlier than crews on the Columbia River to take advantage of high catches that were obtained at Snake River dams early in the 1991 season. For this same reason, the mobile crew was deployed to Snake River dams early in the season in 1992 (Table 2).

We had some success with these adjustments of effort at Snake River dams in 1992. Catch rates at Snake River dams were below rates recorded at Columbia River dams in 1992 (Table 3), substantiating our decision to concentrate proportionately more effort at Columbia River dams. Our decision to start resident crews and the mobile crew early on the Snake River did not prove to be productive compared to other alternatives. High catches at Snake River dams early in the 1991 season did not recur in 1992 (Figures C-2 and C-3). Therefore, a greater concentration of effort at Columbia versus Snake River dams early in the season would have yielded better results.

The exceptional (among Snake River dams) increase in CPAH at Ice Harbor Dam from 1991 to 1992 may reflect the large ***decrease*** (by 81% , Table 3) in effort there. This assumes, as described above, that catch ***rate*** is inversely related to the level of effort.

Previous Removals

Previous removals may have contributed to the decline in catch rates at Snake River dams in 1992 from 1991. In 1990 and 1991, roughly 45,000 northern squawfish were reportedly removed from the lower Snake River (from the confluence of the Clearwater River to the tailrace of Ice Harbor Dam) by predator control program fisheries (Nigro 1990, Willis and Nigro 199 1). In 1992, approximately 40,000 squawfish were reportedly removed from this same area (field activity reports 1992). Based on predation indexing, northern squawfish are less abundant on the Snake River than on the Columbia River (Ward et al. 1991). Therefore, there may be fewer fish available in the reservoirs to migrate into areas around Snake River dams than there are in Columbia River reservoirs.

Reservoir Druwdown Activities

In March of 1992, the reservoirs behind Lower Granite and Little Goose dams were drawn down (36.5 ft and 12.5 ft below minimum operating pool, respectively) to test the physical effects of lowering reservoir levels to help juvenile salmonids in their downstream migration (U.S. Army Corps of Engineers 1992). Northern squawfish, like other fishes in these reservoirs, may have been entrained in the high flows passed through the turbines and over the spillway during drawdown. Several white sturgeon that had been marked and released in Lower Granite Reservoir prior to the drawdown were afterward recaptured in the tailrace of Lower Granite Dam (U.S. Army Corps of Engineers 1992). More data and analyses are needed to determine to what extent entrainment and other results of drawdown affected changes in catch rates at Snake River dams in 1992.

Bird Wires

Bird wires posed similar problems to anglers at Snake River dams as they did at Columbia River dams. In 1992, bird wires were installed in tailrace areas at each of the Snake River dams. These wires obstructed anglers' ability to fish what were the most productive (measured by total catch) sites in 1991 at Ice Harbor, Little Goose, and Lower Granite dams. Anglers would often tangle their fishing line on these wires, thereby reducing angler effectiveness. The crew at Lower Monumental Dam also reported having difficulty fishing around bird wires.

Supplemental Angling Activities

For both the long-term and short-term comparisons for the mobile crew, our minimum performance standard was the *average* CPAH for alternatives, and the ideal standard was the ***maximum*** CPAH among alternatives, as reflected by the success of resident crews. In the long-term comparison, the mobile crew was below minimum standard in May while stationed on the Snake River, primarily because of the unexpectedly low catches at Little Goose and Lower Granite dams (Table 4). However, the mobile crew performed between minimum and ideal standards during June and July, when they were mostly on the Columbia River. Catch rates were better at Columbia River dams in all months, and the mobile crew could have removed more fish if we had deployed them to Columbia River dams for the entire season (Tables 3 and 4).

In the short-term comparison, the mobile crew did well while on the Snake River, with an overall CPAH that equalled the ideal standard (Table 5). However, the crew could have been used more effectively while on the Columbia River, where its overall CPAH did not meet the minimum standard. The crew's performance may have been better had we been more willing to incur the travel-related expenses of sending them from their station in The Dalles to McNary Dam (over 100 miles away), where catch rates were often high relative to other Columbia River dams.

Preliminary results (i.e., CPAH) suggest that volunteer angling may be effective in targeting productive times and locations, as might boat angling. For example, volunteers can easily fish short 2-4 hour periods in the evening when catch rates are exceptionally high (e.g., at Bonneville Dam's first powerhouse). Personnel management constraints make it more difficult for crews of technicians to work such short hours; those crews will usually have to fish some relatively less productive hours before and/or after the short periods when catches peak. Neither volunteer angling nor boat angling were thoroughly tested in 1992.

Incidental Catch

The incidental catch of other species at all dams combined was much less in 1992 than in 1991, both in absolute numbers (Beaty et al. 1991, Appendix Table A-10, Appendix Table A- 15) and proportion of total catch (Figure C-7). Measures implemented in 1992 to reduce incidental catch ***(see METHODS, Field Procedures)*** probably contributed to the decline. Also, the same unidentified factors that caused substantially lower catches of northern squawfish at Snake River dams in 1992 may have contributed to changes in incidental catch at those dams.

The incidental catch decreased relative to catches in 1991 at each dam except for Lower Monumental Dam (increase in proportion of total catch) and Little Goose Dam (increase in both proportion of total catch and absolute numbers; Appendix Tables A-12 through A-15, Beaty et al. 1991, Appendix Tables A-10 through A- 13). An increase in the catch of catfish accounts for most of the increase in incidental catch at both dams in 1992. Relatively low catch rates of northern squawfish at these dams may have prompted anglers to explore other angling methods (e.g., fishing closer to the river bottom) that led to greater catches of catfish. A reduction in catch rates for northern squawfish probably also contributed to the increase in the ***proportions*** of catfish and other incidental species at Lower Monumental and Little Goose dams in 1992 relative to 1991.

RECOMMENDATIONS

1. Continue controlled angling fisheries at all eight dams.

2. Continue to shape effort at the dams to be more effective and efficient:

Dam	Anglers	Season & Notes
Bonneville	5	May/June to August/September
The Dalles	6	May to September
John Day	5	May to September
McNary	8	May/June to August
Ice Harbor/ L. Monumental	3	May/June to August. Both dams will be staffed by a single crew that moves between them.
Little Goose/ Lower Granite	5	April/May to September. Both dams will be staffed by a single crew that moves between them.

3. Use a mobile crew to augment resident crew efforts. Crew will consist of five anglers and will work the entire season at Columbia River dams to take advantage of higher catch rates observed there. We will locate the crew to work the most productive dams on the Columbia River, taking into account travel-related costs.

4. Continue efforts to determine the feasibility of controlled boat angling in the boat-restricted zones at some dams (e.g., The Dalles, John Day, and McNary) where northern squawfish are known to be abundant and are inaccessible to dam-based anglers.

5. Increase the use of controlled volunteer angling at high catch dams, specifically Bonneville, The Dalles, and McNary. These efforts will be concentrated during weekends and at peak catch hours (dawn and dusk). All effort will be supervised by project staff and/or technicians and will be coordinated closely with the Corps of Engineers.

6. Work with Animal Damage Control and Corps biologists to relocate bird wires to increase angler access to good fishing sites, while at the same time protecting juvenile salmonids from bird predation.

7. Continue to seek more effective lures and baits for controlled angling fisheries.

8. Conduct limited biological sampling on the many ***incidentally*** caught channel catfish at McNary Dam and the four dams on the lower Snake River. Information gathered will help determine the extent to which catfish prey on salmonid smolts.

9. Develop and evaluate some alternative methods to capture northern squawfish where they concentrate in the mainstem, particularly near hatchery release points.

10. Identify concentrations of northern squawfish in the lower reaches of some Snake and Columbia river tributaries above Bonneville Dam, and determine the extent to which these concentrations comprise members of mainstem populations.

11. Continue analysis of data to better understand factors affecting catch.

12. Promote the development and implementation of effective and efficient squawfish control methods.

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APPENDIX A

Lure and Bait Descriptions and Tabular Data Regarding Angler Effectiveness and Incidental Catches

Appendix Table A-l. Lures and baits used by anglers at the Columbia and Snake River dams in 1992.

Category & type	Description	Color/condition ,
HARD LURES		
Kastmaster	metal spoon	chrome
Roostertail	metal spinner	black
Vibrax spinner	spinner	chrome
Zonar blade	metal blade	chrome
Steely	metal spoon	chrome
Rat-L-Trap	hard plastic plug, diving	blue, silver, black, scale, tiger perch; various combinations
Electric shad	hard plastic plug, diving	shad finish
SOFT LURES		
Grub	plastic; often augmented	black, blue, brown, white, chartreuse, yellow, glo-in-
Twin-tailed grub	with scent	the-dark, red, dark-green, purple, speckled (various
Tube tails		color combinations);
Fish-like		
Slug		
BAIT		
Salmonid smolts	whole, cut	fresh, frozen
Salmonid eggs	whole	cured
Herring	whole, pieces	frozen, salted
Lamprey	whole, cut	fresh, frozen
Squawfish	belly skin	fresh
Nightcrawler, worms	whole or pieces	fresh
Crayfish	whole, pieces	fresh
Shad	juveniles	fresh
Grasshoppers	whole, pieces	fresh

Appendix Table A-Z. Weekly average CPAH at Bonneville Dam, 1992.

Week number[a]	Total hours fished	Number of northern squawfish	CPAH
6	24.0	49	2.0
7	93.0	161	1.7
8	102.3	243	2.4
9	238.1	740	3.1
10	131.6	169	1.3
11	127.4	201	1.6
12	116.6	273	2.3
13	153.0	592	3.9
14	196.4	753	3.8
15	179.5	661	3.7
16	86.5	598	6.9
17	100.1	204	2.0
18	95.7	130	1.4
19	82.7	30	0.4
20	54.4	10	0.2
Seasonal totals	1,781.3	4,814	2.7
Means	118.8	320.9	--

[a] Fishing began at Bonneville Dam during Week 6 (5/24/92 - 5/30/92) and ended Week 20 (8/30/92 - 9/5/92) of the field season.

Appendix Table A-3. Weekly average CPAH at The Dalles Dam, 1992.

Week number[a]	Total hours fished	Number of northern squawfish	CPAH
4	33.6	232	6.9
5	45.8	352	7.7
6	65.8	493	7.5
7	133.2	557	4.2
8	240.9	752	3.1
9	145.2	653	4.5
10	161.9	632	3.9
11	165.7	841	5.1
12	205.7	677	3.3
13	185.9	240	1.3
14	169.5	297	1.8
15	165.1	236	1.4
16	221.8	582	2.6
17	125.7	55	0.4
18	116.4	121	1.0
19	125.6	412	3.3
20	111.2	319	2.9
21	77.2	110	1.4
Seasonal totals	2,496.2	7,561	3.0
Means	138.7	420.1	--

[a] Fishing began at The Dalles Dam during Week 4 (5/10/92 - 5/ 16/92) and ended Week 21 (9/6/92 - 9/12/92) of the field season.

Appendix Table A-4. Weekly average CPAH at John Day Dam, 1992.

Week number[a]	Total hours fished	Number of northern squawfish	CPAH
3	71.4	123	1.7
4	178.7	105	0.6
5	143.1	108	0.8
6	175.6	48	0.3
7	122.3	100	0.8
8	96.7	113	1.2
9	186.9	75	0.4
10	194.5	242	1.2
11	135.8	420	3.1
12	205.0	402	2.0
13	126.3	463	3.7
14	136.9	221	1.6
15	147.3	226	1.5
16	206.1	380	1.8
17	183.8	152	0.8
18	149.1	160	1.1
19	100.6	69	0.7
20	137.4	13	0.1
21	77.2	7	0.1
Seasonal totals	2,774.7	3,427	1.2
Means	146.0	180.4	--

[a] Fishing began at John Day Dam during Week 3 (5/3/92 - 5/9/92) and ended Week 21 (9/6/92 - 9/12/92) of the field season.

Appendix Table A-5. Weekly average CPAH at McNary Dam, 1992.

Week number[a]	Total hours fished	Number of northern squawfish	CPAH
7	110.7	422	3.8
8	175.4	534	3.0
9	192.1	1006	5.2
10	205.1	1086	5.3
11	221.1	1232	5.6
12	251.5	664	2.6
13	206.3	690	3.3
14	227.1	587	2.6
15	199.1	586	2.9
16	210.6	279	1.3
17	166.2	66	0.4
18	152.6	71	0.5
19	205.3	74	0.4
Seasonal totals	2,523.1	7,297	2.9
Means	194.1	561.3	--

[a] Fishing began at McNary Dam during Week 7 (5/31/92 - 6/6/92) and ended Week 19 (8/23/92 - 8/29/92) of the field season.

Appendix Table A-6. Weekly average CPAH at Ice Harbor Dam, 1992.

Week number"	Total hours fished	Number of northern squawfish	CPAH
7	19.2	5	0.3
8	13.2	5	0.4
9	24.6	40	1.6
10	22.2	48	2.2
11	16.0	86	5.4
12	14.0	2	0.1
13	35.5	29	0.8
14	25.6	21	0.8
15	50.9	15	0.3
16	11.5	5	0.4
17	27.3	17	0.6
18	26.1	5	0.2
19	12.0	0	0.0
Seasonal totals	298.1	278	0.9
Means	22.9	21.4	--

' Fishing began at Ice Harbor Dam during Week 7 (5/31/92 - 6/6/92) and ended Week 19 (8/23/92 - 8/29/92) of the field season.

Appendix Table A-7. Weekly average CPAH at Lower Monumental Dam, 1992. During the last week of July (Week 15), this crew worked at Ice Harbor Dam.

Week number[a]	Total hours fished	Number of northern squawfish	CPAH
3	74.2	15	0.2
4	93.3	24	0.3
5	92.8	99	1.1
6	75.4	38	0.5
7	89.1	26	0.3
8	93.9	37	0.4
9	65.0	17	0.3
10	43.7	70	1.6
11	57.4	53	0.9
12	72.7	37	0.5
13	36.8	17	0.5
14	12.9	9	0.7
15	0.0	0	--
16	45.5	11	0.2
17	29.8	8	0.3
18	32.1	5	0.2
19	28.5	9	0.3
Seasonal totals	943.1	475	0.5
Means	58.9	29.7	--

[a] Fishing began at Lower Monumental Dam during Week 3 (5/3/92 - 5/9/92) and ended Week 19 (8/23/92 - 8/29/92) of the field season.

Appendix Table A-8. Weekly average CPAH at Little Goose Dam, 1992.

Week number[a]	Total hours fished	Number of northern squawfish	CPAH
1	98.5	40	0.4
2	131.3	55	0.4
3	185.5	46	0.2
4	172.9	113	0.7
5	176.5	114	0.6
6	169.1	59	0.3
7	141.8	54	0.4
8	146.7	71	0.5
9	123.8	27	0.2
10	158.6	9	0.1
11	137.7	9	0.1
12	134.0	7	0.1
13	138.4	18	0.1
14	125.5	21	0.2
15	140.1	90	0.6
16	144.6	104	0.7
17	132.1	93	0.7
18	152.8	139	0.9
19	151.9	179	1.2
20	105.5	126	1.2
21	194.5	290	1.5
Seasonal totals	3,061.8	1,664	0.5
Means	145.8	79.2	--

[a] Fishing began at Little Goose Dam during Week 1 (4/19/92 - 4/25/92) and ended Week 21 (9/6/92 - 9/12/92) of the field season.

Appendix Table A-9. Weekly average CPAH at Lower Granite Dam, 1992.

Week number”	Total hours fished	Number of northern squawfish	CPAH
1	102.9	139	1.4
2	136.0	143	1.1
3	143.7	123	0.9
4	203.1	321	1.6
5	179.5	267	1.5
6	197.7	237	1.2
7	228.7	300	1.3
8	144.2	193	1.3
9	145.9	39	0.3
10	171.8	30	0.2
11	120.8	15	0.1
12	115.3	77	0.7
13	150.8	80	0.5
14	137.4	30	0.2
15	114.4	24	0.2
16	108.1	20	0.2
17	131.2	61	0.5
18	140.0	115	0.8
19	118.7	67	0.6
20	90.3	‘71	0.8
Seasonal totals	2,880.5	2,352	0.8
Means	144.0	117.6	--

* Fishing began at Lower Granite Dam during Week 1 (4/19/92 - 4/25/92) and ended Week 20 (8/30/92 - 9/5/92) of the field season.

Appendix Table A-10. Monthly catch of incidental species by condition at release for Columbia and Snake river dams, 1992. Condition codes: (1) minimal injury, certain to survive; (2) moderate injury, may or may not survive; (3) dead, nearly dead, or certain to die; (L) line cut or broken, fish not removed from the water.

	Total catch (all species)	Total incidental catch	Salmonids				Sturgeon				Bass			Catfish			Walleye			Shad	Other
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3		
COLUMBIA R.																					
May	1,592	82	*0*	*0*	*0*	*0*	3 7	1	0	4	22	1	1	11	0	0	10		0	2	2
June	8,912	88	10		0	0	18	0	0	10	12	0	0	25	1	0	0	0	0	9	12
July	9,016	93	0	0	0	0	32	0	0	11	23	0	0	16	0	0	2	0	0	8	1
August	3,583	131	0	0	0	0	25	0	0	12	62	0	1	13	1	O	4	0	0	11	2
Sept	435	45	10		0	0	3	1	0	5	19	2	0	12	0	0	10		0	1	0
Season	23,538	439	2	0	0	0	115	2	0	42	138	3	2	77	2	0	s	0	0	31	17
SNAKE R.																					
April	434	57	3	0		01	2	0	0	3	*0*	*0*	*0*	42	1	1	0	0	0	0	4
May	1,675	219	2	0	0	3	4	0	0	11	26	0	1	158	6	1	0	0	0	1	6
June	1,265	254	0	0	0	0	5	0	0	14	19	0	0	206	6	0	0	0	0	0	4
July	978	378	0	0	0	0	3	0	0	6	39	0	4	304	4	5	0	0	0	2	11
August	1,188	317	13	0	0	0	0	0	0	10	49	0	0	234	5	1	0	0	0	0	5
Sept	496	42	0	0	0	0	0	0	0	0	13	0	0	28	0	0	0	0	0	0	1
Season	6,036	1,267	la	0	0	4	14	0	0	44	146	0	5	972	22	8	-6	0	0	3	**31**
GRAND TOTAL																					
April	434	57	3	0		01	2	0	0	3	*0*	*0*	*0*	42	1	1	0	0	0	0	4
May	3,267	301	2	0	0	3	41	1	0	15	48	1	2	169	6	1	10		0	3	8
June	10,177	342	10		0	0	23	0	0	24	31	0	0	231	7	0	0	0	0	9	16
July	9,994	471	0	0	0	0	35	0	0	17	62	0	4	320	4	5	2	0	0	10	12
August	4,771	448	13	0	0	0	25	0	0	22	111	0	1	247	6	1	4	0	0	11	7
Sept	931	87	10		0	0	3	1	0	5	32	2	0	40	0	0	1	0	0	1	1
Season	29,574	1,706	20	0	0	4	129	2	0	**86**	284	3	7	1,049	24	**8**	**8**	0	0	34	48

Appendix Table A-11. Monthly species composition of dam angling catch for Columbia and Snake river dams, 1992.

Month	Percent northern squawfish in total catch	Percent incidental species in total catch	Percent of total catch (all species)						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
COLUMBIA R.									
May	94.85	5.15	0.00	2.64	1.51	0.69	0.06	0.13	0.13
June	99.01	0.99	0.01	0.31	0.13	0.29	0.00	0.10	0.13
July	98.97	1.03	0.00	0.48	0.25	0.18	0.02	0.09	0.01
August	96.34	3.66	0.00	1.03	1.76	0.39	0.11	0.31	0.06
Sept	89.66	10.34	0.23	2.07	4.83	2.76	0.23	0.23	0.00
Season	98.13	1.87	0.01	0.68	0.61	0.34	0.03	0.13	0.07'
SNAKE R.									
April	86.87	13.13	0.92	1.15	0.00	10.14	0.00	0.00	0.92
May	86.93	13.07	0.30	0.89	1.61	9.85	0.00	0.06	0.36
June	79.92	20.08	0.00	1.50	1.50	16.76	0.00	0.00	0.32
July	61.35	38.65	0.00	0.92	4.40	32.00	0.00	0.20	1.12
August	73.32	26.68	1.09	0.84	4.12	20.20	0.00	0.00	0.42
Sept	91.53	8.47	0.00	0.00	2.62	5.65	0.00	0.00	0.20
Season	79.01	20.99	0.36	0.96	2.50	16.60	0.00	0.05	0.51
GRAND TOTAL									
April	86.87	13.13	0.92	1.15	0.00	10.14	0.00	0.00	0.92
May	90.79	9.21	0.15	1.74	1.56	5.39	0.03	0.09	0.24
June	96.64	3.36	0.01	0.46	0.30	2.34	0.00	0.09	0.16
July	95.29	4.71	0.00	0.52	0.66	3.29	0.02	0.10	0.12
August	90.61	9.39	0.27	0.99	2.35	5.32	0.08	0.23	0.15
Sept	90.66	9.34	0.11	0.97	3.65	4.30	0.11	0.11	0.11
Season	94.23	5.77	0.08	0.73	0.99	3.66	0.03	0.11	0.16

Appendix Table A-12. Monthly catch of incidental species by condition at release for Columbia River dams, 1992. Condition codes: (1) minimal injury, certain to survive; (2) moderate injury, may or may not survive; (3) dead, nearly dead, or certain to die; (L) line cut or broken, fish not removed from the water.

Month	Total catch (all species)	Total incidental catch	Salmonids				Sturgeon				Bass			Catfish			Walleye			Shad	Other
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3		
BONNEVILLE																					
May	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	1,384	2	10		0	0	10		0	0	0	0	0	0	0	0	0	0	0	0	0
July	2,419	8	0	0	0	0	10		0	0	0	0	0	0	0	0	0	0	0	7	0
Aug	971	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Sept	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	4,827	13	10		0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	**10**	**0**
THE DALLES																					
May	1,102	25	0	0	0	0	2	0		01	19	1	1	0	0	0	0	0	0	0	1
June	2,973	21	0	0	0	0	3	0		01	10	0	0	0	0	0	0	0	0	4	3
July	1,965	32	0	0	0	0	6	0	0	0	22	0	0	10		0	2	0	0	1	0
Aug	1,287	57	0	0	0	0	6	0	0	2	44	0	1	0	0	0	2	0	0	1	1
Sept	388	19	0	0	0	0	0	0	0	4	15	0	0	0	0	0	0	0	0	0	0
Total	7,715	154	0	0	0	0	17	0	0	8	110	1	2	10		0	4	0	0	**6**	5
JOHN DAY																					
May	441	57	0	0	0	0	3 5	1	0	3	3	0	0	11	0	0	10		0	2	1
June	733	6	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	1
July	1,537	2	0	0	0	0	0	0	0	0	1	0	0	10		0	0	0	0	0	0
Aug	772	8	0	0	0	0	0	0		01	10		0	2	0	0	2	0	0	2	0
Sept	43	26	10		0	0	3	1	0	1	4	2	0	12	0	0	10		0	1	0
Total	3,526	99	10		0	0	38	2	0	**5**	10	2	0	30	0	0	4	0	0	**5**	**2**
McNARY																					
June	3,822	59	0	0	0	0	14	0	0	9	10		0	21	1	0	0	0	0	5	8
July	3,095	51	0	0	0	0	25	0	0	11	0	0	0	14	0	0	0	0	0	0	1
Aug	553	63	0	0	0	0	19	0	0	9	17	0	0	11	1	0	0	0	0	5	1
Total	7,470	173	0	0	0	0	58	0	0	29	18	0	0	46	2	0	0	0	0	**10**	**10**

Appendix Table A-13. Monthly species composition of dam angling catch for Columbia River dams, 1992.

Month	Percent northern squawfish in total catch	Percent incidental species in total catch	Percent of total catch (all species)						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
BONNEVILLE									
May	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June	99.86	0.14	0.07	0.07	0.00	0.00	0.00	0.00	0.00
July	99.67	0.33	0.00	0.04	0.00	0.00	0.00	0.29	0.00
Aug	99.69	0.31	0.00	0.00	0.00	0.00	0.00	0.31	0.00
Sept	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Season	99.73	0.27	0.02	0.04	0.00	0.00	0.00	0.21	0.00
THE DALLES									
May	97.73	2.27	0.00	0.27	1.91	0.00	0.00	0.00	0.09
June	99.29	0.71	0.00	0.13	0.34	0.00	0.00	0.13	0.10
July	98.37	1.63	0.00	0.31	1.12	0.05	0.10	0.05	0.00
Aug	95.57	4.43	0.00	0.62	3.50	0.00	0.15	0.08	0.08
Sept	95.10	4.90	0.00	1.03	3.87	0.00	0.00	0.00	0.00
Season	98.00	2.00	0.00	0.32	1.46	0.01	0.05	0.08	0.06
JOHN DAY									
May	87.07	12.93	0.00	8.84	0.68	2.49	0.23	0.45	0.23
June	'99.18	0.82	0.00	0.00	0.14	0.54	0.00	0.00	0.14
July	99.87	0.13	0.00	0.00	0.06	0.07	0.00	0.00	0.00
Aug	98.96	1.04	0.00	0.13	0.13	0.26	0.26	0.26	0.00
Sept	39.53	60.47	2.32	11.63	13.95	27.91	2.33	2.33	0.00
Season	97.19	2.81	0.03	1.28	0.34	0.85	0.11	0.14	0.06
McNARY									
June	98.46	1.54	0.00	0.60	0.03	0.57	0.00	0.13	0.21
July	98.35	1.65	0.00	1.16	0.00	0.45	0.00	0.00	0.03
Aug	88.61	11.39	0.00	5.06	3.07	2.17	0.00	0.90	0.18
Season	97.68	2.32	0.00	1.16	0.24	0.64	0.00	0.13	0.13

Appendix Table A-14. Monthly catch of incidental species by condition at release for Snake River dams, 1992. Condition codes: (1) minimal injury, certain to survive; (2) moderate injury, may or may not survive; (3) dead, nearly dead, or certain to die; (L) line cut or broken, fish not removed from the water.

Month	Total catch (all species)	Total incidental catch	Salmonids				Sturgeon				Bass			Catfish			Walleye			Shad	Other
			1	2	3	L	1	2	3	L	1	2	3	1	2	3	1	2	3		
ICE HARBOR																					
June	147	49	0	0	0	0	2	0	0	0	0	0	0	42	5	0	0	0	0	0	0
July	207	54	0	0	0	0	0	0		01	0	0	0	53	0	0	0	0	0	0	0
Aug	67	40	0	0	0	0	0	0	0	5	0	0	0	35	0	0	0	0	0	0	0
Total	421	143	0	0	0	0	2	0	0	6	0	0	0	130	5	0	0	0	0	0	0
LOWER MONUMENTAL																					
May	251	75	10		0	3	0	0	0	3	2	0	0	64	1	0	0	0	0	0	1
June	288	115	0	0	0	0	0	0	0	11	4	0	0	99	0	0	0	0	0	0	1
July	264	171	0	0	0	0	0	0	0	3	10		0	165	0	0	0	0	0	0	2
Aug	99	66	0	0	0	0	0	0	0	2	3	0	0	61	0	0	0	0	0	0	0
Total	902	427	10		0	3	0	0	0	19	10	0	0	389	1	0	0	0	0	0	a
LITTLE GOOSE																					
April	140	45	0	0		01	0	0	0	0	0	0	0	38	1	1	0	0	0	0	4
May	445	113	10		0	0	0	0	0	0	22	0	1	78	5	1	0	0	0	1	4
June	237	72	0	0	0	0	0	0	0	0	15	0	0	54	0	0	0	0	0	0	3
July	278	137	0	0	0	0	0	0	0	0	38	0	4	75	4	5	0	0	0	2	9
Aug	722	207	13	0	0	0	0	0	0	3	45	0	0	135	5	1	0	0	0	0	5
Sept	452	36	0	0	0	0	0	0	0	0	13	0	0	22	0	0	0	0	0	0	1
Total	2,214	610	14	0		01	0	0	0	3	133	0	5	402	15	8	0	0	0	3	26
LOWER GRANITE																					
April	294	12	3	0	0	0	2	0	0	3	0	0	0	4	0	0	0	0	0	0	0
May	979	31	0	0	0	0	4	0	0	a	2	0	0	16	0	0	0	0	0	0	1
June	593	la	0	0	0	0	3	0	0	3	0	0	0	11	1	0	0	0	0	0	0
July	229	16	0	0	0	0	3	0	0	2	0	0	0	11	0	0	0	0	0	0	0
Aug	300	4	0	0	0	0	0	0	0	0	10		0	3	0	0	0	0	0	0	0
Sept	44	6	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
Total	2,439	87	3	0	0	0	12	0	0	16	3	0	0	51	1	0	0	0	0	0	1

Appendix Table A-15. Monthly species composition of dam angling catch for Snake River dams, 1992.

Month	Percent northern squawfish in total catch	Percent incidental species in total catch	Percent of total catch (all species)						
			Salmonids	Sturgeon	Bass	Catfish	Walleye	Shad	Other
ICE HARBOR									
June	66.67	33.33	0.00	1.36	0.00	31.97	0.00	0.00	0.00
July	73.91	26.09	0.00	0.48	0.00	25.60	0.00	0.00	0.00
Aug	40.30	59.70	0.00	7.46	0.00	52.24	0.00	0.00	0.00
Season	66.03	33.97	0.00	1.90	0.00	32.07	0.00	0.00	0.00
LOWER MONUMENTAL									
May	70.12	29.88	1.59	1.19	0.80	25.90	0.00	0.00	0.40
June	60.07	39.93	0.00	3.82	1.39	34.37	0.00	0.00	0.35
July	35.23	64.77	0.00	1.14	0.38	62.50	0.00	0.00	0.76
Aug	33.33	66.67	0.00	2.02	3.03	61.62	0.00	0.00	0.00
Season	52.66	47.34	0.44	2.11	1.11	43.24	0.00	0.00	0.44
LITTLE GOOSE									
April	67.86	32.14	0.71	0.00	0.00	28.57	0.00	0.00	2.86
May	74.61	25.39	0.22	0.00	5.17	18.88	0.00	0.22	0.90
June	69.62	30.38	0.00	0.00	6.33	22.78	0.00	0.00	1.27
July	50.72	49.28	0.00	0.00	15.11	30.21	0.00	0.72	3.24
Aug	71.33	28.67	1.80	0.42	6.23	19.53	0.00	0.00	0.69
Sept	92.04	7.96	0.00	0.00	2.88	4.87	0.00	0.00	0.22
Season	73.18	26.82	0.66	0.13	6.07	18.69	0.00	0.13	1.14
LOWER GRANITE									
April	95.92	4.08	1.02	1.70	0.00	1.36	0.00	0.00	0.00
May	96.83	3.17	0.00	1.22	0.20	1.63	0.00	0.00	0.10
June	96.96	3.04	0.00	1.01	0.00	2.02	0.00	0.00	0.00
July	93.01	6.99	0.00	2.18	0.00	4.80	0.00	0.00	0.00
Aug	98.67	1.33	0.00	0.00	0.33	1.00	0.00	0.00	0.00
Sept	86.36	13.64	0.00	0.00	0.00	13.64	0.00	0.00	0.00
Season	96.43	3.57	0.12	1.15	0.12	2.13	0.00	0.00	0.04

REPORT D

Evaluation of Harvest Technology for Squawfish Control in Columbia River Reservoirs

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1992 Annual Report

CONTENTS

RESEARCH SUMMARY

During 1992, the University of Washington (UW) continued its efforts to develop large-scale removal methods for northern squawfish on the Columbia River. At the start of the fourth and possibly final year of harvest technology development and evaluation, the most promising methods for removal that remained untested were mobile floating trap nets and boat-based electrofishing.

Merwin trapping has proven to be successful at capturing squawfish without harming incidental fish species. However, Merwin traps as originally designed and tested are not mobile enough to be operated throughout the Columbia River system. During the past winter (1991-92), a mobile version of the Merwin trap was designed based on major modifications to the prototype mobile trap that was constructed and operated by UW in 1991. It was expected that this newly designed smaller mobile trap would be equally successful in capturing squawfish to the full size stationary Merwin trap; data are contained in this report to indicate this. An in-depth evaluation on the effectiveness of the Merwin trap as a squawfish control mechanism is provided in a Master of Science thesis authored by James Lynch at the University of Washington, April 1993 (Lynch 1993).

Additionally, fishing restrictions and regulations for a potential large-scale floating trap net fishery were also investigated. Such variables as what time of day to operate the traps to avoid incidental capture of salmonids, how to remove incidental salmonids from the trap in the least harmful way, and logistic requirements for operating the newly developed mobile trap were explored. A comprehensive mobile trap site survey was performed on the Columbia and Snake rivers during the winter of 1993 and has been provided to the Oregon Department of Fish and Wildlife (ODFW) under separate cover.

The second gear type to be evaluated in 1992 for large-scale removal of squawfish was boat-based electrofishing. This method has been traditionally used in the ODFW predator indexing efforts and has consistently produced a high rate of squawfish catch per unit of effort. If this gear were used for removal efforts instead of research, catch rates on squawfish could be substantial.

The most prohibitive factor in boat-based electrofishing is the potential harm to incidental species. UW has completed a comprehensive literature survey and synopsis of electrofishing procedures and has been presented in Appendix B (Mahoney et al. 1993).

It is known that squawfish congregate at the dams for feeding and apparently school up in midriver locations for spawning. Since electrofishing for squawfish was restricted at the dams due to incidental salmonid catch criteria, spawning congregations were sought away from the dams where large catches of squawfish might be achieved with very little effort. A portion of this study was dedicated to determining if these spawning concentrations can actually be found and easily removed.

The final task of this project was to present a report that comprehensively discussed all methods that have been investigated for squawfish removal. Each gear was evaluated as to squawfish catch rates, incidental catch rates, ease of deployment, and potential contribution to the overall squawfish removal program. This report was presented to ODFW as a "special issue paper" in October 1992 (Mathews et al. 1993).

MERWIN TRAPPING

Introduction

Merwin traps have been found to be an effective gear for capturing northern squawfish (*Ptychocheilus oregonensis*). In 1991, the University of Washington (UW) caught 4,206 squawfish in a Merwin trap operated in The Dalles Dam cul-de-sac from May through August (Mathews et al. 1991). Results from the 1991 study indicated that floating traps could capture significant numbers of squawfish, but the high degree of incidental catch raised questions as to their potential as a large-scale squawfish removal method. The two main areas of concern regarding this gear observed in 1991 were its high incidental catch of salmonids and its lack of mobility for operating in mid-river locations. In 1992, efforts were directed at resolving these concerns to prepare this gear for large-scale application.

The high incidental catch and potential delay of migrating salmonids was of particular concern to the Fish Passage Advisory Council (FPAC) prior to the 1992 field season. As a result of its concerns, restrictions were placed upon UW operations in 1992 to ensure limited delay and stress to migrating salmonids. Specific criteria (listed in the "Methods" section of this report) were placed on the maximum amount of time salmon could be held and the periods of the day fishing could occur during the course of the season. In addition, alternative methods of incidental catch removal were to be investigated to limit, if not avoid, the use of dipnets. Fishing operations were to be determined by squawfish to salmon catch ratios as well as overall salmon catch rates. These operating criteria created the need to determine the specific times of the day a trap could be fished to maximize squawfish catch while limiting salmonid catch.

Data regarding the physiology of squawfish were again collected in 1992 to relate the efficiency of this gear to the maturity of squawfish during the course of a season. Correlations among environmental conditions, squawfish maturity, and trap catches will provide insight as to what periods of the season trapping effort should be concentrated.

An objective of last season (1991) was to construct and deploy a "mobile" version of the Merwin trap to target mid-reservoir populations of squawfish. The mobile trap that was constructed in 1991 met with limited success. With experience acquired in 1991, it was possible to develop a workable model capable of fishing throughout the Columbia River in 1992.

Floating trap net research was carried out in 1992 with the objective of evaluating its use in a large-scale removal fishery for northern squawfish. This was achieved by improving the efficiency of the stationary Merwin trap and learning specific fish behavioral patterns in the cul-de-sac area around The Dalles Dam. Also, development of an efficient mobile version of the trap was continued. The results from these investigations can be used to determine potential fishing regulations for a large-scale removal fishery in the future.

Methods

Stationary Trap

With the bulk of design and logistical work done in 1991, it was possible to identify seasonal and diurnal periods of fishing that might reduce incidental salmon catch while maintaining a significant squawfish removal effort. As previously stated, determinations regarding fishing times were guided by operational criteria imposed by FPAC. These criteria included:

1. Fishing only in six-hour intervals until a 1:1 salmon to squawfish ratio was exceeded.

2. When a 1: 1 ratio was exceeded, fishing would only be performed at night (roughly 6 p.m. to 6 a.m.).

3. When salmon catch exceeded 40 individuals in a six-hour interval, fishing periods would be shortened to three-hour intervals.

4. When salmon catch exceeded 40 individuals in a three-hour interval, fishing was to be discontinued until ladder counts indicated that salmon catches would decline.

5. Efforts would be made to devise alternative methods for removing salmonids from the trap net other than the use of dipnets.

Based on these FPAC criteria and data collected in 1991 regarding diurnal trends in salmonid abundance, fishing periods were determined that would provide insight into species availability at different periods of the day. Results from 1991 studies indicated that the period from dusk until dawn yielded relatively high squawfish catch rates while minimizing incidental salmon catch. For this reason, fishing occurred during the hours of 6 p.m. to 6 a.m. in time intervals of three to six hours to identify peak squawfish and salmonid catches according to time of day. In addition to these periods, permission was granted by FPAC to carry out daytime fishing experiments to supplement 1991 daytime catch data.

One of our main objectives for the 1992 season was to develop the least harmful way to remove salmonids from the traps. Several methods were employed including zippered pockets in the webbing, lowering the cork line to facilitate release, installing a weir to separate salmon from squawfish and developing an efficient dipnet design and dipnetting procedure that would limit handling stress on salmonids. Each of these modifications was tested and evaluated with the purpose of determining the least stressful method of removing incidentally encountered salmonids from the trap.

Specific physiological data collected regarding squawfish included lengths and sexes (when possible) of all squawfish. A gonadal somatic index (GSI) ratio of maturing squawfish was determined by comparing gonad weights to total body weights of squawfish. This ratio is an indication of squawfish maturity and can be used to predict the peak vulnerability of squawfish to this gear during the course of a season. In addition to these data, approximately 100 squawfish per week were tagged to estimate squawfish abundance near The Dalles Dam. Detailed information regarding these estimates can be found in Lynch 1993.

Mobile Traps

Development of the mobile trap design began prior to the 1992 field season. With knowledge obtained from operating a prototype mobile trap during the 1991 field season, it became evident that a lightweight, easily trailerable trap design was needed if this gear was to be effective. Plans for a mobile trap were developed prior to the 1992 season and the first mobile trap was completed by the first week of May.

Trap frames were designed to be assembled and disassembled with minimal effort (Appendix A). The mobile traps were composed of lightweight materials to limit the weight and bulk of individual components. Flotation was provided by two aluminum pontoons (24.5’ long x 2’ wide x 2’ deep) that were connected by three aluminum walkways (11’ long x 1.5’ wide x 3” deep). These walkways were held in place by a series of poles that could be removed to allow collapsing and trailering of components (Appendix A). Netting consisted of 1.25-inch stretched, knotless mesh, identical to that used in the stationary trap.

After the first mobile trap was delivered for use on May 5, 1992, it became evident that the height of the pontoons caused instability in towing and assembly. The individual pontoons tended to roll onto their side making it difficult to connect the walkways. As a result of this observation, modifications in the design were made prior to the construction of the second mobile trap, which was delivered on June 1, 1992. This second trap had pontoons that were 24 feet long by 2 feet wide by 16 inches deep. These pontoons tended to float upright, easing the assembly process.

Experimental mobile traps were fished in a variety of locations in the Columbia and Snake rivers, both near dams and midriver. The main goal of the mobile trap research was to develop and operate this gear in a variety of environmental conditions (e.g., substrate, current strength, wind exposure) to see how such variables would affect squawfish catch rates. It was felt that this gear had been proven effective for capturing squawfish in previous seasons and that a better evaluation of its logistical and operable parameters was needed.

In addition to exploring this gear's limitations and capabilities from a mechanistic standpoint, efforts were made to compare the catch efficiency of the mobile trap to the already established, stationary trap fished at The Dalles Dam. Such a comparison would indicate whether a large-scale squawfish removal effort utilizing mobile gear would be practical,

Results

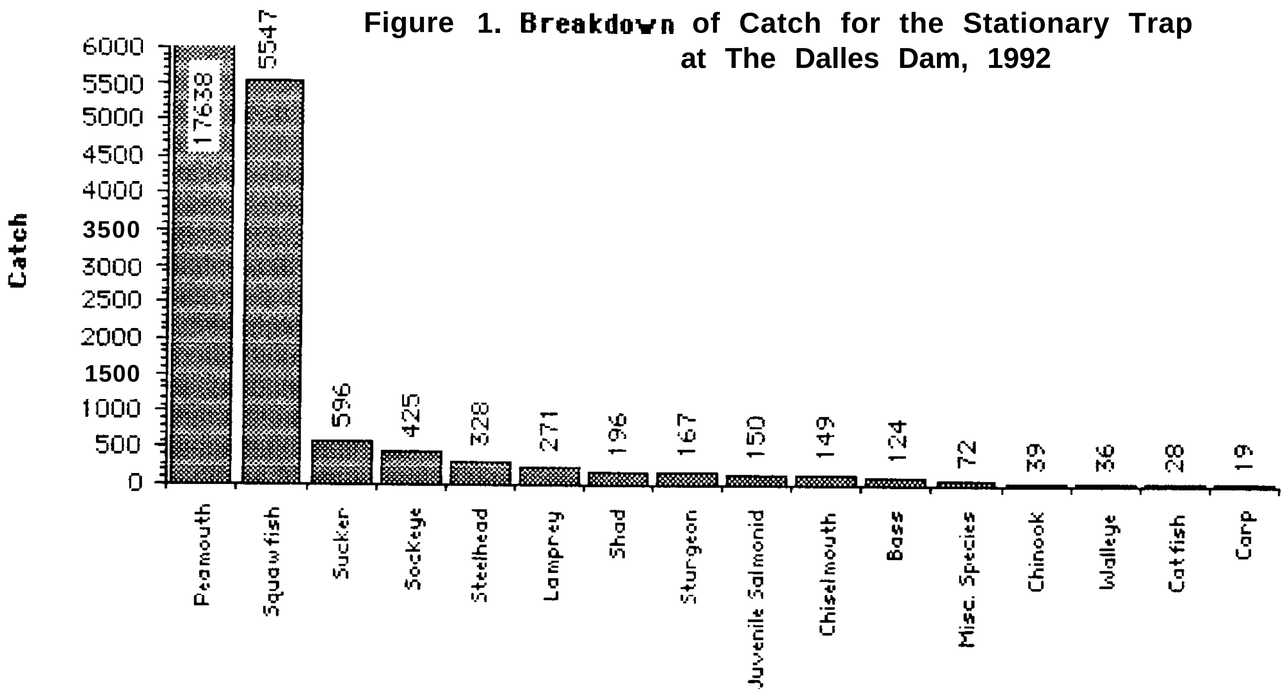
Stationary Trap

Catches of the stationary trap in the cul-de-sac of The Dalles Dam indicate that this gear can be fished in such a manner that limits incidental salmonid catch and delay while maintaining a significant squawfish removal effort. Over 5,500 squawfish were captured during the 1992 season, accounting for 2 1.5 % of the overall catch of all species in the stationary trap (Figures 1 and 2). Squawfish were exceeded only by peamouth (68.4%) in total catch with all species of salmonids comprising 3.63% of the total catch. The salmonid catch decreased by over 82.6% from 199 1 levels while the total squawtish catch increased by 3 1.9% over 1991 levels (Table 1). Comparisons of trap catches with ladder counts in both years indicate that changes in trap operation were primarily responsible for the decreased catch of salmonids in 1992 (Lynch 1993).

Squawfish catches peaked early in the summer (May 1) and then again late in the summer (August 17) with squawfish catch per hour (cph) peaking during August (Figure 3). The initial peak catch consisted of mature, migrating individuals, whereas the second peak consisted primarily of small, juvenile squawfish (< 250 mm in length). As Figure 4 indicates, catch rates increased in August as average length of squawfish decreased. If the smaller fish (< 250 mm) were excluded from the data in Figure 3, the distribution of catch per hour by week would be more similar to that observed in 1991 (Figure 5). The increased catch of juvenile squawfish in 1992 may indicate a spike in recruitment, a possibility which should be closely monitored.

The overall mean length of squawfish captured in the cul-de-sac declined from 314 mm (N= 1 ,011) in 1991 to 295 mm (N=2,478) (Figures 6 and 7). The decrease in overall mean length is a direct result of the increased number of juvenile squawfish encountered in 1992. Of the 4,206 squawfish caught in 1991, approximately 3% were less than 250 mm long. Of the 5,547 squawfish captured in 1992, approximately 49% were less than 250 mm in length. This 46% increase in catch of squawfish less than 250 mm resulted from the large number of juvenile squawfish encountered during the month of August.

Figure 1. Breakdown of Catch for the Stationary Trap at The Dalles Dam, 1992



Misc. species : crappie, sunfish, whitefish, sculpin

Figure 2. Breakdown of Catch for the UW Stationary Trap The Dalles Dam, 1992

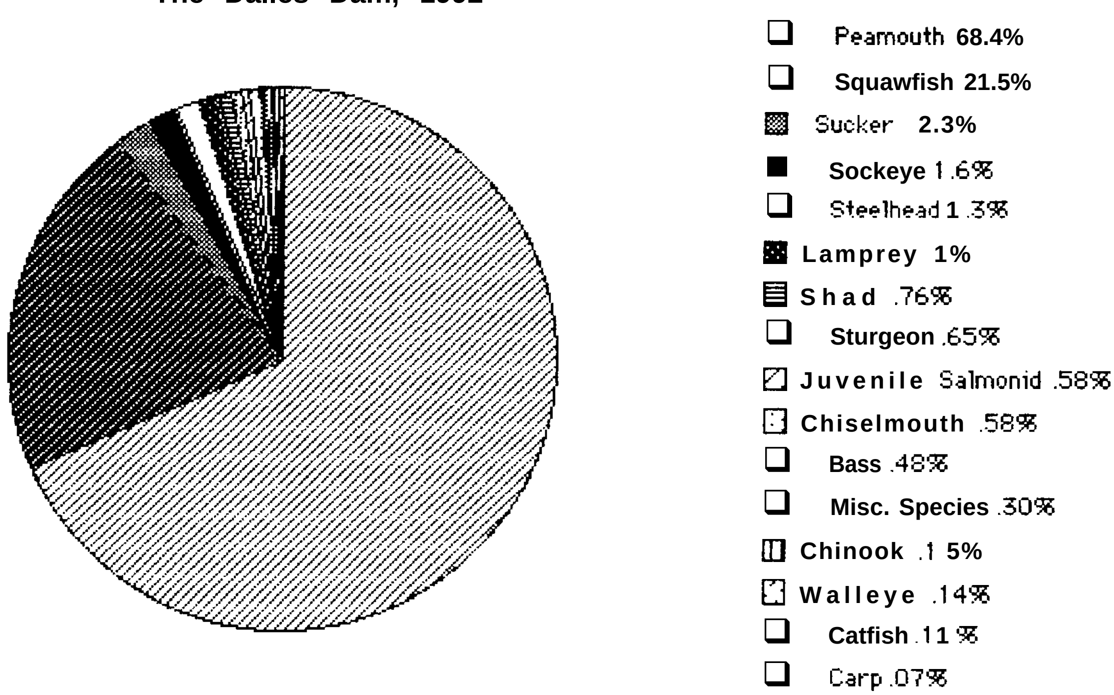


Table 1. Comparison of 1991 and 1992 Mervin Trap Catches The Dalles Dam Cul-de-sac

	1991 Totals	1992 Totals	Percent Change 1991 to 1992
Squawfish	4206	5547	31.9
Salmonids	5427	942	-82.6
Sockeye	2643	425	-83.9
Steelhead	1685	328	-80.5
Chinook	366	39	-89.3
Coho	13	0	-100
Juvenile	720	150	-79.2
Sturgeon	261	167	-36
Walleye	69	36	-47.8
Bass	63	124	96.8
Catfish	25	28	12
Shad	4306	196	- 95.4
Chiselmouth	2830	149	-94.7
Peamouth	1625	17638	985.4
Lamprey	1257	271	-78.4
Sucker	2171 .	596	-72.5
Carp	22	19	-13.6
Total	22262	25713	15.5
Total Hours Fished	1588.55	1538	-3.2

Figure 3. Catch per Hour of Squavfish for the Stationary Trap at The Dalles Dam, 1992

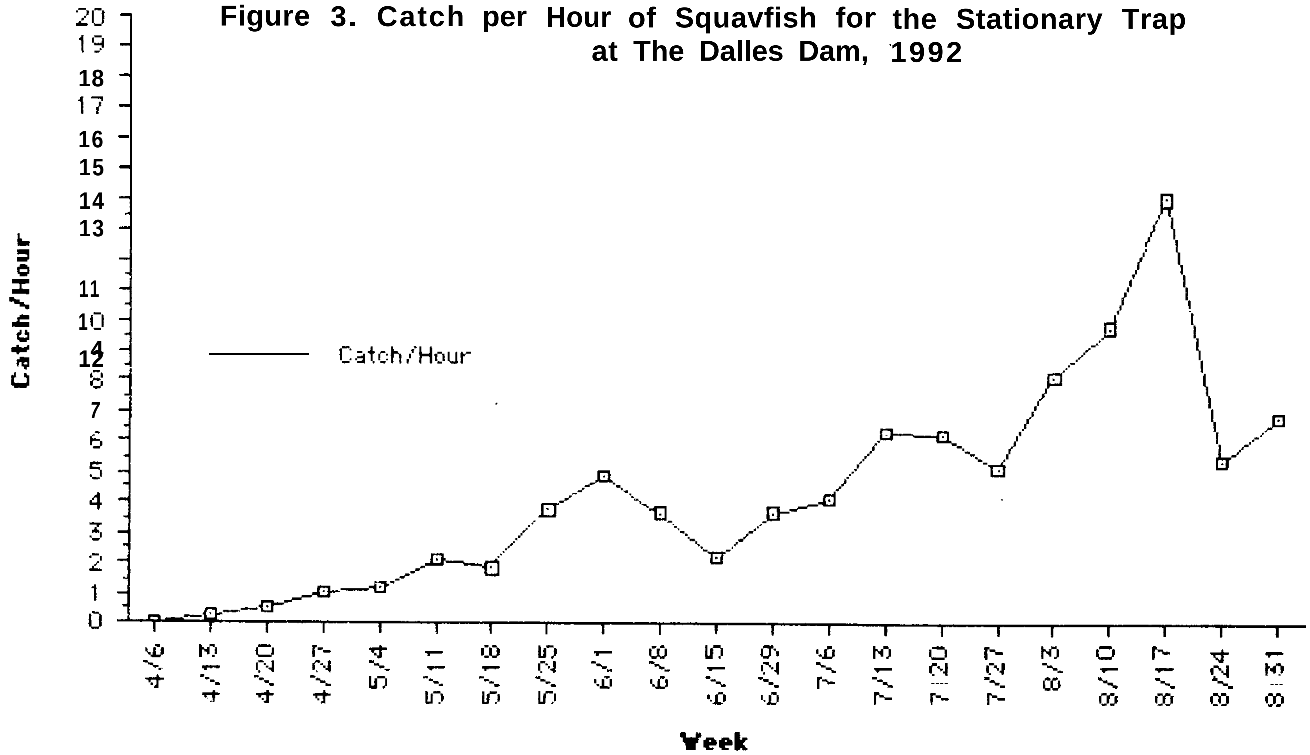


Figure 4. Average Length of Squavfish by Week at The Dalles Dam, 1992

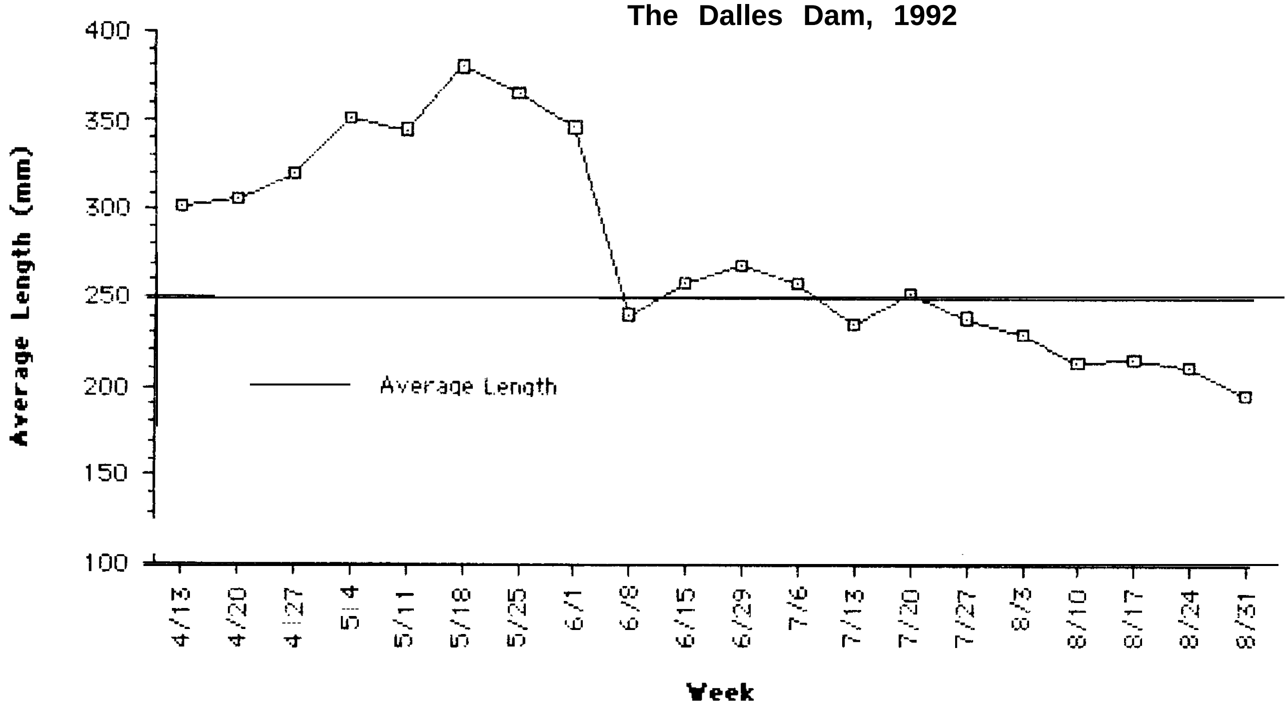


Figure 5. Catch per Hour of Squawfish for the Stationary Trap at The-Dalles Dam, 1991

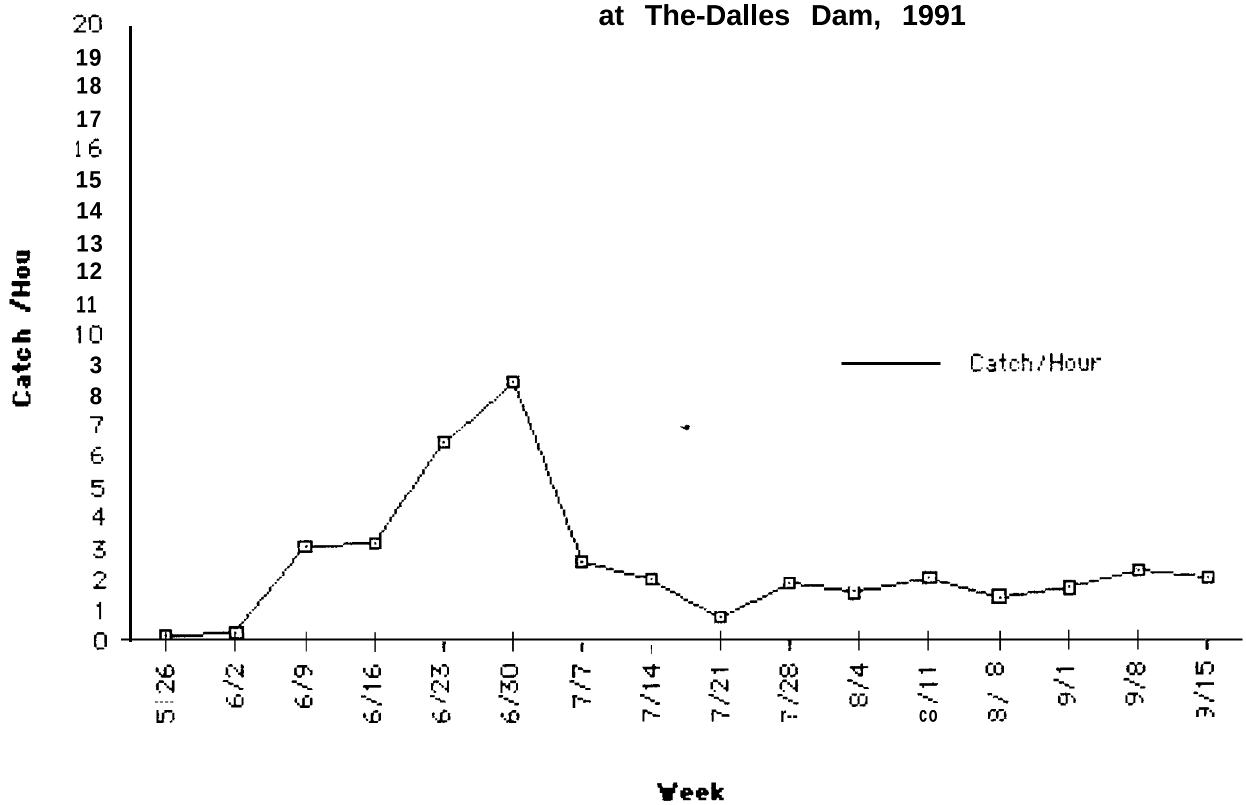


Figure 6. Length Frequency Distribution of Squawfish
The Dalles Dam, 1992

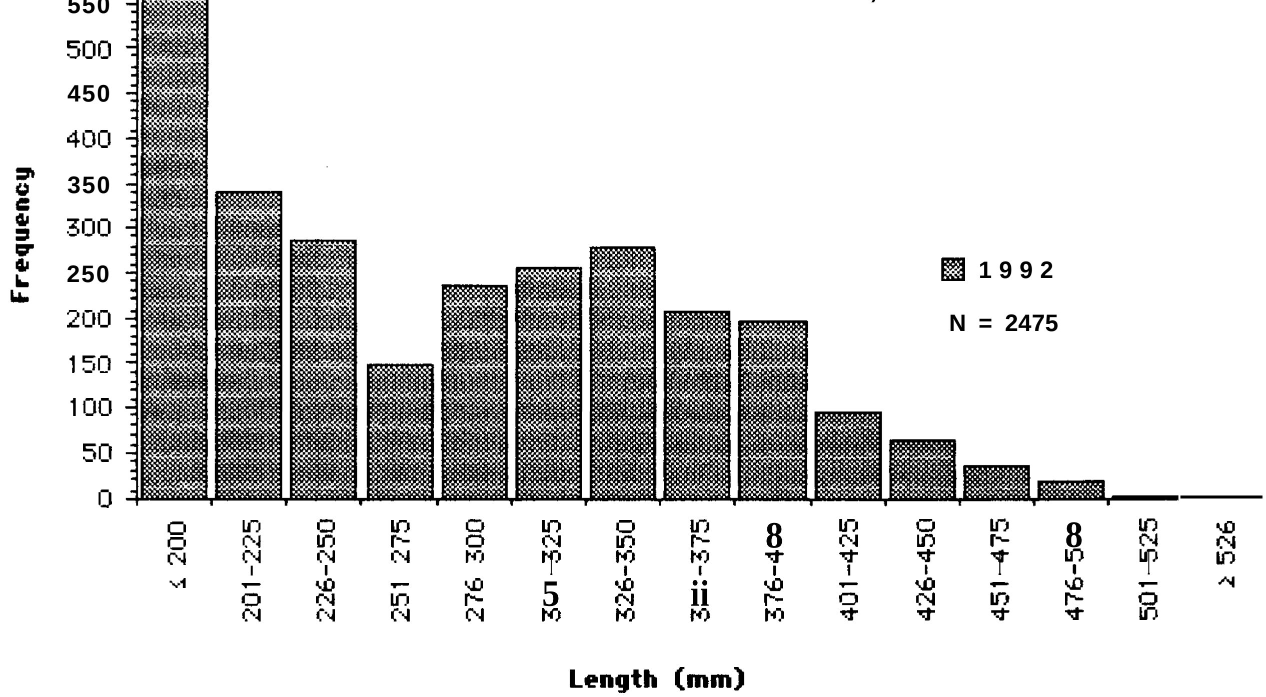
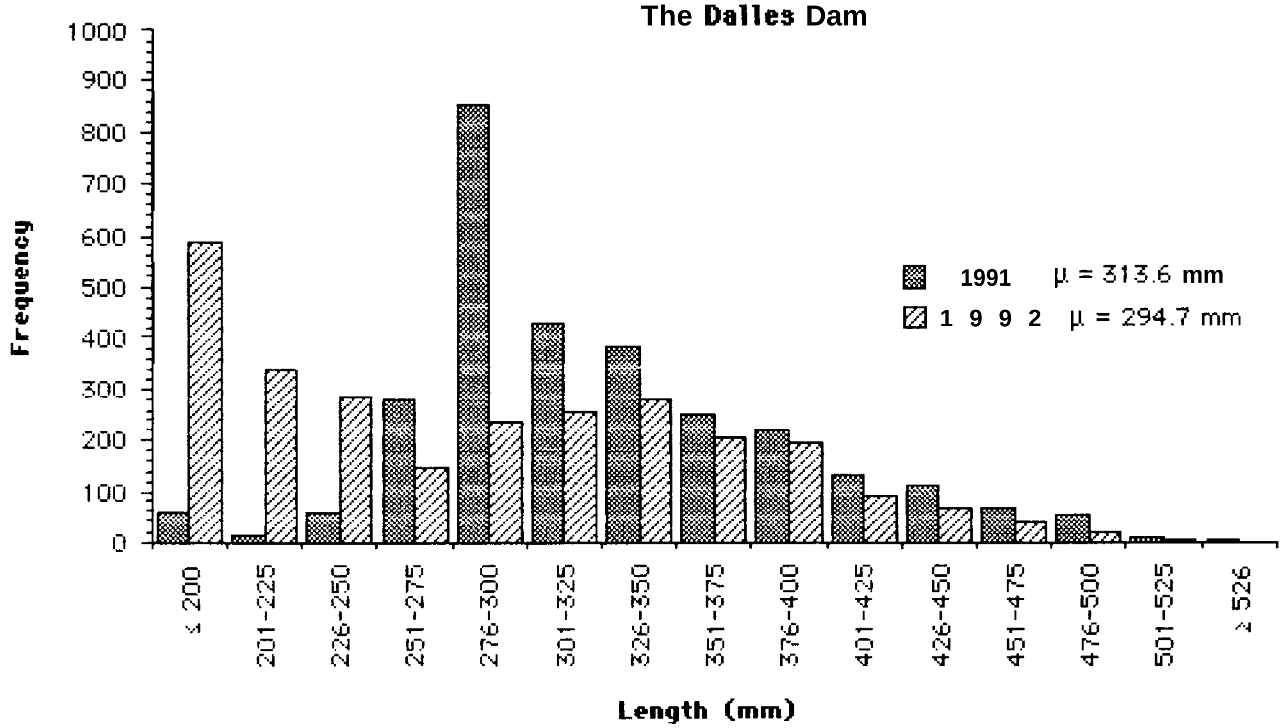


Figure 7. 1991 and 1992 Length Frequencies
The Dalles Dam



Fishing in various time periods during the day and night indicate that salmonids tend to be most vulnerable to this gear during periods of peak daylight (6 a.m. to 6 p.m.) whereas squawfish tend to be most vulnerable to this gear during periods of peak darkness (6 p.m. to 6 a.m.; Table 2; Lynch 1993). Furthermore, during periods of peak sockeye migration, the highest incidentally encountered salmonid, squawfish catches tended to peak during the periods of 9 p.m. to 3 a.m. (Tables 2 and 3). The seasonal and diel vulnerabilities of squawfish and sockeye indicate that selective fishing of traps can significantly reduce incidental salmonid catches without significantly reducing squawfish catches (Lynch 1993).

Observations regarding trap catches and squawfish maturity indicate a strong correlation between trap catch, and squawfish maturity, which in turn is highly correlated with water temperature. In both 1991 and 1992, trap catches of predaceous-sized squawfish peaked when GSI ratios peaked (Figures 8-11). In addition, female squawfish maturity peaked in both seasons when water temperatures reached 63" F, approximately one month earlier in 1992 compared to 1991 (Figure 12). These data indicate that squawfish maturity is highly correlated with water temperature, a fact that should enable a trap fishery to be operated so as to maximize effort during periods of peak squawfish vulnerability (Lynch 1993).

Experimental results obtained with alternative salmonid removal techniques have lead us to conclude that dipnets are by far the most effective and least stressful means of removing salmonids from floating fish traps. Several alternative removal methods were attempted including zippered holes, which were installed in the spiller portion of the net. It was thought that these escape holes would enable salmonids to escape while detaining squawfish. However, this modification proved ineffective due to the fact that as the zipper was opened, all fish within the spiller tended to escape including squawfish. Attempts were made to guide salmonids through these escape holes, but the amount of stress to salmonids resulting from being guided greatly surpassed that of customary dipnetting techniques.

The zippered escape holes (2 feet in diameter) were installed in both the pot and spiller portions of the net, roughly 6 inches below water level. Based on observations during 1991 Merwin trapping operations, it was known that salmonids maintain a position near the surface while holding in the trap and squawfish tended to hold near the bottom of the trap. Due to this observation, the escape holes were left open for a period of time in the hopes that squawfish and salmonids would separate by depth and the salmonids, being nearer surface, would exit through these holes. Unfortunately, all fish including squawfish found and used the escape holes making this modification useless.

Table 2. Incidental Catch of Mervin Trap Fished in Different Time Periods The Dalles Dam, 1992

Month	Time of Day Fished	Effort (Hours)	Squawfish Catch	Incidental Salmon Catch: Sockeye	Incidental Salmon Catch: Chinook	Incidental Salmon Catch: Steelhead	Catch/Hour Salmonids	Catch/Hour Squawfish
April	0600-1200	70.5	9	0	1	7	0.11	0.13
	1200-1800	53.75	5	0	2	4	0.1	0.08
	1800-2400	41.25	49	0	2	4	0.15	1.19
	2400-0600	43.5	46	0	1	3	0.04	1.06
	Total	215	109	0	6	18	0.11	0.51
May	0600-1200	117.5	165	0	5	16	0.18	1.4
	1200-1800	84.5	174	0	4	8	0.14	2.06
	1800-2400	65.25	158	0	2	6	0.12	2.42
	2400-0600	95	190	0	3	10	0.14	2
	Total	362.25	68[illegible]	0	14	40	0.15	1.9
June	0600-1200	47.5	69	47	2	3	1.09	1.45
	1200-1800	37	82	58	1	5	1.73	2.22
	1800-2400	26.75	[illegible]	13	1	10	0.3	4.6
	2400-0600	21.25	[illegible]	6	1	0	0.33	2.96
	Total	132.5	337	124	5	18	1.11	2.54

Table 2. Continued

Month	Time of Day Fished	Effort (Hours)	Squawfish Catch	Incidental Salmon Catch: Sockeye	Chinook	Steelhead	Catch/Hour Salmonids	Catch/Hour Squawfish
July	0600-1200	0	0	0	0	0		
	1200-1800	0	0	0	0	0		
	1800-2400	90.75	432	137	0	48	2.04	4.76
	2400-0600	63.5	347	134	2	32	2.65	5 46
	• 3 hour sets from 1800 to 0300							
	1800-2100	21.75	18	52	0	16	3.13	0.83
	2100-2400	39	309	40	0	15	1.41	7.92
	2400-0300	13	77	30	0	2	2.46	5.92
	Total	154.25	779	271	2	80	2.29	5.05
August	0600-1200	11.5	3	0	2	9	0.96	0.26
	1200-1800	0	0	0	0	0		
	1800-2400	75	1253	7	0	31	0.51	16.71
	2400-0600	92.5	431	7	0	58	0.7	4.66
	Total	179	1687	14	2	98	0.64	9.42
September	0600-1200	0	0	0	0	0		
	1200-1800	0	0	0	0	0		
	1800-2400	17.5	158	0	0	13	0.74	9.03
	2400-0600	11.5	47	0	0	8	0.7	4.09
	Total	29	205	0	0	21	0.72	7.07

Table 3. Salmon and Squavfish Catch by Honth for the Mervin Trap
The Dalles Dam, 1992

Time Period (approx.)	Hours	Squawfish Catch	Squawfish Catch/Hr	Sockeye Catch	Sockeye Catch/Hr	Steelhead Catch	Steelhead Catch/Hr	Chinook Catch	Chinook Catch/Hr
April	322	195	Cl.61	0	0	26	0.08	14	0.04
May	429.43	988	2.3	0	0	46	0.11	14	0.03
June	369.33	1421	3.85	120	Cl.32	41	0.11	6	0.02
July	167.67	857	5.1 1	294	1.75	93	0.55	2	0.01
August	190.91	1869	9.79	11	0.06	100	0.52	7	0.04
September	30	205	6.83	0	0	21	0.7	0	0

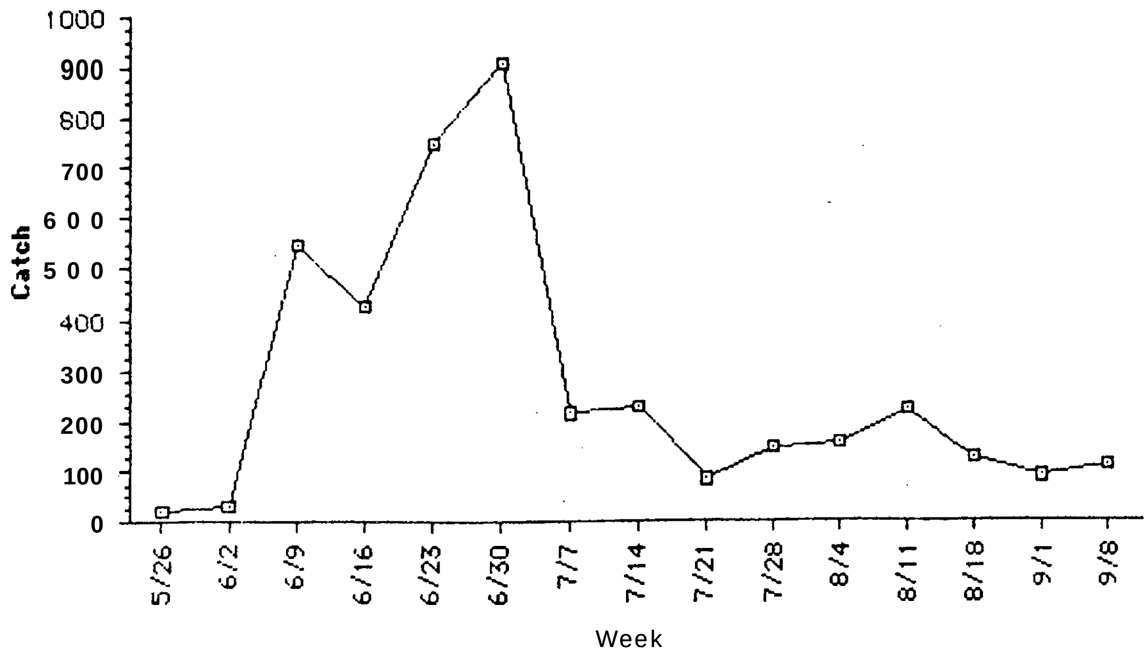


Figure 8. Weekly Squavfish Catch by the Mervin Trap The Dalles Dam, 1991

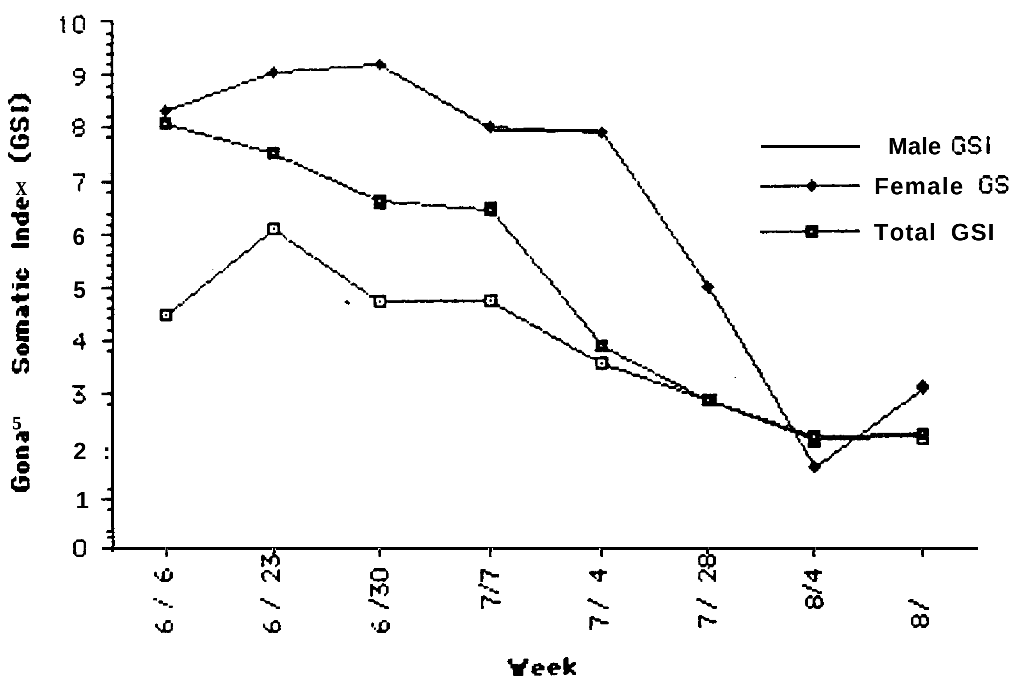


Figure 9. Average Weekly GSI Ratio of Squavfish at The Dalles Dam, 1991

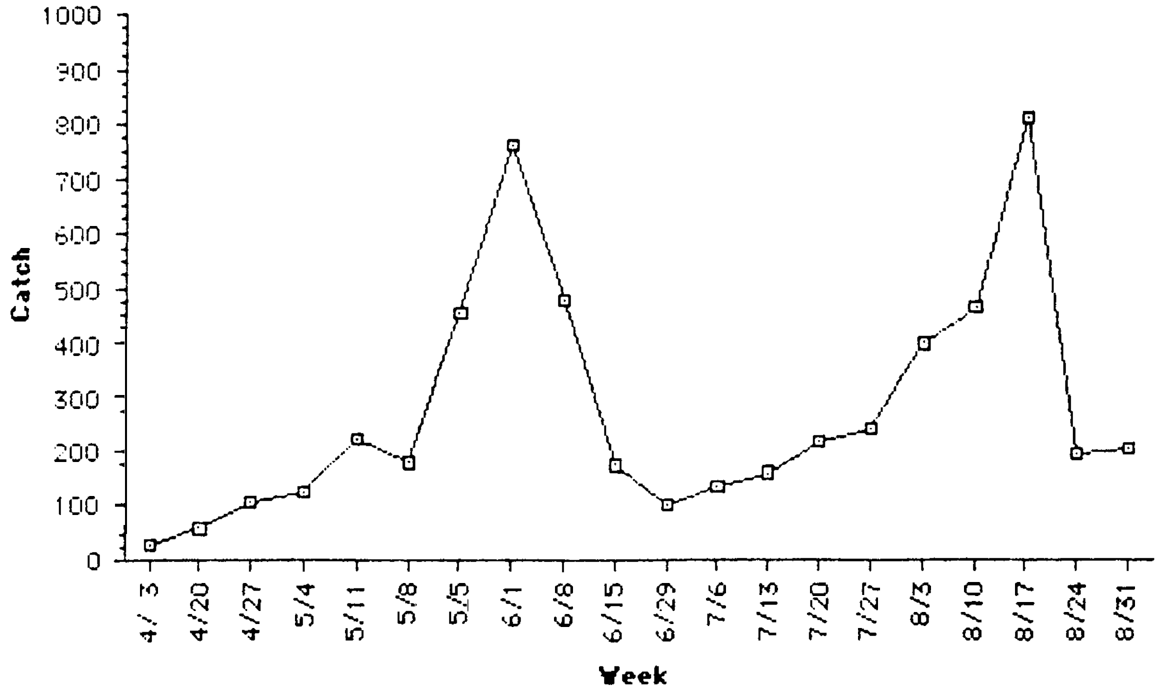


Figure 10. Weekly Squavfish Catch by the Mervin Trap
The Dalles Dam, 1992

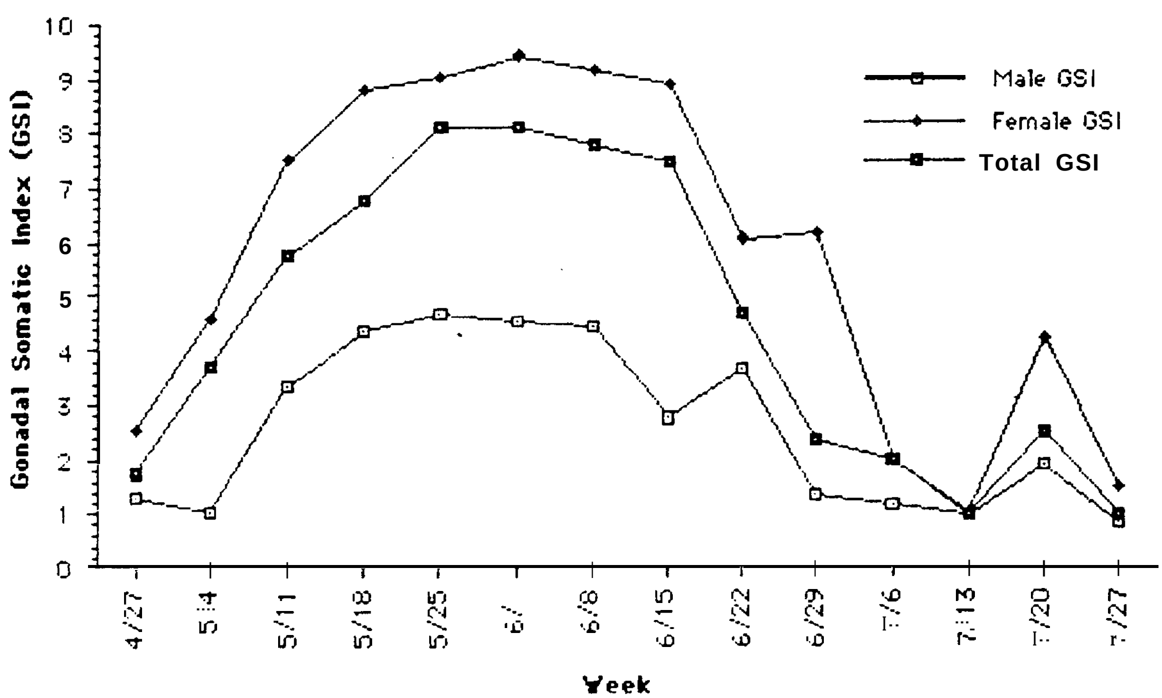


Figure 1 1. Average Weekly GSI Ratio of Squavfish at
The Dalles Dam, 1992

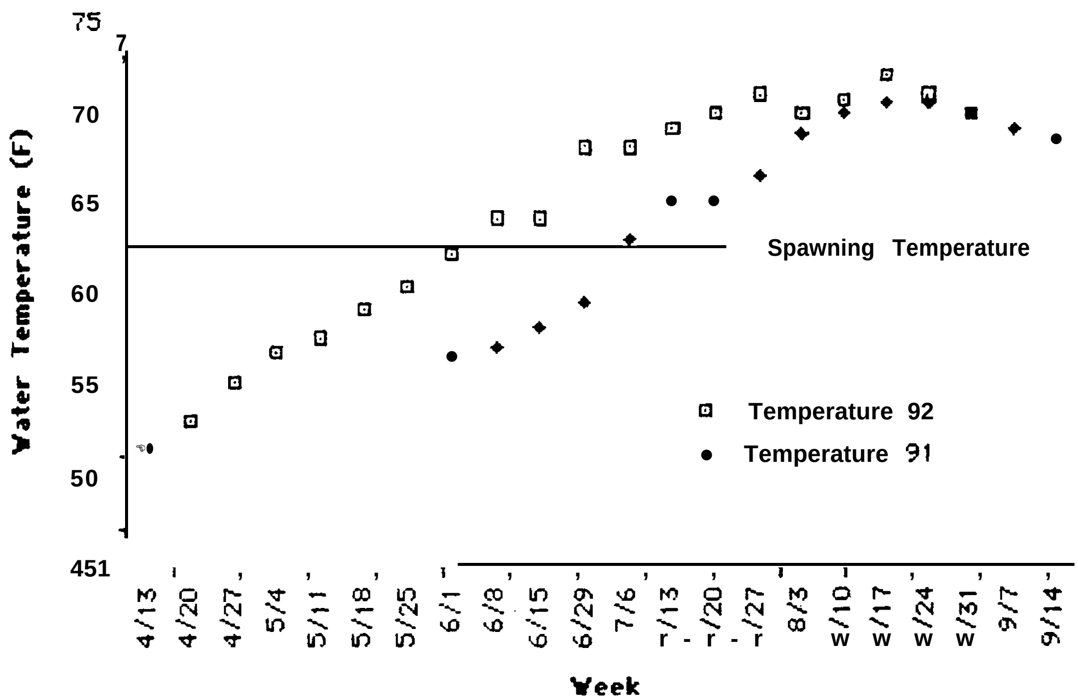


Figure 12. Average Weekly Water Temperature
The Dalles Dam, 1991 and 1992

In addition to zippered escape holes, a picket weir was installed between the pot and spiller portions of the trap with the hope of separating larger salmonids from squawfish, leaving the large fish (primarily salmonids) in the pot while allowing the smaller fish (squawfish) to enter the spiller portion of the net (Figure 13). This weir, consisting of 1.25 inch, PVC pipes spaced five inches apart, served to separate larger salmonids from other species. However, sockeye were found to be of similar size and shape to squawfish, thereby limiting the overall effectiveness of this modification. Future applications of this gear may be able to devise similar, more effective strategies for separating squawfish and salmonids, given more time and resources.

Given the limited success of the structural modifications at reducing the handling of salmonids, efforts were made to develop a dipnetting procedure that inflicted the least possible amount of stress to salmonids. Although dipnetting might seem stressful in theory, it has proven to be the least stressful, most expedient method for removing salmonids from floating fish traps as well as other types of sampling gear. Large dipnets, 30 inches in diameter with very soft webbing material (l/2-inch stretch mesh) can be hung in such a way as to create a very shallow bag (6 inches in depth). This dipnet configuration enabled the removal of salmonids from the trap with least amount of stress.

Minor problems were encountered this season in the cul-de-sac area with various forms of predators (e.g., herons and/or otters). Several fish including two salmonids were found having fresh wounds resulting from predator attacks. Steps were taken to eliminate predator attacks with the installation of bird netting around holding areas. Due to the unwieldy nature of this material, an alternative was necessitated. It was determined that a plastic tarp could be mounted flush at the tops of holding areas, similar to a swimming pool cover. This barrier proved to be sufficient in stopping further predator attacks and proved to be more easily manageable than the bird netting.

Mobile Trapping

Crew and equipment requirements for the mobile traps consisted of three individuals, a small jet-powered outboard boat (16 feet long), a 20-foot trailer and two trucks equipped for towing. Three individuals were able to deploy and operate two mobile traps in most locations in an efficient manner. The mobile traps could be deployed in two to four hours depending on site accessibility and environmental conditions (current strength, wind speed, etc.). Both traps were transported via a 20-foot, flatbed trailer that held the trap frames and a 2-ton, flatbed truck that held the webbing for both nets.

Fishing occurred in a variety of locations throughout the Columbia River during the 1992 season. Mobile traps were fished a total of 79 days, capturing 1,108 squawfish (Table 4 and Figure 14). Squawfish comprised 21.2% of the total catch (Figure 15). Miscellaneous species such as peamouth, chiselmouth, sunfish and carp comprised 56.7% of the total catch. Salmonids accounted for 14.3% of the total catch with nearly 75% of these fish caught in two sets near McNary Dam during the peak of the sockeye run.

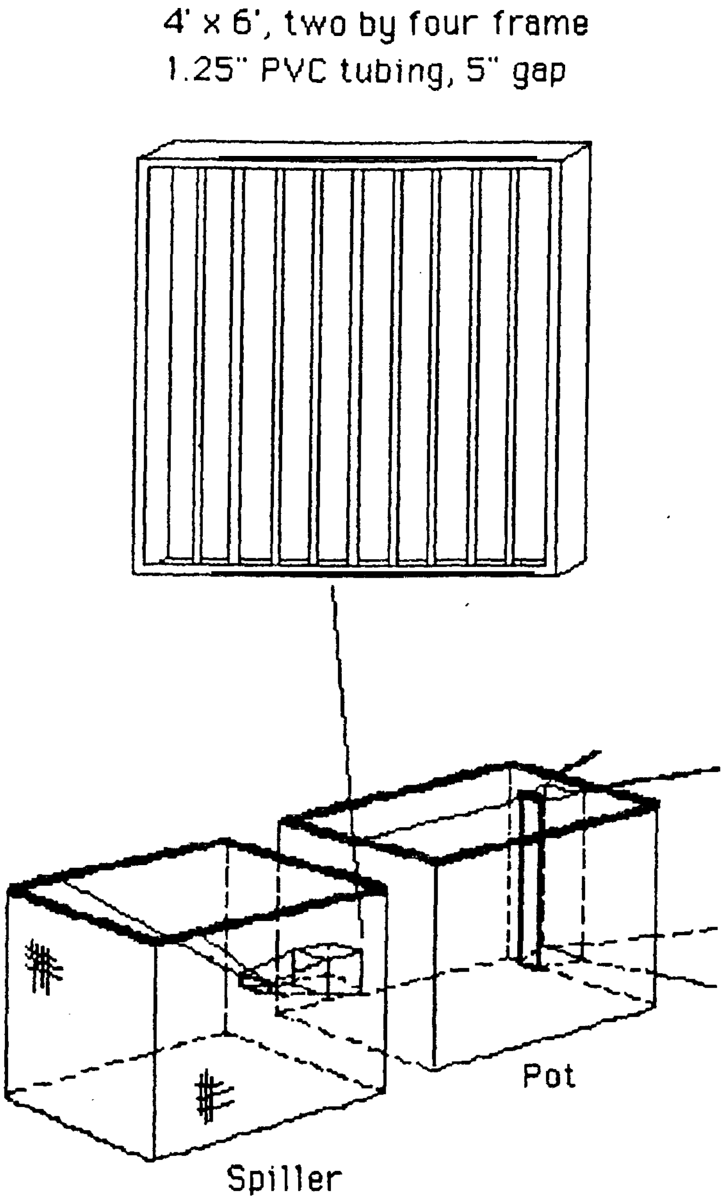


Figure 13. Experimental Fish Weir

(Note: 1 foot = 3.048 meters; 1 inch = 2.54 centimeters)

Table 4. location and Catch of Mobile Mervin traps, 1992.

Location	Dates Fished	Days Fished	Squawfish Catch	Squawfish Catch per Day	Adult Sal monid Catch	Adult Sal monid Catch per Day
Lyons Ferry area	5/11-5/14	3	10	3.33	0	0
Lower Granite Dam	5/19-5/29	6	75	12.5	1	0.17
The Dalles Dam cul-de-sac	6/1-6/30	22	259	11.77	147	6.68
McNary Dam area	7/1-7/10	8	64	8	141	17.63
Drano Lake	7/21-7/24	5	82	16.4	2	0.4
Horsethief Lake	7/22-7/24	3	2	0.67	0	0
CarrollsChannel	7/27-8/7	10	20	2	8	0.8
Elochoman Slough	8/3-8/14	10	142	14.2	0	0
Wallace Slough	8/10-8/19	8	26	3.25	1	0.13
The Dalles Dam cul-de-sac	8/26-9/1	4	428	107	9	2.25
	Total	79	1108	14.03	309	3.91

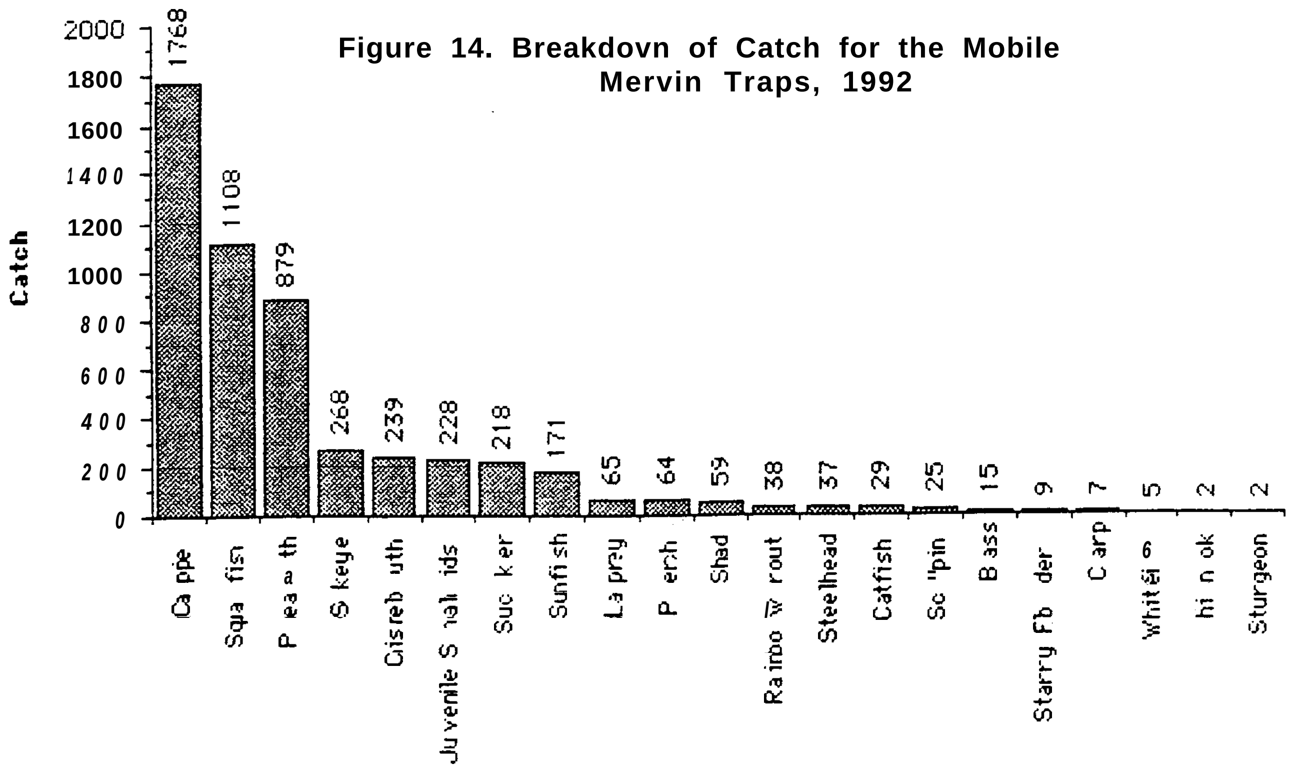
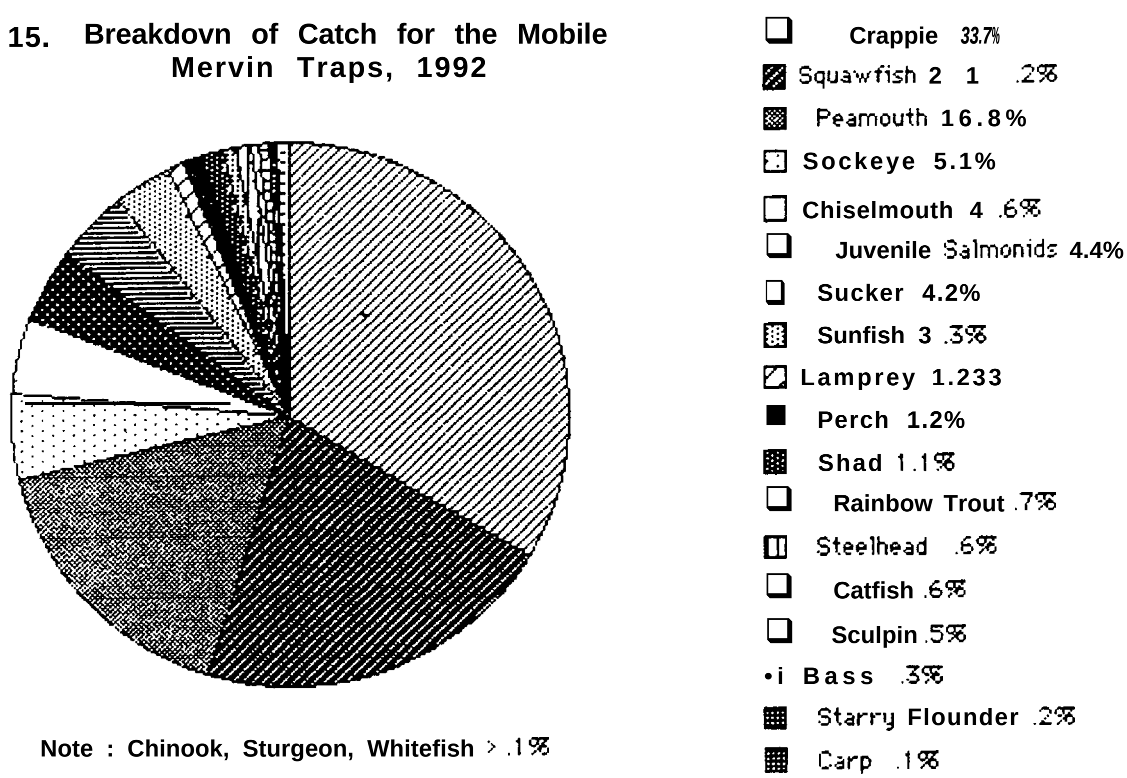


Figure 14. Breakdovn of Catch for the Mobile Mervin Traps, 1992

Figure 15. Breakdovn of Catch for the Mobile Mervin Traps, 1992



Note : Chinook, Sturgeon, Whitefish > .1%

The length frequency of squawfish captured with mobile traps outside of boat restricted areas closely resembles that of the larger trap operated in The Dalles Dam cul-de-sac (Figure 16). When squawfish catches occurring during late August (when juvenile squawfish were known to be present in large numbers from stationary trap catches) are removed from the length distribution, length classes in the range of 200 mm to 250 mm and 300 mm to 350 mm are represented in much the same manner as the stationary trap.

During the final two weeks of the 1992 season, comparisons of catch rates were made between the stationary and mobile traps in The Dalles Dam cul-de-sac. During the weeks of August 24 to August 28 and August 31 to September 3, the stationary trap and a mobile trap were fished alternately, two days per week, with the traps being checked every six hours. Squawfish catches during this period were very similar for both gears with the stationary trap catching 373 squawfish in 54 hours of fishing and the mobile trap catching 428 squawfish in 54 hours of fishing (Table 5). Results from this experiment indicate that both traps fish with similar effectiveness. However, these results may be biased due to the fact that 80% of the squawfish caught by both traps were less than 250 mm long.

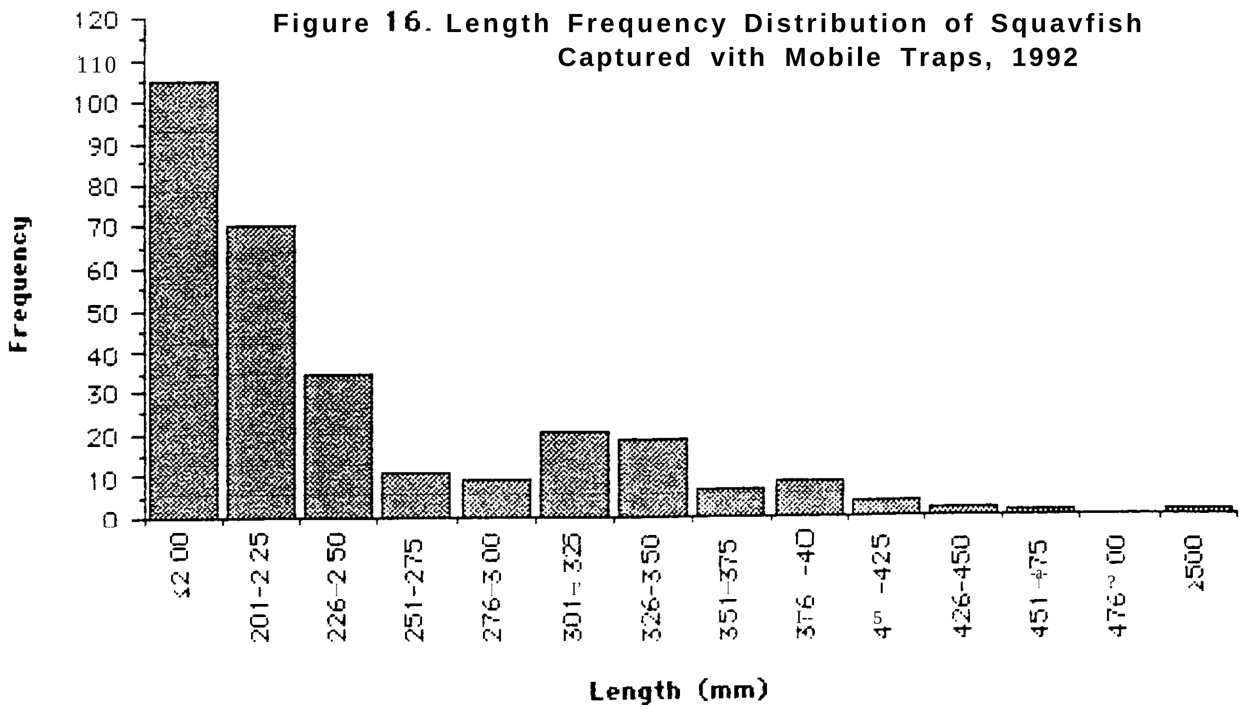
The favorable environmental characteristics associated with efficient mobile trapping have been identified to include (1) moderate flow (<1 foot per second), (2) relatively stable river level, (3) gentle sloping of submerged bank (the trap lead should maintain contact with the bottom while still presenting a uniform vertical barrier to the fish), and (4) adequate site accessibility via modern boat ramps (used as trap staging and launching areas).

A comprehensive riverwide survey was performed by UW during the winter of 1993. This survey was primarily concerned with the general physical characteristics of the river necessary for setting mobile trap nets. The survey evaluated 209 locations for accessibility, trap set potential, and estimated squawfish catch qualities. Trap sites targeted at tributary outflows, embayments and enhanced bank structures (e.g., bridge jetties, causeways, and artificial ponds) possessed good potential for success. Spring flows, current, incidental catch, and gear conflicts would limit trap net operations.

Conclusions

Research carried out in 1991 and 1992 with floating trap nets indicates that this gear could be an effective squawfish removal method on a larger scale. Incidental salmonid catches were greatly reduced in 1992 near dams while maintaining a significant squawfish removal effort. Delay of migrating salmonids and incidental mortality due to predators was also overcome with minor adjustments in operational procedures. Based on these results and the fact that salmonid concentrations away from dams would most likely be low, adverse impacts on incidental salmonids in a large-scale program are thought to be negligible.

Figure 16. Length Frequency Distribution of Squavfish Captured vith Mobile Traps, 1992



Note: Fish captured in BRZ's not included

Table 5. Comparison of Catch Rates for the Stationary Met-win Trap and a Mobile Merwin Trap The Dalles Dam, August 24throuqh September 3, 1992

Gear	Fish time (Hours)	Species	Catch	Catch per Hour
Stationary Trap	54	Squawfish	373	6.91
		Steel head	47	0.87
		Juvenile	0	0
		Bass	2	0.04
		St urqeon	18	0.33
		Catfish	0	0
		Other	521	9.65
		Total	**961**	17.8
Mobile Trap	54	Squawfish	428	7.93
		Steel head	9	0.17
		Juvenile	2	0.04
		Bass	0	0
		Sturgeon	0	0
		Catfish	2	0.04
		Other	720	13.33
		Total	1161	21.5

Modifications made in mobile trap designs illustrate that this gear can be easily transported and deployed with limited effort. Comparisons carried out with mobile traps and the stationary trap indicate similar catch effectiveness, enabling the use of mobile versions while maintaining fishing power. Similar length frequency distributions of squawfish caught in both gears indicate that midreservoir locations could remove target species at a rate similar to locations within boat restricted zones near dams.

Mobile trapping was found to be effective to varying degrees based upon amount of current and tidal influence present in a given area. Areas fished below Bonneville Dam, near Longview and Cathlamet, Washington, possessed strong tidal fluctuations that would strand traps during low tide or place tremendous amounts of stress on components during changing tides. Squawfish catches in these areas were good when traps could be fished effectively, therefore, further modifications to trap net design should enable mobile traps to be fished in areas that have been shown to possess significant squawfish populations and extraordinarily high current.

Mobile trapping carried out in areas of relatively moderate current was found to be the most conducive to fishing. Sites in Drano Lake and Elochoman Slough provided ideal conditions for trapping due to their relatively moderate current. Fishing carried out in the cul-de-sac at The Dalles Dam was also quite productive. These sites possess similar characteristics in that current and water level were relatively stable over time, allowing for better trapping efficiency.

In addition to current and water level requirements, traps were most successful in areas of similar bottom topography. Using depth sounding equipment, bottom topography was categorized at all sites fished. Areas that sloped away from banks to a depth of 30 feet provided best conditions for trapping with a 25-foot deep lead. These conditions are logical due to the mode of operation of the trap (fish encounter an obstacle that leads them into the trapping portion). Shallower depths were not as productive, indicating that alterations in trap components may be necessary to fish in a variety of conditions.

ELECTROFISHING

Introduction

In 1992, the University of Washington operated an electrofishing boat in the Columbia and Snake rivers to evaluate the effectiveness of electrofishing as a squawfish removal method. Since 1983, the Oregon Department of Fish and Wildlife (ODFW) and U.S. Fish and Wildlife Service have used similar boat-based electrofishing gear in their ongoing studies of predation by resident fish on juvenile salmonids in the Columbia River (Poe and Rieman 1988). Electrofishing was chosen for these studies due to its historical effectiveness as a capture method.

For all electrofishing efforts on the Columbia River in 1990 through 1992, catch per unit effort (CPUE) averaged 24.77 squawfish per hour of on-time (Table 6). From 1984 to 1986, CPUE averaged 28.27 in the McNary Dam tailrace boat restricted zone (BRZ) and 1.89 throughout the rest of the John Day Reservoir (Table 7).

Electrofishing has been demonstrated to be an effective method for capturing squawfish. However, it is possible that past CPUE figures are conservative in assessing what an implemented control effort might yield. The ODFW predator indexing studies are research oriented and not direct attempts to maximize total squawfish catch. It is expected that if an electrofishing boat was assigned the sole task of squawfish removal, total catch could significantly contribute to the overall squawfish program exploitation rates.

Due to the extensive electrofishing operations planned for evaluating this gear as a removal method, the Fish Passage Advisory Council (FPAC) expressed concerns with the 1992 UW research. These concerns focused primarily on two issues: (1) potential incidental harm and delay to salmonids, specifically Snake River sockeye and salmonid concentrations in dam boat restricted zones (BRZs), and (2) addressing the existing levels of interagency (National Marine Fisheries Service, ODFW, University of Idaho) BRZ electrofishing. Restrictions were placed on the electrofishing operations during 1992 electrofishing research that addressed these concerns; these are listed in the "Methods" section of this report.

Methods

The first step in developing the UW electrofishing program was to complete an annotated bibliography and comprehensive synopsis of electrofishing (Appendix B, Mahoney et al. 1993). This report was intended to familiarize our crews with contemporary electrofishing theory, principles, and practices.

The electrofishing boat used for this study was equipped with a Smith Root Model 5.0 GPP electrofishing system. This unit has an output capacity of 5,000 watts, O-750 RMS volts AC or 0-1,000 volts pulsed DC at frequencies of 7.5 up to 120 hertz (pulses per second). Electrical output was delivered into the water via two model UAA-6, dropper anode arrays. These boom anodes were bow-mounted at 20" and 90º off the starboard beam. The boat's aluminum hull was used as one large cathode.

Table 6. Historical CPUE of northern squawfish by electrofishing on the Columbia and Snake rivers, 1990-92 (effort in on-time hours).

	Squawfish	On-Time Hours	CPUE
1990 ODFW Abundance Indexing (a)	1,014	102.25	9.92
1990 USFWS Consumption Indexing (a)	1,876	141.00	13.30
1991 ODFW/USFWS Predator Indexing (b)	1,732	221.50	7.82
1991 NMFS/USFWS/ODFW (c)	2,012	19.68	102.24
1992 ODFW Abundance Indexing (d)	4,924	133.75	36.81
1992 NMFS/USFWS/ODFW (e)	2,173	26.34	82.42
1992 NMFS Creek studies (f)	2,565	135.20	18.97
1992 UW Removal Efforts	4,076	43.16	94.44
1990-92 Electrofishing Totals	20,372	822.88	24.76

a - Vigg 1990.
b - Dave Ward, ODFW, Personal Communication.
c - Tom Poe, USFWS, Personal Communication.
d - 1992 ODFW Field Activity Reports.
e - Ledgerwood 1992.
f - 1992 NMFS Field Activity Reports.

Table 7. Comparison of electrofishing catch by ODFW predator indexing crews in the John Day Reservoir inside and outside of McNary Dam boat restricted zone, 1984-86. (Nigro et al. 1985a, Nigro et al. 1985b, Beamesderfer et al. 1987).

	1984	1985	1986	1984-86
John Day Reservoir				
Squawfish catch	874	799	511	2184
Effort (hours on time)	384	452	318	1154
CPUE	2.28	1.77	1.61	1.89
McNary boat restricted zone				
Squawfish catch	440	822	1367	2629
Effort (hours on time)	13	23	57	93
CPUE	33.85	35.74	23.98	28.27

The electrofishing system was installed on a 28-foot, shallow draft, aluminum boat powered by a 400 hp inboard engine with a jet drive. A crew of three (one driver and two dipnetters) was required for electrofishing operations. The increased size and horse power of this boat provided many advantages over the traditional 16- to 22-foot electrofishing boats: (1) a safe and stable work platform for up to three dipnetters, (2) an extended fishing range, typically 15 to 30 river miles round trip per night, (3) durability in rough weather and strong currents, (4) versatility for multi-purpose use (e.g., beach or purse seining, floating trap tender, survey vessel, and electrofisher), (5) large fish holds and long-term live-well capacity, (6) protection from the weather, and (7) a large cathode area (boat hull) that acted to efficiently distribute the electrical field, concentrating it toward the anodes.

The disadvantages to this increased boat size were: (1) limited manageability in strong winds due to the high wind-profile created by the boat's cabin and extended water line, (2) restrictive trailering (the boat's 10.5-foot beam required the use of special oversize permits and restrictive travel times -- daylight and weekdays only), (3) limited boat ramp access, and (4) prohibitive trailering and boat fuel costs (250 gallon capacity). It was strongly felt that the size of the vessel was by far an advantage in the overall removal operation.

The standard unit of effort for electrofishing is given as one hour of electrofishing unit on-time. Generally, a fishing run has a duration of 900 seconds (15 minutes of on-time). Two basic electrotishing techniques are used, steady on and power pulsing. The difference between these two methods is related to power unit on/off output time ratio. With steady on, electrical output remains on at all times. With power pulsing, generally a 1:3 time ratio is maintained. A power-pulsing, 900-second fishing run often takes up to an hour to complete. Power pulsing tends to catch more fish since it effectively reduces an electrofrshing unit's applied perception zone, resulting in fewer fish being frightened out of an area before the electrofishing boat can get into an effective capture range.

During the day (9 a.m. - 3 p.m.) selected river reaches were surveyed for areas of desirable squawfish habitat (e.g., submerged rip-rap, moderate current, good visibility, steep slope, and associated prey holding areas); selected areas were then fished at night (9 p.m. - 3 a.m.). Standard practice was to use the power pulsing capture technique (900 seconds on-time per run) with three dipnetters selectively removing northern squawfish from the river and estimating the counts of all other species within the electric field. Two boom anodes were placed to one side of the boat (20" and 90° off the beam), which enabled the electric field to remain in constant contact with the shoreline.

Actual electrical parameters were maintained at the minimal levels required for satisfactory capture of squawfish. These parameters fluctuated by the physical constraints of the sampling area (e.g., water conductivity, temperature, flow, bottom substrate, turbidity). Commonly used output settings for squawfish in the Columbia River were 200 volts at 60 Hz pulsed DC on 40% duty cycle yielding a current of 3.5 amps to 5.0 amps.

Electrofishing operations were regulated by the following FPAC guidelines: (1) no fishing in any hydroelectric project boat restricted zone, (2) immediate stopping of fishing whenever a smolt or adult salmon was encountered, (3) moving to a new fishing area upon encountering a second salmon, and (4) ceasing electrofishing for the night whenever a total of more than two adult salmon were encountered.

Results

From May 5 to July 30, 1992, UW spent 45 nights electrofishing on the Columbia and Snake rivers. A total of 4,076 squawfish were taken in 43.16 hours of unit on-time, yielding a CPUE of 94.44 squawfish/hour on time (Table 8). Electrofishing occurred on the Snake River from May 4 to May 29. During this four-week period, 448 squawfish were removed in 15.15 hours of electrofishing resulting in a CPUE of 29.57 squawfish/hour on-time (Table 8). The remaining eight weeks of the season, June 1 to July 31, were spent on the Columbia River where 3,628 squawfish were taken with 28.01 hours of effort for a CPUE of 129.53 squawfish/hour on-time (Table 8).

Roughly 80% of the squawfish caught during the 1992 UW efforts were 250 mm or smaller. The overall CPUE for squawfish greater than 250 mm was 18.9 squawfish/hour on-time. Factors that tended to skew length-frequency to the smaller size were (1) electrofishing away from project BRZs tends to yield smaller, resident fish, (2) effort occurred early in the season (most of the field season coincided with high CRITFC dam-angling catch rates of larger fish, indicating that the larger squawfish are probably concentrated in and around the hydroelectric projects, which, effectively removes them from the midreservoir fishing regions), and (3) inclement spring weather reduced boat handling and dip-netting efficiency, resulting in a reduction of CPUE. During the last two weeks, July 13-27, there was a significant increase in the number of squawfish greater than 250 mm in the nightly catch, suggesting a migration of larger fish away from the dams.

Conservative visual estimates were recorded by fishing run for incidental fish species affected by the electrofishing gear. The UW squawfish removal of 4,076 represents 13.72 % of the 29,719 observed fish (Table 9). Suckers comprised 50.44% of the affected fish, while peamouth and chiselmouth chubs combined for an additional 22.89%. In all, 25,273 incidentally affected fish were recorded; of these, 316 (1.06%) were salmonid smolts and 54 (0.19%) were adult salmonids (Table 9).

Midreservoir encounters with salmonids were isolated occurrences. Whenever a smolt or adult salmonid was observed, electrofishing was immediately stopped. Typically adult salmon were observed along the periphery of the electric field. Upon encountering the field, adult salmon exhibited a fright response, actively escaping any further contact with the electrical impulses. Salmonid smolts exhibited a wide range of responses (fright, taxis, tetanus) to the electric field. All species identification for salmonids were subjective visual estimates since fishing ceased upon the appearance of an individual in the electric field and fish quickly swam out of sight once the power was ceased. Some fish were only observed on the periphery of the electrical field, and therefore the counts in Table 8 may not be 100% accurate for salmonids.

Table 8. UW experimental electrofishing catch and effort, 1992.

Date	Area	Duration (On time Hours)	Squaw-fish	Salmonids Smolts	Salmonids Adults	Total Fish	SQF/HR
5/4	Lyons Ferry	3.31	62	78	6	816	18.75
5/11	Lyons Ferry	5.61	111	59	0	1,925	19.77
5/18	Boyer Marina	4.09	164	91	2	2,172	40.13
5/25	Boyer Marina	2.15	111	21	1	1,329	51.75
Total	Snake River	15.15	448	249	9	6,242	29.57
6/1	Maryhill	4.24	188	38	1	2,920	44.38
6/8	Maryhill	5.38	287	6	2	1,169	53.34
6/15	Umatilla	2.78	357	10	11	4,300	128.55
6/22	The Dalles	1.63	629	3	9	1,369	386.55
6/29	The Dalles	3.69	557	4	12	1,638	150.79
7/6	Cascade Locks	2.68	611	0	2	1,711	227.99
7/13	Hood River	3.63	162	2	2	5,749	44.59
7/27	The Dalles	3.98	837	4	6	4,621	210.27
Total	Columbia River	28.01	3,628	67	45	23,477	129.53
Total	All Areas	43.16	4,076	316	54	29,719	94.44

Table 9. 1992 UW electrofishing, observed species composition. (These Figures represent visual estimates. While sampling, only squawfish were intentionally removed from the water.)

Species	Totals	Percentage of Catch
Suckers	14,989	50.44%
Squawfish	4,076	13.72%
Peamouth	3,606	12.13%
Chiselmouth	3,198	10.76%
Smallmouth Bass	1,820	6.12%
Shad	940	3.16%
Cottids	333	1.12%
Smolts	316	1.06%
Carp	174	0.59%
Yellow Perch	51	0.17%
Crappie	47	0.16%
Sunfish	44	0.15%
Sockeye	35	0.12%
Trout	33	0.11%
Steelhead	18	0.06%
Whitefish	16	0.05%
Sturgeon	12	0.04%
Channel Catfish	9	0.03%
Chinook	1	NA
Walleye	1	NA
Total	29,719	

A significant obstacle to midreservoir electrofishing was the seasonally unsettled weather of the Columbia River Gorge. Persistent strong winds and large waves resulted in inconsistent boat-handling and increased water turbidity. These environmental constraints caused significant numbers of stunned squawfish to be missed by dipnetters when fishing in waters deeper than 4 feet.

As a result of the 1992 evaluation, it was determined that certain environmental and diurnal characteristics tend to be associated with better squawfish electrofishing catch results:

SUBSTRATE TYPE	CPUE
Silt	7.81
Cobble	26.09
Large Cobble	36.96
Rip-Rap	42.69
Ledge	17.14

TIME OF DAY	CPUE
10 p.m. to 5 a.m.	56.63
5 a.m. to 10 p.m.	13.86

CPUE for squawfish was significantly higher at night, in areas of submerged rip-rap or large cobble with moderate current and low turbidity.

UW field operations were intended to be highly mobile and responsive. Generally, the crew was stationed directly on the river saving two to four hours of travel and preparation time each day. During the course of the season, areas were selectively sampled from above Lower Granite Dam on the Snake River to below Bonneville Dam on the Columbia River, encompassing a range of over 300 river miles.

A project goal was to identify and remove squawfish spawning concentrations. Gonadal somatic indexing (GSI), the ratio of gonad to body weight in female fish, and interagency weekly catch reports were used in this effort. GSI data along with visual inspections suggested that the majority of large squawfish (> 250 mm) taken by the electrofishing gear were spawned out individuals. UW midreservoir electrofishing was unable to positively identify large or persistent squawfish spawning congregations.

Initially, UW planned to beach seine potential squawfish spawning locations as indicated by the electrofishing catch results and habitat survey work. However, it was not possible to positively identify any squawfish spawning concentrations with our catch data. In addition, all of the productive squawfish habitat areas (moderate flow, submerged rip-rap, steep slope, weedy prey fish holding areas) proved to be far too difficult to seine effectively and, therefore, this method had to be dropped from the removal procedures.

Conclusions

Historically, the most successful capture method for squawfish has been electrofishing in hydroelectric project tailrace and BRZ areas (Table 7). The UW CPUE for squawfish greater than 250 mm of 18.9 fish/hour of unit on-time compares favorably to the 1984-86 ODFW midreservoir CPUE of 1.9 squawfish/hour on-time, Of course this comparison is biased since ODFW efforts were research oriented and not direct attempts to maximize squawfish catch. However, results from UW research indicate that electrofishing efforts primarily focused on removal of squawfish can significantly increase CPUE and total catch when fishing in midreservoir locations (Table 8). Therefore, electrofishing has tremendous potential as a control method in the squawfish management program.

However, the amount of incidental catch by electrofishing is significant. Over 29,000 fish were affected by the 1992 UW efforts alone. Also, electric fields will have some effect on any fish that encounters them. A majority of the electrolishing induced injuries we observed resulted from fish coming in direct contact with the anodes. The standard (radio antenna or cable) anodes presently in use on the Columbia River create dangerously high voltage gradients close to the anode often burning or branding the fish. Increasing the anode diameter greatly decreases the voltage gradient in this area, reducing the amount of injury caused from direct contact with the anodes.

The short- and long-term effects of pulsed direct current electrofishing on fish from the Columbia River is not well-documented; of special concern are the effects on salmonids. Reports on electrofishing-induced harm are study-specific, yielding a tremendously wide range of results (Sharber and Carothers 1988; Holmes et. al. 1990; Roach 1992). Fredenberg (1992), through x-ray and autopsy, reported that 60 Hz pulsed DC current results in excessive injury rates to both rainbow (60-98% injury) and brown trout (44-62% injury) in Montana streams. These studies show that incidental harm research on the Columbia River is long overdue. Before electrofishing could be used as a control method, the potential incidental effects on salmonids and resident species should be investigated. According to our catch rates, current interagency electrofishing efforts could be potentially impacting over 30,000 resident and anadromous fish per boat each season.

When electrofishing in tailrace areas, some interaction with salmonids is unavoidable. Two issues that demand attention before any large-scale electrofishing operation can begin are (1) to what degree are resident fish being affected (e.g., short-term effects, mortality) and (2) how much incidental catch is acceptable. Presently there are no sufficient data that could be used to determine the expected rates of harm to these fish.

The number of places open to electrofishing are primarily limited by environmental (wind and current) and safety considerations. When winds approach the 15- to 25-knot range, the combination of difficult boat handling, large waves, and turbidity makes dipnetting difficult, significantly reducing CPUE. Continued fishing under such conditions is counterproductive since many of the affected fish are missed by the netters and operators become quickly fatigued. There is evidence to suggest fish that are stunned, but not removed experience spatial displacement and may acquire a hyper-sensitivity to induced electric fields (Gatz et al. 1986, Gatz and Adams 1987, Mesa 1989). These fish may be temporarily lost to a sampling population. Generally a two- to three-week hiatus between repeated electrofishing efforts is recommended.

Although midreservoir electrofishing should be judged as a successful squawfish control tool, there exists room for improvement. Adjustments to operational procedure that improved UW CPUE were (1) fishing at night, (2) identifying and concentrating effort in squawfish holding areas, (3) employing the power-pulsing technique, and (4) increasing the number of dipnetters to three persons. Additional ways to increase the CPUE of large squawfish may include applying some portion of effort in the BRZ areas (e.g., one hour of on-time per week) and fishing later in the season (June 1 to September 30), thereby taking advantage of calmer, midsummer weather while intercepting larger squawfish as they disperse away from the dams.

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APPENDIX A

University of Washington
1992 Mobile Trap Description and Specifications

University of Washington Mobile Trap Net Bid Specifications

The following is a verbal description for bid specifications for two sizes of mobile floating fish traps that will be used for a squawfish removal program on the Columbia River in 1993. The 15’ and 25’ designations refer to the fishing depth of the trap lead and heart. The floating squawfish trap is a large, passive capture technique that has been developed specifically to be highly mobile and easily assembled. Because several of these traps are being constructed, it is important that each trap is built identical to the others in order for various parts to be interchangeable. These nets are supported by separate aluminum frames which provide a working platform and necessary buoyancy for accessing the fish holding areas of the trap. The aluminum frames will be interchangeable between either the 15’ or 25’ nets and are built under a separate bid request.

The trap net is constructed in three major parts: lead, heart, and pot/spiller (see attached drawings). Each of these parts is connected to each other using large Y.K.K. # 10 nylon separating zippers. This accelerates the assembly process in the field. The webbing used for all parts of these nets is 1¼" stretch mesh, #252 knotless nylon webbing. Framing lines and corklines are 3/8" braided polypropylene line. All leadlines are 4 pound per fathom except in the spiller tunnel where 2 pound per fathom leadline is used (Sampson Flexcore leadline or equivalent will be used). Floats on the heart and lead will be equivalent in size and buoyancy to Spongex K-4 expanded PVC floats. Upon completion, the entire net will be dipped in a green water-base latex netcoat (i.e. Flexdip Netcoat) in order to bind all fibers and prolong the life of these nets.

The Lead

The lead will be built in 2 or 3 sections depending on the size of the trap. Each section is 50 feet long with the shore-end section of the small trap and the mid-section of the large trap tapering to accommodate the bottom contour of the river. Y.K.K. #10 nylon separating zippers will be attached on both ends of the middle sections and only on the trap end of the shore sections. These vertical zippers should have their origin at the corkline and connect towards the bottom or leadline. The side of the zipper with the coupling piece attached (female) should be permanently attached on the shore end of the zipper and the trap end of the lead section; therefore, on each lead section a half zipper with the coupling piece permanently attached (female) should be on the trap end of the 50’ section while a half zipper without the coupling piece (male) should be on the shore end. No zipper should be on the shore end of the shore section.

The Spongex K-4 (or equivalent) corks will be spaced on 9 inch centers over the 3/8" braided polypropylene corkline. A ±2½ inch (inner diameter) loop should be left on either end of the cork and lead lines for connecting lead sections by use of a snap shackle. The leadline should be 4 pound per fathom in weight (equivalent in durability to Sampson Flexcore). Webbing will be 1¼" stretch mesh, #252 knotless nylon webbing.

The Heart

The heart section of the trap is the most complicated. The heart works as a funnel to force fish to swim into the pot/spiller. The wings provide a wall that will redirect fish into the pot tunnel if they turn away before entering. There is an apron on the bottom of the heart to prevent fish from escaping by diving under the net. The heart entrance is split in two by a lead section. On this lead section there will be a half zipper attached on the shore end that does not have a coupling piece on it (male). In this way, all other lead sections will be able to attach to the heart. There will also be two zippers that attach the heart to the pot at the entrance to the pot tunnel. These zippers will start at the bottom middle of the pot tunnel entrance and follow the perimeter up each side of the pot tunnel entrance: out 3 feet and up 7% feet on the small trap and up 12 feet on the large trap. The zippers' origin should be at the bottom middle of the pot tunnel entrance and the zippers will close towards the surface or corkline. This allows the heart to be completely separated from the pot at the pot tunnel entrance.

Again, Spongex K-4 (or equivalent) corks will be spaced on 9 inch centers over the 3/8" braided polypropylene corkline throughout the heart, The leadline will be 4 pound per fathom in weight (equivalent in durability to Sampson Flexcore). Webbing will be 1¼" stretch mesh, #252 knotless nylon webbing. Loops should be left in the lead and cork lines wherever zippers are located. Also, loops should be left in all places where the spreader bars will attach: outer wings, terminus of inner wings, terminus of lead section, and the shore end of both the inner and outer wings.

There are two lines not shown in the accompanying drawings that should be added to each of the outer wings. These tie down lines should be 6' long and attach on the outer wing corkline, 4 feet from the front pot wall. When tied to the aluminum frame, this line will enable the wings to be used for anchoring the trap on shore without pulling the heart, pot and spiller out of shape.

The Pot/Spiller

The pot and spiller portions of the trap function as the holding area for captured fish. It is split in two sections by the mid panel. The length and width dimension for the pot/spiller will be the same for both the large and small traps (10' wide X 8' 7½" pot length X 10' 1½" spiller length); however, the depth will be different due to fishing depth of the two traps. In this way, each aluminum mobile trap frame will be able to attach to either a large or small trap net.

The pot tunnel protrudes into the pot and is a continuation of the heart. Two zippers serve as the connection between the pot tunnel and heart (see Heart description). At the exit to the pot tunnel, inside the pot, a 1% foot spreader bar should be attached to the leadiine which will hold the pot tunnel open while fishing. Any material that sinks can be used for this purpose; for example, we have used ¾" galvanized water pipe. On the corkline of the pot tunnel, a ¼" polypropylene line should be provided that holds the tunnel open; a spreader bar is not necessary. The spreader line should simply be a bridle (Y) that ties at the center of the mid panel on the aluminum frame and branches in two, half way to the pot tunnel. Each branch of this bridle should tie to either side of the pot tunnel at the corklines.

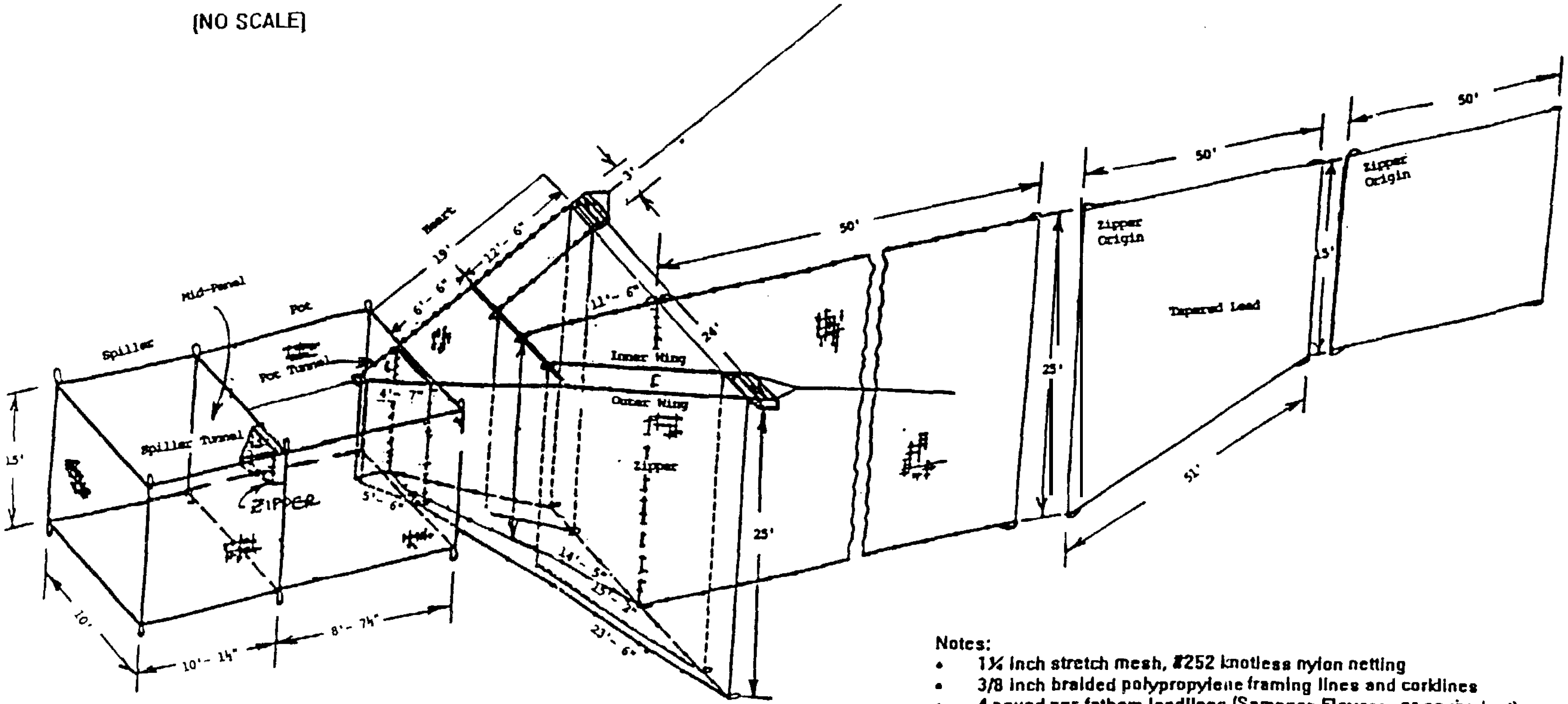
The spiller tunnel protrudes from the mid panel into the spiller portion of the net. This tunnel is removable from the mid panel. Two zippers are used that originate at the bottom, center of the tunnel entrance and follow the boundary with the mid panel out 1% feet, up the sides 3 feet, and close back towards the middle an additional 1½ feet. In this way, the tunnel can be removed while assembling the net. The spiller tunnel also needs a spreader support for the tunnel exit. This support should be a 1 foot square made out of a lightweight material (i.e. 3/8 inch round aluminum stock) and permanently attached to the tunnel exit. Two 9 foot lines (¼" braided polypropylene) should be attached to either side of this support. These lines will tie into the side of the aluminum floating frame and hold the spiller tunnel open.

No corks will be used in the pot/spiller section of the trap with the exception of the corklines on the pot tunnel. Leadiine will be used for the perimeter of the bottom of the pot/spiller section including the mid panel. Loops should be left on all four corners of the pot/spiller and on the two ends of the mid panel at the corkline and at the leadline. These loops will provide locations for the attachment of weights on the leadiine and improve ease of handling. The webbing, used in all parts of these nets, is 1%" stretch mesh, #252 knotless nylon webbing. Framing lines and cork lines are 3/8" braided polypropylene line. All leadlines are 4 pound per fathom except in the spiller tunnel where 2 pound per fathom ieadiine is used (Sampson Fiexcore leadiine or equivalent will be used).

Upon completion, the entire net will be dipped in a green water-base latex netcoat (i.e. Flexdip Netcoat) in order to bind ail fibers and prolong the life of these nets, University of Washington Mobile Squawfish Trap

25’ Net Layout

(NO SCALE)



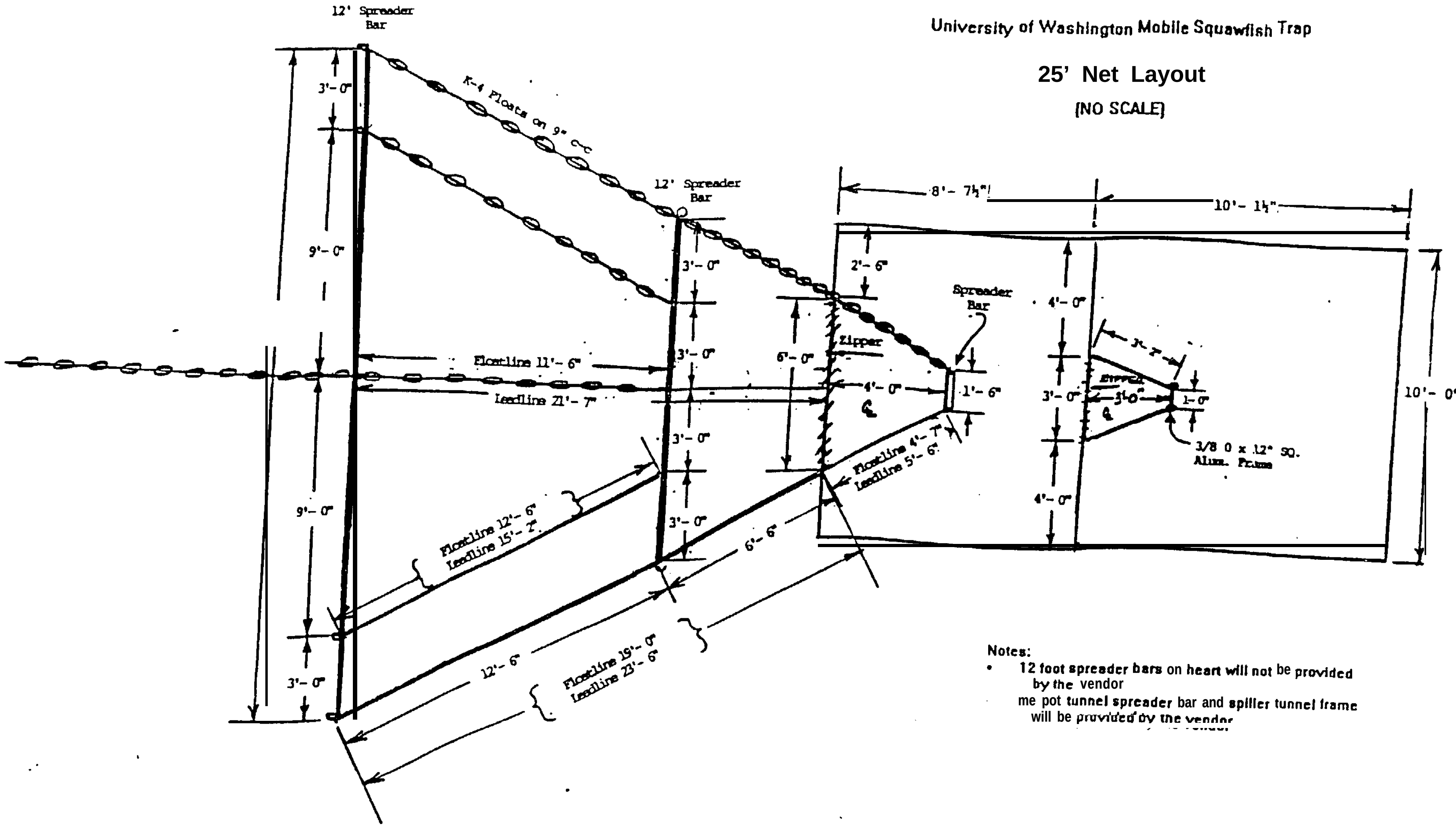
Notes:

- 1¼ inch stretch mesh, #252 knotless nylon netting
- 3/8 inch braided polypropylene framing lines and corklines
- 4 pound per fathom leadlines (Sampson Flexcore or equivalent)
- 2 pound per fathom leadlines in spiller tunnel only
- Y.K.K. #10 separating zippers
- Spongex K-4 expanded PVC floats or equivalent
- green water-base latex netcoat (Flexdip Netcoat or equivalent)
- see attached verbal description for further instructions

University of Washington Mobile Squawfish Trap

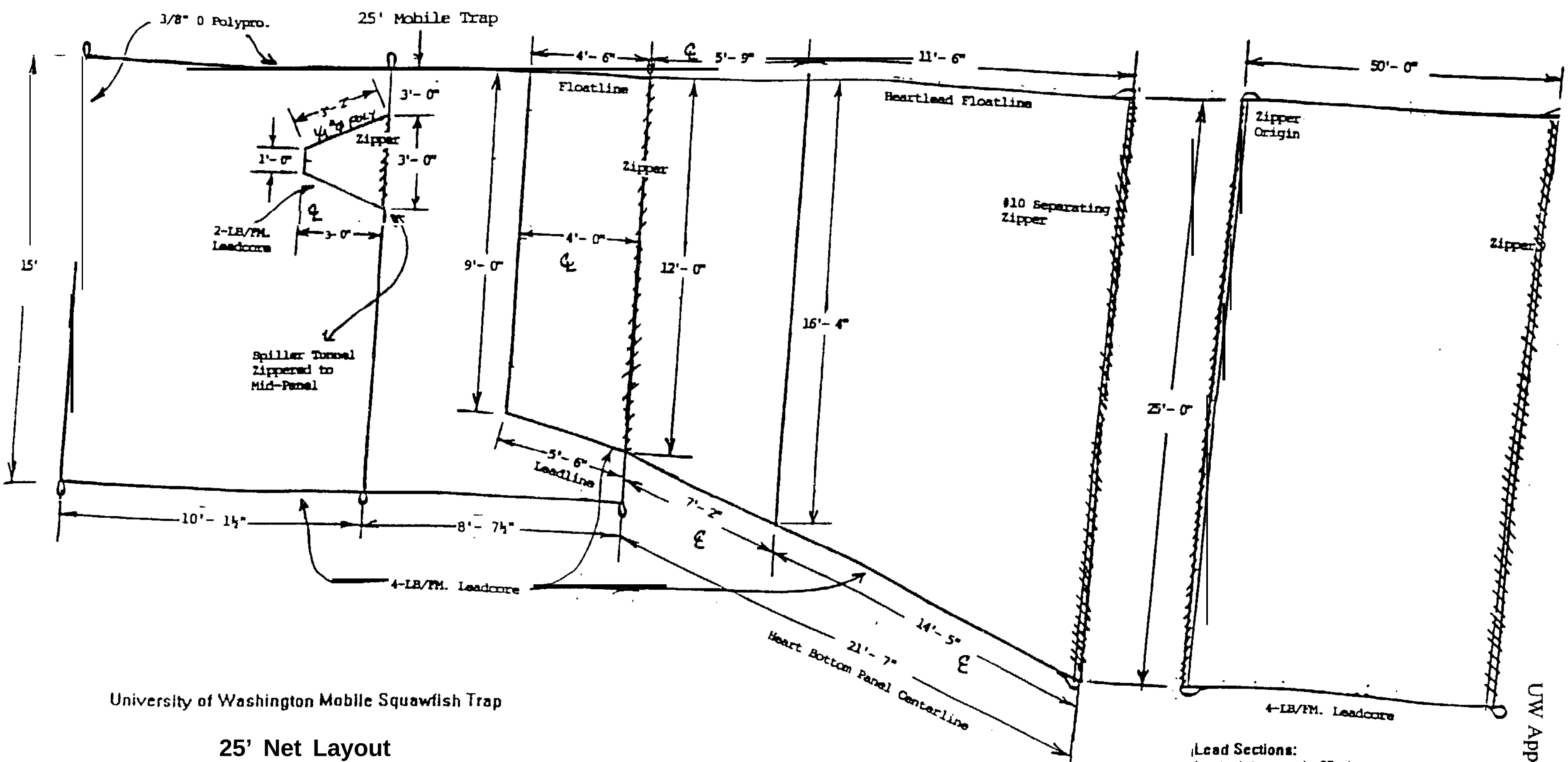
25' Net Layout

(NO SCALE)



Notes:

- 12 foot spreader bars on heart will not be provided by the vendor
- me pot tunnel spreader bar and spiller tunnel frame will be provided by the vendor



University of Washington Mobile Squawfish Trap

25' Net Layout

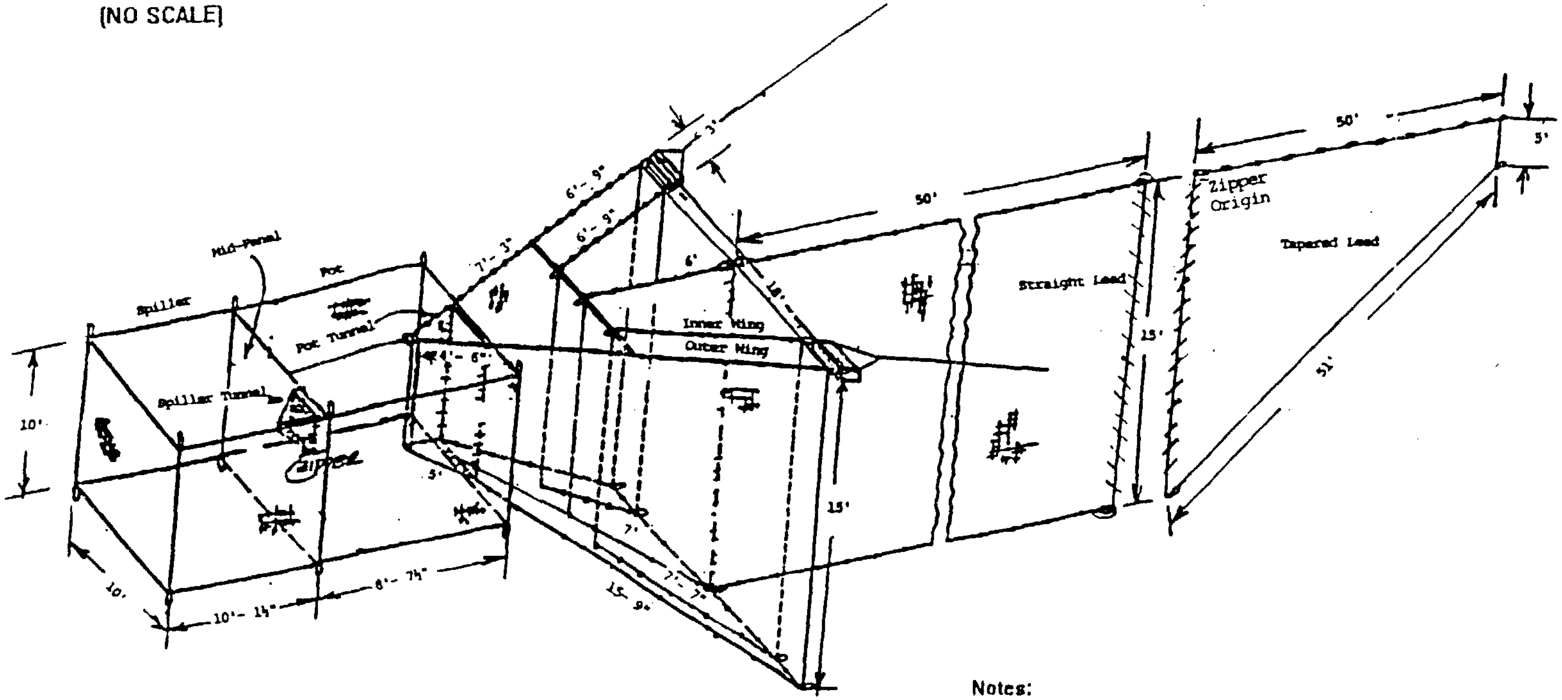
(NO SCALE)

Lead Sections:
1 straight panel - 25; deep X 50' long
1 tapered panel - 25 deep X 50' long X 15' deep
1 straight panel - 15' deep X 50' long

University of Washington Mobile Squawfish Trap

15' Net Layout

(NO SCALE)



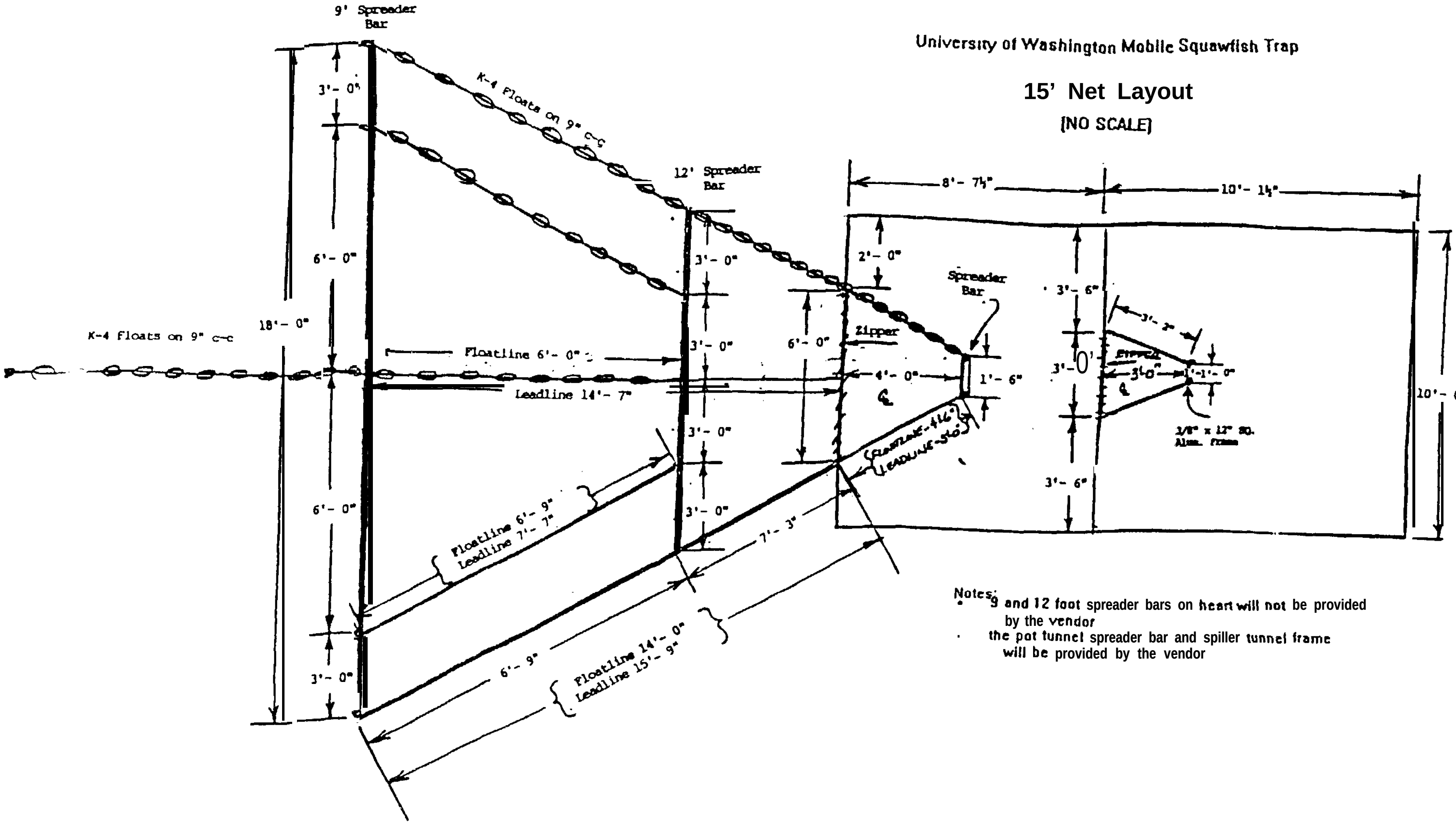
Notes:

- 1¼ inch stretch mesh. #252 knotless nylon netting
- 3/8 inch braided polypropylene framing lines and corklines
- 4 pound per fathom leadlines (Sampson Flexcore or equivalent)
- 2 pound per fathom leadlines in spiller tunnel only
- Y.K.K. #10 separating zippers
- Spongex K-4 expanded PVC floats or equivalent
- green water-base latex netcoat (Flexdip Netcoat or equivalent)
- see attached verbal description for further instructions

University of Washington Mobile Squawfish Trap

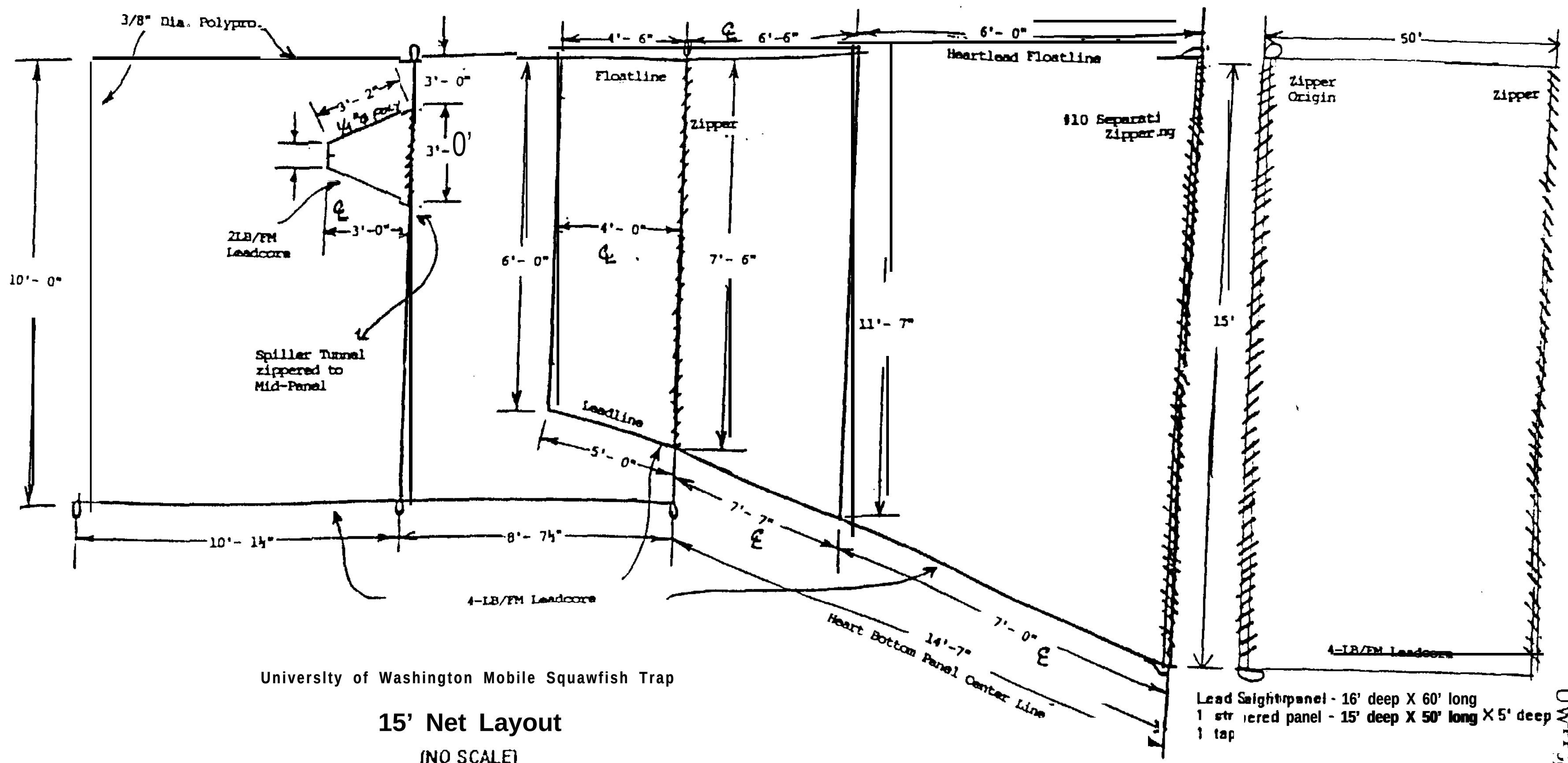
15' Net Layout

[NO SCALE]



Notes:

- 9 and 12 foot spreader bars on heart will not be provided by the vendor
- the pot tunnel spreader bar and spiller tunnel frame will be provided by the vendor



University of Washington Mobile Squawfish Trap

15' Net Layout

(NO SCALE)

UW MOBILE TRAP FRAME SPECIFICATIONS

This trap is designed for fishing several remote locations on the Columbia and Snake rivers. For this reason it needs to be lightweight and transportable. This design emphasizes long term survivability, durability, and mobility. All of which are essential qualities for successful use throughout the Columbia and Snake river watersheds.

Specific design elements of the frame need to include the following: (1) reliability and ease of trailering over long distances and launching at remote field sites, (2) ease of on site assembly and break down, (3) in river stability and maneuverability while being towed behind a 17 foot trap tender boat to trapping locations at high speeds.

This prototype will be constructed as per the instructions below and the attached drawings. Vendor suggested modifications to the existing design and material specifications are encouraged.

Frame Construction

Pontoons:

The Merwin Trap is supported by two 24 foot 6 inch by 2 foot wide and 2 foot deep air tight aluminum pontoons. Each pontoon will have four deck mounted (outboard) 8 inch mooring cleats and two 4 inch diameter sailing winches(inboard) both fore and aft. Each pontoon will have three recessed 1 foot 6 inch by 2 foot wide and 3 inch deep walkway connection wells. These connection wells are centered (aft to forward) at 1 foot 9 inches, 12 feet 6 inches, and 23 feet 9 inches. Pontoons are to be decked with aluminum 'diamond plate'. Anchor wells 2 feet 6 inches long will be recessed and centered aft at 4 feet 3 inches in each. Net hooks are placed on 2 foot centers along both inboard sides 1 inch below the deck surface. These should be recessed if possible. The frame should be able to collapse in order to attach the pontoons together for towing and transporting.

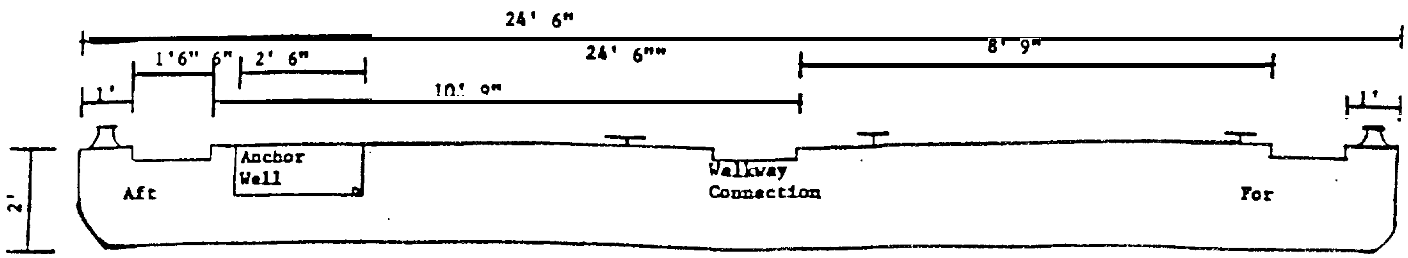
Walkways:

Three 11 feet by 1 foot 6 inch wide and 3 inch deep aluminum walkways will join the two pontoons. These walkways will be filled with styrofoam or other buoyant material. Walkways join the pontoons at the recessed connection wells presenting a flush deck surface. Connection to the pontoons is via an interlocking pin and flange system or an appropriate system suggested by vendor. Decks will be surfaced in 'diamond plate'. Net hooks will be placed on 2 foot centers 1 inch below deck surface along the forward edge of the aft and mid walkways, recessed if possible. Similar net hooks are placed along the aft edge of the forward walkway. This walkway has four additional net hooks placed 1 inch below the deck surface at each intersection point with the pot tunnel.

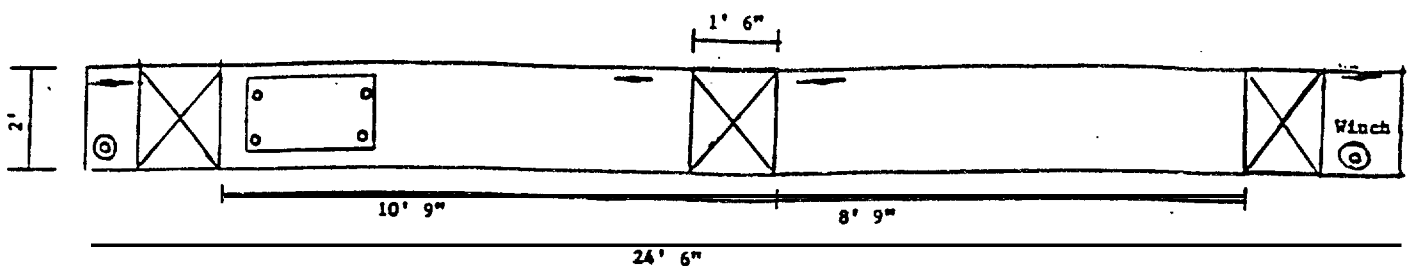
UW Mobile Trap Frame

Pontoons:

Side View

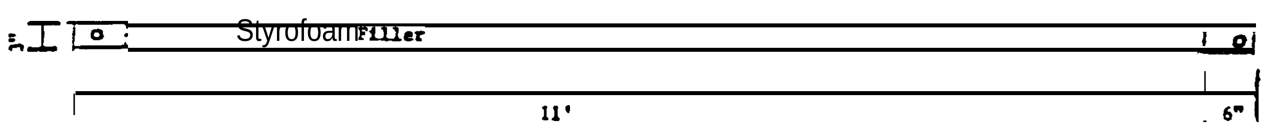


Top View

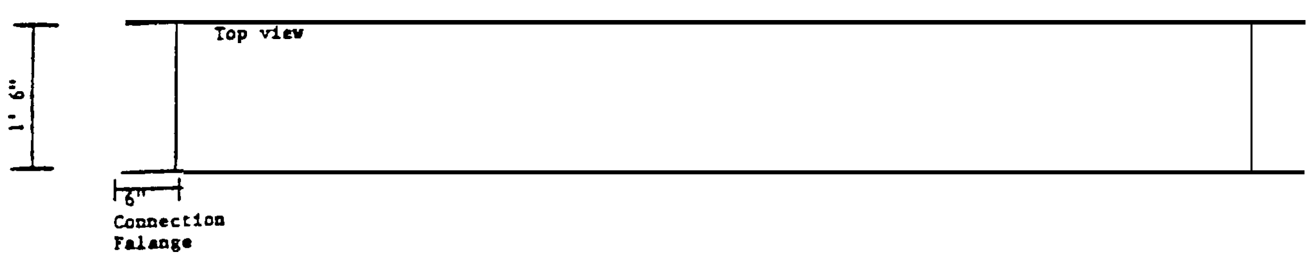


Walways:

Side View



Top View



APPENDIX B

University of Washington
1992 Electrofishing Synopsis and Annotated Bibliography

FRI-UW-9306
April 1993

FISHERIES RESEARCH INSTITUTE
SCHOOL OF FISHERIES
UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

SYNOPSIS AND ANNOTATED BIBLIOGRAPHY ON ELECTROFISHING WITH SPECIAL REFERENCE TO COLUMBIA RIVER SQUAWFISH CONTROL

B.D. MAHONEY, T.K. IVERSON, AND S.B. MATHEWS
CENTER FOR QUANTITATIVE SCIENCE

Approved

Submitted 2 April 1993 ______________________

Director

CONTENTS

LIST OF TABLES

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We would especially like to thank Marcus Duke and Abby Simpson for their patience and efforts in editing this report and presenting a legible product.

KEY WORDS

electrofishing, injury, mortality, sampling methodology

INTRODUCTION

This report has two objectives: (1) to provide an introduction to electrofishing theory and practical application and (2) to review the existing electrofishing literature, emphasizing how the knowledge and experience of previous studies could be applied to squawtish removal efforts on the Columbia River. Some general principles and guidelines are provided for the understanding, construction, and application of safe, efficient, boat-based electric fishing equipment.

This review heavily relies on information from the following authors: Reynolds (1983) on principles of electrofishing, Koltz (1989) electricity and its application in electrotishing, Lazauski and Malvestuto (1990) on electrofishing and safety, Lamarque (1990) on fish response to electric shock and factors affecting electrofishing efficiency, Novotny and Priegel (1974 on electric fields and electrofishing equipment, Smith (1989) and D. Snyder (Colorado State Univ., Ft. Collins, pers. comm.) on the principles and techniques of electrofishing, and Zalewski and Cowx (1990) on factors affecting electrofishing efficiency.

HISTORY

Electric fishing is a well-established research and management tool for fisheries biologists. The history of electric fishing is surprisingly lengthy. The first patent for an electric fishing machine was granted in London, England, in 1863. The most important developments in the theory and application of boat based electric fishing occurred in the early 1970s.

At the University of Wisconsin, Novotny and Priegel (1973) developed a boat-mounted, multi-anode, boom-array electric fishing system, which was the forebearer of today's commercially available electrofishing units. In the past most electric fishing equipment was "home made" by biologists with limited electrical engineering backgrounds. For today's fisheries biologist, there exists a wide inventory of field-tested, dependable, commercially available electric-fishing equipment. The developments in today's electric-fishing gear have been directed towards reducing harm to fish, saving time and money, reducing the possibility of serious injury to fishery workers, and increasing catch-per-unit-effort.

BASIC ELECTRICITY

All matter consists of charged particles that attract or repel each other because of the positive or negative charges they bear. Electricity is the form of energy that results from this attraction or repelling of particles. Electricity can be defined as the force that moves electrons (Smith 1989). A circuit is a closed path along which an electric charge moves. The rate of flow or intensity that moves the charge is the current, which is measured in amperes. The electromotive force that moves the current is voltage and is measured in volts. Voltage may also be defined as the potential force available to move electrons through the circuit. The restriction of electron flow in the circuit is resistance and it is measured in ohms. Electrical power is the rate at which electrical work is done and is measured in watts. One watt of power results when a current of one ampere flows through a resistance of one ohm under the force of one volt. The relationship between current, voltage, and resistance in a closed circuit is given by Ohm's Law:

Current (amperes) = voltage (volts) / resistance (ohms)

The current in a circuit is directly proportional to the applied voltage and inversely proportional to the circuit resistance. That is:

$$I = V/R$$

where I = current in amperes (amount of electron flow),
v = voltage in volts (amount of charge causing electron flow), and
R = resistance in ohms (restriction of electron flow).

The flow of current in a circuit is like the flow of water in a pipe. The pressure (voltage) drives the flow (current) through the pipe (circuit). The amount of flow the pipe can handle depends on its size and material (resistance). As the flow reaches the end of the pipe, it releases energy to do work at some rate (power).

Only two of the three Ohm's Law quantities are needed to calculate power:

$$w = VI,$$
$$= V^2/R, \text{ and}$$
$$= I^2R.$$

Wattage is simply the product of voltage and amperage.

When electrofishing, the Ohm's Law parameters are redefined in three-dimensional terms. In electrofishing, a closed circuit is created by passing electric current between two submerged electrodes through the water and fish. Current of sufficient densities will either frighten, lead, stun, or kill fish. As current flow leaves the electrodes, passing through the water, it spreads out in all directions forming a field pattern. Ohm's Law parameters for water now become voltage gradient, current density, and resistivity:

Resistivity ($ohms/cm^3$) = voltage gradient (volts/cm)/current density (amps/cm*).

Current density can be visualized as a measure of intensity of electron flow (current) at a given point in the water. The voltage gradient is the voltage between two closely spaced points causing the electron flow between the two points. Resistivity is the measure of the quality of the water as an electrical conductor. Resistivity is often referred to as conductivity and is the inverse of resistance (Smith 1989).

ELECTROPHYSIOLOGY

The basic principle of electric fishing is the transfer of electrical current into the water via electrodes and through the fish at high enough current densities to produce a desired effect (taxis, repulsion, or death). It is possible to stimulate or catch fish with any kind of electrical current (of a sufficiently strong field), but in order to maximize catch-per-unit-effort (CPUE), to avoid causing injury to the fish, or to fish under adverse physical conditions, the proper choice of electrical parameters and current is important. There are three types of current: alternating current (AC), pulsed direct current (PDC), and constant direct current (DC).

It is well established that AC can efficiently tetanize (immobilize) fish. A serious side effect of AC is the potential to kill a high percentage of affected fish. Unlike DC, current direction is changing every half cycle. In an AC field, the fish faces the cathode and anode successively as many times as the current alternates (Lamarque 1990). Above a certain field strength, this continuous reversing of current polarity quickly overwhelms the fish's nervous system. Constant DC has the desirable characteristic of producing anodic galvanotaxis (forced swimming toward the anode) with less harm to the fish. However, constant DC has a more limited effective range and generally large and inefficient power requirements.

At the same peak power, AC, DC, and PDC will have similar or equivalent fields in terms of size and intensity. However the response threshold levels of fish are higher for DC, thereby reducing the 'effective zone.' Also for DC, peak power = average power, whereas for PDC and AC average power, which determines the size of the generator, is much less (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.). The effects of pulsed DC are intermediate between that of AC and DC. Pulsed DC is most commonly used in boat-based electric fishing.

in choosing the appropriate electric parameters, we need to understand the behavior of fish in electric fields (electrophysiology). Unfortunately, fish electrophysiology is generally not well documented nor understood. Galvanotaxis is believed by some to be a result of direct stimulation of the central and autonomic nervous systems that control the fishes voluntary and involuntary reactions.

Many authors have classified fish reactions in electric fields, attempting to fully explain their causative mechanisms (Halsband 1967, Lamarque 1967, Vibert 1967, Sternin et al. 1972, Edwards and Higgins 1973). A general agreement of the results has proven difficult to achieve. The one matter that most scientists agree on is that AC is more harmful than DC. Pulsed DC can produce the desirable effects of both AC and DC while limiting the negative side effects (Lamarque 1990).

Fish may exhibit four general responses to induced electric fields (i.e., PDC at 60Hz), avoidance, taxis, narcosis, and tetany. These responses depend on the total duration and level of current density experienced. When electrofishing, it is necessary to establish an electric field of sufficient current density to achieve the desired response from fish. The field established is defined by three zones of increasing density: the perception zone, effective zone, and danger zone. If the perception zone is too large, fish are frightened and avoid capture. The desirable effect of taxis (forced swimming) occurs within the effective zone. If fish are not removed in a timely manner, narcosis (an induced relaxation of the body) occurs. Fish exposed to the danger zone will experience seizure or tetany. Tetany is the rigid immobilization of all musculature. Fish become tetanized by the increased levels of current densities. Tetany most often causes death by asphyxiation. Ideally an electrofishing unit produces the smallest perception zones, largest effective zone and no danger zone.

A fish's first reaction to AC is to take up a transverse position to the electric field lines: oscillotaxis (Koltz and Reynolds 1989). The fish then repeatedly attempts to face the 'anode and cathode until the threshold current is reached, causing the fish to be tetanized on the spot. Some authors also describe movements toward, as well as away from the electrodes (Lamarque 1990). Little agreement on results was apparent in our literature review of electrophysiology.

In DC electrofishing, electric current flows continuously from the negative cathode to the positive anode. The actual mechanism for electron flow is electrolysis, that is the movement through water of ions that collect electrons at the cathode and release them at the anode (electron flow). The reaction of fish to DC is quite different than to AC. The first reaction observed in a DC field is a quivering of fish body muscles or fins; this occurs as the fish enters the perception zone. What happens after a fish enters the perception zone depends on a number of factors: the fish's orientation to the electric field (facing anode or cathode), species electrophysiological characteristics (resistance, fatigue), and current density. Assuming the fish does not flee (the perception zone), it then moves into the effective zone. As the fish moves through the effective zone it experiences increasing current densities, causing inhibited swimming followed by galvanotaxis. If the fish is not removed from the increasing field densities, it will continue its forced swimming toward the anode until relaxation of all its muscles is induced (galvanonarcosis). With prolonged exposure to DC, a second forced swimming occurs, which sends the fish into the area of highest current densities, the danger zone. Here tetany occurs, often followed by death (Lamarque 1990). If a fish is removed from the danger zone in time and allowed to recover under optimal conditions, death from tetany may be averted (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.).

Strong anodictaxis is possible with pulsed direct current. Lamarque (1990) suggests that the mechanisms of taxis are quite different for DC and PDC. PDC is produced by interrupting a steady DC current flow with an electronically controlled switch. The switch gives the number of ON-OFF pulses per second (frequency). Research has shown a species-specific reaction to frequency and pulse width. In general, pulse shapes with a fast rise and slow decay enhance anodictaxis. With PDC, no narcosis or second swimming towards the anode occurs. In the effective zone, fish are drawn more directly from a greater distance than DC toward the anode, generally becoming immobilized before reaching the danger zone.

The establishment of the perception, effective, and danger zones in AC, DC, and PDC depends on field strength, water conductivity, and electrode size. In review, DC produces galvanotaxis. inducing tetanus only near the electrode and after prolonged exposure, and is the least harmful to fish. However it has the most limited effective range and highest power requirements. PDC produces strong galvanotaxis, and has a large effective zone and greatly reduced power requirements. PDC does tend to immobilize a large portion of the catch farther away from the anode than DC. AC has the greatest effective range but little or no taxis, with the potential for tetanizing fish, resulting in the death and loss of capture.

INJURIES TO FISH

At its worst, electric fishing can kill or produce strong muscle fatigue. Normally a head to tail voltage gradient from 0.1 to 1 volts/cm of fish is required to safely collect fish with an electric current (Halsband 1967). The degree of injury depends on voltage gradient experienced across the fish's body (Stewart 1962), exposure time (Chmielewiski et al. 1973, Whaley et al. 1978), current form (Lamarque 1967), and species and size of fish (Stewart 1962, Chmielewiski et al. 1973).

The most common damage caused by electric fishing involves vertebral malformations, recovery from which is long term if not impossible. The rate of mortality following electric fishing capture has a wide range depending on the particular study. For trout mortality, rates ranged from <5% to 90% (Hauck 1949, Pratt 1954, McCrimmon and Bidgood 1965, Hudy 1985, Holmes et al. 1990, Fredenberg 1992, Newman 1992, Reynolds et al. 1992), and warm-water species ranged from 0% to 28% (Spencer 1967, Holmes et al. 1990, Newman 1992). Hauck (1949) also reported internal damage and bleeding from gill filaments in electrofished trout. Mortalities from electrofishing may be broken into two broad groups, those caused by injuries and those due to asphyxiation.

Electric fishing induces the typical changes in blood lactate levels normally observed when fish are stressed. Schreck et al. (1976) observed changes in lactate levels in the blood of rainbow trout (*Oncorhynchus mykiss*) after shocking (DC current). The lactic acid levels in the blood doubled immediately after the fish were shocked, remained high for 1 hr, and recovered to pre-shock levels after approximately 3 hr (Schreck et al. 1976).

In general AC, DC and PDC can produce mortality. The worst currents are condenser or burst form charges: AC at 50-60 Hz and 1/2 wave rectified AC at 50-60 Hz (Lamarque 1990). Currents that tend to draw fish towards the anode are least harmful. Mortality results from physical injury or asphyxiation brought on by physiological stress. The most common injuries are broken or ruptured vertebrae resulting from electrically induced, violent muscle contractions. The frequency and severity of vertebral injury is increased in spawning fish owing to decalcification (Stewart 1962). Other observed injuries include damage to internal organs and burst blood vessels in the gills and brain.

With salmonids, one can determine if vertebrae are damaged by examining the skin. Dark spots or bands will appear in proximity to the damaged vertebrae. While such marks typically represent vertebrae injury, they are not always present when spinal injury has occurred (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.). This discoloration is thought to be caused by the excitation of skin chromatophores when the sympathetic nerve fibers are damaged (Lamarque 1990). Also such discoloration could be caused by hemorrhages of damaged tissue near the skin surface; if a fish actually touches an electrode it will be burned (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.). The degree of vertebrae dislocation largely depends on the current type, water conductivity, operator ability, and exposure time. AC tends to cause breaks while DC results in compressions or misalignment of the vertebrae (Stewart 1962). Presently, numerous authors (Holmes et al. 1990, Fredenberg 1992, Reynolds et al. 1992) are closely examining the electrofishing-induced harm caused by PDC.

Physiological stress occurs when the fish has been overexposed to a tetanizing current. Death usually results from respiratory failure brought on by radical increases in fish blood lactate levels, critically reducing the oxygen carrying capacity (Black 1958, Schreck et al. 1976, Emery 1984). Once the lactic acid reaches a certain level, a fish will not fully recover. Such a fish may appear fine at release; however, it will eventually die, usually within l-3 days. The complex physiological processes experienced by fish have been investigated by (Black 1958, Black et al. 1960, Sternin et al. 1972, Schreck et al. 1976, Wood et ai ·83, Holeton and Heister 1953, Emery 1984). Emery (1984) succinctly explains these physiological processes.

In a successful electric fishing operation, an electrotaxic current is desirable, i.e., a current that attracts a fish to the anode but does not tetanize it. Some commonly used electrotaxic currents are as follows: constant DC, 3-phase fully rectified AC at 30 Hz, and PDC square wave currents at 30-60 Hz and 10-50% duty cycles, rectangular pulsed DC at 400 Hz on 10% duty cycle and Complex Pulse System (CPS™). The key to a successful electric fishing removal operation (e.g., squawfish control on the Columbia River) is flexibility in current form (AC, PDC, DC) and shape (square, sine, smooth, CPS™), and minimal harm caused to fish. An electric fishing unit must have the ability to adapt to the variable physical conditions (conductivity, water temperature, and water velocity) of a selected sampling site. Fortunately, modem commercially available electric fishing units offer such a range of electrical current parameters.

SYSTEM COMPONENTS

Basically the function of an electric fishing system is to produce an appropriate electrical stimulus in fish near the electrodes to-permit easy capture by netting or to cause fish to stay in areas where nets, trawls, or traps can be readily used (Novotny 1990). Any electric fishing system requires some minimum effective value of current density produced from the electrodes. The minimum value will vary with water conductivity, temperature, and target fish. This current level establishes the perception, effective, and danger zones in the electric field surrounding the anode.

The components of an electric fishing system can be classified into six subsystems according to function. These are (1) power supply to provide the electrical energy to the system, (2) power conditioner to condition (or modify) the raw electric energy to meet the requirements of the specific application, (3) instrumentation to provide knowledge of the electrical performance of the system. (4) interconnection systems to safely carry the conditioned power to the electrodes, (5) electrodes to properly couple the conditioned electrical power to the water, and (6) auxiliary equipment to provide the peripheral functions necessary for successful electric fishing (nets, lights, pumps, aerators, rubber gear, etc.) (Novotny 1990).

When electrofishing, it is advantageous to produce a galvanotaxic current (PDC or DC). DC generators, however, are prohibitively large for boat-based operations. A three-phase AC generator is generally preferred for most boat-based electric fishing applications because it is smaller and lighter (for the same power rating) and better suited as a supply source for most power conditioners (Novotny 1990). AC generators are more flexible in their output parameters than DC generators and, therefore, more adaptable to a wider range of fishing conditions and water conductivities.

Raw, AC-generated electric power is modified via power conditioners. The function of the power conditioner is to provide the appropriate voltage level and wave form (DC, AC, PDC, CPS™, etc. j to suit the specific electric fishing application. A major advantage of modem power conditioners (i.e., Coffelt VVP-15, Mark 22, or Smith-Root GPP 7.5) is the flexibility they afford in terms of wave form, voltage level, pulse rate, and duty cycle. This flexibility enables a single electric fishing system to be used in a wide range of applications. Modem electric fishing systems may employ a combination of transformers, rectifiers, filters, and choppers in their power conditioners.

The individual components of the electric fishing system must be electrically interconnected in order to form the complete system. The interconnection system provides the following functions: (1) the main disconnection switch between the power supply and the rest of the system, (2) circuit protection devices, preferably circuit breakers, (3) suitable meters and instrumentation, (4) appropriate safety (dead man) switches and, most importantly, (5) proper electrical bonding of the cases of all the components to each other and to any metallic parts of the supporting structures. The bonding ensures that no two external metallic parts of the entire system (including the boat or other support structures) can ever have a potential voltage between them (Novotny 1990). The interconnection system should be carefully checked by qualified personnel in order to avoid a potentially dangerous situation.

The requirements of an effective electrode system include (1) establishment of a large effective zone while minimizing the perception and danger zones, (2) flexibility to meet variable water conductivities, (3) ability to negotiate weeds, obstructions and current while producing as little physical disturbance as possible, (4) ease of safe assembly (Novotny 1990). Commonly used electrode configurations t&at incorporate these principles are Coffelt's Wisconsin Ring, Smith-Roots UAA-6, and various sphere anode arrays.

The two basic electrode shapes are spherical and cylindrical. Spherical electrodes have generally superior electrical properties but have many mechanical disadvantages. The most effective electrode arrays combine the positive aspects of both electrode shapes. Cylindrical electrodes, arranged into a circular shape, achieves this. The best example of such a design is the commercially available Wisconsin Ring array. This design utilizes the desirable properties of spherical shapes (limited perception zone, no danger zone, large effective zone), while maintaining the advantageous mechanical properties of the cylindrical electrodes (ease of negotiating obstacles, little physical disturbance, and larger overall effective range).

Two guiding principles with electrodes are (1) always use the largest electrodes possible within the limitations imposed by the physical constraints and electrical limits imposed by the generator and electrical control system (Novotny and Priegel 1974); and (2) if possible, mechanically shield the anodes so fish can not come in direct contact with them (Holmes et al. 1990).

FACTORS AFFECTING EFFICIENCY

The parameters that regulate electric fishing efficiency are numerous: choice of current (AC, DC, PDC), electrical output, electrode shape and size, turbidity, water conductivity, temperature, depth, habitat, operator ability, fish species, behavior, and size. The most important parameter under the control of the electric unit operator is choice of current. To succeed at electrofishing, one must understand the actual electrical output characteristics (voltage, current, pulse rate, etc.) expected in the field. Operators also must understand the widely varying sampling conditions and be able to control current, voltage, and pulse shape to properly manipulate the electric fishing equipment, thereby maximizing catch-per-unit-effort.

The knowledge of electrical parameters and the components of an electric fishing system must be integrated with the understanding of all the biotic and abiotic external factors affecting catch rate. The most important factors are detailed below (adopted from Lamarque 1990).

Water conductivities in fresh water are divided into three groups. Low conductivity waters, 5-30 microsiemens per cm (µS/cm), are represented by mountain streams and lakes or areas associated with high rain runoff. Medium conductivity waters range from 30-500 µS/cm; the Columbia River is of medium conductivity ranging from 80-250 µS/cm. High conductivity waters have values greater than 500 µS/cm; these are mainly estuaries, brackish lagoons, and the sea.

Different fishing strategies must be adopted for each conductivity range. Fishing low conductivity waters is difficult, but good results may be achieved by using very large electrodes (anode diameter >60 cm) and high peak voltages (800- 1,650 volts). Best results in medium conductivity waters are achieved with a combination of large anodes and galvanotaxic current. In high conductivity water, PDC (rectangular waves of either 400 Hz or 100 Hz at 10% duty cycle) and smaller electrodes are needed to reduce energy requirements (Lamarque 1990).

Fish behavior in electric fields (electrophysiology) has a measurable effect on CPUE. The physical characteristics of the sampling habitat also play an important role in determining fishing success.

Predator fish (e.g., Salmonidae, Percidae, Centrarchidae) are more easily caught than prey species. Spawning or territorial fish are less likely to be frightened out of an area, thus allowing the boat to come in close. Bottomfish and poor swimmers are relatively difficult to catch. Thick-scaled fish like carp seem to be more electrically resistant than thin-scaled fish such as trout. Many fish build up a tolerance to subsequent electric fishings. Schooling species are easily frightened out of a fisher's effective zone by physical disturbances in the water. Smaller fish have less body size for a voltage difference to develop across, making them harder to catch than larger fish. Vegetation and cover can hide stunned fish from capture.

Fishing over a gravel substrate produces the best results. Electrode contact with muddy bottoms can short-circuit the field, causing a decrease in resistance, which can lead to overloading of the generator. In strong current, tetanized fish often are not visible and, therefore, are washed away from the netters. Turbid water allows a close approach towards fish but reduces catching efficiency through poor visual contact. In general, electrofishing efficiency decreases in moderately fast waters deeper than 10 ft.

The following table summarizes the factors affecting the efficiency of electric fishing.

ENVIRONMENTAL	BIOLOGICAL	TECHNICAL
1 Abiotic	1. Community structure	1 Personnel
a. Conductivity	a. Species diversity	a. Size of crew
b. Water quality	b. Species composition	b. Experience
c. Water clarity		c. Motivation
2. Habitat	2. Population structure	2. Equipment
a. Habitat structure	a. Density	a. Design
b. Habitat dimensions	b. Size distribution	b . Maintenance
c. Substrate	c. Age structure	
d. Water velocity		
3. Seasonality	3. Species specific	3. Organization
a. Temperature	a. Behavior	a. Site selection
b. Weather	b. Physiology	b Standard effort
	c. Morphology	

(Adapted from Zalewski and Cowx 1990.)

SAFETY

Safety should be a primary consideration in all electric fishing operations. All personnel involved in electrofishing operations should be instructed as to the fundamentals of electricity, and understand and observe the safety requirements associated with electrofishing. The single most important factor in both electrofishing efficiency and safety is the training and experience of the crew. Regardless of the safety precautions given, the capability of the crew in adhering to those guidelines and good common sense in handling unforeseen circumstances, is of cardinal importance (Smith 1989). It is recommended that crew leaders attend the U.S. Fish and Wildlife Services' Fisheries Academy Course, "Principals and Techniques of Electrofishing." For further information on this course, contact Alan J. Temple, Chief Fisheries Management Training, Fish and Wildlife Service Office of Technical Fisheries Training, Route 3, Box 49, Kearneysville, WV 25430; telephone number (304) 725-8461, ext. 370.

A standard set of safety practices are listed below along with two daily field check lists concerning boat and electric fishing equipment. Safety practices should include the following (adapted from Lazauski H.G. and Malvestuto, 1990)

1. All United States Coast Guard safety equipment for the operation of a 28 ft. boat should be used.
2. Red Cross first aid and CPR training should be provided for all members of the electric fishing boat crew.
3. All members of the crew should be familiar with the electrical system of the boat.

4. All dip netters should wear rubber gloves, rubber boots, life vests and noise arresters if needed.
5. Boat operators should wear life vests, rubber boots and noise arresters if needed.
6. Electric fishing runs should be kept under 1 hr to avoid netter fatigue.
7. A strict check, via checklists, should be made of all electrical systems before each day's work in the field.
8. All fishing should cease at the first sign of lightning, rain, high winds, or dip netter fatigue.
9. Alcohol should never be allowed on an electric fishing boat.
10. Never touch the water or an electrode while the current is on.
11. Refuel the generator after engine has sufficiently cooled.
12. The boat driver should not make sudden turns or changes in boat speed.
13. No unauthorized passengers should ever be allowed on an electric fishing operation.
14. Know the range of your electric field. Avoid public recreation areas. Do not electrofish near people or animals.
15. Avoid all unprofessional conduct (horse play).
16. Carry appropriate spare equipment for the particular boat.
17. Carryafirstaidkit.

Check lists should be developed for all phases of electric fishing operations. These should include items that are used daily, such as boat launching and electrical connections. An example of an electric fishing boat unit inspection sheet is given in Table 1.

A detailed instruction guide or manual should accompany each electric fishing apparatus to assist the operator. The operator should be familiar with both the unit and manual before fishing begins. A log book should also be available to record dates and times of use, maintenance, problems, and repairs.

An important emergency procedure is to have a pre-determined plan in the event of an accident. A documented route to medical facilities and procedures to follow is essential.

These safety procedures should be adhered to by all project personnel at all times. The safety check list and log book should be filled out every day. Also, all operational parameters (control box settings and meter readings) should be recorded with field data and any observations of abnormal appearance, behavior, or mortality. This data will help refine parameters for future trips, avoid undesirable effects, and add to the data base on such effects (D. Snyder, Colorado State Univ., Ft. Collins, pers. comm.). All members of the fishing crew should be familiar with the checklist material and compliance procedures.

Table 1. Daily check sheet for electric fishing boat safety inspection (adapted from Goodchild 1990).

Boat #____________________ Date____________

Crew leader____________________ Time____________

Crew members____________________

Location____________________

Log Book up to date Y/N

Manual present Y/N

BOAT

__ Hull integrity
__ Safety railings intact and sturdy
__ Decks clean, free of excess water/bilges dry
__ Adequate mechanical protection of wiring
__ Adequate connectors and interlocking (integral with hull;
__ All metal equipment in boat electrically bonded to hull (check with volt/ohm meter)
__ Batteries fully charged-properly enclosed and vented
__ Communication gear working (where applicable)
__ Boat clean-equipment neatly stored
__ Auxiliary motor present and working (where applicable)
__ Oars/paddles present
__ Anchors/bailers present
__ Controls and gauges operational
__ hv output checks done
__ Adequate mechanical protection of wiring
__ Audible tone generator working
__ hv flashing light working
__ All foot switches working
__ KILL SWITCH' working
__ Operators safety switch working

GENERATOR/ALTERNATOR

__ Unit electrically bonded/connected to hull
__ Exhaust directed away from operator
__ All electrical connections secure and protected
__ Oil level O.K.
__ Gas topped off

BOATMOTOR

Inboard

__ Oil level O.K.
__ Components secure
__ Belts O.K.
__ Visual inspection O.K.
__ Proper venting of exhaust
__ No gas leaks
__ Auxiliary motor working
__ Bilge blower working

Outboard

__ Fastened securely-safety chain
__ Adequate gas supply

ANCILLARY EQUIPMENT

__ Fire extinguisher present-fully charged
__ First aid kit and flash light present
__ Communication gear working
__ Lights working

PERSONNEL/CREW MEMBERS

__ Each crew member briefed on boat operations
__ Minimum number of crew trained in CPR and basic electronics
__ Crew wearing PFD's
__ Crew wearing rubber gloves (long arm)
__ Crew wearing rubber boots
__ Crew weanng protective hearing gear
__ Each crew member has a dead man switch
__ Safety procedures covered
__ Local arrangements covered, i.e., police, erc
__ Hospital route outlined

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ELECTROFISHING GLOSSARY*

GENERAL

Alternating current: cyclic current, the mean value of which is nil during a total period. An alternating current is characterized by a sequence of positive and negative waves that are equal, usually sinusoidal, and follow each other alternatively at regular time intervals.

Anode: the positive electrode, usually hung from a boom extending away from the electrofishing vessel.

Aperiodic impulses: impulses following each other at varying time intervals.

Bonding: the permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity, with the capacity to safely conduct current.

Branch circuit: the circuit conductors between the final overcurrent device protecting the circuit and the electrical load(s).

Cathode: the negative electrode, usually located on the hull of the electrofishing vessel.

Circuit breakers: a device designed to open and close a circuit by a non-automatic means, and to open the circuit automatically on the predetermined overcurrent without damage to itself when properly applied within its rating.

Complex pulse system (CPS™): a complex pulse train or burst form of pulsed direct current by Coffelt Manufacturing, Inc., developed in response to recently detected high mortality rates caused by commercially available PDC wave forms.

Condenser discharges: current composed of a steady sequence of exponential discharges

Conductivity: the ratio of the density of the unvarying current in a conductor to the voltage gradient that produces it; the common unit of measurement is the µsiemen/cm = µmhos/cm.

Conductance: the measure of the ability of a component to conduct electricity, the reciprocal of resistance: the unit of measurement is the siemen (mho).

Current: the rate of electrical charge flow in a circuit; the practical unit is the ampere (amps), which is one coulomb per second.

Current shape: the geometric shape of the current during one cycle; usually this refers to the rate of growth and decay of an impulse.

Cycle: one full revolution of a periodic phenomenon.

Deadman switch: a switch that requires constant pressure to supply electrical current to the circuit.

Direct current (continuous, galvanic): unidirectional constant current.

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*Adapted from Cowx. I G. and P. Lamarque. 1990. Fishing with Electricity. Applications in Freshwater Fisheries Management; and Koltz, A K 1989 A Power Transfer Theory for Electrofishing

Effective fish conductivity: the apparent conductivity of live fish as determined by statistically fitting electroshock response data to the theoretical curve developed for the concept of constant power.

Electrical charge: a fundamental property of matter that can be classified as a fundamental physical quantity; the practical unit is the coulomb. The electron, the smallest charge identified in nature, has a magnitude of 1.6 x 10-19 coulomb.

Electrofishing: the use of electricity to provide a sufficient electrical stimulus in fish to permit easy capture by netting.

Frequency: total number of cycles per time unit measured in hertz; 1 Hz equals one cycle per second.

Ground: a conducting connection between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

Half-wave rectified current: current composed of a sequence of half sine waves in the same direction, separated by pauses of equal duration. This is obtained by passing an alternating current through a rectifier.

Impulse: electric phenomenon of short duration compared with the period.

Interrupted direct current: unidirectional current interrupted by periodic pauses. See pulsed direct current.

Isolation transformer: a transformer inserted into a system to separate one section of the system from undesired influences with other sections.

Mismatch ratio: the ratio of either the two resistance values or two conductivity values deter-mined for adjoining media. For electrofishing, this is the ratio of conductivity of the water to the effective conductivity of the fish.

Multiphase current: the number of phases, the whole of n being alternating currents originating from the same source and out of phase with each other by 1/n of a period (1/3 of a period with three phase current).

Netter: the individual who nets the captured fish during electrofishing operations.

Pause duration: interval between two electric phenomena.

Period: time interval between two identical stages in an electric sequence.

Power: the rate of doing work or the energy-per-unit-of-time; the practical unit is the watt (W), which is one joule per second.

Applied power: incidental power at an electrical interface separating two mediae.

Constant transferred power: the constant value of transferred power desired under all conditions of mismatch.

Maximum output power: the maximum available power delivered to an external load from a power source having an internal resistance equal to that of the external load.

Reflected power: the portion of applied power that is not transferred to the second medium

Transferred power: the portion of applied power transferred from the first medium to the second medium.

Power control circuit: the circuit that interconnects and adjusts the power from the pulsator or generator to the electrodes.

Power density: the power or energy-per-unit-of-time dissipated in a given volume of material. The unit measurement is watts per cubic centimeter (W/cm^3).

Applied power density: power density available for transfer to a fish at a particular location in the water.

Power density in fish: the desired constant value of power density to be transferred to a fish, Also, the threshold of in vivo power density required to produce a specific electroshock response at a specific conductivity.

Pulse duration (pulse length): duration of an impulse.

Pulsed current (pulsating AC **or DC):** unidirectional current composed of a sequence of cyclic impulses.

Quarter-sine wave current: a special kind if current electronically obtained from alternating current, usually from V-max to zero.

Rectified alternating current: current composed of an uninterrupted sequence of half sine waves in the same direction, and obtained from an alternating current by means of a four-way bridge rectifier. Also called, full-wave rectified current.

Resistance: the ability to react to the flow of AC or DC with an opposition to the flow of current. Also, the ratio of the applied voltage to the induced current that it produces; the unit of measurement is the ohm.

Resistivity: the reciprocal of conductivity; the common unit of measurement is the ohm-cm.

Smooth rectified current: direct current derived from alternating current by using rectifiers and a suitable capacitance inductance filter. When insufficiently filtered, the current shows weak sinusoidal variations and is called 'partly smoothed rectified current,' or ripple current, or undulating current.

Square wave (syn. rectangular pulses): cyclic waveform with steep rise and fall time, with flat top and bottom.

Variable voltage pulsator electroshocker: the device used to deliver the pulsed electric current.

Volts or Voltage: the energy-per-unit-of-electrical-charge; the volt (V) is the unit of measure where one volt is one Joule per coulomb.

Voltage gradient: the rate of change of voltage with distance. Also, the force-per-unit-of-electrical-charge; the common unit of measurement is volts per centimeter (V/cm).

ELECTRIC FIELD CHARACTERISTICS

Anode (or cathode) field: in electric fishing, field around the electrode beyond which the values of potential gradient are unimportant.

Conductivity (of water): conductance of 1 cm^3 of water. Conductivity is the inverse of resistivity.

Critical zone of current density: in electric fishing, current density area around the electrode in which a fish is shocked.

Current lines (flow lines, equiflux): imaginary lines that represent direction of current flow perpendicular to equipotential surfaces.

Density (of current): current intensity passing through one unit of cross-sectional area perpendicular to the current lines of an electric field.

Equipotential surface: a surface on which all points are at the same electrical potential. Equipotential surfaces are perpendicular to the direction of the current flow.

External resistance: electrical resistance between electrodes.

Heterogeneous field: field in which current density and potential gradient decrease as a function of the distance from electrodes.

Horizontal field: see vertical field.

Isolines: lines of equal potential gradient.

Moving field (syn. movable field): field in which surfaces of equal relative potential (related to the supply voltage) are displaced as a function of time (rotating field, intersecting field, etc.).

Potential gradient: potential difference in an electric field-per-unit-length on the direction perpendicular to the equipotential surfaces; this gradient is measured in volts per centimeter (V/cm).

Resistivity (of water): resistance of 1 cm^3. Resistivity is the inverse of conductivity.

Stationary field: field in which surfaces of equal potential (related to the supply voltage) are steady.

Vertical field: field in which the potential gradient is lower on a ground plane than on a vertical plane, so that a fish swimming horizontally into the field will be subject to a body voltage much lower than if the field were horizontal itself at the same distance from the electrode.

BEHAVIOR AND PHYSIOLOGY

Anelectrotonus: decrease of nerve excitability on the anode side.

Anodic (cathodic) curvature: curving of the fish body towards the anode (cathode) under the influence of a unidirectional current, when the fish is perpendicular to the current lines.

Ascending current: according to conventional direction of current (from + towards -), electric current ascending into the system from the periphery towards the fish nervous centers, occurring when the fish is facing the cathode.

Autorhythm: excitability of nerve and muscle provoked and sustained by a constant continuous current.

Body voltage: measured potential difference between head and tail of a fish in an electric field.

Catelectrotonus: increase of nerve excitability on the cathode side of a shocked fish.

Closing of the circuit reaction: nerve or muscle excitation produced by closing the circuit

Descending current: electric current going down into the system from nervous centers towards the periphery (see ascending current), as in the case of fish facing the anode.

Electrotaxis: fish swimming induced by any kind of electric current

Fixation: state of immobility of fish resulting from tetanus under the action of electric current, distinct from galvanonarcosis.

Forced swimming (first swimming towards the anode): a very fast swimming motion towards the anode, induced by a constant current.

Frightening effect: fish escape from an electrode under the action of current.

Galvanonarcosis: state of immobility of fish resulting from muscular slackening, under pulsating direct current.

Inhibition of swimming: slowing down of swimming movements; produced by a low and constant continuous current when a fish faces the anode.

Narcosis: state of immobility resulting from muscular slackening.

Opening of the circuit reaction: nerve or muscle excitation produced by opening the circuit.

Oscillotaxis: swimming artificially induced by an alternating current.

Pseudo-forced swimming (second swimming towards the anode): out of balance swimming produced by a strong and constant continuous current. Occurs when a fish faces the anode.

Rheobase: minimal intensity of current indefinitely maintained to release the excitation of nerve of muscle.

Spatial summation: cumulative effect produced on a neuron by means of several simultaneous stimuli.

Taxis: artificial swimming induced by a stimulating agent.

Temporal summation: cumulative effect produced on a neuron by a series of stimuli.

Tetanus: state of muscular rigidity.

Threshold: minimal value of current parameter inducing a determined reaction

Useful time: minimal time during which an electric current of a given value must be maintained to produce an excitation.

ANNOTATED BIBLIOGRAPHY

The following paper provides a review of current literature in electrofishing. Seventy five entries are indexed into four broad categories: (1) effects of electric fields on fish response and electrofishing efficiency (effects(E)), (2) gear design, construction and operations (techniques(T)), (3) applications, sampling design and analysis (applications(A)), and (4) safety, regulations and guidelines (safety(S)). A paper listed in one category often covers material that overlaps into another. This bibliography was prepared for a review of the existing electrofishing literature as it might pertain to our ensuing northern squawfish control efforts on the Columbia River. This work is intended to serve only as a quick reference and/or review, and not as a replacement to any of the cited literature.

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Adams, W.J., D.J. Behmer and W.O. Weingarten. 1972. Recovery of shocked common shiner, *Notropis conutus*, related to electric energy. Trans. Am. Fish. Soc. 101(3):553-555.

Common shiner (*Notropis conutus*), physiology, electrical parameters, pulsed direct current, electric fishing.

The time necessary for electroshocked fish to recover swimming equilibrium (recovery time) was evaluated for the common shiner under the controlled conditions of the laboratory. Halsband (1967) and Lamarque (1967) both established that it is the 'head to tail' potential voltage drop that determines just how much applied electric energy an electroshocked fish is actually exposed to. Larger fish experience more current through their bodies. Electric fishing is size selective and has a more pronounced effect on larger fish.

Adams et al. showed that after treatment with pulsed direct current (15 seconds duration), longer fish (total length) experienced a longer recovery time and greater mortality than similarly exposed shorter fish, Recovery time for all fish increased with an increase in exposure time to the current. Twenty-four hours was the suggested time necessary for a full physiological recovery in the laboratory. In the field it is suggested that retained electroshocked fish be held out of the applied electric field for minimum time needed to regain their swimming equilibrium, before release.

An attempt was made to establish which variable (voltage drop, current, duration. or power density) could be used to best define an expected electrical stimulus in fish. It was suggested that power density,

Power Density = E^2 / R x (Volume of a Fish)

E = Voltage and R = Resistance,

may be a more meaningful measure of experienced electrical stimulus than potential voltage drop.

The physiological effects to incidentals (salmon, walleye, and sturgeon) of electrofishing for squawfish in the Columbia River should be evaluated. The recommended observation period is from 24 to 72 hours. As long as practicality allows, non-game incidentals (sculpins. peamouth, suckers, etc.) should be held in electrically isolated holding tanks, at least until swimming equilibrium has been re-established, so as to reduce the loss of lethargic fish to predators. Unfortunately, the limitations of holding space and sampling time may greatly restrict this activity.

Amiro, P.G. 1990. Variation in juvenile Atlantic salmon population densities between consecutive 'enclosed sections of streams. Pages 96- 101 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), Nova Scotia, electric fishing, hand-held electrode, Coffelt VVP-2C, barrier nets, modeling.

The homogeneity of juvenile Atlantic salmon densities was tested for consecutive sections of wadeable streams. Densities were generally heterogeneous between sections for all size or age classes. This paper suggests that larger sampling areas and consolidating effort to suitable locations within an area (habitat pro-rating) may be required for meanmgful comparisons of inter-site or inter-river fish densities.

Although the target species and sampling habitat detailed within are unique, the sampling procedures suggested here may also be employed in the removal of Columbia River squawfish.

Armstrong, M.C. and J.H. Mundie. 1983. Floating fish shocker. Prog. Fish Cult. 45(4):236-237.

Coho salmon (*Oncorhynchus kisutch*), Nanaimo, British Columbia, electric fishing, fish culture, habitat improvement.

This short paper describes construction and operational specifications for a floating fish shocker proven suitable for removing fish from channels and raceways. The shocker consists of a hand-held switch, 12 aluminum dropper electrodes suspended from an aluminum pipe made buoyant by six Styrofoam net floats, and a flexible ground electrode of four lengths of copper pipe, each one meter long.

This equipment could prove to be useful as an auxiliary piece of collection gear. The floating shocker could be used in areas inaccessible to an electric-fishing boat. It could also be used in collecting juvenile lampreys for squawfish longline bait.

Balayave, L.A. 198 1. The behavior of ecologically different fish in electric fields. II. Threshold of anode reactions and tetanus. J. Ichthy. 21: 134- 143.

Baltic Sea, Black Sea, behavior, anodic reactions of various ocean fishes.

The behavior of 18 Black Sea and 4 Baltic species of fish in an electric field of rectified current was investigated. The fish were divided into three behavioral groups, strong anodic reaction (galvanotaxis), intermediate galvanotaxis, and no galvanotaxis. Galvanotaxis was characteristic of active swimming fishes. Sessile or bottom fish responded to the applied electric current by trying to hide or burrow into the bottom. The behavioral responses of the intermediate group, which consisted of active, migrating, and bottom species, were more difficult to label.

This paper concludes: (1) the presence or absence of galvanotaxis depends on the ecological stereotype of behavior; (2) irrespective of the presence or absence of galvanotaxis, all species can distinguish the anode from the cathode, preferring the anode; (3) narcosis or tetanus does not depend on the orientation of the fish in the electric field, but rather on field intensity.

This paper provides useful insight into the behavior of fish within a field of rectified current. Electrofishing for squawfish will employ various forms of rectified electric current. Squawfish may be classified as an active species. It is expected that squawfish will show strong galvanotaxis to an appropriately applied field. greatly increasing our catch potential,

Bird, D. and I.G. Cowx. 1990. The response of fish muscle to various electric fields. Pages 23-33 *in* I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Rainbow trout (*Oncorhynchus mykiss*), roach (*Rutilus rutilus*), European eel (*Anguilla anguilla*), physiology, electric stimuli, muscle stimulation, fatigue, inter-specific and intra-specific variability.

Electric fishing is a well-established technique for sampling fish populations in freshwater. Recently, the applications of methods to improve the efficiency and accuracy of the technique have received considerable attention. These developments. however, have been hindered by an incomplete understanding of the precise effects of electric fields on fish (electrophysiology).

In this study. the response of fish musculature to direct electrical stimulation was investigated. Individual variability in contractile performance was high in muscle preparation for each of the species tested. Nega linear relationships were found between fatigue resistance and pulse frequency for the three species examined. Therefore, the longer a fish is exposed to high-frequency current, the greater the chances are of that fish becoming tetanized, permanently damaged, and lost to a collection effort.

Bowles, F.J., A.A. Frake and R.H.K. Mann. 1990. A comparison of efficiency between two electric fishing techniques on a section of the River Avon, Hampshire. Pages 229-235 *in* I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Roach (*Rutilus rutilus*), coarse fish populations, Hampshire, United Kingdom, electric fishing, hand-held electrodes, boom-boat, stop nets, modeling, efficiency and cost comparisons.

A pilot survey was carried out to assess the most suitable electric fishing technique for a fish population study of the Hampshire Avon in the United Kingdom.

The initial technique was to adapt the traditional electric fishing boat technique by using three boats fishing in tandem downstream with two hand-held anodes on each, and to conduct a four-catch depletion survey. This method produced very low catches of fish. Catch efficiency was assessed by introducing a known marked population into an isolated section of stream and then fishing them.

This paper compares the catch rate and population estimates produced by the 'three boat' method on a known population of roach, with a second trial on the same section using boom-mounted equipment. The labor and equipment costs of each are compared.

The 'three boat' technique recaptured 11% of the 570 introduced roach after four catches. The boom boat caught a greater percentage of the stocked fish, 36% after three. runs. Both methods of capture underestimated population size. The mean percentage caught was 3% for the 'three boat' and 13% for the boom boat. The boom boat was later chosen for the main survey since it caught a larger proponion of the introduced fish, gave a more accurate population estimate. and was more cost effective.

The squawfish removal effort on the Columbia River will employ boom-mounted electric fishing boats. The multi-anode arrays described in this paper differ in that the anodes are arranged in a straight line equidistant along the boom. For our effort, two Wisconsin Ring arrays, or Smith Root UAA-6 dropper arrays, will be used.

Cave, J. 1990. Trapping salmon with the electro-net. Pages 65-69 *in* I.G. *Cowx,* ed., Developments in Electric Fishing. Oxford: Sport Fishing News, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), electric gear, electric fences, electric fishing, fish culture, habitat improvement, comparison of catch methods.

An electric trammel net was developed to catch Atlantic salmon (*Salmo salar*) of Tyne River origin for stripping and rearing at a hatchery. The resultant progeny were restocked to replace the anticipated juvenile losses caused by a hydrodam. With constant modification, the catch-per-unit-effort (CPUE) of the equipment increased sixteen times in four years. Rod catches per season improved five times in the same period. An increase of salmon on the spawning fjords was related to improvements in the estuaries' water quality.

This paper shows that the addition of electricity to some existing fishing gear increases those gears' efficiency. In future investigations on the Columbia, the CPUE of purse seining and Merwin Traps for squawfish could possibly be increased if so modified.

Cowx, I.G., A. Wheatly and P. Hickley. 1988. Development of boom electric fishing equipment for use in large rivers and canals in the United Kingdom. Aquacult. Fish. Manage. 19: 205-712.

Fishing gear research, fishery surveys, canals, rivers, British Isles, electric fishing.

The construction of a multiple-electrode fishing boom is described. The efficiency of the equipment was compared with more conventional hand-held electric fishing equipment and seine netting in a series of field trials.

The boom electric fishing equipment with a direct current output produced more consistent catches and is considered to be a good cost-effective method for sampling large slow-moving bodies of water. Hand-held electrodes are limited in their horizontal and vertical effective range. Seines were of limited use because of excessive current (>1 m/s), underwater obstacles, and large manpower requirements.

Multi-electrode boom arrays have been developed to overcome the problems associated with sampling large rivers and canals. Boom fishing is common practice in the United States. The results from this investigation show that the boom-mounted, pulsed direct current equipment caught 48.4% of a known population, compared with 24.6% for hand-held gear. Three advantages of boom fishing were low cost, increased maneuverability, and greater CPUE. This gear, however, still underestimated the known population size by 25.6%.

Cowx, LG., G.A. Wheatly, P. Hickley and A.S. Starkie. 1990. Evaluation of electric fishing equipment for stock assessment in large rivers and canals in the United Kingdom. Pages 34-40 in I.G. Cowx. ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publication Ltd.

Roach (*Rutilus rutilus*), electric fishing, multiple-electrode fishing boom, hand-held electrodes, assessment of efficiency of equipment under varied conditions.

In order to efficiently sample large rivers, canals and lakes in the United Kingdom. a cost-effective approach to boat-based electric fishing, similar to that used in the United States by Novotny, was developed. The Cowx boom differs from Novotny's Wisconsin Ring in that it is composed of ten pendant anodes spaced equidistant along a nine-meter boom made of reinforced polyester hydroglass tubing.

To overcome the excessive power demands required to fish high conductivity waters (>800 mhos), a pulsating direct current (PDC) control box was developed. It fires up to ten electrodes. energizing one at a time, beginning outward and progressing inward. This sequential firing system presents the electrode array as a single elongated anode with a field of more than nine meters. This system can successfully fish waters with conductivities of more than 4000 mhos. There may be some inadequacies to this system when it is used in very fast, deep, and wide rivers.

The squawfish removal effort will use commercially available equipment from either Smith-Root Inc. or Coffelt Manufacturing. This gear owes much to Novotny's original work.

Cowx, I.G. 1990. Developments in electric fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Physiology, fishing gear, CPUE, sampling, modeling, electric screens, safety, electric fishing

A symposium 'Fishing With Electricity' was hosted by the Humberside International Fisheries Institute in Hull, England, 12-16 April 1988. The objective of this symposium was to advance the scientific basis of electric fishing and provide a medium for the dissemination and exchange of ideas. The main symposium was attended by 128 delegates from 23 countries. Fifty-five papers were organized into seven sessions. The presentations demonstrated that electric fishing has advanced considerably in equipment technology, safety, and sampling design; however, it has remained static in our understanding of electrophysiology. the response of fish to electric currents and factors affecting the efficiency of electric fishing.

This text contains forty-two selected papers from the symposium, and, along with its complement, Developments in Electric Fishing, should be considered a primary reference source and required reading for any electric fishing project.

Cowx I.G. and P. Lamarque. 1990. Fishing with electricity; applications in freshwater fisheries management. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Physiology, fishing gear, electric parameters, modeling, electric gear, electric screens, electric fishing, safety, text on the theory and applications of electric fishing.

In April 1988 the European Inland Fisheries Advisory Commission (ELFAC) held a symposium to analyze and evaluate the many improvements and applications of contemporary electric fishing in Europe and the United States. The results of this symposium are available in the form of two new books, Fishing With Electricity and Developments in Electric Fishing. Both texts should be required reading for any electrofishing personnel.

Fishing With Electricity details the following: Electrophysiology of fish in electric fields. electric fishing apparatus and electric fields, factors affecting the efficiency of electric fishing, electric fishing for sampling and stock assessment, electric screens and guides, electric fishing and safety, electric fishing in practice, and the future of electric fishing.

Cross, D.G. and B. Stott. 1975. The effect of electric fishing on subsequent captures of fish. Journal of Fish Biology 7:349-357.

Roach (*Rutilus rutilus*), gudgeon *(Gobio gobio L.)*, Great Britain, modeling, bias in electrofishing population estimates.

This paper addresses the question of decreased catchability experienced during a series of replicated electric fishing passes and the resulting negative bias in various catch depletion population estimates. The experiments conducted clearly showed electrofishing can cause a decrease in catchability so that second and subsequent catches are made from reduced populations. This fact violates the equal catchability assumption associated with catch depletion methods, resulting in seriously low population estimates. The authors provide a method for adjusting population estimates for this factor of decreased catchability.

Dwyer, W.P. and D.A. Erdahl. 1992. Effects of electroshock voltage, wave form, and frequency on trout egg mortality [Abstract]. Page 13 *in* Western Division of The American Fisheries

Society, July 13- 16, 1992, Colorado State University, Program abstracts [Annual meeting]. American Fisheries Society, Western Division, Fort Collins, Colorado.

Rainbow trout (*Oncorhynchus mykiss*), eggs, injury, mortality, electrofishing, Montana, DC, PDC, Coffelt Pulsed System (CPS).

This study raises the question of how much incidental harm is being done to salmonid eggs while in the redd if an electrofishing operation passes over them. Tests with trout eggs have shown that electrofishing may be having more detrimental effects than previously thought. When shocking over redds. it was shown that eggs in the laboratory can be killed during the sensitive period by electroshock. Tests in the field yield similar results. This paper reports the results of testing and defining the effects of continuous DC, PDC and CPS. at different voltages. Electrofishing should be avoided in spawning areas of any species of fish. The levels of incidental harm to eggs, larval and weakened adult fish. are too significant.

Edwards, J.L. and J.D. Higgins. 1973. The effects of electric currents on fish. Final Technical Report. Projects B-397, B-400 and E 200-301. Game and Fish Division, Department of Natural Resources. Atlanta, Georgia. 75 p.

Channel catfish (*Ictalurus punctatus*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), bowfin (*Amia calva*), behavior, electric field, teleostean, controlled conditions.

To improve the effectiveness of electrofishing techniques, an investigation into the physiological mechanisms responsible for the reaction of fish to electric currents of various types was performed. It is clear that the responses often involve the sensory and motor nerve system, but the mechanisms are complex and not completely understood.

Pulsed direct current at low current densities produces agitation or fright. At higher current densities, the fish move involuntary toward the anode. At still higher densities the fish are immobilized. If alternating current is used. there is no tendency to swim toward either electrode, and fish tend to take up a transverse orientation between the electrodes. At sufficiently high current levels the fish are immobilized.

This study had two goals: to investigate the possibility of selectively affecting a particular species or size of fish by choosing the appropriate wave form and other electrical parameters, and to investigate the possibility of reducing average power requirements through the use of pulsed shapes and frequencies to which fish exhibit a particular sensitivity.

Pulsed direct currents were the most effective at inducing temporary immobilization of fish. Rectangular and exponential pulse shapes were tested at frequencies up to 200 pulses per second (burst form). Various wave forms were compared at the value of peak field strength required to immobilize 75% of a similar group of fish. Twelve different wave forms were tested on six groups representing four species. No species variation could be discerned. The data showed that larger fish are generally more susceptible to electric shocks than small, because larger fish intercept more current.

Three techniques were demonstrated to be effective in reducing the required average power: reduction of duty cycle. use of exponentially decaying pulses, and periodic interruption of the pulse trains. Power reductions of' 92% to 99% as compared with those required when using continuous DC were demonstrated.

Eloranta, A. 1990. Electric fishing in the stony littoral zone of lakes. Pages 91-95 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Bullhead (*Cottus gabio*), burbot (*Lota lota*), oligotrophic lakes, Finland, sampling, electric fishing.

The fish populations of stony littoral areas have been poorly known until recently. Although this habitat is quite open and easy to approach, the small size, night activity and benthic behavior of fish found there have made it difficult to use conventional capture methods. This paper deals with fishing strategy, effects of different catching conditions and results achieved from DC electric fishing in the Finnish Lake District.

Direct-current electric fishing worked well for catching night-active bottom-feeders from the stony littoral zone. Ideal conditions were when the weather was calm and light with few shadows or reflections on the water, shallow depth (< 1 M), good water clarity, a homogeneous gravel bottom, gently sloping shore and the lack of vegetation. Stop nets were used, but shown to be unnecessary; on average, less than 3% of the total catch migrated in or out of the sampling area.

Direct current worked well in low conductivities (30 to 50 μhos). Temperature ranged from 4 to 14 degrees Celsius. Moderate winds (5 to 7 m/s) disturbed fishing, especially on deep and exposed shores, and high waves made fishing impossible. Fishing was abandoned during ram.

This paper details procedural aspects that would be important to any electric fishing operation.

Eloranta, A., E. Jutila, and S. Kanno. 1990. Electric fishing and its safety requirements in Finland. Pages 340-343 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Safety, fishery research, electric fishing, fishery technology, Finland.

Finnish tradition in electric fishing is short. The method was not established in Finnish fisheries until the 1970s. This paper presents a review of the shortcomings observed in the electric fishing method and suggests some improvements.

In 1987, there were over forty electric fishing units operational in Finland. The majority were DC units powered by 0.5 - 2.0 KVA generators. All systems were made in Nordic countries, most less than ten years old. Most electrofishing was in small streams and rivers with backpack units.

Legal requirements of electric fishing are detailed along with a list of suggestions for improving fishing methods, with regard to electrical and other equipment and operating procedures. This list should be reviewed and used with the similar safety guidelines from Hickley (1990), McLean (1990) and Lazauski (1990) in order to produce a set of standard operating procedures for fishing with electricity.

Frankenberger, L. 1960. Applications of a boat-rigged direct-current shocker on lakes and streams in west central Wisconsin. Prog. Fish Cult. 22: 124- 128.

Walleye (*Stizostedion vitreum*), Wisconsin, aquaculture, fishing gear, electric fishing, applications of experimental gear.

Many of the problems associated with AC electric fishing (stunning of fish out of sight, physical harm or death, high power requirements) may be overcome by using PDC to achieve electrotaxic effects on fish. The boat-rigged direct-current shocker described in this paper was effective because the fish are attracted to the grid suspended just below the water, This unit was developed primarily for use as a sampling and cropping device in walleye rearing ponds.

Detailed construction and operational specifications are given for an experimental pulsed DC boom-boat shocker. Much of this information is still applicable to a present-day electric fishing operation.

Fredenberg, W. 1992. Evaluation of electrofishing-induced spinal injuries resulting from field electrofishing surveys in Montana. Montana Dept. Fish, Wildl. Parks.

Electrofishing, PDC, rainbow trout (*Oncorhynchus mykiss*), injury mortality, Montana.

This paper, along with Holmes (1990), addresses the issues of potential electrofishing-induced injury that were raised by Sharber and Carothers' (1988) work. About nine hundred fish were examined during this research. Sampling was designed to evaluate the differences in injury rates due to various factors, including variability in electrical wave forms and electrofishing methods, as well as species and size of fish. The two primary wave forms compared were 60 Hz square PDC and smooth DC (Coffelt VVP15). Substantial evidence demonstrated that 60 Hz PDC results in excessive injury rates to both rainbow trout (60-98% injury) and brown trout (44 62% injury). regardless of wave form (rectified sine-wave). water conductivity (33-900 mhos/cm), and equipment design variables. Limited sampling of Arctic grayling, sauger. and shovelnose sturgeon did not reveal spinal injury problems with these species. A discussion of electrotishing efficiency and proposed guidelines for minimizing spinal injury are included.

Because of the unacceptable high injury rates to salmonids, all electrofishing with PDC 60Hz square wave has been halted in Montana. This same method of electrofishing has been used extensively in the Columbia River for population indexing, and the removal of northern squawfish. The results reported by Sharber and Carothers (1988), Holmes (1990). and Reynolds (1992) will need to be evaluated and applied to the ongoing northern squawfish electrofishing work on the Columbia River. In 1993, the University of Washington will propose to evaluate electrotishing-induced harm on resident fish.

Gatz, A.J., Jr and S.M. Adams. 1987. Effects of repeated electroshocking on growth of bluegill x green sunfish hybrids. N. Am. J. Fish. Manage. 7:448-450.

Hybrid sunfish, bluegill (*Lepomis macrochirus*) x green sunfish (*Lepomis cyanellus*), physiology, laboratory, electrofishing, DC backpack electrofisher.

Gatz et al. (1986) reported that 2 to 7 exposures to electroshocking within a 12-month period significantly reduced the growth rate of wild rainbow trout. This follow-up paper showed that similar results could be obtained with hybrid sunfish (bluegill x green sunfish) that were electroshocked in the laboratory over a three-month period.

Hybrid sunfish that were shocked once a week for three months experienced a reduction in average growth rate as compared with less frequently shocked fish and unshocked fish. The reduced growth in the frequently shocked fish was attributed to fish having to expend a greater portion of their total energy reserves for tissue repair and respiration. Gatz et al. (1986) reported that the reduction in growth of wild rainbow trout was due to behavioral interactions between shocked and unshocked trout. Unshocked fish were able to dislodge shocked fish from prime feeding areas. Shocked fish tended to seek cover and show no interest in feeding following electroshock.

Repeated exposure to the voltages necessary to capture fish in the fieid will induce some negative behavioral and physiological response, the severity of which depends on the quality and amount of a particular electrotishing effort. habitat quality, food availability. and species of fish in question. Gatz suggests that repeated electrofishing at intervals of less than three months may be harmful to some species of fish.

Gatz, A.J., Jr., J.M. Loar, and G.F. Cada 1986. Effects of repeated electroshocking on instantaneous growth of trout. N. Am. J. Fish. Manage. 6: 176- 182.

Rainbow trout (Oncorhynchus mykiss), brown trout (Salmo trutra), North Carolina, Tennessee, small streams, population estimates, growth, backpack electrofishing, PDC.

Electroshocking is a commonly used method for collecting fish in streams. Many fisheries management studies employ techniques that require multiple captures of fish. This paper explored the non-lethal side effects of repeated exposure to electroshocking and the possibility of any bias in population estimates that may result.

Instantaneous growth rates were calculated for age I+, 2+, and 3+ wild rainbow and brown trout. The growth rates of individual trout that had been electroshocked 2 to 7 times within a 12-month period were shown to be lower than the average growth rate of similar age class unshocked fish. The reduced growth rates were attributed to fish expending energy reserves to repair damaged tissue, physiological and behavioral responses to handling stress, and especially, fish experiencing a loss of stamina (Horak and Kline 1967) resulting in shocked individuals being pushed out of prime feeding habitat by competing unshocked similar-sized trout. Decrease in growth rate happened more often and to a greater extent in age I+ and 2+ trout than those 3 and older, and more frequently among trout that had been electroshocked within the last two and a half months than among trout that had three or more months to recover from their last electroshock.

The results reported here are of practical significance to fisheries studies that estimate growth of production in streams from a series of collections obtained by electrofishing. Researchers should be aware that their results could be negatively biased if more than a small fraction (e.g., >20%) of the total population is shocked repeatedly. Bias will be greatest on younger age classes. To avoid bias it is recommended that repeated electrofishing occur at intervals of greater than three months.

Hauck, F.R. 1949. Some harmful effects of the electroshocker on large rainbow trout. Trans. Am. Fish. Soc. 77:61-64.

Rainbow trout (Oncorhynchus ***mykiss),*** morphology, physiology, fish dissection, fisheries management, electric fishing.

The use of the electric shocker in the salvage of rainbow trout from an irrigation canal is described. An account is given also of physiological effects observed during shocking and the morphological effects determined by dissection.

Dissection of some specimens disclosed fractured vertebrae, ruptured arteries and veins, hemorrhaging, death of tissues, curvature of the spine, and extreme dilation of blood vessels in various parts of the body, including the brain.

Power was supplied via a portable gas-powered generator of l 10 volt 60 cycle alternating current with a maximum output of 495 watts. Captured trout were transferred to a local hatchery and observed for 2 to 5 days. An output of 80 to 90 volts was sufficient to stun fish momentarily. The effective range was a radius of ten feet and to a depth of five feet. The water was alkaline, pH 7.5, and temperature was 58 IO 70 degrees Fahrenheit.’

Ten rainbow trout that exhibited representative symptoms of injury were selected for dissection. The total mortality of fish due to shocking was only 2% of the entire test group. Low mortality may have been attributable to low voltages applied, short observation time and the controlled conditions in the hatchery.

Hickley, P. 1985. Aspects of fishing electrode design. Aquaculture and Fisheries Management 1: 297-298.

Electric fishing, design, electrodes.

Two important aspects of equipment design are commonly ignored by manufacturers. Connectors are placed on the end of the anode pole so it can be quickly detached from the power cable. The cable from the electrode must be continuous from within the hollow electrode handle as far as to its terminal plugs used for connection to the control box. The mixing of high and low power tension in the same connector is not safe.

The fixing of separate high tension and low tension plugs onto the same piece of three-core anode cable is schematically detailed.

Hickley, P. and A. Starkie. 1985. Cost-effective sampling of fish populations in large bodies of water. J. Fish. Biol. 27(Supplement A):151-161.

Sampling, economics, lakes, fishery surveys, stock assessment, fishery management, British Isles, methodology.

The problems of estimating fish populations in large bodies of water are addressed. Case histories are presented showing how a range of large habitat types have been surveyed. The survey methods are discussed in terms of relative success and cost. (1) The status of the River Sevem fish population was monitored by postal questionnaires addressed to contest fishermen, cost effectively collecting valuable data. (2) A predator cull and population estimate for a 35-hectare lake was made by sequential netting of sections. The popu: :on estimates arrived at were questionable and the results in general were poor. This sampling method proved to be very labor intensive and costly. (3) A boat-based electric fishing technique was used in estimating fish populations in large canals. The boat-based electric fishing unit and sampling methods used are described by Cowx:. The perpendicular, ten pendant, bow mounted anode array gave the most consistent catch-per-unit-effort, while operating at a cost-effective level.

This paper details alternative effective electic-fishing techniques for streams and rivers.

Hickley, P. and B. Millwood. 1990. The United Kingdom safety guidelines for electric fishing: its relevance and application. Pages 3 1 l-323 *in* LG. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Electric fishing, electric gear, construction, health and safety, fishery survey.

The United Kingdom. unlike the United States, has adopted legislation that strictly regulates the applications and procedures of electric fishing. This paper reviews recommendations for all aspects of working with electricity. from daily working procedure to equipment design. Established national safety guidelines are discussed in the context of their relevance, necessity, and suitability for application in the field.

Al! components of the electrical equipment must be suitable for exposure in a wet. outdoor environment. and particular attention should be given to standards of enclosure. robustness, construction, mounting of components, termination. plugs. and sockets--in short, a durable solid-state system is required.

In electrofishing operations, power supplies are restricted to those from portable generators or spill-proof batteries. Power must always be fed via a control box, the primary reason for this being operator protection when a high-tension generator is used. Generators must be modified so that they are not grounded internally and must be clearly labeled to this effect. The generator must be housed in an insulated, ventilated enclosure so as to prevent bodily contact with any person while the generator is running.

This paper provides a comprehensive review of safety requirements, along with a safety checklist of gear specifications for prospective purchasers. This information should be incorporated into any electric fishing operation.

Hollender, B. 1992. Injury of wild brook trout by backpack electrofishing [Abstract]. Page 13 in Western DI sion American Fisheries Society, July 13-16, Colorado State University Program Abstracts [Annual meeting]. Am. Fish. Soc. Western Div., Ft. Collins, Colorado.

Brown trout (Salmo truttu), rainbow trout (Oncorhynchus mykiss), brook trout (Salvelinus fontinaIis), alternating current (AC), PDC, backpack electrofishing, injury, mortality, Pennsylvania.

The objective of this study was to assess internal injuries of wild brook trout that were captured with AC and PDC backpack electrofishing units in four small infertile streams. X-ray and autopsy were used to assess injury rate of 579 brook trout captured by electrofishing and 89 captured by angling. Injuries consisted of internal hemorrhages, and spinal-misalignment and fracture, or both. There were 74 hemorrhages and 9 l spinal injuries. Injury rates were not significantly different between current types: 26% for AC and 22% for DC. It was concluded that even for relatively small trout in infertile waters, the incidence of electrofishing-induced injury can be significant.

A review of this and other papers contained in this synopsis makes it clear that the harmful effects of any type of electrofishing need to be evaluated (with standard evaluation protocols) on an individual project basis.

Holmes, R., D. McBride, T. Vivant and J.B. Reynolds 1990. Electrofrshing mortality and injury to rainbow trout, Arctic grayling, humpback whitefish, least cisco, and northern pike. Fishery Manuscript 90-3. Alaska Dept. Fish Game, Anchorage. 95 p.

Electrofishing, PDC, rainbow trout (Oncorhynchus mykiss), Arctic grayling (*Thymallus arcticus)*, northern pike (*Esox lucius*), humpback whitefish, (*Coregonus pidschian*), least cisco *(Coregonus sardinella*), injury, mortality, Kenai River, Alaska, Coffelt VVP- 15.

The publication of Sharber and Carothers' (1988) work on the possible deleterious effects of PDC electrofishing on large rainbow trout in the Colorado River has stimulated ongoing debate and agency-wide re-evaluation of The Standard Principals and Field Practices of electrofishing.

Before their work, it was generally believed that PDC electrofishing presented limited incidental harm to fish. Sharber and Carothers reported a range of 44% to 67% spinal injury to large rainbow trout exposed to standard PDC. Holmes et al. took this information and set out to test the applicability of these results to Alaska's electrofishing efforts.

This paper examined the effects of PDC electrofishing on all species for which electrofishing was being used as a sampling method by the Alaska Department of Fish and Game. The huge injury and mortality rates for large rainbow trout were confirmed. Large rainbow trout are unique in their hypersensitivity to electric current. The paper addresses this by examining five different species of fish and evaluating the observed short-term mortality, and injury caused by electrofishing. Rainbow trout sustained the highest rate of mortality (13.9%) and injury (40.9%). Northern pike sustained zero mortality and an injury rate of 12.5%. Two species of whitefish had a short-term (7 days) mortahty of 5.4% and 0% electrofishing-caused injury. The injury rates for Arctic grayling varied from 0% to 18.3%.

With this information in hand, the study then addresses the issue of establishing species-specific threshold power levels, and detailed methods for mechanically shielding the anodes, as ways to reduce harm from electrofishing. In order to make comparisons between different species and study sites, the capture methods, sampling protocols and sample test must be as uniform as possible. For this reason, this paper, along with Fredenberg's (1992), Reynolds' (1992). and Sharber Carothers' (1988), will establish the sampling program and research focus for the University of Washington's 1993 proposal to evaluate electrofishing-induced mortality and injury to fish species in the Columbia River.

Horak, D.L. and W.D. Klien. 1967. Influence of capture methods on fishing success, stamina, and mortality of rainbow trout in Colorado. Trans. Am. Fish. Soc. 96:220-222.

Rainbow trout (*Oncorhynchus mykiss*), Parvin Lake, Colorado, physiology, morphology, aquaculture, methodology, electric fishing, fly fishing.

Delayed mortality caused by various capture methods is of concern to fishery managers. Bouck and Ball (1966) encountered 87% delayed mortality within ten days after collecting hatchery rainbow trout with artificial lures. This paper evaluates effective capture techniques and their effects on 'put and take' fish populations.

The criteria used to evaluate the effect of capture methods were: (1) return to the creel of stocked trout before and after special fishing size limit regulations were imposed, (2) stamina evaluation of collection by electrofishing and fly fishing, and (3) mortality after collection by electrofishing and fly fishing.

Under the special fishery regulations (slot limits), fishermen harvested 37.7% of a known population of marked rainbow with subsequent returns of individual plantings ranging from 28.2% to 49.9%.

Two groups of hatchery trout were tested for stamina. one group collected by fly fishing, the second with a PDC electrofisher. Both capture methods resulted in reductions in individuals' swimming stamina (performance index). The higher an individual's performance index (P.I.), the greater its stamina. The control group performance index was 60 minutes, fly fishing P.I. was 54.7 minutes. and electrofishing P.I. was 35.2 minutes The low conductivity of the hatchery water may have introduced a negative bias on the electrofished group: 39% of shocked fish were visibly burned, indicating that excessive power may have been applied to the water.

Mortalities in the three groups were recorded over a five--week period. The control group had five delayed mortalities; fly fishing had five initial hooking mortalities and three delayed mortalities: and electrofishing suffered only two delayed mortalities over 35 days.

Hudy, M. 1985. Rainbow trout and brook trout mortality from high voltage AC electrofishing in a controlled environment. N. Am. J. Fish. Manage. 5:475-479.

Rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), physiology, morphology, alternating current, sampling, electrofishing.

Delayed mortality could: (I) bias population estimates (Pratt 1954), (2) limit spawning success (Maxfield et al. 1971), or (3) cause misinterpreted change in population level or structure. In moderate to high conductivity waters where low AC or DC current voltages are effective for stunning fish (Vibert 1976). mortality from electrofishing is negligible (Godfrey 1954, Horak and Kline 1967, Maxfield 1971). This paper presents data on immediate mortality, delayed mortality and vertebral injuries in hatchery rainbow and brook trout following rlectrofishing with high AC voltages.

The immediate, delayed, and total mortalities were low with no significant differences (analysis of variance, p > 0.05, N = 12) among treatment means for both rainbow and brook trout, or for the combined data from both species. Only 28 of 3,000 fish in the experiment died, 7 immediately and 2 I delayed over a 15-day period. Rainbow u-out represented 79% total mortality, while the brook trout accounted for the remaining 21% of the mortality. The combined total mortality was 0.0% for the control group (unshocked), 1.8% at 350 volts, 1.3% at 700 volts, and 0.5% at 760 volts.

The number of survivors with visible abnormalities (bums, erratic swimming) was low, 0.0% for the control group, I .6% at 360 V, 2.4% at 700 V, and 0.8% at 760 V. Radiographs showed that only 21% (6 of 28) of the dead trout had fractured or dislocated vertebrae; 77% (27 of 36) of the abnormal surviving fish had fractured or dislocated vertebrae, the injury usually occurring between the 15th and 25th abdominal vertebrae.

Hudy, M. 1986. Comments: Mortality from high voltage AC electrofishing. N. Am. J. Fish. Manage. 6: 134.

Rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), morphology, electric fishing, electrodes.

Hudy responds to Norman G. Sharber's criticism of his 1985 results, defending his conclusion that "high voltage AC electrofishing probably is acceptable for most management uses in low conductivity waters."

Jesien, R. and R. Hocutt. 1990. Method for evaluating fish response to electric fields. Pages 10-18 *in* I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Channel catfish (*Ictalurus punctatus*), controlled environment, physiology, electric gear, electric parameters, electric fishing.

Experimental apparatus designed to investigate fish response to electric fields induced by commercially available electric fishing units is described. The objective of the study was to determine threshold power densities to tetanize channel cattish over a range of conductivities, pulsed AC and 30 Hz and 120 Hz PDC were used. Fish were exposed to the field for one second. The threshold power densities increased with increasing conductivity. Peak power densities required to tetanize fish at 100 µS/cm ranged from 4.8 to 13.5 $\mu W/cm^3$ and at 10.000 µS/cm ranged from 8 1.0 to 5 15 $\mu W/cm^3$. Average power density to tetanus ranged from 0.5 to 2.4 $\mu W/cm^3$ at 100 µS/cm and from 8.7 to 53.0 $\mu W/cm^3$.

Fish were more sensitive to DC when facing the cathode and sensitivity became more apparent as conductivity Increased.

Understanding electric parameters and fish electrophysiology will greatly increase the CPUE of the Columbia River predator control fishery.

Johnson, I.K., W.R.C. Beaumont and J.S. Welton. 1990. The use of electric fish screens in the Hampshire Test, Itchen, England. Pages 256-265 *in* I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), Hampshire, England, experimental gear, electric screens, fish passage.

Electric fish screens provide an alternative method to mechanical devices for blocking upstream fish passage. Electric fish screens were used in conjunction with resistivity fish counters in an investigation of upstream migration of salmonids in the Hampshire test. Three sites of differing configurations are presently being used. The experimental design and the preliminary results from using the screens are discussed.

Electric screens may prove to be an effective method to frighten squawfish away from areas of high smolt concentration, such as the tailrace areas of dams.

Koltz, A.L. and J.B. Reynolds. 1990. A power threshold method for the estimation of fish conductivity. Pages 5-9 *in* I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Gold fish (*Carassius auratus*), physiology, controlled environment, electric fishing, electrical parameters.

Electric fishing is primarily a problem of transferring electrical power from water to fish. If a sufficient amount of power is transferred, a particular response, such as taxis or narcosis, can be achieved. The major deterrent to power transfer is the difference between the conductivities of water and fish.

Goldfish were exposed to various voltage gradients in a tank containing water of IO to 10.000 mhos conductivity. The resultant power densities applied to the water in order to achieve various responses (twitch. galvanotaxis or narcosis), when plotted as a function of water conductivity, conformed to the theory of maximum power transfer, i.e.. when conductivities of fish and water were equal, the applied power needed was at a minimum. The resultant estimates of fish conductivity proved to be 5 to IO times lower than reported elsewhere.

Lamarque, P. 1990. Twenty years of electric fishing expeditions throughout the world. Pages 344-35 1 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Electric fishing, electric gear, electric parameters, sampling.

The parameters that regulate electric fishing efficiency are numerous: water conductivity, temperature. depth. current velocity. turbidity, vegetation, operator ability, electrode suitability, fishing methods, and fish species and size. Electric fishing conditions from site to site are rarely similar. Comparisons of like fishing techniques are scarce. There is no general agreement among users as to the single best method There is only a quasi-general agreement: direct current is the most efficient method if conductivities permit its use.

This paper outlines the characteristics of successful electric fishing operations. in a successful electrofishing operation it is highly desirable to produce an electrotaxic current (i.e., a current which attracts fish to the anode but does not tetanize them). The most commonly used electrotactic currents are constant DC, 3-phase fully rectified AC, single phase fully rectified AC at 30 Hz, and rectangular pulsed DC at 400 Hz on 10% duty cycle. The key to a successful electric fishing operation is flexibility in current form and shape.

Water conductivities are divided into three groups: Low conductivity waters (5 to 30 µS/cm), such as mountain streams and lakes, or areas associated with high rain runoff: medium conductivity waters (30 to 500 µS/cm), such as the Columbia River, which ranges from 80 to 200 @/cm; and high conductivity waters (values greater than 500 µS/cm), mainly estuaries, brackish lagoons, and the sea.

Different fishing strategies must be adopted for each conductivity range. Fishing low-conductivity waters is difficult, but good results may be achieved by using very large electrodes (anode diameter >60 cm) and high peak voltages (800 to 1650 volts). Best results in medium waters are achieved with the combination of large anodes and electrotactic current. In high-conductivity water, pulsed DC (rectangular waves of either 400 Hz or 100 Hz at 10% duty cycle) and smaller electrodes need to be used in order to reduce energy requirements.

In general, all pulsed current can produce some mortality. The worst currents are condenser charges, AC at 50 to 60 Hz and 1/2 wave rectified AC at 50 to 60 Hz. Currents with electrotactic characteristics are least harmful Mortality is species dependent, being the result of synaptic exhaustion (violent shock) or dislocation of vertebrae, particularly if the fish is decalcified because of spawning or poor nutrition.

Predator fish (e.g., salmonids, Percidae, Centrarchidae, Esocidae) are more easily caught than prey species. Bottom fish and poor swimmers are also difficult to catch. Carp and tilapia seem to build up a tolerance to subsequent electric fishing. Many species are frightened out of a fisher's effective zone by physical disturbances in the water. Smaller fish tend to be more resistant than larger fish. Vegetation and cover can hide stunned fish from capture. Electrode contact with muddy bottoms causes a diminution effect in the field; this may cause an increase in resistance and lead to overloading of the generator. In strong current, tetanized fish often are washed away from the catchers. Turbidity allows a close approach towards fish but reduces catching efficiency through poor visual contact.

The experiences gained from Lamarque's twenty years of work in electric fishing should be applied to the removal effort for squawtish.

Latta, W.L. and G.F. Myers. 1961. Night use of a direct current electric shocker to collect trout in lakes. Trans. Am. Fish. Soc. 90:81-83.

Brook trout (*Salvelinus fontinalis*), lakes, Michigan, traps, electric fishing gear, electric fishing, gear efficiency.

Fishing was done at night from a small electrofishing boat. A Homelite DC generator (230 volts, 9.3 amperes) provided power both for underwater illumination and for the electrical field. The specifications on wiring and boat layout were detailed.

Eight hours of electrofishing at night in 1959 in a small lake produced 5 14 fish from a known population of 700 fish. Night shocking resulted in the capture of as many trout per hour as did 36 trap days (one trap day being equivalent to one submerged wire trap set for 24 hours). Similarly in Ford lake, night shocking yielded as many trout per hour as did 30 trap days.

The CPUE for squawfish collected by electrofishing during the day and night should be compared as are day and night Merwin trap catches. Such comparisons would establish the best times for catching squawfish.

[illegible]auski, H G. and S.P. Malvestuto. 1990. Electric fishing: results of a survey on boat construction contiguration and safety in the United States. Pages 327-339 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd

Electric fishing, electric gear, methods, survey, United States.

The intention of this survey was to gather information pertaining to: (I) boat types and uses, (2) anode and cathode design, (3) boat construction, (4) formation of standards for electric fishing boat configuration, construction, and safety. The comprehensive standards detailed for boat construction, configuration and safety should be reviewed and adopted by any electrofishing operation.

The survey results showed that a combination of techniques (current types) was preferred over any one technique. Most agencies use both backpack and boat shocking. Population estimation, tagging, and specimen collection were the most common reasons that agencies electrofished. The majority of electric fishing is done in the 100 to 200 µS/cm conductivity range. Only a minority of agencies indicated that they had ever actually assessed the efficiency of their equipment. The most common electrode design closely followed that of Novotny and Priegel (1974), using their circular Wisconsin ring array. Many agencies used homemade electric boats (271 units). All commercial units were purchased from either Smith Root Inc. or Coffelt Electronics.

Loeb, H.A. 1958. Comparison of estimates of fish populations in lakes. New York Fish and Game 5:66-76.

Carp (*Cyprinus carpio*), New York, population estimates, fishing gear, traps, electric fishing, electric seine, rotenone.

Population studies involving a number of fish, primarily carp, were carried out in three lakes ranging from 30 to 800 acres in size. Different sampling techniques were used and the data analyzed by both the Schnabel method and direct proportion. Loeb showed clearly that electrotishing for some species was more effective at night than during the daylight hours. Often the increase in effectiveness of this tool when used at night is ignored.

CPUE data for electrofishing on squawfish during the day vs. nighttime needs to be assessed and incorporated into our sampling schedule.

Lui Q.. W. Darning, X. Ronngong and L. Jiefu. 1990. A method of improving fishing efficiency in lakes by using a seine net with pulsed current. Pages 41-45 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Common carp (*Cyprinus carpio*), crucian carp (*Carassius auratus*), China, aquaculture, electric seine, electric fishing, fisheries management, efficiency comparison.

In ponds with uneven, heavily silted bottoms, it is difficult to harvest the bottom-living common carp and 21cructian carp Capture efficiency using the traditional seine netting method was as low as 5%. Carp exhibit diving behavior once enclosed in a seine, often escaping capture. In order to improve catch efficiency. an electric seine-net equipped with pulsed current was developed. The foot rope of a 1200-m drag seine-net was bound to an electric wire with 20% of its insulation stripped off to act as an anode, The power output was three phase. 220 V, half wave rectified AC irregularly pulsed at a frequency of 10 Hz. This current can be controlled to drive, concentrate and seine the escaping fish. Capture efficiency increased, ranging from 20% to 30%. Because squawfish also exhibit diving behavior in a net, future seining efforts may test electric seining.

Lui, Q. 1990. Development of the model SC-3 alternating current scan fish driving device. Pages 46-50 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications. Ltd.

Silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), aquaculture, electric gear, electric parameters, electric fishing, gillnets, physiology.

The response of silver and bighead carp to alternating current was studied. It was reported that frequencies of the order of 80 Hz appear to have the greatest long-term residual effects on fish. but above and below this value the effect is less traumatic. The threshold electric field intensity for the different responses decreased with elevated conductivity. Significant differences were also found in the threshold field intensity between continuous and intermittent alternating currents.

The SC-3 Alternating Current Scan Fish Driving Device was developed to catch silver and bighead carp in reservoirs. With use of this gear, the catching efficiency was of the order of 62%, increasing to a maximum of 92%.

The concepts explored here may prove useful to a future capture technique that could combine the congregating effects of electricity on fish with a purse OF large beach seine.

Mann, R.H.K. and T. Penczak. 1984. The efficiency of a new electrofishing technique in determining fish numbers in a large river in Central Poland. J. Fish. Biol. 24: 173- 185.

Pilica River, Poland, fisheries management, sampling, electric gear, AC electric barrier, electric fishing.

A new method for determining fish populations in large rivers, which entailed electrofishing from boats downstream to an AC electric barrier, produced capture efficiencies ranging from 28% to 82%.

This study had two objectives: (1) to test a new electrofishing technique for estimating the numbers of fish in a large river, (2) to compare these catch results with those made before changes occurred in the management of the river.

A section of river to be sampled was divided into three subareas (A, B, C). A 220 V AC barrier was set across A. B, and C at the end of the fishing site. The subareas were fished simultaneously, each with boat-mounted pulsed DC equipment (3 Kw, 220 V, 50 Hz). Energy was delivered to the water via two hand-held anodes. The boats were steered downstream towards the AC barrier. Any fish not picked up by the boats were driven into the AC barrier and killed by the current. Most fish were recovered 25 m downstream of the AC barrier.

This sampling technique yielded good catch results. However, many of the captured fish were killed by the AC barrier. Therefore, this sampling technique would not be applicable in a project where incidental mortality is of concern.

Malvestuto, S.P. and B.J. Sonski. 1990. Catch rate and stock structure: a comparison of daytime versus nighttime electric fishing on West Point Reservoir, Georgia. Pages 210-218 in LG. Cowx. ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis mucrochirus),* West Point Reservoir, Georgia, CPUE, nighttime, daytime, size distribution, electric fishing.

A boom mounted electric fishing boat was used to sample shoreline areas of West Point Lake. A three phase, 120 to 240 V, 3.5 Kw, AC generator was used to supply pulsed DC via Coffelt model VVP-2C variable voltage pulsator. Catch rate (number of stock-sized fish caught per 45 minutes electric fishing sample) and stock structure (proportional stock density, PSD) were compared for daytime versus nighttime samples of largemouth bass >20 cm in total length and for bluegill >8 cm total length.

Six paired (day, night) samples were taken during fall, spring, and summer. Statistical analysis showed a significant difference ($p = 0.05$) between catch rate of bass captured during the day vs. night for the summer season only, with an increase of nine bass for sample at night. Bluegill catch rates were significantly greater during the night for all seasons.

Electrofishing at night is generally thought to be more effective than electrofishing during the day. This paper showed the importance of incorporating the seasonal and diel movements of the target species when establishing a sampling regime.

Maxfield, G.H., G.E. Monan and H.L. Garrett. 1969. Electrical installation for the control of the northern squawfish. U.S. Fish Wildl. Serv. Spec. Sci. Rep. No. 583. 14 p.

Squawfish (*Ptychocheilus oregonensis),* Cascade Reservoir, Idaho, electricity, trap, experiment to trap squawfish for the purpose of control.

Electricity was tested in Cascade Reservoir, Idaho, as a means to attract squawfish into traps during their spawning migration. Significantly more squawfish entered the traps when power (140 to 180 volts, AC) was on (354 fish) than off (110 fish). A variety of voltages, pulse durations and frequencies were tested. Other fish species were also captured in the traps.

This study demonstrated that electricity could be used to enhance catches of squawfish. However. electricity may not be useful for controlling squawfish throughout the Columbia River because of safety restrictions and the need for electrical generators when fishing away from a dam.

Maxfield, G.H., R. H. Lander and C.D. Volts. 1970. Laboratory tests of an electric barrier for controlling predation by northern squawfish. U.S. Fish Wildl. Serv. Spec. Sci. Rep. No. 611. 8 p.

Squawfish (*Ptychocheilus* oregonensis), salmon, Drano Lake, Columbia River. electricity, control of movements and predation of squawfish below hatcheries.

Preliminary laboratory results suggest that squawtish will avoid electrical fields, which could be used to reduce predation during releases of hatchery smolts. Although results may vary with water temperature and resistivity. these data suggest that electrodes placed 61 cm apart were most effective. Approximately 85%, 93% and 96% of the swimming squawfish were blocked by voltage gradients of 0.75, 1.00, and 1.25 volts, respectively. Electricity appears to have potential for blocking squawfish movements, although field testing is needed.

Maxfield, G.H., R.H. Lander and K.L. Liscom. 1971. Survival, growth, and fecundity of hatchery-reared rainbow trout after exposure to pulsating direct current. Trans. Am. Fish. Soc. 3:546-552.

Rainbow trout (*Oncorhynchus mykiss*), morphology, physiology, controlled environment, electric fishing.

Unshocked control and shocked test rainbow trout were held through spawning to determine the effects of electrical shock on the survival, growth, and fecundity of two year classes--young-of-the-year 1953 and yearlings of the 1952 year class--and on the survival of the eggs and fry of the exposed fish. The test fish were exposed for 30 seconds to one of two sets of electrical conditions. Exposure was longer than that usually encountered by fish during either electrical guiding or collection with a pulsating direct current shocker.

The survival, growth, and fecundity of the fish apparently were not affected by the electric shock, nor were the survival and development of their offspring. For the 1952 year class, cumulative survival percentages were 92.9 for the test fish and 89.6 for the controls. For the 1953 year class, the respective percentages were 90.1 and 84.0.

McCrimmon, H.R. and B. Bidgood. 1965. Abnormal vertebrae in the rainbow trout with particular reference to electrofishing. Trans. Am. Fish. Soc. 94:84-88.

Rainbow trout (*Oncorhynchus mykiss*), Great Lakes, laboratory experiments, morphology, gear comparisons, electric parameters, electric fishing, x-ray.

Rainbow trout collected by AC and DC electrofishing from four distinct Great Lakes watersheds were found, when x-rayed for taxonomic purposes, to include fish with abnormal vertebrae. Damage caused by electrofishing shock was compared with naturally occurring abnormal vertebrae in immature and mature fish.

Of 291 trout taken by electrofishing, 7.6% showed abnormal vertebrae. An examination of the vertebral columns of 80 hatchery-reared trout prior to shocking showed 3.8% abnormal vertebrae. A reexamination of the vertebral columns of the hatchery-reared fish following electrofishing showed no change in the incidence of abnormal vertebrae.

A total of 371 hatchery trout were shocked and examined by x-ray. The 371 trout examined had an average of 62.4 vertebra. In 23 of the 25 fish with damaged vertebrae, the damage was between the 17th and 44th vertebrae, the abdominal region between the dorsal and pelvic fins. There was an average of 6.2 damaged vertebrae. Dissection of the trout with abnormal vertebrae showed these vertebrae to be immovably and permanently fused together (25%-40% thicker than adjacent normal vertebrae). This fusion precludes any possibility that this condition was caused by electrofishing shock.

The prevalence of abnormal vertebrae among fish is well established (Gabriel 1944). Hauck (1947) reported on several types of injuries found in rainbow trout subjected to 80 to 90 volts AC, including damaged vertebrae. Unless fish are x-rayed prior to shocking, as done in this study, the extent of damage to the vertebral column actually caused by shocking may be difficult to assess.

The incidental damage to non-target species. salmonids especially, needs to be monitored. This paper presents useful information as to the type and frequency of naturally occurring vertebral damage.

McLean, I.A. 1990. Safety in electric fishing: a United Kingdom view. Pages 324-326 *in* I.G. Cowx. ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Electric fishing, safety survey, United Kingdom.

In 1986, the Health and Safety Executive Board carried out a survey within the United Kingdom to examine present electric-fishing practices. The aim of the survey was twofold: (1) to examine the safety aspects of electric fishing equipment actually being used, (2) to examine safety procedures followed in electric fishing and compare those with existing national guidelines.

Safety in electrofishing should be a project's number one concern. All information regarding this topic should be given special consideration.

Mesa, M.G., and C.B. Schreck. 1989. Electrofishing mark-recapture and depletion methodologies evoke behavioral and physiological changes in cutthroat trout. Trans. Am, Fish. Soc. 118:644-658.

Cutthroat trout (*Oncorhynchus clarki*), Yamhill River, Oregon, hatchery, streams, behavior, physiology, electrofishing.

This paper evaluated electrofishing for use in population estimation studies. The effects of capture, handling, marking and multiple electro-shocks on normal behavior and physiology of cutthroat trout were described. Electrofishing and the procedures involved in estimating fish population size (capture, handling, marking) elicit a general stress response in fish. In a natural stream, cutthroat trout released after capture by electrofishing and marking showed distinct behavioral changes: fish immediately sought cover. remained inactive, did not feed, and were easily approachable by a diver. A 3-4 hour recovery time was required for 50% of the fish. In an artificial stream. hatchery-reared and wild trout decreased their rate of feeding and aggression. Hatchery fish appeared to return to normal after 2-3 hours, wild fish recovering in 24 hours. Hierarchical rank was affected only among the wild trout: socially dominant fish recovered faster than intermediate and subordinate fish. Physiologically, multiple electroshocks elicited the most severe stress response by elevating blood levels of lactate and cortisol. Plasma concentrations of cortisol and lactate returned to control levels by 6 hours after electroshock treatment.

The behavioral and physiological responses of fish to electrofishing affect the accuracy of catch depletion population estimates by violating key assumptions of the methods, especially the assumption of equal catchability of fish.

Newman, L.E. 1992. Spinal injury of walleye caused by PDC electrofishing [Abstract] Page 14 in Western Division of the American Fisheries Society, Program Abstracts [Annual meeting]. American Fisheries Society, July 13-16 1992, Western Division, Bethesda, Maryland.

Walleye (*Stizostedion vitreum*), electrofishing, PDC, injury, mortality, Wisconsin.

Walleye were taken by PDC electrotishing and analyzed by x-ray and autopsy for final injuries. Of the 30 fish examined 9 (28%) had spinal injuries involving fractured vertebrae, and ruptured dorsal arteries. There was no difference in injury rate between 30 Hz and 120 Hz. Future work will include tests using larger sample sizes. controls and egg viability

Nigro, A. et al. 1985. Abundance and distribution of walleye, northern squawfish and smalimouth bass in John Day Reservoir. Annual progress report, 1985. Oregon Dept. Fish. Wildl. 162 p.

Squawfish (*Ptychocheilus oregonensis*), walleye (*Stizostedion vitreum*), smallmouth bass (*Micropterus dolomieui*), Columbia River, gillnets, trapnets, boat electrofishing, hook and line, radio tracking, angler survey, characteristics of salmon predator populations.

A variety of gear types were used to determine the distribution, abundance, and rates of growth and mortality of squawfish. walleye, and smallmouth bass in the John Day Reservoir. Radio tagging indicated that squawfish and walleye moved throughout the reservoir, although they tended to be close to the shore during periods of high water velocity. Squawfish were captured in greatest quantities during May to July. Abundance of squawfish (>250 mm), walleye (250 mm), and smallmouth bass was approximately 95,000, 16,000, and l 1,000 fish. respectively.

Detailed records of catch data are given in an appendix and may be used for comparison in the squawfish control study. Greatest catch rates of squawfish were made by electrotishing (3 to 4 fish per hour) and the small-mesh bottom gillnet (1.34 fish per hour).

Novotny D.W. and G.R. Priegel. 1974. Electrofishing boats. Improved designs and operational guidelines to increase the effectiveness of boom shockers. Technical Bulletin No. 73. Department of Natural Resources. Madison Wisconsin 49 p.

Electric gear, electric parameters, boat configurations, construction, safety, electric fishing.

The first segment of this report presents basic concepts and design guidelines for electrofishing boats, including a summary of problem areas, descriptions of the basic aspects of electricity, safety, and general design and operating guidelines.

Experimental and operational PDC, DC, and AC electrofishing boats designed during the project are described in detail in the second segment. Elecuofishing performance and operating guidelines based on actual field operation as well as design information on power supplies, controls and electrode systems are presented. Supporting information on electrofishing safety, calculations of electrode resistance, wiring diagrams and lists of components used in newly designed electrofishing boats are included in the appendices.

This paper should be considered required reading for any persons working with electrofishing equipment. The material presented here has served as the baseline standard from which present-day commercially available electric fishing gear has evolved.

Paragamian, V.L. 1989. A comparison of day and night electrofishing: size structure and catch-per-unit-effort for smallmouth bass. N. Am. J. Fish. Manage. 9:500-503.

Smallmouth bass (*Micropterus dolomieui*), catch-per-unit-effort, modeling, Maquoketa River, Iowa, electrofishing, day vs. night fishing comparisons.

Catch-per-unit-effort and proportional stock density (PSD) of smallmouth bass were compared between day and night electrotishing samples. The data were collected from the Maquoketa River, Iowa. during the spring of 1978. CPUE for all size ranges of smallmouth bass was significantly higher for night fishing than for daytime. Smallmouth bass were captured with the aid of a boat-mounted, 230-V, AC, 3,000-W, 7.5-A electrofishing unit and two experienced dipnetters. The PSD from daytime catches was 27, whereas it was 33 for night. a 22% increase. Night electrofishing in rivers is recommended for this species to improve gear efficiency, reduce the time necessary to make population estimates, and increase sample size for determining length frequency distributions and age structures.

Squawfish are active nocturnal feeders. An electrofishing evaluation for potential removal programs should have a strong night fishing component to it.

Penczack, T., and H. Jakubowski. 1990. Drawbacks of electric fishing in rivers. Pages 115-122 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Large rivers, Poland, modeling, site characteristic vs. fishing efficiency, behavior, electric fishing.

In order to obtain an accurate picture of the fish community and population structure in large rivers. it is necessary to have not only an adequate sampling technique but also a knowledge of the biology of the fish species (Hunt and Jones 1974).

The number of a species caught is related to the importance of each species in the community structure and their migratory habits. Increased fishing effort (number of successive runs) on each sampling occasion can determine the importance of a species in a community, while repetition of electric fishing during each year is required to fully assess the contribution of migratory species. The relationship between site characteristics and catching efficiency for some species is well pronounced.

Squawfish exhibit a spawning migration and then form feeding aggregations. To be most effective, a removal effort should be aligned with these seasonal and behavioral patterns.

Pierce, R.B., D.W. Coble and S.D. Corley. 1985. Influence of river stage on shoreline electrofishing catches in the upper Mississippi River. Trans. Am. Fish. Soc. 114:857-860.

Bluegill (*Lepomis macrochirus*), drum (*Aplodinotus grunniens*), modeling, catch-per-unit-effort, upper Mississippi River, Illinois, boom electrofishing boats, electric fishing.

The numbers of fish and the species caught per unit of effort along main channel shorelines in pool areas of the upper Mississippi River were inversely related to river water level.

Fish were stunned with AC electrofishing gear. A boom shocker. described by Novotny and Priegel (1974), was initially operated at 9 to I I amps with 320 V, and later at 7 to 9 amps with 230 V because of bleeding observed on shocked fish. A second catcher boat was used to pick up fish missed by the netting crew. A total of 5,652 fish of 50 species was caught. Sampling occurred in June, August and October in 1978 and 1979. and in June and August in 1980.

Lower catch-per-unit-effort at higher river stages could be caused by reduced fish abundance along shorelines. reduced electrotishing efficiency, or both. In general. electrofishing catches are inversely related to water level. but it varies for individual species--strong for some. no relation for others.

Squawfish catch rates may be low during the high flows of spring. Increased catch-per-unit-effort should be experienced after the Snake and Columbia River Dams cease spilling.

Pratt, S.V. 1954. Fish mortality caused by electrical shockers. Trans. Am. Fish. Soc. 84:93-96.

Brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), controlled environment, morphology, electric parameters, AC current verses DC current, electric fishing.

Under experimental conditions, legal-sized brook, brown, and rainbow trout were exposed to 110 volt AC and 230 volt DC. The average mortality was 6.4%. Immediate mortality was 4.3% and delayed mortality accounted for 2.1%. Of the trout exposed to AC, 11. 1% died, whereas only 2.0% treated with DC were killed. Mortality appeared unrelated to species or size.

Hauck (1949). using 495 watt, 110 volt AC with hand-held electrodes, reported a 26% mortality in the rescue of large rainbow trout (average weight, 3.7 pounds) from an irrigation canal. Shelter (1947), using similar equipment on smaller trout in Michigan streams had a mortality rate of generally less than 1.0%. In Pratt's work, all of the fish that were killed immediately had been accidentally left in the electric field longer than the prescribed period (one foot away from an electrode for 15 seconds).

Incidental harm and delayed mortality to salmonids from electrofishing for squawfish need to be evaluated and kept at a minimum.

Pugh, J.R., G.E. Monan and J.R. Smith. 1970. Effects of water velocity on the fish-guiding efficiency of an electrical guiding system. U.S. Fish Wildl. Serv., Fish. Bull. 68(2):307-324.

Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (0. *kisutch*), rainbow trout (0. *mykiss*), Yakima River, Prosser, Washington, fish passage, electrical screens, inclined screen trap, gear efficiency.

This study was performed in 1962 in a diversion of the Yakima River near Prosser, Washington. Massive structures for regulating the water velocity, producing the desired electrical field, and collecting the guided fish were installed. The fish tested were wild downstream migrating fingerlings of chinook salmon. coho salmon, and rainbow trout.

Fish guiding efficiency tended to decrease with increasing water velocity. The guiding efficiencies of the electrical system at water velocities of 0.2, 0.5, and 0.8 m/s were. respectively, 84.2. 54.2 and 50.2% for chinook; 82.4, 47.8. and 42.8% for coho; and 69.9. 40.2, and 448% for rainbow. The use of electricity to guide juvenile migrating salmon may be feasible in certain environments where water velocity does not exceed 0.3 m/s.

If future squawfish removal efforts were to include electric traps, weirs, or nets, the effects ot water velocity on the efficiency need to be addressed

Randall, R.G. 1990. Effect of water temperature, depth, conductivity and survey area on the catchability of juvenile Atlantic salmon by fishing in New Brunswick streams. Pages 79-80 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), small streams, New Brunswick, Canada, modeling, environmental factors, gear efficiency, electric fishing.

During the electric fishing surveys in the Miramichi and Restigouche rivers, New Brunswick, probabilities of capture of juvenile Atlantic salmon varied significantly, both spatially and temporally. Average capture probabilities were significantly greater for parr (0.5) than fry (0.4). The hypothesis that environmental factors at the time of sampling (water temperature, conductivity, depth. discharge, and survey area) significantly affected capture probabilities could not be rejected. However, correlations between environmental factors and catchability were poor and inconsistent. Environmental conditions that would maximize capture probabilities could not be identified. Therefore, at least four electric fishing sweeps are necessary to estimate in-stream juvenile salmon populations.

Although the habitat and objectives detailed here are unique, the basic principles of factors affecting electrofishing success are applicable to squawfish removal.

Reynolds, J.B., S.M. Roach, and T.T. Taube. 1992. Injury and survival of northern pike and rainbow trout captured by electrofishing [Abstract] Page 15 in Western Division of the American Fisheries Society, Program Abstracts [Annual Meeting]. Am. Fish. Soc., July 1- 16 1992 Western Division, Bethesda, Maryland.

Northern pike (*Esox lucius*), rainbow trout (*Oncorhynchus mykiss*), PDC, Coffelt Pulsed System (CPS), injury, mortality, Alaska.

The 1990 and 1991 studies were conducted to determine the effects of various electrical wave forms on large northern pike and rainbow trout. The results were quite different for the two species. PDC (30-60 Hz, 100-400V) produced spinal injury rates among northern pike of only 5-12%, with an increase to 29% when a 120Hz wave form was applied at 300-600V. Survival and growth of injured and control groups of pike held for nearly one year were not significantly different. All types of conventional PDC (20-60Hz) produced spinal injury rates of 40-60% in hatchery rainbow trout. Only continuous DC and CPS™ produced injury rate under 18% in the hatchery. In the field. CPS™ produced the lowest injury rates. It was concluded that 60Hz PDC could be used to capture northern pike with minimal injury problems and the DC and CPS™ should be further evaluated for electrofishing rainbow trout. Electrofishing-induced injuries vary among species and studies. More species need to be studied.

Saltveit, S.J. 1990. Studies on juvenile fish in large rivers. Pages 109-I 14 *in* I.G. Cowx, ed.. Developments in Electric Fishing. Oxford: Fishing News Books. Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), Norwegian rivers. population parameters, hydroelectric power. habitat surveys, electric fishing.

Norway is the largest user of hydroelectric power per capita in the world. In order to evaluate the effect ot regulating large rivers and to identify the necessary mitigation measures (in-stream flows. stocking, fish passage). power companies have organized studies both before and after regulation. Electric fishing IS a commonly used tool in these studies. Electric tishing has been used together with other sampling techniques to study the habitat preference of juvenile Atlantic salmon and brown trout in some Norwegian rivers.

This paper details alternative uses and parameters of electric fishing.

Schreck, C.B., R.A. Whaley, M.L. Bass, O.E. Maughan and M. Solazzi. 1976. Physiological responses of rainbow trout (*Salmo gairdneri*) to electroshock. J. Fish. Res. Board Can. :76-84.

Rainbow trout (*Oncorhynchus mykiss*), physiology, lactate, pulsed direct current, controlled environment, electric fishing.

This paper investigated the physiological consequences of electroshock-induced paralysis in rainbow trout as part of an investigation into the efficiency of electroshocking as a tool for population estimation. The assumption tested was that once a fish is shocked and swims away, it rapidly returns to a normal physiological condition, or whether there are lasting residual effects (stress, avoidance or mortality) that would reduce an individual's chance for recapture. A total of 48 15-month-old hatchery-reared rainbow trout (average weight, 169 +/- 5.4 g) was held outside in concrete raceways. A Coffelt backpack shocker (230 V, 2.3 A DC) was used to simulate electrofishing in a stream.

The results showed that electroshocking elicited an immediate increase in plasma corticoid and lactate concentrations. Plasma lactic acid levels doubled immediately after shocking and remained high for one hour and returned to near normal within three hours. Plasma protein, calcium. magnesium, and androgen levels were not measurably affected. A violent 'coughing' response was noted. Normal breathing resumed after 60 seconds. The circulatory efficiency of these fish was impaired by raised blood lactate levels.

Schreck postulates that electrofishing elicits a general stress response lasting several hours. This stress closely parallels that induced by hypoxia (oxygen debt) or severe muscular activity, the degree of stress being directly related to the severity and duration of applied electric field.

Death of fish collected by electrofishing may be the result of both acute and chronic factors. Immediate death is due to direct trauma, i.e., respiratory failure, hemorrhaging, or fractured vertebrae. Delayed mortality results from the combined effects of trauma, factors associated with the repayment of oxygen debt, and stress-induced exhaustion.

If electrofishing is to be used as the capture technique in a mark-recapture population study for squawfish in the Columbia River, the sampling bias of the electrofishing unit used in such a regime should be carefully assessed.

Sharber, N.G. and S.W. Carothers. 1987. Submerged, electrically shielded live tank for electrofishing boats. N. Am. J. Fish. Manage. 7:453-455.

Humpback chub (*Gila cypha*), Colorado River, physiology, electric gear, Faraday's law, electric fishing.

Fish caught by electrofishing are usually held in live tanks until data are recorded. If water in these holding tanks is not circulated, changes in temperature and oxygen concentration may be harmful to the fish.

This paper derails the design specifications for a successfully used live tank which is submerged through the hull of a catamaran type white water raft. The tank is placed in rhe water being electrofished so that power free, continuous water circulation is maintained. Fish in the tank are protected from the electrofishing field by the design of the tank. which uses to advantage a phenomenon known as Faraday shielding (an electrostatic shield created with conductor, ground, and a series of parallel wires). This tank is easy and inexpensive to construct and safe to use on many styles of boat.

Sharber, N.G. and S.W. Carothers. 1990. Influence of electric fishing pulse shape on spinal injuries in adult rainbow trout. Pages 19-26 *in* I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Rainbow trout (*Oncorhynchus mykiss*), Colorado River, morphology, x-ray, autopsy, electric parameters, electric fishing.

Adult rainbow trout captured from the Colorado River by electric fishing were analyzed for spinal injury by x-ray and autopsy techniques. During electric fishing, three pulse shapes were used and compared. The analysis of 209 x-rays showed that 50.2% of the fish suffered spinal injuries involving an average of eight vertebrae (dislocated and/or splintered vertebrae). The number of fish injured was significantly different between the exponential pulse (44.4%) and the 1/4 sine wave pulse (67.3%) and between the square wave (43.6%) and the 1/4 sine wave (67.3%). The severity of the injuries in the spinal column changed as a function of pulse shape. The average number of vertebrae displaced or broken was significantly greater with the 1/4 sine wave (9.5) than for the exponential pulse (6.6). Of the three commonly used pulsed wave shapes, the exponential pulse is the most effective and least traumatic.

In this study, electric fishing was performed at night using a boat-mounted Honda 6.5 KVA. gas-powered single-phase (60 Hz), 240 volt generator. Electrodes were two stainless steel balls 30 cm in diameter. Captured fish were placed in a Faraday shielded live well (Sharber and Carothers 1987). A Coffelt WP-15 (variable volt pulsator) generated the square wave and 1/4 sine waves. The exponential pulse was generated through a pulsator of the authors' design (Vector Max 101). Water temperature ranged from 9 to 11 degrees Celsius, conductivity ranged from 600 to 800 µS/cm, and water depth ranged from 1 to 3 meters. The trout had a mean total length of 360 mm.

During x-ray analysis and autopsy, it was possible to distinguish between the abnormalities caused by electric fishing and those occurring naturally. Natural abnormalities were indicated by more dense and fused section of the vertebral column. Electric-induced injuries are usually separations of the vertebrae showing visible misalignment. All injuries noted were associated with internal bleeding and/or splintered bones due to compression fractures caused by tetanus in the muscle tissue along the spinal column. Fish that possessed natural ab normalities (compacted vertebrae) displayed no hematoma or splintered bone.

The incidence of injury (43.6% - 67.3%) reported here represents the highest level of electric fishing induced damage to fish vertebrae and nearby soft tissue yet reported. Hauck (1949) recorded 26% mortality with large rainbow trout, Pratt (1954) reported 6.4% mortality on rainbow. Hudy (1985) recorded >5% on brook and rainbow trout, McCrimmon and Bidgood (1965) reported 7.6% in rainbow trout, and Spencer (1967) had mortalities on bluegill which ranged from 1.5% to 12.2%.

It has been Sharber and Carothers' ground-breaking work on electrofishing-induced injuries that has established the need for extensive re-evaluation of accepted electrofishing principles and practices.

Simpson, D.E. and J.B. Reynolds. 1977. Use of boat-mounted electrofishing gear by fishery biologists in the United States. Prog. Fish Cult. 3(2):88-89.

Mail survey, United States, fishery biologists, electric gear, electric fishing.

A 1976 mail survey of fishery biologists in the continental United States indicated that boat-mounted electrofishing gear was used on lakes more often than streams (71%), and for management rather than research (54%, 231 respondents). Alternating current was used by 62%, and about two thirds had at least one device for modifying electrical current (e.g., variable voltage pulsator). PDC was used more often in research than in management, in steams than in lakes, and in the West than in other regions of the country.

A boat-mounted Smith-Root 7.5 GPP or Coffelt VVP-I5 electrotishing system would prove effective at removing squawfish from the Columbia River.

Snyder, D.E. and S. A. Johnson 1991. Draft index bibliography of electrotishing literature. Prepared for USDI Bureau of Reclamation and Glen Canyon Environmental Studies Team. Larval Fish Laboratory, Colorado State Univ., Ft. Collins, CO 8052 1.

Eiectrofishing, indexed bibliography.

This topically indexed bibliography of 854 references was prepared for a review of fish injuries and mortality caused by electrofishing and the various factors associated with these impacts. This bibliography is extensive and should be considered a primary reference source for any electrofishing project. The topic headings covered are: effects of electric tields on fish, factors affecting fish response and electrofishing efficiency, comparisons of effects of factors with non-electric gear as technical gear design, construction and operation, application, sampling design and analysis, safety regulations and guidelines. The required research involved in establishing and maintaining an electrofishing operation would be greatly facilitated by use of this bibliography,

Spencer, S.L. 1967. Internal injuries of largemouth bass and bluegill caused by electricity. Prog. Fish Cult. 29: 168-169.

Largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), controlled conditions, Alabama, harm caused by AC, DC eiectrofishing.

This paper reported on the incidence and severity of injury on three warm-water species of fish (bluegill, largemouth bass and channel catfish) after being exposed to several common types of AC and DC elecuofishing current.

Fish were subjected to the selected voltage and exposure period, frozen, and then later dissected. In bluegill, dislocated vertebrae and ruptured dorsal arteries were easily seen with the unaided eye. Most ruptures were accompanied by a local blood clot. In every test with bluegill 230 volts AC gave the highest incidence (12.2 %) of injury, 115 volts AC gave 4.6% injury, and I 15 volts DC gave 1.5% injury. Additional tests on bluegill showed that there is no apparent relationship between exposure time and incidence of injured vertebrae. Vertebral injury appears to occur immediately upon exposure to the electrical stimulus.

When electrofishing for squawfish, potentially harmful effects on incidentals such as bluegill may be abated by operating the electrofishing equipment at less harmful current and waveforms (i.e., pulsating I15 volt DC over AC).

Steinmets, B. 1990. Electric fishing: some remarks on its use. Pages l-4 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Mail survey, European Inland Fisheries Advisory Commission (EIFAC), fishery biologists, electric gear, electric fishing.

A questionnaire to identify the present use of electric fishing was sent to 25 EIFAC national correspondents. Replies from 30 agencies in 10 European countries were received. Classical wading and classical boat fishing (two hand-held anodes) on large water bodies are the main electric fishing activities in Europe. In the United States, boat fishing with boom-mounted arrays is most common (Lazauski and Malvestuto 1984).

Sternin, V.G., I.V. Nikonorov and Y.K. Bumeister. 1972. Electric fishing, theory and practice. Translated from Russian by Israel Program for Scientific Translations. Jerusalem, 1976.

Electric parameters, behavior, physiology, morphology, fishing gear, electric gear, electric fishing.

This textbook presents detailed material on electric theory, electrical conductivities in water, electrode function and design. electrical fields in water, conductivities of fish, fish behavior in electric fields, the effects of electricity on fish, and electric fishing gear and its operation.

This book should be considered a complementary text to I.G. Cowx's Fishing with Electricity

Stewart, P.A.M. 1990. Electrified barriers for marine fish. Pages 243-255 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Atlantic salmon (*Salmo salar*), marine aquaculture, Aberdeen, Scotland, controlled environment, behavior, physiology. electric parameters, electric barriers, behavior of fish to electric barriers.

This study was concerned with low-powered electrified fish barriers. Useful basic information on the form ot electric stimulus needed to operate a barrier by defining the pulse shapes which induce significant muscular contractions in fish is detailed. These contractions are an irritant. which do not themselves produce a particular behavioral reaction, but can induce fish to leave an electrified zone.

It was found in both aquarium and sea-cage experiments that the electrified zone has to be clearly visible to the fish before it acts as a barrier. The electric field appears to reinforce the visual impact of a barrier. Observations on the effects of an electrified barrier in a sea cage found that flat fish, but not round fish, could be confined. A bubble curtain tested under the same conditions confined round fish, but not flat fish.

It is feasible that present Merwin Traps could be upgraded to include electric barriers.

Taylor, G.N., L.S. Cole and W.F. Sigler. 1957. Galvanotaxic response of fish to pulsating direct current. J. Wildl. Manage. 21(2):201-213.

Rainbow trout (*Oncorhynchus mykiss*), physiology, electrical parameters, continuous direct current, pulsating direct current, alternating current.

The galvanotaxic response of fish to PDC and DC was investigated. Both PDC (96 pulses per second) and DC using duty cycles of 0.33, 0.47, and 0.88 yielded good galvanotaxic responses in rainbow trout. Pulsed DC reduced the necessary power requirements by 45% as compared with continuous DC. Tests using 0.47 and 0.88 duty cycles indicate that they were less efficient at producing galvanotaxis than the 0.33 duty cycle.

There were no mortalities on the 91 fish treated with continuous DC, 0.3% mortality occurred in the 1,641 PDC-treated fish, and 42% mortality occurred in the 46 fish treated with alternating current. In general, this study suggests that PDC (triangular pulse shapes) run at lower duty cycles with a fast pulse rate (96 Hz) is an effective and efficient method of electrofishing. This information could be directly applied to the squawfish electrofishing removal effort.

Vibert, R. 1963. Neurophysiology of electric fishing. Trans. Am. Fish. Soc. 92(3):265-275.

European eel (*Anguilla anguilla*), brown trout, (*Salmo trutta fario*), rainbow trout (*Oncorhynchus mykiss*), neurophysiology, laboratory experiment, direct current, galvanotaxis, electric fishing.

The basis for contemporary understanding of the causative mechanisms involved with fish neurophysiology in electrofishing has been established primarily by the work of R. Vibert and fellow Frenchman P. Lamarque.

This paper summarized Vibert's 100-page study that comprehensively identified the main reactions fish demonstrate in a continuous direct current electric field. The mechanisms of the observed behavior were investigated and explained in terms of the fish nervous system.

Vibert described the following reactions of fish to a direct-current field of increasing strength: (1) primary reactions without galvanotaxis, fins and muscular twitching, (2) inhibition of normal swimming, (3) galvanotaxis, induced forced swimming (4) narcosis, relaxation of musculature, (5) pseudo-forced swimming. tetanus, second stage of forced swimming period, (6) tetanus hypertonic stiffness, seizure of musculature being induced at high voltages, often followed by death.

The material presented by Vibert is one of the definitive works on fish neurophysiology in electric fields. This material is still directly applicable to today's electrofishing operations.

Weisser, J.W. and G.T. Klar. 1990. Electric fishing for sea lampreys (*Petromyzon marinus*) in the Great Lakes. Pages 59-64 in I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications, Ltd.

Sea lamprey (*Petromyzon marinus*), Great Lakes, fishery management, fishing gear, traps, poison, electric weirs, electric fishing.

By the mid 1940s. it was apparent that the parasitic-phase sea lamprey were rapidly depleting valuable fish stocks in the Great Lakes (Smith et al. 1974). This paper summarizes electric fishing gear developed to collect adult and larval sea lampreys in the tributaries and offshore areas of the Great lakes.

Electric fishing for lampreys in the Great Lakes began with stream surveys in the 1940s. The tirst control effort began in 1952 with the development of in-stream electric weirs. More than 750.000 adult sea lampreys were trapped and destroyed from 1953 to 1969 (Smith 1971). Juvenile lampreys were collected with various backpack shocking units, the most modern and effective being the Abp-2 backpack electrofishing unit. Electric trawls were also used, but with limited success. being later replaced by an effective bottom toxicant.

Future agency-operated squawtish removal methods could include electric weirs or electrified Merwin Traps. The present longline commercial fishery could utilize the backpack units in the collection of juvenile lampreys for bait purposes.

Welton, J.S., W.R.C. Beaumont and R.H.K. Mann. 1990. The use of boom-mounted multi-anode electric fishing equipment for a survey of the fish stocks of the Hampshire Avon. Pages 236-242 *in* I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications. Ltd.

River Avon, Hampshire, United Kingdom, collection methods, site selection, modeling, electric gear, electric fishing, comparison of capture techniques.

Two methods were compared: (1) three wooden punts deployed across a width of river, each containing a fishing team with a generator and two hand-held anodes, and (2) a boom-mounted, multi-anode electric fishing system on a single boat. After a series of trials, the boom-mounted multi -node system was chosen to be used in the main survey of the river.

The boom electric fishing boat was modeled after the system designed by the Severn-Trent Water Authority (Cowx et al. 1988). It was a 4.3 meter long cathedral hulled boat, propelled by a Honda 100 (9.9 HP) outboard, with a 10 m boom pivoted in the center and mounted on the bow. Ten 800 mm tubular copper anodes (30 mm diameter) were suspended at equally spaced intervals along the boom. Two inflatable rubber boats were rowed behind the main boat to act as additional catchers. Electrical power was from a 7.5 KVA Allan generator to a Millstream LR (FB8A) electric fishing box. This produced an output of 230 V, 18 A at 100 pulses per second.

Fishing down stream, four successive fishing runs were carried out at each site. The boom was kept at right angles to the bank. Speed was maintained at slightly faster than the current.

In this study, 14 species of fish were caught, totaling 2,807 individuals ranging in size from 3 to 1,100 mm. Catch efficiency ranged from 33% (grayling) to 52% (barbell). The efficiency per fishing run for all species combined at each site ranged from 33% to 50%, with an average of 42%.

In an attempt to increase catch efficiency, stop nets were set around electrofishing sites. Difficulties were encountered in setting stop nets in the river. If placed where water velocity was high, a large bag developed. making it impossible to extract weed or fish from the net. Accumulation of weed in the net disrupted sampling (lead line lifted). There was no evidence of fish being driven in front of the boat. If no stop nets were used, larger sections of the river could be fished in the time available. The net setting and retrieval took two to three hours per day.

The electric fishing gear detailed here represents a successful alternative to Novotny's Wisconsin ring. Regardless of which anode is used, the sampling procedure outlined. for the multi-anode boom boat, would be successful in the Columbia River.

Whaley, R.A., O.E. Maughan and P.H. Whiley. 1978. Lethality of electroshock to two freshwater fishes. Prog. Fish Cult. 40(4):161-163.

Fantail darter (*Etheostoma flabellare*), bluegill (*Lepomis macrochirus*), electrophysiology, electric fishing.

The lethality of electroshock to bluegill and fan-tailed darters subjected to commonly employed ranges of pulsating direct current was examined. The knowledge of lethality of electric shock to targeted fish is of primary concern to fisheries biologists in the field. If electroshock is employed as a capture tool of a catch-depletion-based population estimate, fish not captured during the first electrofishing attempt must remain available for capture during later attempts.

Whaley et al. showed that even electrotaxic currents (pulsed DC) produce some amount of mortality. Duration of exposure time appeared to be the factor most responsible for the death of fish. Mortalities were low when exposure time was kept under fifteen seconds. With experience and by understanding the electro-physiological responses in fish, researchers can adjust electrofishing units to operate efficiently with minimal harm to fish.

Willemstad, J. 1990. The electrified trawl as an alternative type of fishing gear to eel traps. Pages 70-78 ***in*** I.G. Cowx, ed., Developments in Electric Fishing. Oxford: Fishing News Books, Blackwell Scientific Publications. Ltd.

European eel (*Anguilla anguilla*), perch (***Perca fluviatilis***), Lake Ijssel, Netherlands, commercial fishing, fishing gear, beam trawl, electric beam trawl, electric fishing.

This study investigates whether an electrified beam trawl would be a good alternative to the commercial eel trap, a gear which causes high incidental mortality among the young of other commercially important species. The electrified trawl proved to be effective for catching eel. Catch rates were 7 to 20 times greater in nets with electric current than without. Incidental catches of perch, bream, and roach were reduced by a factor of two to three.

Future squawfish removal efforts may want to upgrade existing trap or purse seine equipment by adding electricity to their design.

Willis, C.F. et al. 1985. Abundance and distribution of northern squawfish and walleye in the John Day Reservoir and Tailrace, 1982. Annual Progress Report, 1982. Oregon Dept. Fish Wildl.. 33 p.

Squawfish (***Ptychocheilus oregonensis), walleye (Stizostedion*** *vitreum*), Columbia River, drift and stationary **gillnets,** trap nets, boat electrofishing, hook and line, radio 'tag, abundance and distribution of salmon predator populations.

A variety of gear types were used to assess the abundance and distribution of squawfish and walleye in the John Day Reservoir. Squawfish abundance in the boat restricted zones of John Day and McNary Dams was approximately 4,600 and 8,500 fish, respectively. Walleye abundance could not be estimated because they were not recaptured.

Angling appeared to be the most effective method in capturing squawfish near the dams (2,100 fish. 4 fish per hour), compared with other gear types (670 fish, <1 fish per hour). Beach seines (20 sets) were ineffective at catching either species. Electrofishing tended to capture smaller fish, whereas angling captured squawfish >300 mm. Squawfish moved into the tailrace area after spilling stopped.

Witt, A.J. and R.S. Cambell. 1959. Refinements of equipment and procedures in electrofishing. Trans. Am. Fish. Soc. 88:33-35.

Centrarchids, Missouri, seine nets, electric fishing gear, electric fishing, efficiency comparison.

A boat-mounted electric seine is described. This, boom seine was three times more efficient at night than during the day. The catch of the boom seine in a Missouri impoundment is compared with the catch from nets. This gear was found to be selective for centrarchids (except white crappie) in waters where nets were selective toward white crappie, gizzard shad. white bass and freshwater drum. Selectivity was related to the behavior of fishes and the habitat where fishing was done. Average catch for diurnal electrofishing in June was 98 fish per hour and for nocturnal electroftshing on the same day was 346 per hour.

The results of electroftshing for any one species is dependent on its diel movements. Having an understanding of squawfish behavior will greatly increase capture rates.

Yundt, S. 1983. Changes in catchability related to multiple electroshock. Proceedings of the Annual Conference, Western Association of Fish and Wildlife Agencies 63: 116-123.

Rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta fario*), Bighorn River, Wyoming, population estimates, electrofishing, throwing electrode.

The purpose of this study was to determine whether the length of time between electrofishing mark-and-recapture runs affected population estimates, and if so, to determine which population model assumptions had been violated.

Electrofishing mark/recapture population estimates were shown to be affected by the length of time between fishing runs. The assumption that all fish have the same probability of being recaptured is violated if subsequent electrofishing runs occur too close together. Electroshocked fish develop avoidance behavior and experience spatial drift, making them less available to subsequent sampling efforts.

Squawfish population indexing efforts in the Columbia River have accounted for the potential sampling bias of electrofishing by allowing for sufficient recovery time between re-sampling of designated areas. Our efforts in the Columbia will concentrate on simple squawfish removal. not population estimates. Therefore, the induced bias of unequal catchability will have only a limited effect on our efforts.

REPORT E

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

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1992 Annual Report

CONTENTS

INTRODUCTION

Despite the almost universal belief that removal of northern squawfish (*Ptychocheilus oregonensis*) will increase survival of juvenile salmonids (*Oncorhynchus* spp.) in the Columbia River Basin (Figure 1), there has yet to be a direct demonstration of the benefit of predator removal. Heretofore, research has focused on estimating abundance of northern squawfish in selected locations (e.g., tailraces and forebays of dams, particular reservoir reaches and near-hatchery release sites) and assessing northern squawfish predation on smolts (Thompson 1959, Uremovich et al. 1980, Poe et al. 1991, Vigg et al. 1991, Nigro 1990).

In 1987, survival of subyearling chinook salmon (0. *tshawytscha*) released at the shoreline downstream from Bonneville Dam was poor compared to that of fish released at midstream and was thought to be related to increased predation by northern squawfish (Ledgerwood et al. 1990). Northern squawfish are known to inhabit protected shoreline areas; a large population of northern squawfish exists in the tailrace area of Bonneville Dam adjacent to Tanner Creek (Vigg et al. 1990, Petersen et al. 1990). Poor survival of smolts released at the shoreline prompted the National Marine Fisheries Service (NMFS), in cooperation with Oregon Department of Fish and Wildlife (ODFW), to begin a release-site survival study at Bonneville Hatchery to evaluate the advantage of midstream Columbia River release.

Bonneville Hatchery is located about 1 km downstream from Bonneville Dam. Fish are normally released into Tanner Creek, which enters the Columbia River about 400 m downstream from the hatchery. Subyearling fall chinook salmon were marked, then simultaneously released into Tanner Creek and into the midstream Columbia River, lateral to its confluence with Tanner Creek (Figure 2). Differences among seine recoveries of juvenile salmon in the estuary indicated that survival following the 157-km migration was dramatically better for midstream Columbia-River-release groups than for Tanner Creek-release groups. In 1989 and 1990, the differences were about 65% and 40%, respectively. These differences were also thought to be related to greater predation by northern squawfish on fish released into Tanner Creek than on fish released into the deep-water/high-current area of the midstream Columbia River.

In 1991, a second cooperative study was begun by NMFS, ODFW, and the U.S. Fish and Wildlife Service (USFWS) to demonstrate the effectiveness of removing northern squawfish from the migration route of juvenile salmon released at Bonneville Hatchery (Ledgerwood et al., in prep.). About 400,000 juvenile fall chinook salmon (upriver bright stock) were marked with both coded wire tags (CWT) and freeze brands at Bonneville Hatchery for the study. Two paired groups of 100,000 fish were released into the midstream Columbia River and into Tanner Creek four days apart. On intervening nights, northern squawfish in the vicinity of the hatchery release site were removed by electrofishing. Stomach contents of captured northern squawfish were examined for the presence of CWTs from study fish. As in previous years, subyearling chinook salmon released into the midstream Columbia River had significantly higher survival rates than fish released into

Tanner Creek. It also was apparent from CWT recoveries in the stomachs of northern squawfish that Tanner Creek-released juveniles were more vulnerable to predation than juveniles released in midstream. However, the electrofishing efforts did not significantly reduce the survival difference between midstream Columbia River and Tanner Creek release groups, although the survival difference of about 2 1% in 1991 was considerably less than the previous years and appeared to be inversely related to the movement rate of the Tanner Creek release groups to the estuary. We speculate that the higher river flow in 1991 dispersed test fish more rapidly, reduced their exposure time to predation, and resulted in higher survival rates for the Tanner Creek releases. Additional data, with different river conditions, were needed to better understand the effectiveness of localized predator removal on survival rates of juvenile salmon.

This report summarizes the results of a third cooperative study conducted in 1992, with objectives similar to 1991 research: (1) to assess survival differences for juvenile salmon after the removal of northern squawfish from Tanner Creek and adjacent shoreline areas of the Columbia River; (2) to assess effectiveness of electrofishing to remove northern squawfish from the migration route of juvenile salmon in the vicinity of the hatchery release site; (3) to assess prey consumption by northern squawfish before and after large-scale predator removal efforts to determine the effects of predator size and density on the rate at which juvenile salmonids are consumed; and (4) to provide samples of study fish collected in the estuary to determine the degree of smoltification (ATPase activity, reflectance, and morphometrics)[1], feeding behavior (stomach fullness and diet), and diel migratory behavior of study fish.

METHODS

Experimental Design

Prior to northern squawfish removal efforts, one uniquely marked group of 100,000 juvenile fall chinook salmon was released into Tanner Creek and another into the midstream Columbia River, lateral to the confluence of Tanner Creek. During the following four nights, extensive electrofishing efforts were made to remove northern squawfish from Tanner Creek and from the adjacent shoreline areas of the Columbia River extending 1 km upstream and 6 km downstream from the release sites. Catch per unit effort (CPUE), size of fish removed, numbers of salmon ingested, and overall food consumption by northern squawfish were assessed to evaluate changes in the local northern squawfish population and their impacts on released salmon. Following the northern squawfish removal efforts, a second pair of uniquely marked 100,000-fish groups was released at the two study sites. The second

[1] Smoltification work was conducted by the USFWS (Alec Maule and Phil Haner) under a separate contract to Bonneville Power Administration and will be reported independently.

pair of releases was followed by another two nights of extensive electrofishing for northern squawfish to evaluate their possible response to the reintroduction of juvenile salmon.

Purse and beach seining were conducted near the upper boundary of the Columbia River estuary at Jones Beach, River Kilometer (RK) 75, to recover marked fish. Recovery percentages were used for evaluating short-term survival differences between fish groups released at the two study sites before and after northern squawfish removal efforts. Similar comparisons of the relative contribution of marked fish recovered in ocean and river fisheries and returning to the hatchery will provide a long-term evaluation for all release groups.

Test Fish

Test fish were the progeny of fall chinook salmon (upriver bright stock) collected by ODFW personnel at Bonneville Hatchery. About 400,000 of these fish were reared at the hatchery for this study. At release, the mean size of these subyearling-age fish was 6.0 g (76 fish/lb), which was similar to that of fish used in the 1989 ($\bar{x}$ = 7.0 g), 1990 ($\bar{x}$ = 6.3 g), and 1991 ($\bar{x}$ = 7.4 g) studies.

Marking Procedures

Test fish were marked from May to June 3, Monday through Friday, by two eight-person crews marking fish eight hours per day; about 40,000 fish were marked each day. Each marked group had unique CWTs (Bergman et al. 1968). Cold brands (Mighell 1969) were applied to allow visual identification of fish from different treatment groups in samples seined from the estuary.

Logistics for marking fish were similar to those described by Ledgerwood et al. (1990). Two measures were taken to ensure that marked groups did not differ in fish size, fish condition, rearing history, or mark quality: (1) the four groups were marked simultaneously; and (2) differences in mark quality among groups were minimized by rotating fish markers and mark codes among fish marking stations every two hours so that each marker and each station contributed equivalent numbers of marked fish to each treatment group. To assess and maintain quality control in the tagging process, samples of 30 to 100 fish from each treatment were collected intermittently from outfall pipes at the marking trailer and checked for CWTs (Appendix Table A-l). Similarly, samples of about six fish from each treatment were diverted into net pens eight times each day and held for a minimum of 29 days to determine tag loss. Samples from each treatment were held in separate net pens. Estimates of tag loss ranged from 3.5% to 7.3% ($\bar{x}$ = 5.2, n = 1,610; Appendix Table A-2). Release numbers for each CWT release group were adjusted for estimated tag loss based on tag loss for the marked fish held a minimum of 29 days.

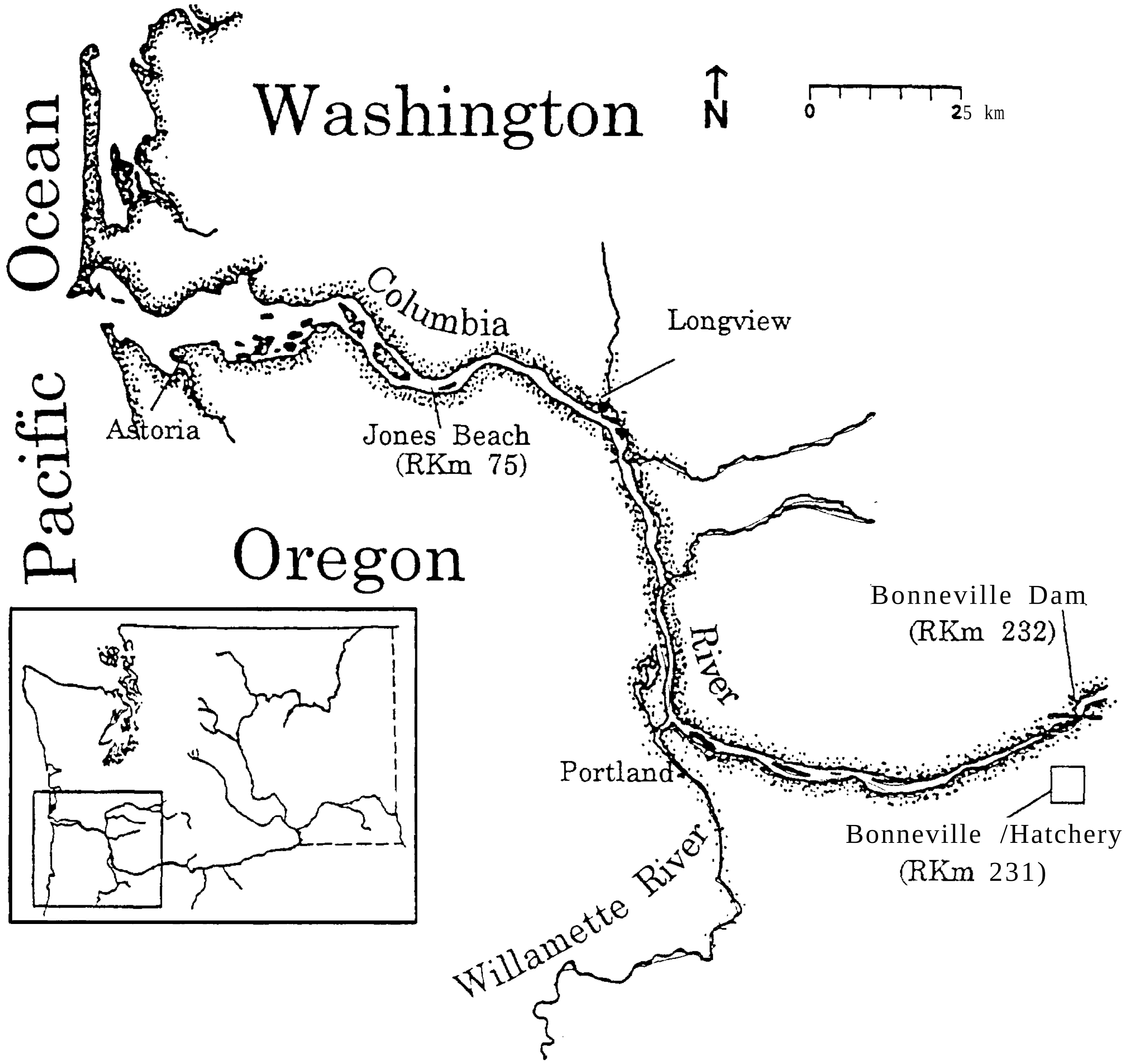

Figure l.--Columbia River Basin showing the study area.

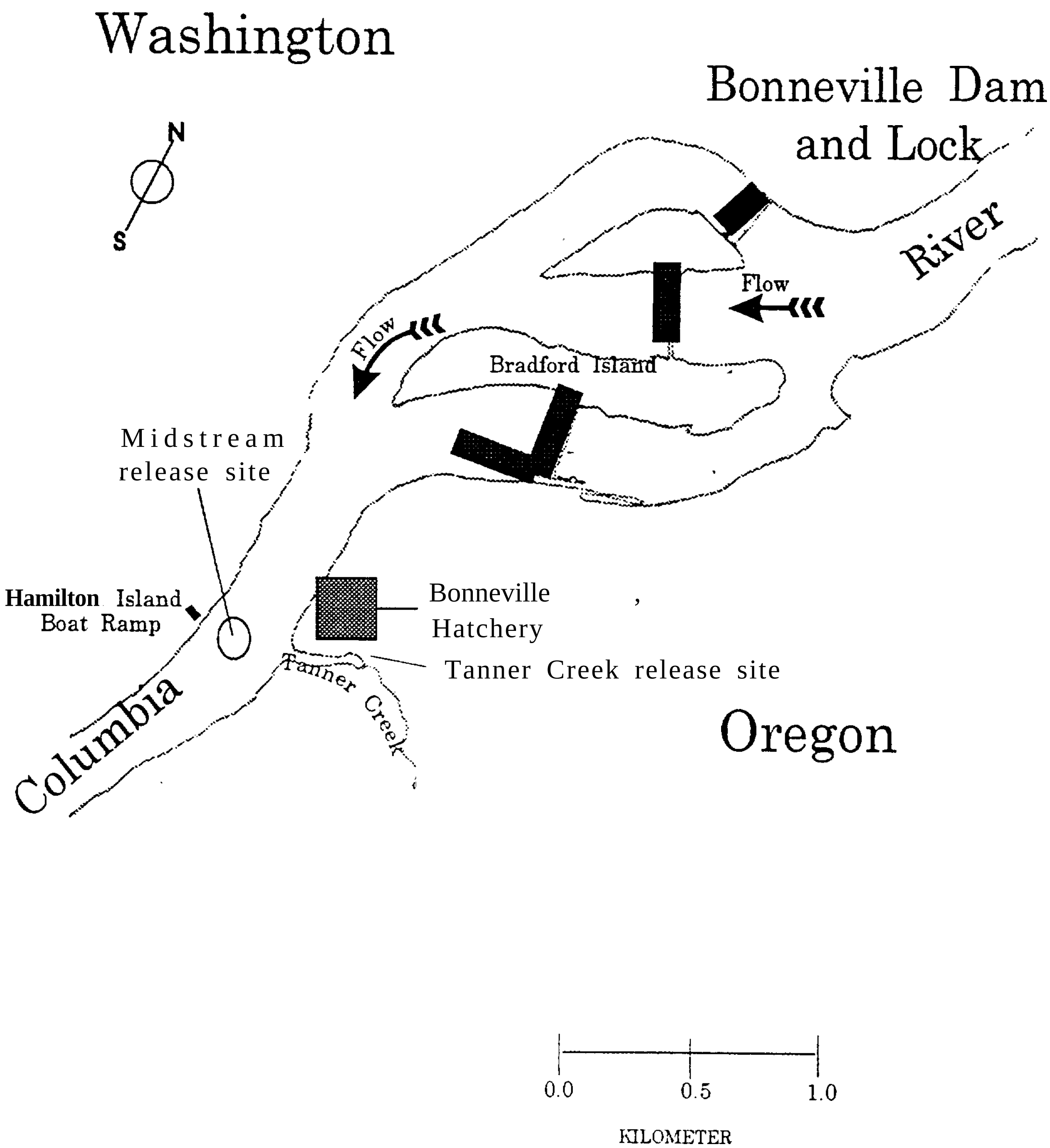

Figure 2.--Release locations for subyearling chinook salmon, 1991-1992.

Release Locations and Procedures

Groups of marked fish were released into Tanner Creek (the normal hatchery release site) and into the midstream Columbia River, lateral to the confluence of Tanner Creek (Figure 2). The specific release locations and procedures were as follows.

1. Tanner Creek: Test fish were released using the normal hatchery procedure of drawing down the water in the rearing pond and crowding fish into an underground flume. The flume carried fish about 650 m to Tanner Creek, where they were free to migrate to its confluence with the Columbia River, about 400 m downstream. At the confluence, fish were lateral to and about 150 m from the midstream Columbia River release site. Tanner Creek releases began at 8:30 p.m., about an hour prior to midstream releases, to provide extra time for fish traveling to the Columbia River.

2. Midstream Columbia River: Test fish were pumped through a hose with a diameter of 15 cm into 4,000-L tanker trucks; three trucks were used on each release night. Each truck was loaded with about 34,000 fish to maintain transport densities of about 60 g fish/L water (0.5 lb/gal). The trucks were loaded aboard a barge at the boat launch on Hamilton Island with one truck per barge trip. At midstream, the fish were released into the river through a 3-m-long hose with a diameter of 15 cm. Releases occurred between 9:30 p.m. and 11 p.m. at about RK 232.

Electrofishing Northern Squawfish

Two 5.5-m electrofishing boats (Smith-Root brand, model SR-18E)[2] were used to capture northern squawfish. The bow platform of each boat was equipped with a pair of adjustable booms fitted with umbrella anode arrays. These arrays consisted of six stainless steel cables, which were lowered into the water when fishing. All electrofishing was pulsed direct current using 60 pulses/sec, 400-500 volts, and 4-5 amperes.

Electrofishing activities began at 3 a.m. on June 16, about six hours following the first pair of releases (Appendix Table B-l). On subsequent nights through June 19, electrofishing was conducted from 9 p.m. to 9 a.m. Electrofishing was delayed the first night to allow test fish to disperse following release. Nine areas between RK 232 and RK 225 were electrofished, one in lower Tanner Creek and eight others in nearshore areas in the Columbia River (Figure 3). Each area was electrofished at least twice for about 30 minutes during each electrofishing period. Though transects on both the Oregon and Washington sides of the Columbia River were electrofished, removal efforts were more concentrated in transect areas closest to the release locations.

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2 Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

Northern squawfish stunned from electrofishing generally came to the water surface and were collected with a dipnet; some stunned fish were lost in the swift currents. Netted fish were placed in a lethal solution of tricaine methane sulfonate (MS-222) and within about 40 minutes of capture, taken to a processing station on shore where weight (g), fork length (mm), sex, and state of sexual maturity were recorded for each fish. The digestive tract (esophagus to anus) was removed from each fish, placed in a plastic bag, and frozen for later analysis.

In the laboratory, frozen digestive tracts were thawed and prepared for analysis using a digestive enzyme solution (pancreatin) to dissolve flesh, but leave diagnostic bones and CWTs from ingested fish intact (Petersen et al. 1990). The 2% (by weight) pancreatin solution, prepared using lukewarm tap water, also contained 1% sodium sulfide. This solution was added to the plastic bags containing the digestive tracts and the bags were placed in a 40" C desiccating oven for 24 hours. The stainless steel CWTs, having a greater density than bone, sank to the bottom after agitation of the digested samples, and were removed. In addition, these samples were checked for missed CWTs using an electronic tag detector. CWTs were decoded using a compound microscope (Appendix Table B-2). The solid contents of the bags were then rinsed through a 425 μm sieve using tap water. A compound microscope and forceps were used to remove diagnostic bones (primarily cleithra, dentaries, and opercles) from the samples (Hansel et al. 1988). Diagnostic bones were identified and paired to enumerate salmonids and other prey consumed.

Sampling at Jones Beach

Short-term survival differences among release groups were assessed from comparisons of tagged fish recovered near the upper boundary of the Columbia River estuary at Jones Beach (RK 75). In addition to determining recovery differences, captured fish were observed for differences in descaling, injuries, size, feeding, and migration behavior. Dawley et al. (1985, 1988) described the sampling site and the fishing gear.

Sampling was conducted by two or three crews working seven days per week for eight to 12 hours per day, beginning at sunrise (Appendix Table C-l). Both purse seines (midstream) and beach seines (Oregon shore) were used to determine whether study fish were more abundant in midstream or near shore (Figure 4) and to maximize effort using the gear type that captured the greatest numbers of study fish.

All captured fish were processed aboard the purse seine vessels. The catch from each set was anesthetized in a 50-mg/L solution of ethyl p-aminobenzoate (benzocaine) and enumerated by species. Numbers of dead, injured, or descaled salmonids were recorded. Subyearling chinook salmon were examined for excised adipose fins and brands (possible study fish) and separated for mark processing. Non-study fish were returned to the river immediately after counting, evaluation, and recovery from anesthesia. Descaling was judged rapidly while counting and separating study fish from non-study fish. Fish were classified as descaled when 25% or more of their scales on one side were missing.

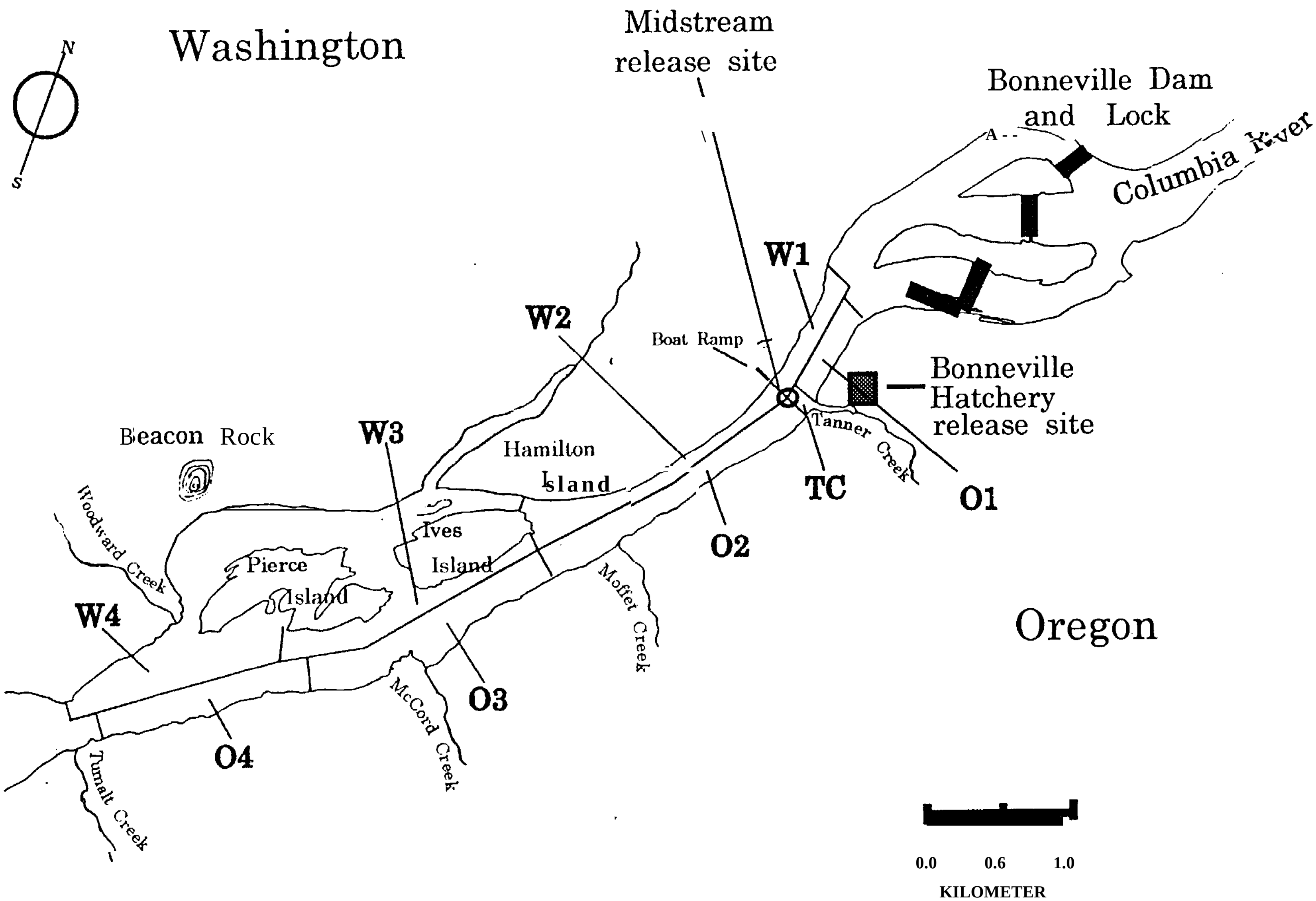

Figure 3.--Electrofishing areas in Tanner Creek and adjacent shoreline areas of the Columbia River, 1991-1992.

Freeze brands were used to identify study fish for collecting CWTs, obtain biological samples, compare fish size among treatment groups, and adjust the daily sampling effort to attain the desired minimum sample size of 0.5% of the number of fish released. Brand information, biological and associated sampling data (e.g., date, vessel code, gear code, set number, time of examination, fork length, and descaling) were immediately entered into a computer data base and printed. Fork lengths of marked fish were recorded to the nearest mm. All branded fish (including those with illegible brands) were sacrificed to obtain CWTs, which identified treatment group and day of release.

The heads of branded fish were processed in lots, and segregated by recovery day and site of capture. A 40% aqueous solution of potassium hydroxide was used to dissolve the heads and obtain CWTs. All CWTs were decoded and later verified; additional details of tag processing are presented in Appendix D by Ledgerwood et al. (1990).

Purse seine data, obtained from June 19 to July 22, were standardized to a lo-set-per-day effort; beach seine catch data from the same period were standardized to a 5-set-per-day effort. The following formula was used for standardizing each marked group.

$$A_i = N_i\ (S \div P_i)$$

where

A_i = Standardized purse or beach seine catch on day i,
N_i = Actual purse or beach seine catch on day i,
S = Constant (weighted daily average number of purse seine sets (10) or beach seine sets (5) during the sampling period), and
P_i = Actual number of purse or beach seine sets on day i.

On the day when there was no sampling effort for a particular gear type (beach seine, June 25), the standardized catch was derived by averaging standardized catches for one day prior to and one day after the missed day. Dates of median fish recovery for each marked group were determined using the combined standardized data from purse- and beach-seine catches. Movement rates for each CWT group were calculated as the distance from the midstream Columbia River release site (RK 232) to Jones Beach (RK 75) divided by the travel time (in days) from release date to the date of the median fish recovery.

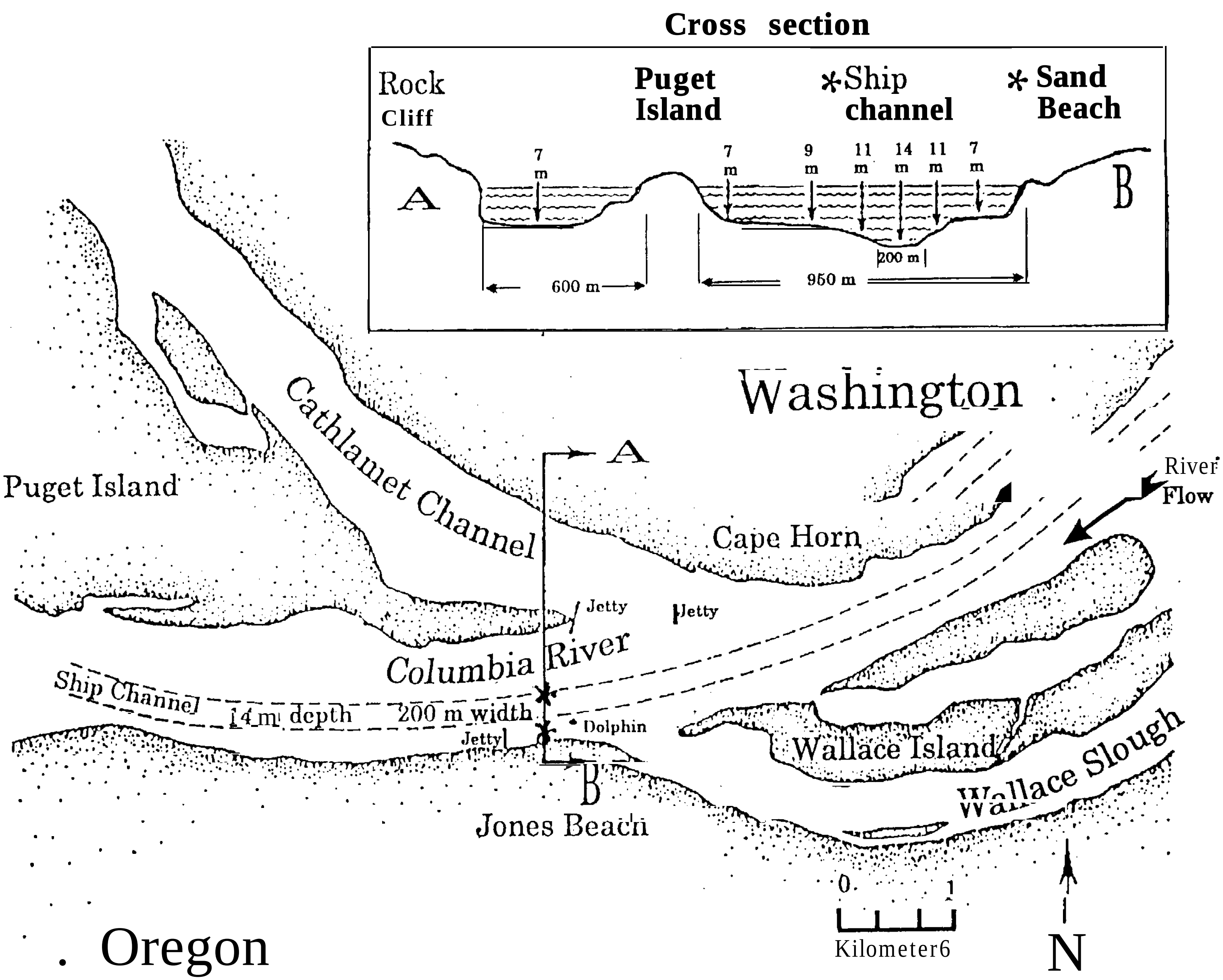

Fig-we 4.--Jones Beach, Columbia River, sampling sites. The beach and purse seining area8 are denoted by asterisks.

Diel, Physiological, and Biological Sampling at Jones Beach

On June 26-27, beach and purse seine sampling was extended through the nighttime hours to determine diel migratory behavior and to assess possible differences among targeted upriver bright and tule stocks[3]. Physiological samples, used for determining degree of smoltification, and stomachs, were taken from selected CWT fish captured during the diel sampling period. Methodology and results for physiological samples will be described in a separate report. Stomachs were excised (esophagus to pyloric caeca), and cleaned of external fat. A stomach fullness value, based on the proportion of the total stomach length containing food, was estimated. A scale of 1 to 7 was used to quantify the fullness as follows: 1 = empty, 2 = trace of food, 3 = one-quarter full, 4 = half full, 5 = three-quarters full, 6 = full, and 7 = distended full (Terry 1977). All stomachs appearing empty were opened for examination, and a value of 2 was assigned if traces of food were observed. Subsamples of stomachs were preserved in 10% buffered formaldehyde solution for weight determination and content analysis (to be reported separately). Holding time prior to fullness observations was about 35 minutes.

Statistical Analyses

The hypothesis that recovery ratios at Jones Beach were equal for fish released into Tanner Creek and the midstream Columbia River was tested using a paired difference z-test. The hypothesis that different marked groups, released the same day, had equal probability of capture through time was tested using chi-square goodness of fit (Zar 1974).

RESULTS

We marked 398,735 fish with freeze brands, CWTs, and excision of the adipose fin before release (Table 1). Between the two release dates, 1,793 northern squawfish were captured and removed from the study area (Table 2). An additional 380 northern squawfish were removed from the study area following the second release. We recovered 1,988 study fish in the estuary (about 0.5% of fish released); 84% of these were captured with purse seines in midstream (Appendix Table C-2). Handling mortality for all subyearling chinook salmon captured at Jones Beach was about 0.2 %; descaling averaged 0.6%, however, no study fish were descaled.

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[3] Two stocks of branded/CWT subyearling chinook salmon were present in the estuary and targeted during the diel sampling period; upriver bright stock used in this study and tule stock used for a concurrent study being conducted at Bonneville Dam (Earl Dawley, NMFS, Hammond, OR, pers. commun.). The goal was to compare behavioral and biological characteristics of the two stocks in the hatcheries prior to release and after migration to the estuary. Detailed results of this sampling will be reported separately.

Electrofishing Northern Squawfish

We captured and removed 2,173 northern squawfish from the nine transect areas during about 26 hours (94,930 seconds) of electrofishing (Table 2). Sixty-six percent (1,438) of those removed were caught in Tanner Creek or adjacent transect areas along the Oregon shore (01, 02, and O3), similar to 1991 (Figure 5). During the June 16-19 electrofishing periods (following the June 15 release), catch rates of northern squawfish were higher than during the June 20-22 electrofishing periods (following the June 19 release) and there was little indication that northern squawfish recolonized the Tanner Creek or adjacent transect areas (Table 3).

The mean fork length (303.0 mm) and weight (234 g) of northern squawfish were fairly consistent throughout the removal periods and considerably smaller than northern squawfish captured during the study in 1991 (means 343.8 mm and 605.9 g; Figure 6). The number of CWTs recovered in the digestive tracts of northern squawfish (representing ingested juvenile salmon) diminished over time. Of the 238 CWTs recovered from the digestive tracts of northern squawfish (Appendix Table B-2), 98% were from study fish and all except one were from study fish released June 15 into Tanner Creek; the exception was a June 15 midstream Columbia River released fish recovered in Transect Area O3[4]. The CPUE was highest in Transect Area 04, along the Oregon shoreline, but no CWTs from study fish were recovered from those northern squawfish (Table 3).

Migration Behavior and Condition of Study Fish

There was no evidence to suggest non-homogeneity between treatment recovery distributions of study fish groups released on the same day (α = 0.05; Appendix D); thus the recovery data were standardized to a constant daily effort to determine the date of median fish recovery and to calculate movement rates (Appendix Table C-2). Temporal catch distributions of each release group are presented in Figure 7.

Movement rates of study fish to Jones Beach ranged from 17.4 to 19.6 km/day, intermediate to movement rates in 1991, but faster than movement rates in 1989 or 1990 (Table 4). Movement rates of fish from the second release groups were about 13% higher than those of the first release groups, probably in part because of increased river flow at the time of the second release (Figure 8).

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4 Northern squawfish captured following the June 19 release were neither weighed nor examined for the presence of CWTs.

Table 1. Summary of releases of marked subyearling chinook salmon, Tanner Creek vs. midstream Columbia River, 1992.

Marking dates	Release date	Brand[a]	Number released: Total[b]	Untagged[c]	Tagged[d]	Wire tag code (AG D1 D2)[e]
Tanner Creek releases						
20 May-3 June	15 June	RD Z2	99,718	4,901	94,817	23 30 07
20 May-3 June	19 June	LD Z2	99.579	3,484	96,095	23 30 08
Midstream Columbia River releases						
20 May-3 June	15 June	RD Z1	99,550	7,310	92.240	23 30 09
20 May-3 June	19 June	LD Z1	99.888	5.054	94,834	23 30 10
		Total	398,735	20,749	377.986	

[a] Brand codes: 1st and 2nd characters, RD = right dorsal position; 3rd character is the brand symbol; 4th character is brand rotation where 1 = symbol in the upright position and 2 = symbol rotated clockwise 90° from upright position.
[b] Total fish marked, branded, tagged, and adipose fin clipped (less observed pre-release mortality and fish retained for tag loss evaluation).
[c] Estimated number of fish released without coded-wire tags (Appendix Table A-2).
[d] Estimated number of tish released with coded-wire tags.
[e] CWT code key: AD D1 D2 = Agency code, Data 1 code, Data 2 code.

Table 2. Number of northern squawfish removed by day (all electrofishing sites) and number of coded wire tags recovered in digestive tracts of northern squawfish, 1992.

	Northern sauawfish removed					CWTs recovered[a] Release site	
Electrofishing period	Time shocker on (sec)	Total catch	CPUE[b]	Mean length (mm)	Mean weight (g)	Tanner' Creek	Mid-stream[d]
Data pertinent to first paired release							
16 June(0300-0900)	9,242	159	62	335	529	156	0
16-17 June(2100-0900)	16,415	753	165	279	380	63	1
17-18 June(2100-0900)	17,097	321	68	296	426	12	0
18-19 June(2100-0900)	25,239	560	80	301	385	3	0
Subtotal"	67,993	1,793	93.75	302.8	430.0	234	1
Data pertinent to second paired release							
20-21 June(2100-0900)	12,829	134	38	337	--[f]		
20-22 June(2 100-0900)	14,108	246	63	270	--	--	--
Subtotal	26,937	380	50.5	303.5	--		
Total	94,930	2,173	79.3	303.0	430.0	234	I

[a] CWT = coded wire tag (Agency code/Data 1 code/Data 2 code). Number of CWTs recovered in the digestive tracts of northern squawfish represent a minimum number of juvenile salmon ingested.
[b] CPUE = catch per unit effort, number of fish caught per hour.
[c] CWT code = 23/30/07, released June 15.
[d] CWT code = 23/30/09, released June 15.
[e] Means weighted by day.
[f] Dashes indicated date not available.

Table 3. Electrofishing effort, number of northern squawfish removed, and number of coded wire tags recovered from the digestive tracts of northern squawfish for each electrofishing transect. 1992.

		Northern sauawfish removed				CWTs recovered[a] Release site	
Location	Mean effort[b] (sec)	Total number	CPUE[d]	Mean length (mm)	Mean weight (g)	Tanner Creek	Mid-stream'
01	14,739	348	29.0	332	598	22	0
02	23,155	678	67.8	275	346	199	0
03	12,964	348	58.0	292	374	6	1
04	6,795	229	45.8	254	262	0	0
W1	10,343	254	31.8	321	496	0	0
w 2	9,213	131	26.2	267	442	0	0
w 3	3,797	22	11.0	337	512	0	0
w 4	10,613	99	19.8	308	439	0	0
TC	3,311	65	7.2	349	630	7	0
Total	94,930	2,174	--	--	--	234	1
mean	10,547.8	241.4	33.0	303.9	455.4	--	

[a] CWT = coded wire tag (Agency code/Data 1 code/Data 2 code). Number of CWTs recovered in the digestive tracts of northern squawfish represent ingested juvenile salmon.
[b] Mean effort per sampling period for each location; total effort (at bottom) is the total time, in seconds, that the shockers were on for all dates and all locations (see Appendix Table Bl).
[c] Location codes (2 characters): TC = Tanner Creek transect area; other Columbia River transect areas, where, 1st character, 0 = Oregon shoreline, and W = Washington shoreline; 2nd character, 1-4, transect areas (refer to Figure 3 for precise locations).
[d] CPUE = catch per unit effort, number of fish caught per hour (Appendix Table B-l).
[e] CWT code = 23/30/07, released June 15.
[f] CWT code = 23/30/09 released June 15.

Table 4. Movement rates to Jones Beach for marked groups of subyearling chinook salmon released in Tanner Creek and in midstream Columbia River, 1989, 1990, 1991, and 1992.

Release date	Movement rate (km/day)[a] Midstream Columbia	Tanner Creek	Mean FL (mm)[b]	Flow (k ft³/sec) At release[c]	At median[d]
29 June 1989	10.4	9.8	101	142	113
1 July 1990	12.1	12.1	91	247	190
24 June 1991	15.7	17.4	92	215	262
28 June 1991	22.4	22.4	92	272	258
15 June 1992	17.4	17.4	95	191	198
19 June 1992	19.6	19.6	94	207	186

[a] Movement rate = distance from the midstream Columbia River release site (RK 232) to recovery site (RK 75) divided by the time in days from release to median fish recovery. Median fish recovery based on purse seine recoveries standardized to a 10 set per day effort plus beach seine recoveries standardized to a 5 set per day effort (Appendix Table C-2).
[b] Mean fork length of tish recovered at Jones Beach.
[c] Average flow through Bonneville Dam on the day that fish were released.
[d] Average flow through Bonneville Dam within 4 days of the date that the median fish was captured; by convention, English units were used for river flow volumes (k . ft^3/sec = 1 .OOO ft^3/sec = 28.3 m^3/sec).

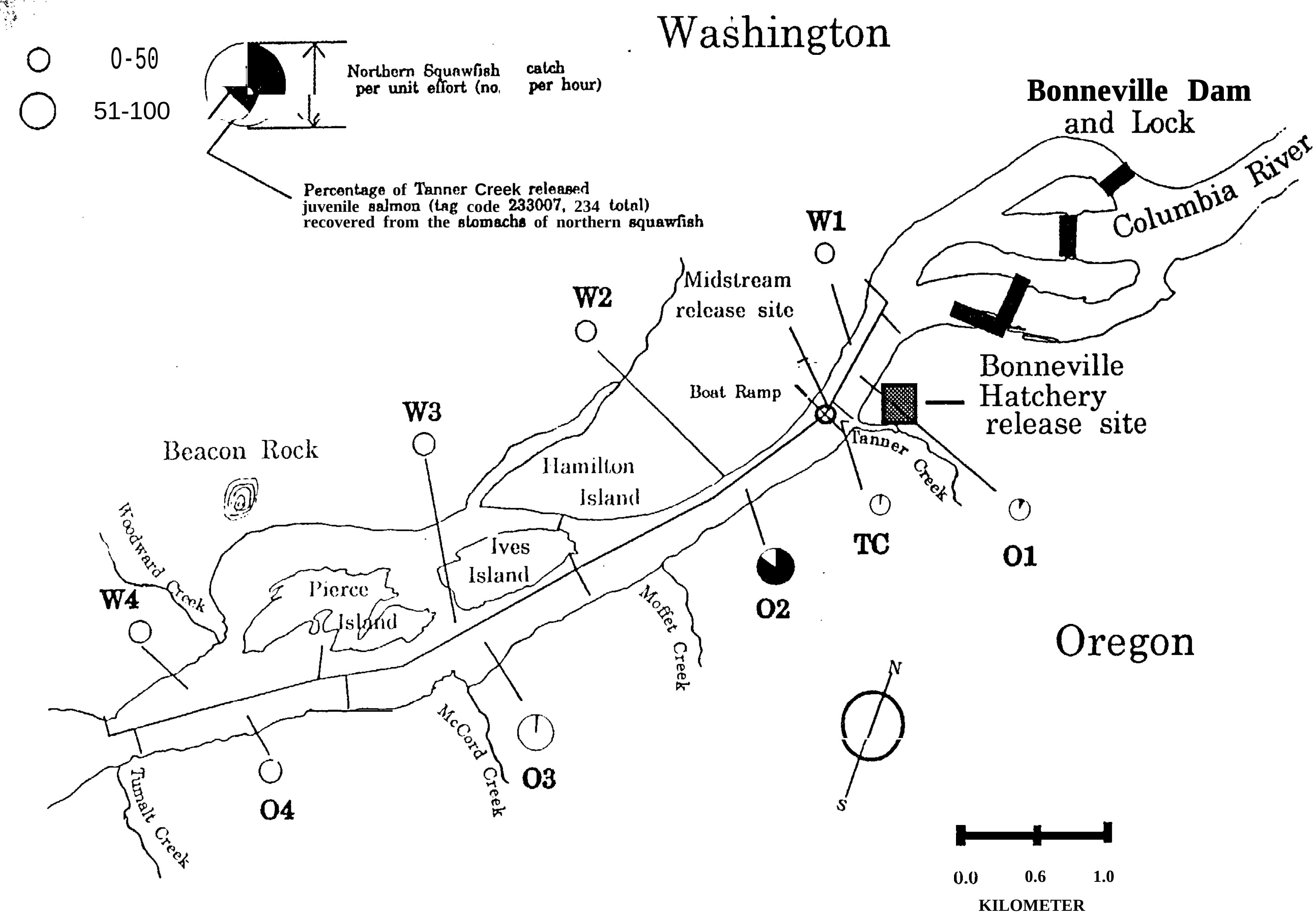


Figure 5.--The study area showing the northern squawfish catch per unit effort at each electrofishing transect area and proportion of tags (representing ingested juvenile salmon) from the 15 June Tanner Creek release group recovered in those northern squawfish, 1992.

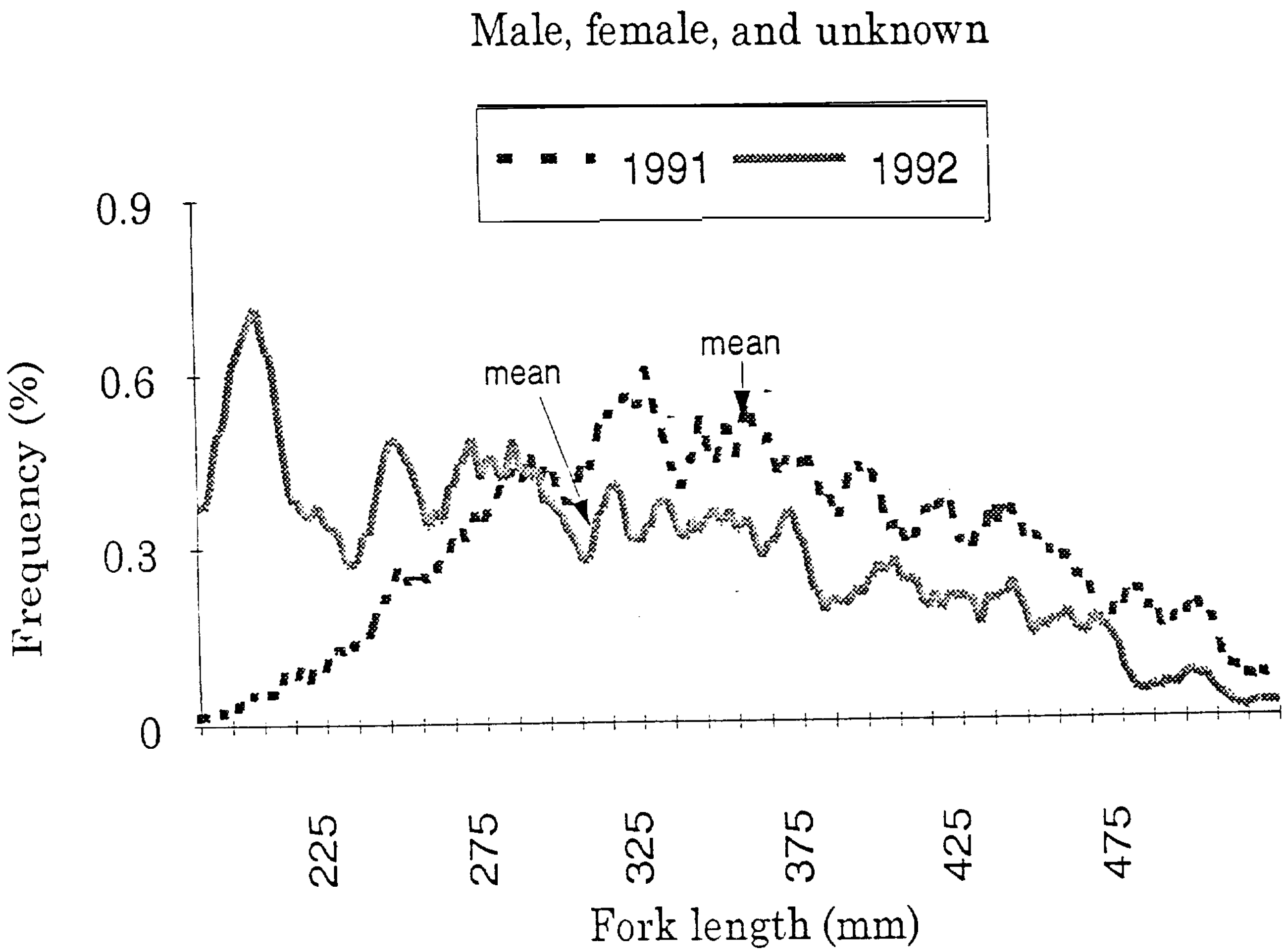


Figure G.--Fork length distributions of northern squawfish removed from the study area by electrofishing, 1991 and 1992.

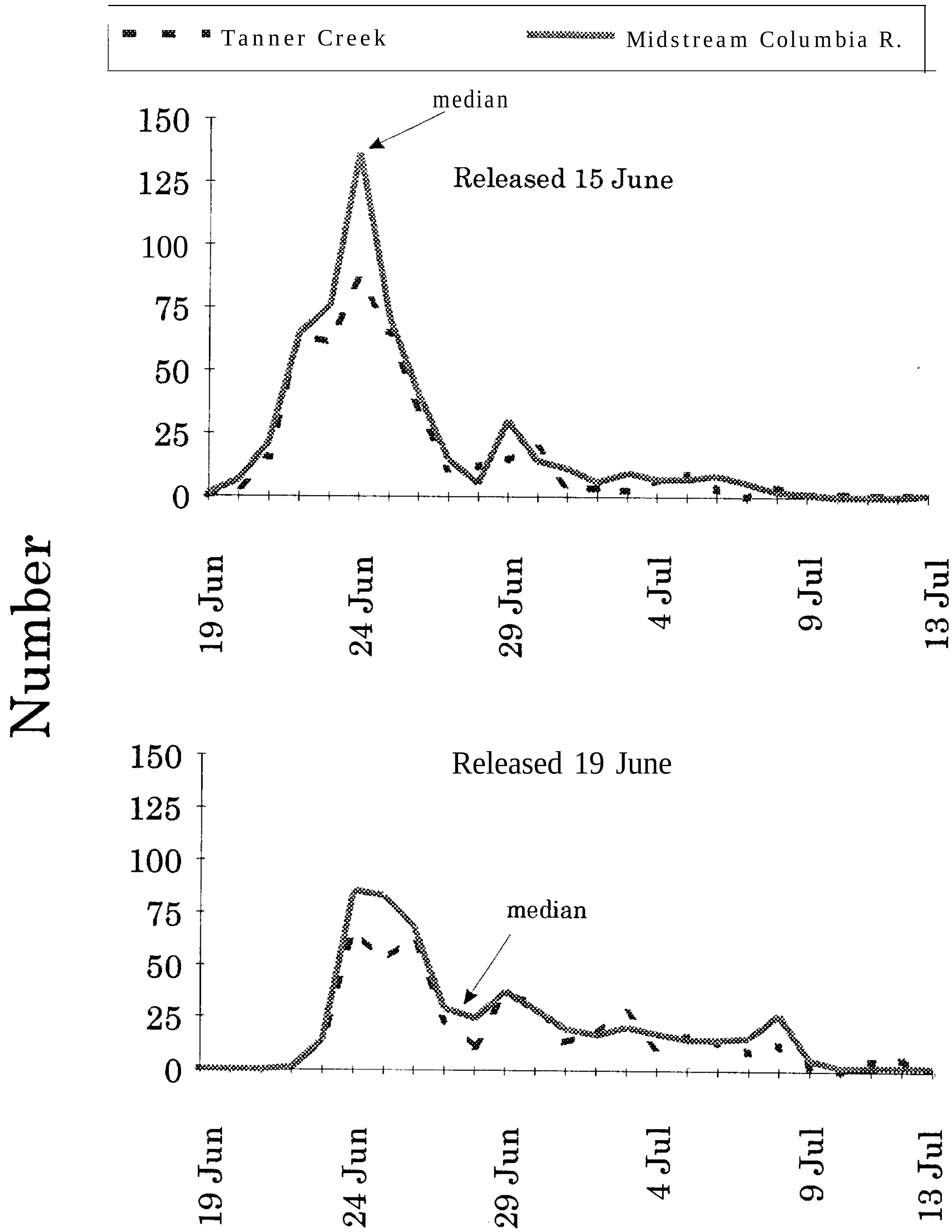


Figure 7.-- Daily recoveries of test fish at Jones Beach (standardized for effort) comparing midstream Columbia River to Tanner Creek release-groups, 1992.

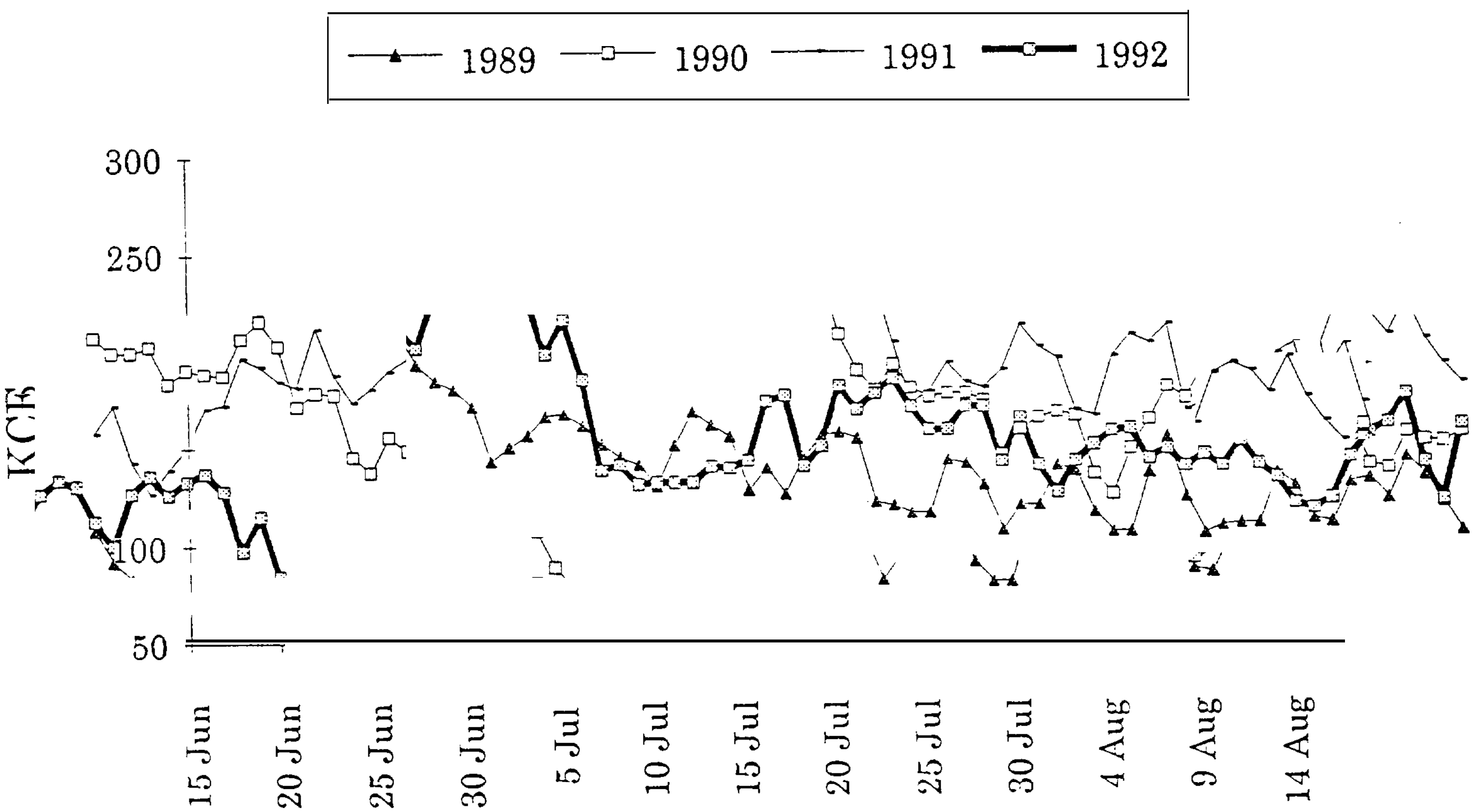


Figure 8.--Daily mean flows of the Columbia River at Bonneville Dam during the estuarine sampling periods, 1989, 1990, 1991, and 1992; flow measurements provided by the U. S. Army Corps of Engineers, Portland, Oregon.

Generally, fish from both pairs of releases showed a decreasing mean length during the first four to six days of the recovery period, followed by increasing mean lengths during the remainder of the recovery period (Figure 9). This suggests that the larger individuals of the released populations traveled faster to Jones Beach and that slower moving individuals grew during the migration period. There were no apparent differences among treatment groups in daily mean lengths at recovery. Comparisons of fork length distributions of study fish at release to those captured at Jones Beach also suggest that all groups grew during the migration period (Figures 10 and 11). The frequency distributions were similar for most groups allowing for a growth rate of about 1 mm per day. The exception may be the June 15 release at Tanner Creek (Figure 10) where the smallest individuals released were not as prevalent in the sample recovered at Jones Beach.

Die1 Recovery Patterns

During the die1 sampling period, about 12,000 and 10,000 subyearling chinook salmon (primarily non-study fish) were captured in the beach seine and in purse seines, respectively (Appendix Table C-3). In the purse seines, catches were highest at sunrise, generally decreased during the afternoon, increased again at dusk, and were lowest at night (Figure 12). In the beach seine, catches peaked about three hours after sunrise, declined during the afternoon, increased again in late afternoon, and were lowest at night. The pattern of very low catches during darkness for both gear types is similar to patterns observed in previous years at Jones Beach (Ledgerwood et al. 1991a, 1991b). Details comparing recoveries of tule and upriver bright stocks will be reported separately.

Stomach Fullness and Smoltification

Based on examination of stomach fullness of selected marked fish, study fish were feeding by the time they arrived at Jones Beach. Stomachs were generally about half full in fish collected during daylight hours. Upriver bright stock used during this study had slightly higher fullness values than tule stock sampled concurrently (means 4.0 and 4.5, respectively; Figure 12). Detailed analyses of diet content, diel feeding patterns, and results of other samples related to the degree of smoltification will be reported separately.

Juvenile Recovery Differences

Analysis of CWT-fish recoveries at Jones Beach (Appendix D) indicated that the recovery percentages for fish released from the midstream Columbia River were significantly higher than for fish released into Tanner Creek for both the first (0.57% versus 0.42%; $P < 0.01$) and the second pair of release groups (0.60% versus 0.51%; $P < 0.01$). After the removal of northern squawfish, the difference in recovery percentages between the two release sites was reduced from 35.7% to 17.6% (Table 5, Figure 13); this 50.7% reduction in recovery percentage differences (35.7 - 17.6) ÷ 35.7 * 100) was insignificant ($P = 0.19$).

Although the recovery percentages of the second pair of groups were higher than those for the first release-group pair, they are not directly comparable because releases made on different dates were subject to different river conditions and sampling effort.

To further assess data consistency, we analyzed purse seine recoveries separate from total recoveries (Appendix Table C-2, Appendix D). Conclusions regarding differences among recovery ratios derived from the purse seine data were the same as those reached with the total catch data; recoveries of study fish released from the midstream Columbia River were significantly higher ($P < 0.01$) than those for fish released into Tanner Creek and no significant change ($P = 0.42$) was observed between recovery percentages following removal of northern squawfish. Beach-seine recoveries separate from total recoveries were too few as a data subset for meaningful analysis (less than 0.1%).

Table 5. Recovery percentages of tagged subyearling chinook salmon at Jones Beach, Tanner Creek release vs. midstream Columbia River release, 1989. 1990, 1991, and 1992.

Release date	Midstream Columbia River[b]	Bonneville Hatchery at Tanner Creek	Benefit” for midstream release (%)
29 June 1989	0.43	0.26	65.4“’
1 July 1990	0.42	0.30	40.0’
24 June 1991	0.37	0.30	23.3’
28 June 1991	0.39	0.33	18.2’
15 June 1992	0.57	0.42	35.7*
19 June 1992	0.60	0.51	17.6*

[a] The percent benefit for midstream Columbia River release (MC) over Tanner Creek release (TC) is calculated as: {(MC% recover - TC% recover) ÷ TC% recover) x 100.
[b] Fish transported by truck and barged to the middle of the Columbia River adjacent to the confluence with Tanner Creek.
[c] Normal hatchery release site.
[d] * = significant difference in recovery percentages for fish released in midstream Columbia River or Tanner Creek ($P \leq 0.05$).

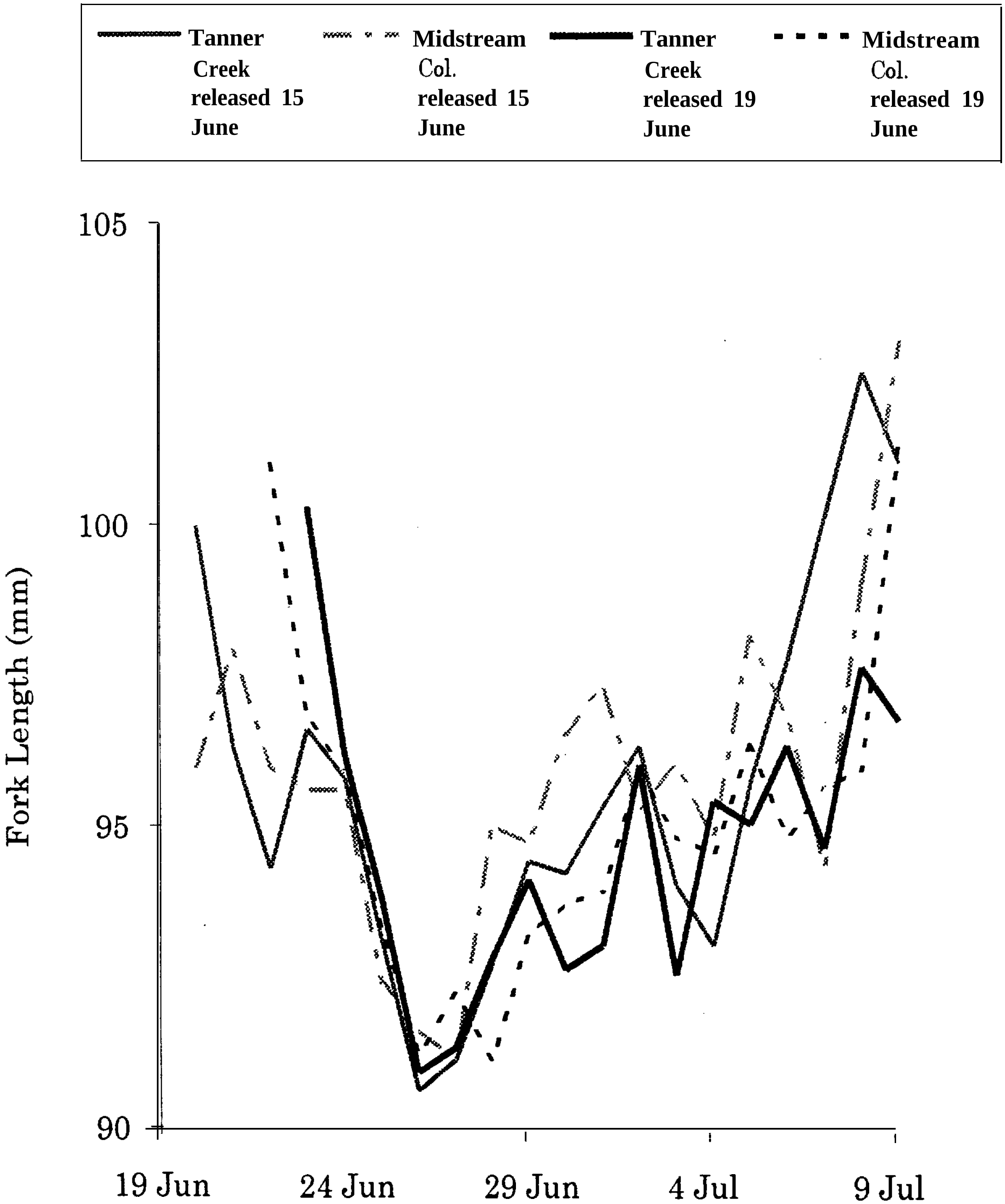


Figure 9.-- Daily mean fork lengths of subyearling chinook salmon recovered at Jones Beach, comparing midstream Columbia River to Tanner Creek release groups, 1992.

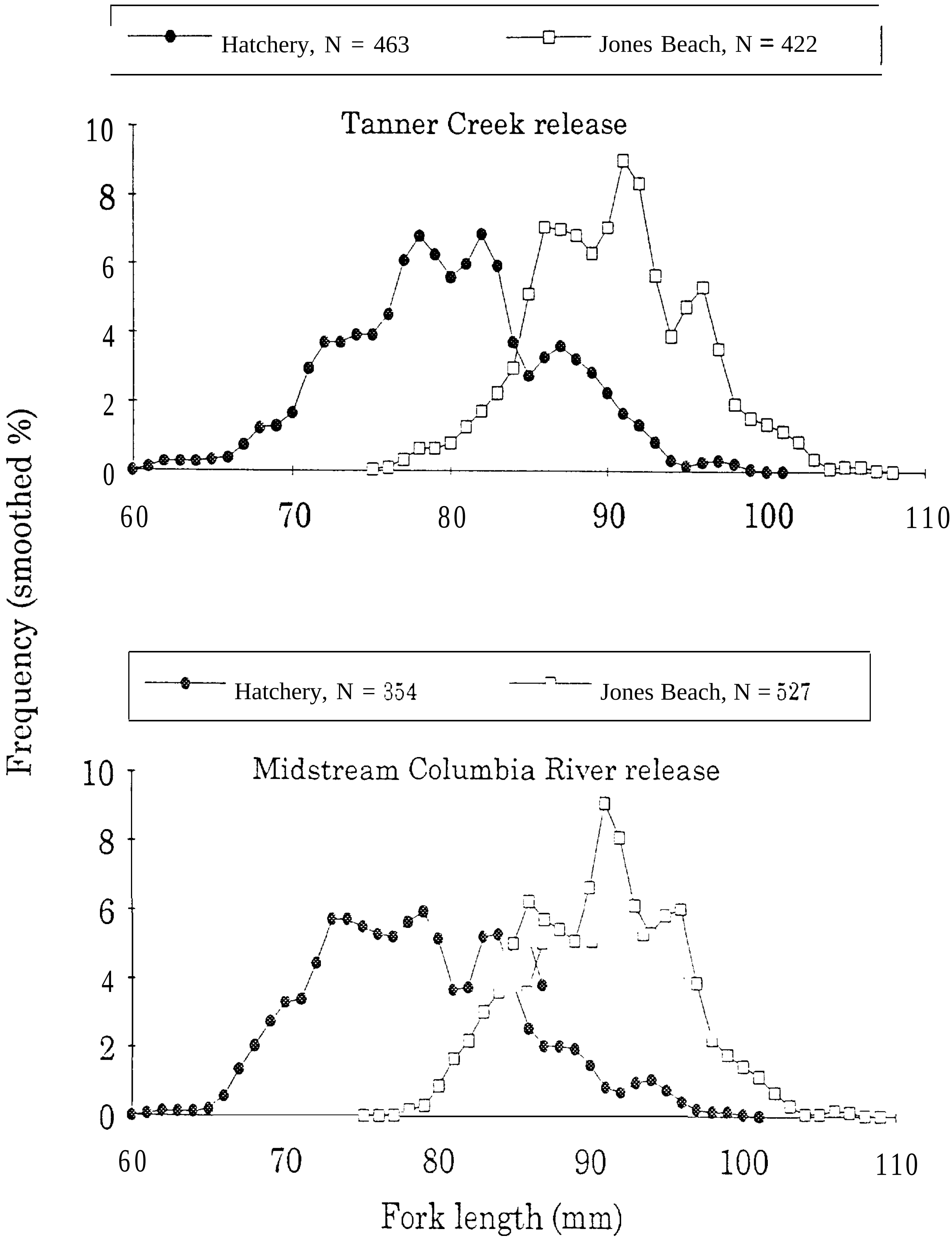


Figure 10.--Fork length distributions of study fish at release and after recovery at Jones Beach; fish released on 15 June 1992.

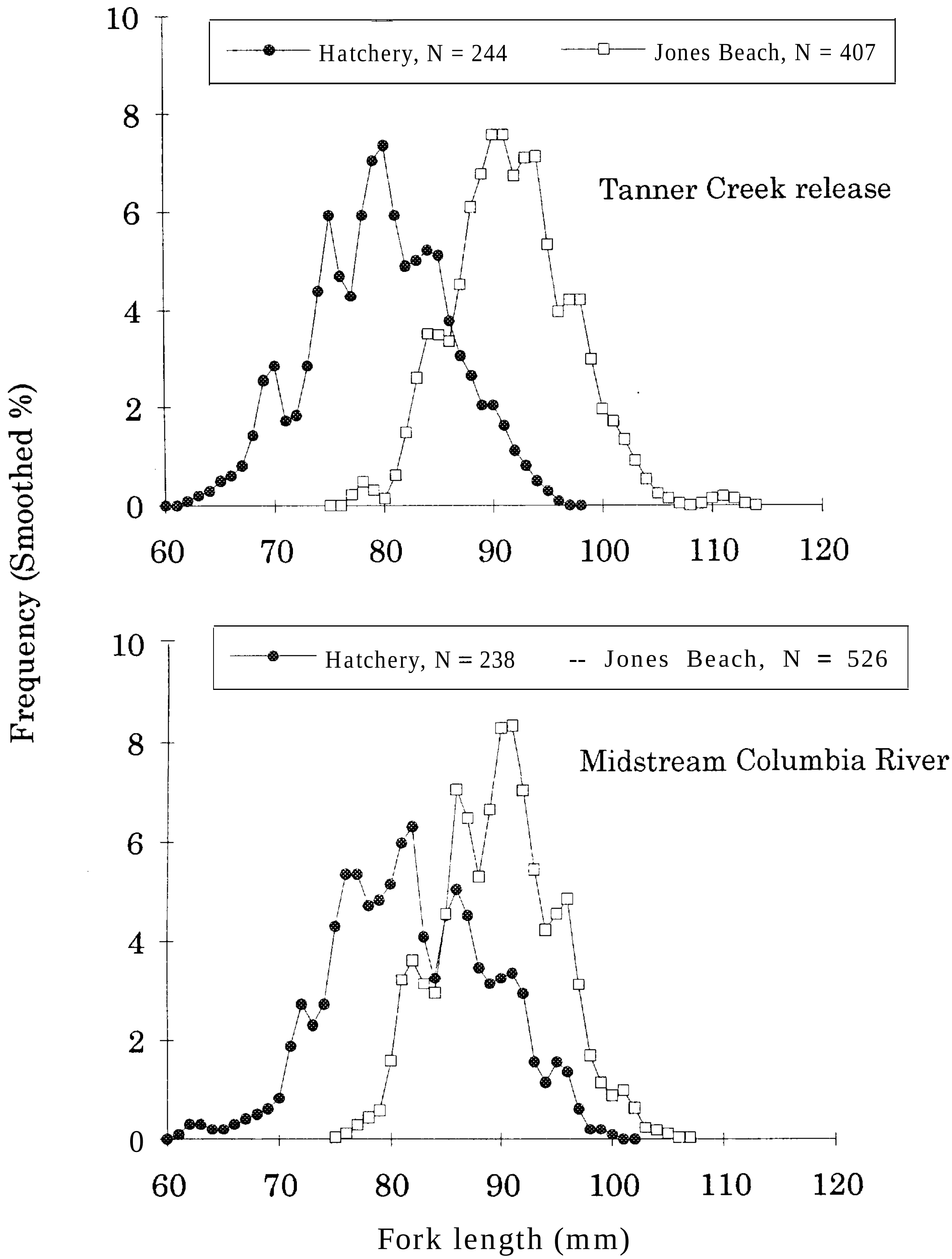
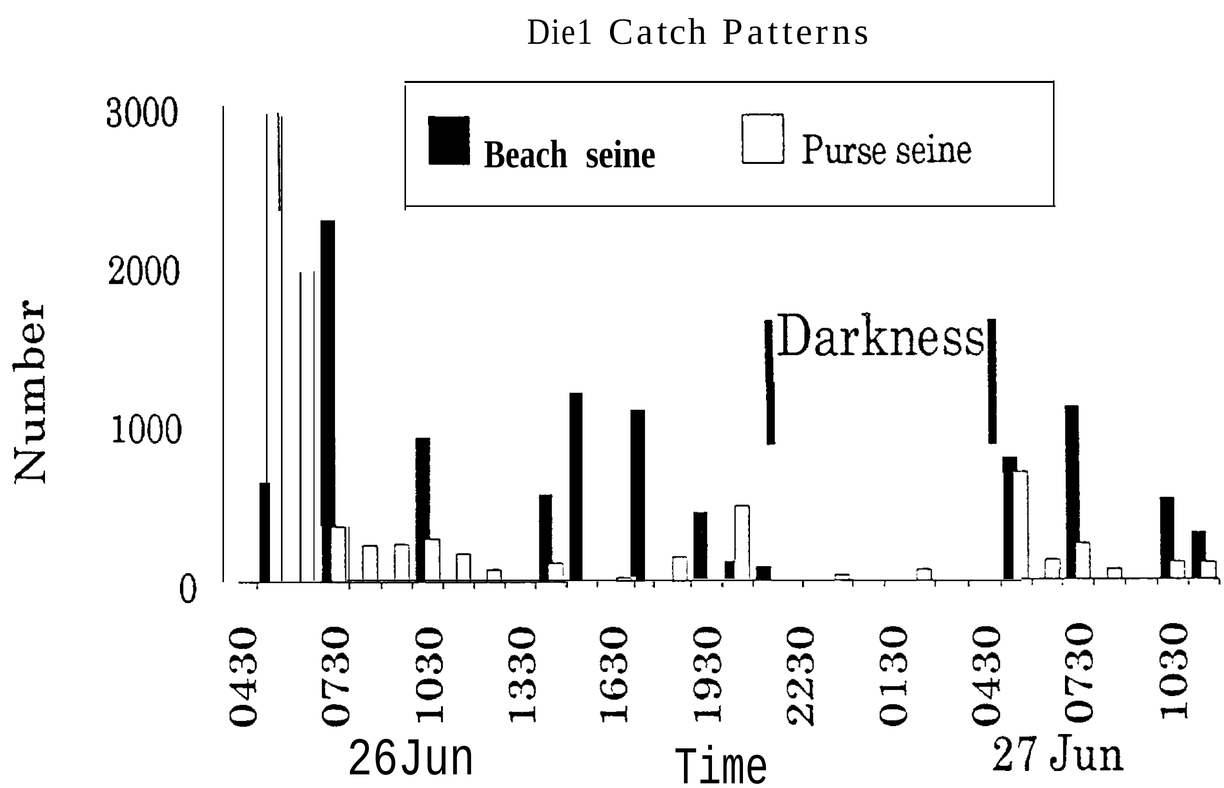


Figure 11.-- Fork length distributions of study fish at release and after recovery at Jones Beach; fish released on 19 June 1992.



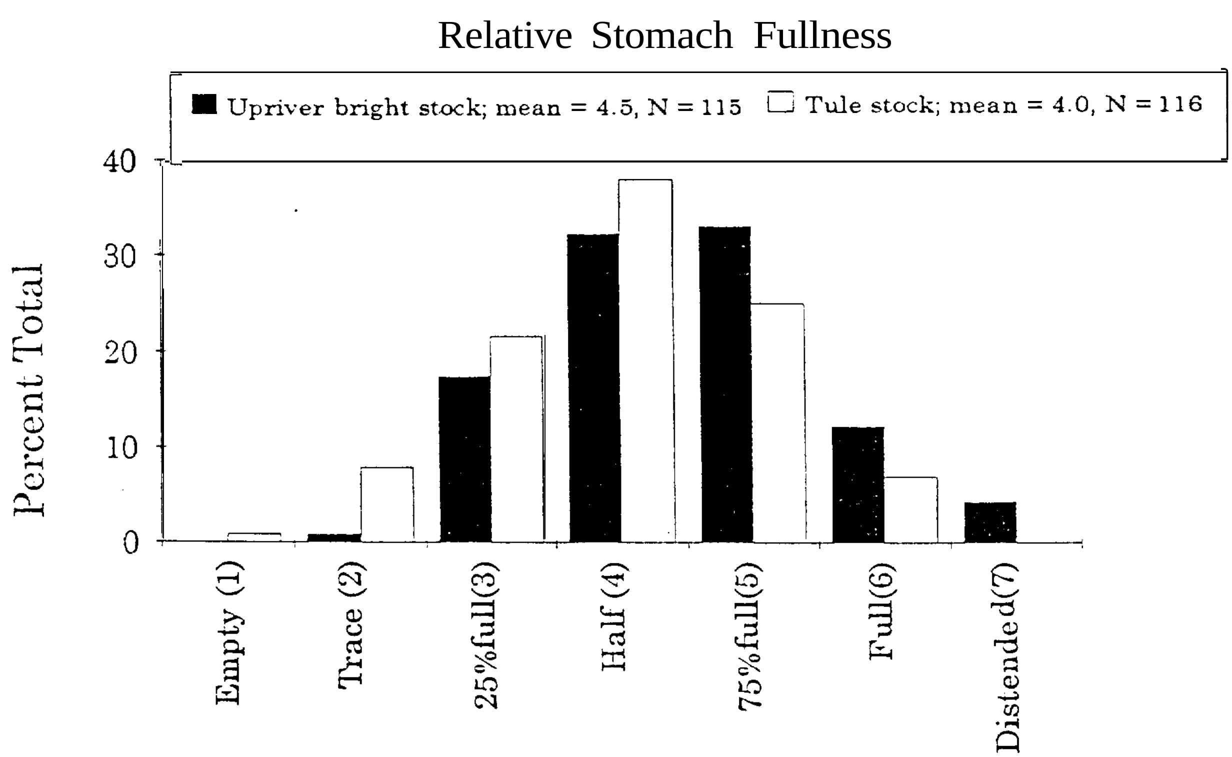


Figure 12.--Diel catch patterns (top) and relative stomach fullness (bottom) for subyearling chinook salmon captured at Jones Beach, 1992.

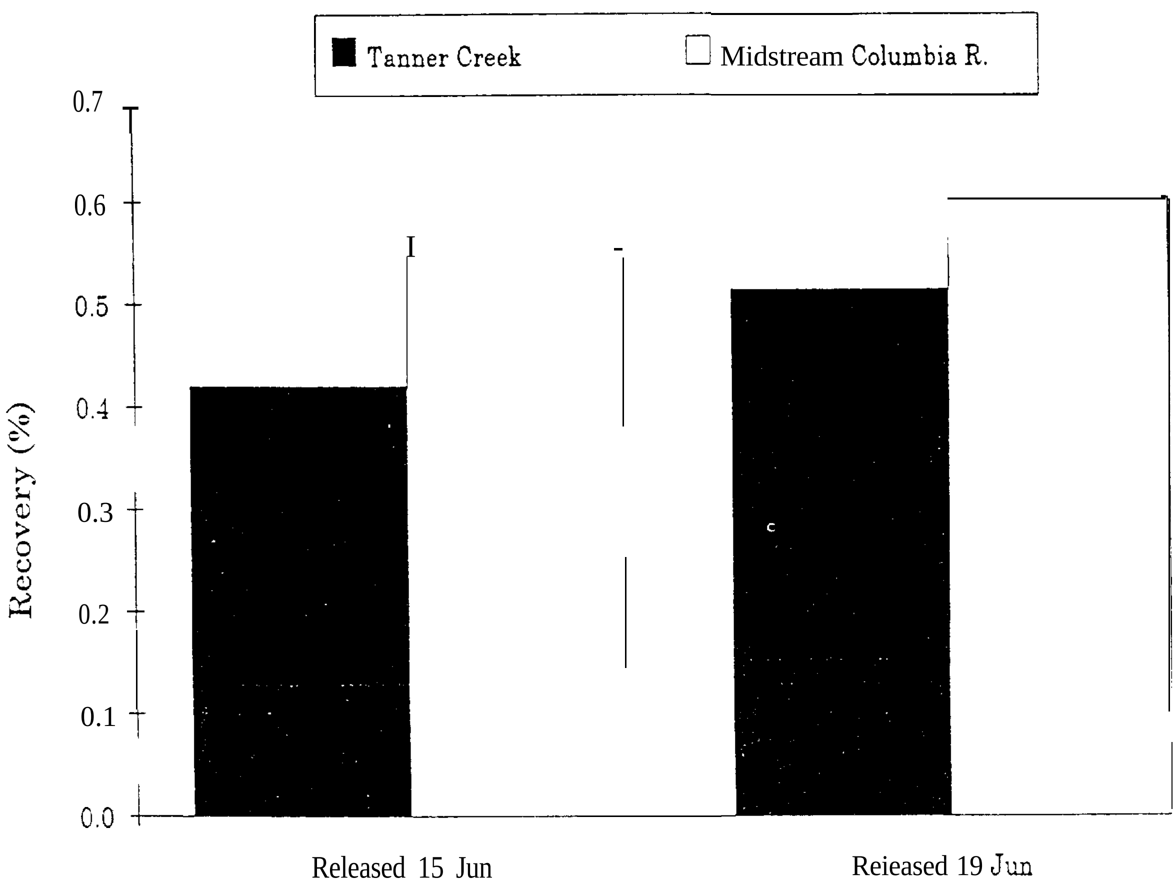


Figure 13.--Mean recovery percentages comparing midstream Columbia River to Tanner Creek release groups, 1992. Northern squawfish were removed by electrofishing between the two release dates, Recovery rates for the midstream releases were si gnificantly higher (P < 0.05) than for the Tanner Creek release groups on both dates.

DISCUSSION

In 1992, recovery at Jones Beach of subyearling chinook salmon released from the midstream Columbia River was significantly higher ($P \leq 0.05$), averaging about 27% greater than for fish released from Bonneville Hatchery into Tanner Creek; there was also considerable, though not significant ($P = 0.19$), reduction in difference between the two release dates in 1992. Through the years of study, 1989-92, the differences in recovery percentages between midstream Columbia River releases and Tanner Creek releases have ranged from 65 % to 18 % (Table 5) with the low values following intensive electrofishing to remove northern squawfish from the migration routes of the Tanner Creek-released fish. One factor contributing to the variability in the data may be differences in the river flow at the time various groups were released. We speculate that higher flows disperse test fish more rapidly, reduce their exposure time to predation, and result in higher survival rates for Tanner Creek releases. The difference in recovery percentages for midstream releases was inversely correlated with the movement rate of Tanner Creek-released fish (R' = 0.87; Figure 14). Movement rate may be a function of both river flow and state of smoltification (Zaugg and Mahnken 1991). Smoltification was assessed in 1992 (reported separately), but not in the earlier years. However, release dates were similar each year (between June 15 and July 1).

In 1992 and 1991, years when we attempted to evaluate the effects of localized removal of northern squawfish on survival of juvenile salmon, the Columbia River flows on the second release date were higher than on the first release date, about 8% higher in 1992 and 27% higher in 1991 (Table 4). About 2,000 northern squawfish were removed from the study area between the two release dates in both years, yet the decline in survival benefit for midstream Columbia River release was more than twice as great in 1992 as in 1991 (5 1% vs. 22% decline). The higher flows for the second release groups resulted in faster movement to Jones Beach and may have increased survival of the Tanner Creek-released fish regardless of predator removal efforts, particularly in 1991. In general, the effectiveness of localized northern squawfish removal at reducing the survival difference between midstream Columbia River and Tanner Creek release may be inversely related to river flow. River flows were substantially higher throughout the migration period in 1991 than in 1992 (Figure 8) and may better explain the difference in survival benefit for midstream Columbia River release groups following localized northern squawfish removal in these two years than removal efforts.

It is difficult to determine if the generally high numbers and catch rates of predators in the study area occurred because northern squawfish congregated near the hatchery release site or because high densities of northern squawfish were prevalent throughout the entire study area. The high catches of northern squawfish along the Oregon shoreline at Transect 04 support the latter explanation (Table 3). The observations that CWT recoveries were concentrated at transects closest to the Tanner Creek release site, and that nearly all the CWTs recovered were from the Tanner Creek release group, suggest that juvenile salmonids released from the hatchery were more vulnerable to predation by northern squawfish in the river region near Bonneville Hatchery than juveniles released in midstream. The CPUE for northern squawfish fluctuated during the removal period, and was somewhat lower for the dates following the second pair of juvenile salmon releases. It is difficult to attribute the 52% decline in survival benefit for midstream Columbia River release to the removal of so few northern squawfish. Rather, a general decline in size of northern squawfish present in 1992 coupled with higher river flows during the second release pair may better explain the decline. In total, over 100,000 northern squawfish were removed from the tailrace area of Bonneville Dam during 1991 and 1992[5], and the proportion of the larger (older) northern squawfish may be declining (Appendix E). The sharp drop in numbers of CWTs in the digestive tracts of northern squawfish by the final day of electrofishing suggests emigration of the released salmon.

CONCLUSIONS

1. Subyearling chinook salmon from Bonneville Hatchery released into the midstream Columbia River exhibited significantly higher survival rates than fish released into Tanner Creek. The difference in survival is in part related to predation by northern squawfish on fish released at the hatchery.

2. The predominance of CWTs from Tanner-Creek-released juvenile salmon in the digestive tracts of northern squawfish indicated that juvenile salmon released from the hatchery were more vulnerable to predation by northern squawfish located in the river region near Bonneville Hatchery than juveniles released in midstream.

3. The survival difference between midstream Columbia River and Tanner Creek release groups appears to be inversely related to the movement rate of Tanner Creek release groups. Faster movement rates for fish were associated with high river flows and may also have been influenced by smoltification differences between years.

4. It was difficult to determine if the high numbers and catch rates of predators at the transects nearest Tanner Creek occurred in response to the hatchery release or to high densities of northern squawfish throughout the study area.

5. Electrofishing efforts to remove northern squawfish from the migration route of juvenile salmon released from Bonneville Hatchery did not significantly reduce the survival difference between midstream Columbia River and Tanner Creek release groups.

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[5] Craig C. Burley, Washington Department of Wildlife, Olympia, pers. commun., May 1992.

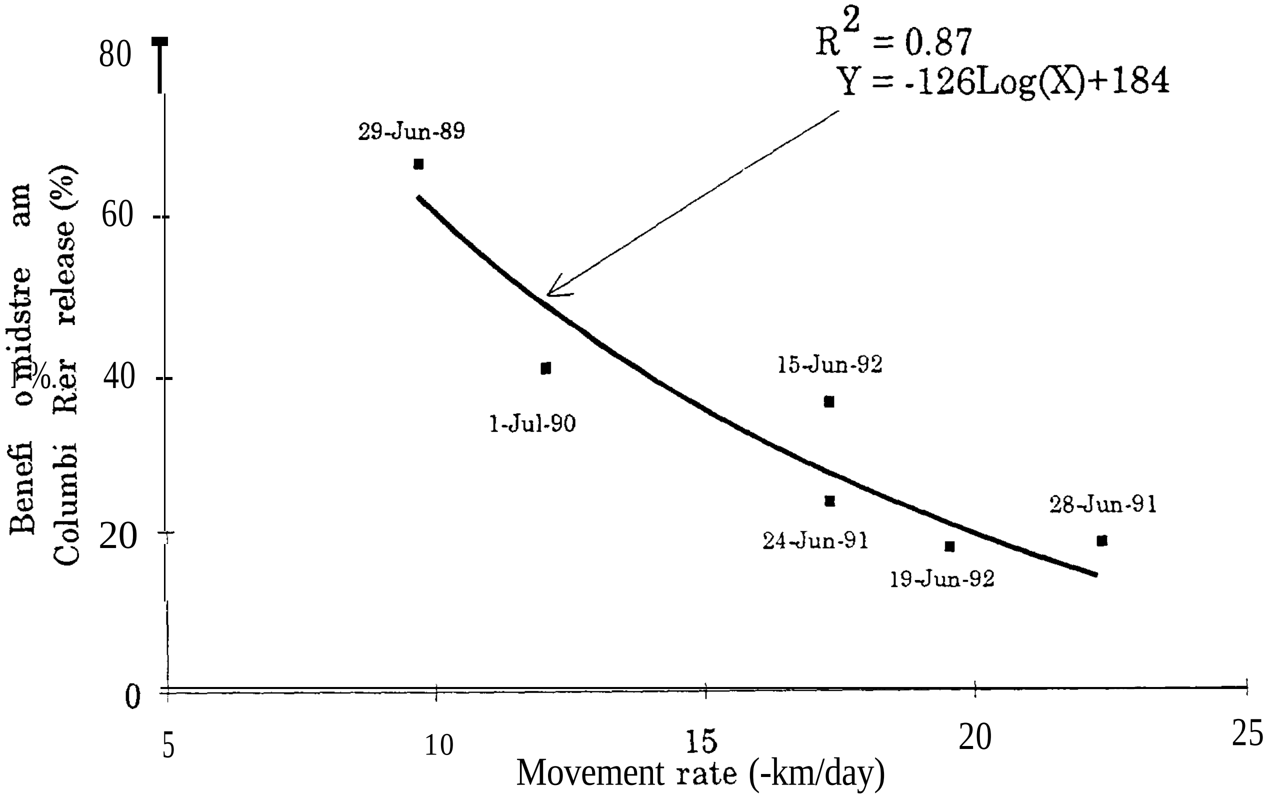

Figure 14.--Movement rate versus percent increase in survival benefit (Table 5, footnote a) for midstream Columbia River releases over Tanner Creek releases of subyearling chinook salmon, 1989- 1992.

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APPENDIX A

Marking Information, Tag Loss Estimates, Release Information, and River Conditions

Appendix Table A-l. Short-term" tag loss for subyearling chinook salmon, 1992.

		Released 15 June				Released 19 June			
		Tanner Creek		Midstream Columbia R.		Tanner Creek		Midstream Columbia R.	
Date marked	Time sampled	NT"	Sample"	NT	Sample	NT	Sample	NT	Sample
20 May	0645	8	100	2	100	0	100	3	100
"	0845	1	100	0	100	1	100	1	100
"	1050	0	100	43	100	--	--	1	100
"	1330	5	50	0	50	1	50	1	50
"	1500	0	50	0	50	0	50	1	50
"	1700	0	50	1	50	0	50	0	50
"	1900	0	50	0	50	0	50	0	50
21 May	0640	0	100	5	100	0	100	0	100
"	0840	1	100	7	100	11	100	2	100
"	1100	5	100	0	100	0	100	3	100
"	1245	9	100	2	100	0	100	1	100
"	1445	0	50	1	50	1	50	1	50
"	1645	0	50	6	50	3	50	1	50
"	1915	0	50	0	50	0	50	0	30
22 May	0630	1	100	0	100	1	100	2	100
"	0845	1	100	3	100	0	100	0	100
"	1100	0	100	0	50	0	100	4	50
"	1230	4	100	0	100	0	100	0	100
"	1945	0	50	--	--	1	50	2	50
27 May	0640	0	100	0	100	16	100	1	100
"	0830	0	100	0	100	2	100	3	100
"	1100	1	loo	0	100	0	100	0	loo
"	1230	1	100	0	100	0	100	0	100
"	1530	0	50	0	50	0	50	0	50
"	1700	0	50	2	50	1	50	0	50
"	1900	0	50	0	50	1	50	0	50
28 May	0830	0	50	1	50	0	50	1	50
"	1215	3	100	0	100	0	100	0	loo
"	1500	0	50	1	50	0	50	1	50
"	1700	0	50	1	50	0	50	0	50
"	1930	0	50	1	50	0	50	0	50
29 May	0615	0	100	0	100	0	100	4	48
"	0800	0	100	--	--	0	100	0	loo
"	1230	--	--	1	100	0	100	0	loo
"	1430	0	50	0	50	2	50	2	50
"	1700	0	50	1	50	0	50	0	50
"	1900	0	50	0	50	2	50	0	50

Appendix Table A-l. Continued.

Date marked	Time sampled	Released 15 June Tanner Creek NT[b]	Sample[c]	Released 15 June Midstream Columbia R. NT	Sample	Released 19 June Tanner Creek NT	Sample	Released 19 June Midstream Columbia R. NT	Sample
1 June	0630	0	100	0	100	0	100	0	100
"	0830	1	loo	1	loo	1	100	2	100
"	1115	0	50	0	50	4	60	0	50
"	1300	3	100	0	100	0	100	0	100
"	1500	0	50	0	50	0	50	1	50
"	1700	0	50	2	50	3	50	0	50
"	1900	0	50	0	50	0	50	0	50
2 June	0630	0	100	0	100	0	100	0	100
"	0830	0	100	3	100	0	100	1	100
"	1130	0	50	1	50	0	50	0	50
"	1230	0	50	0	50	0	50	0	50
"	1500	0	50	0	50	0	50	7	50
"	1700	0	50	0	50	0	50	0	50
"	1900	0	50	0	50	3	50	0	50
3 June	0630	0	50	0	50	0	50	1	50
"	0830	1	50	3	50	0	50	0	50
"	1100	0	50	0	50	0	50	0	50
"	1230	0	50	0	50	0	50	0	50
Total		45	3,850	88	3,750	54	3,860	46	3,828
Percent		1.2		2.3		1.4		1	

[a] Samples taken from the outfall pipe from marking trailer immediately after tagging.
[b] NT = Number of fish that passed through the tag detector and tested negative for a tag.
[c] Number of fish sampled for tag loss.

Appendix Table A-2. Tag loss estimates among marked groups of subyearling chinook salmon after a 29-day holding period; Tanner Creek vs. midstream Columbia River, 1992.

Release dates	Coded Wire Tag (AG D1 D2)[a]	NT[b]	Sample[c]
Tanner Creek releases			
15 June	233007	23	468
19 June	233008	12	343
Midstream releases			
15 June	233009	34	463
19 June	233010	17	336

[a] CWT code key: AG D1 D2 = Agency code, Data 1 code, Data 2 code.
[b] NT = Number of branded fish in the sample with no coded wire tag.
[c] Number of fish checked for the presence of coded wire tags.

APPENDIX B

Northern Squawfish Electrofishing Information

Appendix Table B-l. Northern squawfish electrofishing daily effort and catch results, 1992.

Electrofishing period	Electrofishing date	Electrofishing location[b]	Start time”	Effort (sec)[d]	Catch (no.)	CPUE (no./h)[e]
4	19 Jun	01	0020	809	12	53.4
4	18 Jun	01	2050	995	21	76.0
6	21 Jun	01	2323	1784	25	50.4
3	18 Jun	01	0035	1200	22	66.0
5	21 Jun	01	0100	1501	17	40.8
3	17 Jun	01	2055	1313	48	131.6
4	20 Jun	01	0455	840	30	128.6
2	17 Jun	01	0115	1197	21	63.2
6	21 Jun	01	2138	1623	44	97.6
1	16 Jun	01	0252	919	6	23.5
5	20 Jun	01	2100	855	13	54.7
2	16 Jun	01	2050	703	89	188.1
Subtotal				14,739	348	--
mean				1228.3	29.0	81.2
SE’				102.6	6.5	13.6
1	16 Jun	02	0400	2729	69	91.0
5	20 Jun	02	2253	1448	11	27.3
5	21 Jun	02	0156	2327	13	20.1
4	18 Jun	02	2054	2788	142	183.4
2	16 Jun	02	2043	1629	164	362.4
3	17 Jun	02	2200	2800	76	97.7
6	21 Jun	02	2200	1700	43	91.1
6	22 Jun	02	0115	2244	31	49.7
4	20 Jun	02	0457	2101	31	53.1
2	17 Jun	02	0300	3389	98	104.1
Subtotal				23,155	678	--
mean				2315.5	67.8	108.0
SE				195.4	16.8	31.9
5	20 Jun	03	2100	1017	16	56.6
4	18 Jun	03	2300	5647	86	54.8
4	20 Jun	03	0559	1109	24	77.9
2	16 Jun	03	2243	2168	119	197.6
5	21 Jun	03	0115	1121	1	3.2
4	18 Jun	03	2324	1902	102	193.1
Subtotal				12,964	384	--
mean				2160.7	58.0	97.2
SE				723.8	20.5	32.6

Appendix Table B-l. Continued,

Electrofishing period"	Electrofishing date	Electrofishing location[b]	Start time"	Effort (sec)[d]	Catch (no.)	CPUE (no. /h)
3	18 Jun	04	0310	2667	66	89.1
2	17 Jun	04	0122	1609	144	322.2
6	21 Jun	04	2050	414	5	43.5
5	20 Jun	04	2135	775	7	32.5
4	20 Jun	04	0650	1330	7	18.9
Subtotal				6,795	229	--
mean				1359.0	45.8	101.2-
SE				387.8	27.1	56.5
5	20 Jun	TC	2150	320	9	101.3
3	18 Jun	TC	0210	573	7	44.0
5	21 Jun	TC	0136	432	19	158.3
4	20 Jun	TC	0435	275	6	78.5
6	21 Jun	TC	2200	375	2	19.2
4	18 Jun	TC	2125	330	7	76.4
2	17 Jun	TC	0205	233	6	92.7
4	19 Jun	TC	0005	592	8	48.6
2	16 Jun	TC	2045	181	1	19.9
Subtotal				3,311	65.0	--
mean				367.9	7.2	71.0
SE				47.4	1.7	14.7
3	18 Jun	W1	0220	1787	21	42.3
6	21 Jun	W1	2130	1072	3	10.1
1	16 Jun	WI	025 1	2203	70	114.4
5	20 Jun	WI	2210	483	7	52.2
4	18 Jun	W1	2240	880	30	122.7
2	17 Jun	WI	0236	1659	73	158.4
6	22 Jun	WI	0122	941	15	57.4
4	20 Jun	WI	0317	1318	35	95.6
Subtotal				10,343	254	--
mean				1292.9	31.8	81.4
SE				198.5	9.5	17.4

Appendix Table B-l. Continued.

Electrofishing period	Electrofishing date	Electrofishing location[b]	Start time[c]	Effort (sec)[d]	Catch (no.)	CPUE (no. /h)[e]
6	21 Jun	w 2	2320	2581	56	78.1
5	21 Jun	w 2	0240	1003	3	10.8
6	22 Jun	w 2	0209	1374	22	57.6
3	18 Jun	w 2	0350	2708	32	42.5
5	20 Jun	w 2	2225	1547	18	41.9
Subtotal				9,213	131	--
mean				1842.6	26.2	46.2
SE				339.6	8.8	11.0
3	17 Jun	w 3	2200	1928	14	26.1
1	16 Jun	w 3	0340	1869	8	15.4
Subtotal				3,797	22	--
mean				1898.5	11.0	20.8
SE				29.5	3.0	5.4
4	18 Jun	w 4	2215	2797	17	21.9
4	20 Jun	w 4	0605	1526	2	4.7
1	16 Jun	w 4	0440	1522	6	14.2
3	17 Jun	w 4	2300	2121	35	59.4
2	16 Jun	w 4	2215	2647	39	53.0
Subtotal				10,613	99	--
mean				2122.6	19.8	30.6
SE				268.9	7.5	10.8
Totals				94,930	2,174	--
mean				1947.9	33.0	70.9
SE				216.5	6.9	11.9

[a] Sampling periods generally began at 9 p.m. and terminated the following morning about 9 a.m.
[b] Locations codes (2 characters): TC = Tanner Creek transect; others Columbia River transects, where 1st character 0 = Oregon shoreline and W = Washington shoreline; 2nd character. l-4. transects located progressively downstream (refer to Figure 3 for precise locations).
[c] Time that the electrofishing effort began.
[d] Time that the electrofishing unit was powered on.
[e] CPUE = catch of northern squawfish per unit effort of electrofrshing.
[f] SE - Standard error.

Appendix Table B-2. Coded wire tags from ingested juvenile salmon recovered in the stomachs of northern squawfish during electrofishing efforts, 1992.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)[e]
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	2	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	3	7	233007
	16 Jun	0400	1502	8	7	233007
	16 Jun	0400	1502	8	7	233007
	16 Jun	0400	1502	8	7	233007
	16 Jun	0400	1502	8	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	13	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007
	16 Jun	0400	1502	21	7	233007

Appendix Table B-2. Continued.

Electrofishing period[b]	Date	Start time'	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG Dl D2)
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	21	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	22	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	25	7	233007
1	16 Jun	0400	1502	29	7	23 3007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	29	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	31	7	233007
1	16 Jun	0400	1502	35	7	233007

Appendix Table B-2. Continued.

Electrofishing period"	Date	Start time'	Northern squawfisha Collection no.	Predator no.	Location[d]	Tag code (AG Dl D2)[e]
1	16 Jun	0400	1502	35	7	233007
1	16 Jun	0400	1502	35	7	233007
1	16 Jun	0400	1502	38	7	233007
I	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	38	7	233007
1	16 Jun	0400	1502	41	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	45	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	49	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	50	7	233007
1	16 Jun	0400	1502	54	7	233007
1	16 Jun	0400	1502	54	7	233007
1	16 Jun	0400	1502	54	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007

Appendix Table B-2. Continued.

Electrofishing period[b]	Date	Start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG Dl D2)
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	55	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	58	7	233007
1	16 Jun	0400	1502	59	7	233007
1	16 Jun	0400	1502	59	7	233007
1	16 Jun	0400	1502	59	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	61	7	233007
1	16 Jun	0400	1502	62	7	233007
1	16 Jun	0400	1502	65	7	233007
1	16 Jun	0400	1502	65	7	233007
1	16 Jun	0400	1502	65	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
1	16 Jun	0400	1502	69	7	233007
2	16 Jun	2043	1551	3	7	233007
2	16 Jun	2043	1551	10	7	233007
2	16 Jun	2043	1551	10	7	233007
2	16 Jun	2043	1551	10	7	233007
2	16 Jun	2043	1551	10	7	233007
2	16 Jun	2043	1551	11	7	233007
2	16 Jun	2043	1551	12	7	233007
2	16 Jun	2043	1551	12	7	233007
2	16 Jun	2043	1551	12	7	233007
2	16 Jun	2043	1551	13	7	233007

Appendix Table B-2. Continued.

Electrofishing period[b]	Date	Start time'	Northern squawfish Collection no.	Predator no.	Location[d]	Tag code (AG Dl D2)
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	13	7	233007
2	16 Jun	2043	1551	30	7	233007
2	16 Jun	2043	1551	30	7	233007
2	16 Jun	2043	1551	30	7	233007
2	16 Jun	2043	1551	30	7	233007
2	16 Jun	2043	1551	111	7	233007
2	16 Jun	2043	1551	134	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	138	7	233007
2	16 Jun	2043	1551	145	7	233007
2	16 Jun	2043	1551	145	7	233007
2	16 Jun	2043	1551	145	7	233007
2	16 Jun	2043	1551	145	7	233007
2	16 Jun	2043	1551	147	7	233007
2	16 Jun	2043	1551	147	7	233007
2	16 Jun	2043	1551	162	7	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	36	9	233007
2	16 Jun	2050	1052	50	9	233007
2	16 Jun	2050	1052	50	9	233007
2	16 Jun	2050	1052	50	9	233007
2	16 Jun	2050	1052	50	9	233007

Appendix Table B-2. Continued.

Electrofishing period[b]	Date	start time[c]	Northern squawfish[a] Collection no.	Predator no.	Location[d]	Tag code (AG D1 D2)
2	16 Jun	2050	1052	50	9	233007
2	16 Jun	2050	1052	71	9	233007
2	16 Jun	2243	1552	5	6	233007
2	16 Jun	2243	1552	56	6	233009
2	16 Jun	2243	1552	152	6	233007
2	16 Jun	2243	1552	152	6	233007
2	16 Jun	2243	1552	152	6	233007
2	16 Jun	2243	1552	152	6	233007
2	16 Jun	2243	1552	152	6	233007
2	17 Jun	0300	1056	8	7	233007
2	17 Jun	0300	1056	44	7	233007
2	17 Jun	0300	1056	44	7	233007
2	17 Jun	0300	1056	44	7	233007
3	17 Jun	2055	1101	19	9	233007
3	17 Jun	2055	1101	19	9	233007
3	17 Jun	2055	1101	19	9	233007
3	17 Jun	2055	1101	28	9	233007
3	17 Jun	2200	1601	308	7	233007
3	17 Jun	2200	1601	339		233007
3	18 Jun	0035	1104	12	9	634528
3	18 Jun	0210	1105	4	8	233007
3	18 Jun	0210	1105	4	8	233007
3	18 Jun	0210	1105	4	8	233007
3	18 Jun	0210	1105	5	8	233007
3	18 Jun	0210	1105	6	8	233007
3	18 Jun	0210	1105	6	8	233007
3	18 Jun	0350	1604	24	3	232753
4	18 Jun	2050	1151	12	9	233007
4	18 Jun	2054	1651	306	7	233007
4	19 Jun	0005	1154		8	233007
4	19 Jun	0020	1155	6	9	071429

[a] Individual specimens of northern squawfish are identified as a combination of collection number and predator number.
[b] Sampling periods generally began at 9 p.m. and terminated the following morning about 9 a.m.
[c] Time that the electrofishing effort began.
[d] Locations codes (2 characters): TC = Tanner Creek transect; others Columbia River transects, where 1st character 0 = Oregon shoreline and W = Washington shoreline; 2nd character, 1-4, transects located progressively downstream (refer to Figure 3 for precise locations).
[e] CWT code key: AG D1 D2 = Agency code, Data 1 code, and Data 2 code.

APPENDIX C

Juvenile Salmon Recovery Information

Appendix Table C-l. Daily purse seine and beach seine fishing effort, water temperatures, and Secchi disk transparency measurements at Jones Beach, 1992.

Date	Number of sets Purse	Number of sets Beach	Temp. °C	Secchi depth (m)	Date	Number of sets Purse	Number of sets Beach	Temp. °C	Secchi depth (m)
15 Jun	1	2	18	--[a]	9 Jul	9	9	20	1.5
16 Jun	3	6	17	0.9	10 Jul	6	3	21	1.4
17 Jun	4	7	17	1.1	11 Jul	8	9	20	1.2
18 Jun	5	5	18	1.1	12 Jul	7	6	20	1.1
19 Jun[b]	2	4	18	1.1	13 Jul	12	5	21	1.2
20 Jun	7	4	18	1.2	14 Jul	11	6	21	1.2
21 Jun	3	4	19	1.2	15 Jul	10	9	21	1.1
22 Jun	8	2	19	1.4	16 Jul	9	11	21	1.4
23 Jun	9	4	19	1.2	17 Jul	9	11	21	1.4
24 Jun	10	2	20	1.4	18 Jul	4	10	22	1.2
25 Jun	12	0	20	1.2	19 Jul	8	9	22	1.4
26 Jun	16	11	20	1.4	20 Jul	8	7	22	1.2
27 Jun	9	7	20	1.4	21 Jul	14	3	22	1.1
28 Jun	5	4	20	1.5	22 Jul	11	3	22	1.5
29 Jun	8	5	19	1.1	23 Jul	5	2	22	1.8
30 Jun	12	3	20	1.4	24 Jul	3	3	22	1.5
1 Jul	8	4	20	1.1	25 Jul	6	3	22	1.5
2 Jul	9	10	20	1.2	26 Jul	3	3	21	0.9
3 Jul	10	10	20	1.2	27 Jul	3	3	21	1.2
4 Jul	9	8	20	1.4	28 Jul	3	3	21	1.2
5 Jul	13	8	20	1.7	29 Jul	3	2	22	1.2
6 Jul	15	5	21	1.5	30 Jul	2	1	22	1.5
7 Jul	11	1	21	1.4	31 Jul	2	0	22	1.4
8 Jul	5	5	20	1.4					

[a] Dashes indicate data not available.
[b] First recovery of study fish.

Appendix Table C-2. Daily recoveries, recoveries standardized for effort, dates of median fish recovery, and movement rates to Jones Beach of marked subyearling chinook salmon released from Bonneville Hatchery into Tanner Creek and transported from the hatchery for release in midstream Columbia River, 1992.

	Released 15 June											
	Treatments and tag code (AG D1 D2)											
	Tanner Creek 23 30 07						Midstream Columbia 23 30 09					
Date of	Beach		Purse		Total		Beach		Purse		Total	
recovery	A[b]	S	A	S	A	S	A	S	A	S	A	S
19 Jun	0	0	0	0	0	0	1	1	0	0	1	1
20 Jun	0	0	2	3	2	3	3	4	2	3	5	7
21 Jun	7	9	2	7	9	15	4	5	5	17	9	22
22 Jun	11	28	29	36	40	64	9	23	34	43	43	65
23 Jun	8	10[d]	46	51	54	61	16	20[d]	50	56	66	76
24 Jun	7	18	69	69[d]	76	87[d]	6	15	122	122[d]	128	137[d]
25 Jun	NE	12	64	53	64	65	NE	11	73	61	73	72
26 Jun	13	6	46	29	59	35	14	6	55	34	69	41
27 Jun	4	3	7	8	11	11	4	3	11	12	15	15
28 Jun	0	0	6	12	6	12	1	1	2	4	3	5
29 Jun	1	1	11	14	12	15	3	3	22	28	25	31
30 Jun	0	0	23	19	23	19	0	0	17	14	17	14
1 Jul	0	0	3	4	3	4	0	0	9	11	9	11
2 Jul	0	0	3	3	3	3	5	3	3	3	8	6
3 Jul	1	1	2	2	3	3	5	3	7	7	12	10
4 Jul	2	1	5	6	7	7	4	3	4	4	8	7
5 Jul	1	1	11	8	12	9	0	0	9	7	9	7
6 Jul	0	0	5	3	5	3	1	1	11	7	12	8
7 Jul	0	0	0	0	0	0	0	0	6	5	6	5
8 Jul	0	0	2	4	2	4	0	0	1	2	1	2
9 Jul	0	0	1	1	1	1	0	0	1	1	1	1
10 Jul	2	0	0	1	2	0	0	0	0	0	0	0
11 Jul	1	1	0	0	1	1	0	0	0	0	0	0
12 Jul	0	0	1	1	1	1	0	0	0	0	0	0
13 Jul	0	0	0	0	0	0	1	1	0	0	1	1
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	1	1	0	0	1	1	2	1	0	0	2	1
16 Jul	1	0	0	0	1	0	0	0	1	1	1	1
17 Jul	0	0	0	0	0	0	0	0	0	0	0	0
18 Jul	0	0	0	0	0	0	0	0	0	0	0	0
19 Jul	0	0	0	0	0	0	0	0	0	0	0	0

Appendix Table C-2. Continued.

	Released 15 June											
	Treatments and tag code (AG D1 D2)[a]											
	Tanner Creek 23 30 07						Midstream Columbia 23 30 09					
Date of	Beach		Purse		Total		Beach		Purse		Total	
recovery	A[b]	S[c]	A	S	A	S	A	S	A	S	A	S
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0	0	0	0	0	0	0
22 Jul	0	0	0	0	0	0	0	0	1	1	1	1
NA”	1				1							
Total 546		60	91	338	334	398	424	79	102	446	444	525
Recovery %	0.06	0.10	0.36	0.35	0.42	0.45	0.09	0.11	0.48	0.48	0.57	0.59
Mvmt rate’		19.6		15.7		17.4		19.6		17.4		17.4
19 Jun	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	0	0	0	0	0	0	0	0	0	0	0	0
22 Jun	0	0	1	1	1	1	0	0	1	1	1	1
23 Jun	2	3	10	11	12	14	0	0	13	14	13	14
24 Jun	1	3	64	64	65	67	3	8	78	78	81	86
25 Jun	NE	9	53	44	53	53	NE	10	88	73	88	83
26 Jun	33	15	77	48	110	63	27	12	90	56	117	69
27 Jun	8	6[d]	17	19	25	25[d]	12	9[d]	19	21[d]	31	30[d]
28 Jun	1	1	5	10[d]	6	11	7	9	8	16	15	25
29 Jun	3	3	27	34	30	37	4	4	27	34	31	38
30 Jun	1	2	36	30	37	32	1	2	33	27	34	29
1 Jul	3	4	8	10	11	14	1	1	15	19	16	20
2 Jul	9	5	12	13	21	18	1	1	15	17	16	17
3 Jul	12	6	22	22	34	28	12	6	15	15	27	21
4 Jul	4	3	8	9	12	11	7	4	12	13	19	18
5 Jul	4	3	19	15	23	17	2	1	18	14	20	15
6 Jul	1	1	19	13	20	14	2	2	19	13	21	15
7 Jul	0	0	10	9	10	9	1	5	12	11	13	16
8 Jul	1	1	6	12	7	13	1	1	13	26	14	27
9 Jul	2	1	1	1	3	2	0	0	5	6	5	6
10 Jul	0	0	0	0	0	0	0	0	0	0	1	2
11 Jul	0	0	4	5	4	5	1	1	1	1	2	2
12 Jul	4	3	2	3	6	6	1	1	1	1	2	2
13 Jul	0	0	0	0	0	0	0	0	2	2	2	2

Appendix Table C-2. Continued.

Date of recovery	Released 15 June — Treatments and tag code (AG D1 D2)[a] — Tanner Creek 23 30 07 — Beach A[b]	Beach S[c]	Purse A	Purse S	Total A	Total S	Midstream Columbia 23 30 09 — Beach A	Beach S	Purse A	Purse S	Total A	Total S
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0
15 Jul	0	0	0	0	0	0	0	0	0	0	0	0
16 Jul	0	0	2	2	2	2	0	0	0	0	0	0
17 Jul	0	0	0	0	0	0	0	0	0	0	0	0
18 Jul	0	0	0	0	0	0	0	0	1	3	I	3
19 Jul	0	0	1	1	1	1	0	0	0	0	0	0
20 Jul	0	0	0	0	0	0	0	0	0	0	0	0
21 Jul	0	0	0	0	0	0	0	0	0	0	0	0
22 Jul	0	0	0	0	0	0	0	0	0	0	0	0
NA[e]	1				1		1				1	
Total 538		90	66	404	376	494	442	85	77	486	461	571
Recovery %	0.09	0.07	0.42	0.39	0.51	0.46	0.09	0.08	0.51	0.49	0.60	0.57
Mvmt rate’		19.6		17.4		19.6		19.6		19.6		19.6

[a] AG D1 D2 = Agency code, Data 1 code, Data 2 code.
[b] A = Actual daily purse seine or beach seine catch. NE = No sampling effort.
[c] S = Standardized daily catch. Purse seine data standardized to a 10 set per day effort; beach seine data standardized to a 5 set per day effort.
[d] Day that the median fish was captured (standardized effort).
[e] Date of recovery unavailable. Not used in data standardization.
[f] Mvmt. rate = Movement rate (km/day) = distance traveled (RK 232 to RK 75) divided by the travel time (days from release to median fish recovery).

Appendix Table C-3. Diel catch results from purse and beach seine sampling at Jones Beach through a 24-h period, June 26-27, 1992.

Gear--vessel	Date	Set time	Set	Subyearling chinook salmon
Beach	26 Jun	0455	01	606
Beach	26 Jun	0635	02	2260
Beach	26 Jun	0938	03	957
Beach	26 Jun	1113	04	839
Beach	26 Jun	1334	05	543
Beach	26 Jun	1512	06	1172
Beach	26 Jun	1702	07	1067
Beach	26 Jun	1912	08	423
Beach	26 Jun	2005	09	117
Beach	26 Jun	2108	10	87
Beach	26 Jun	2355	11	6
Beach	27 Jun	0300	01	19
Beach	27 Jun	0455	02	763
Beach	27 Jun	0730	03	830
Beach	27 Jun	0810	04	1333
Beach	27 Jun	0940	05	634
Beach	27 Jun	1030	06	378
Beach	27 Jun	1130	07	293
		Total beach seine	18	12,327
Purse--GW	26 Jun	0520	01	2940
Purse--GW	26 Jun	0700	02	333
Purse--GW	26 Jun	0829	03	228
Purse--GW	26 Jun	1008	04	300
Purse--GW	26 Jun	1117	05	199
Purse--GW	27 Jun	0506	01	871
Purse--GW	27 Jun	0647	02	223
Purse--GW	27 Jun	0822	03	64
		Subtotal	8	5,158
Purse--Rosa	26 Jun	0534	01	1937
Purse--Rosa	26 Jun	0723	02	347
Purse--Rosa	26 Jun	0845	03	236
Purse--Rosa	26 Jun	1013	04	243
Purse--Rosa	26 Jun	1119	05	152
Purse--Rosa	26 Jun	1227	06	76

Appendix Table C-3. Continued.

Gear--vessel	Date	Set time	Set	Subyearling chinook salmon
Purse--Rosa	26 Jun	1410	07	116
Purse--Rosa	26 Jun	1545	08	19
Purse--Rosa	26 Jun	1750	09	148
Purse--Rosa	26 Jun	2032	10	463
Purse--Rosa	26 Jun	2214	11	33
Purse--Rosa	27 Jun	0108	0 1	71
Purse--Rosa	27 Jun	0450	02	468
Purse--Rosa	27 Jun	0620	03	120
Purse--Rosa	27 Jun	0804	04	67
Purse--Rosa	27 Jun	093 1	05	111
Purse--Rosa	27 Jun	1056	06	107
		Subtotal	17	4.714
		Total purse seine	25	9,872

APPENDIX D

Statistical Analyses of Juvenile Salmon Recovery Data

A. Chi-square goodness of fit analysis was used to evaluate differences among observed recoveries (Appendix Table C-Z) through time for different treatment groups released on the same day (Sokal and Rohlf 1981). A non-significant result indicated that there was equal probability of capture at Jones Beach for each treatment group (i.e., that the groups were adequately mixed). Results of this analysis are shown below. For additional details of this procedure see Dawley et al. (1989), Appendix D.

H,: There was homogeneity between recovery distributions of treatments.

Release date	Seine type	Chi-square	df	P
15 June	purse	21.38	16	0.165
19 June	purse	16.92	18	0.529
15 June	beach	8.94	8	0.347
19 June	beach	12.05	8	0.149
15 June	total	24.05	18	0.154
19 June	total	19.45	19	0.428

Conclusion: No evidence to suggest there is non-homogeneity between treatment recovery distributions.

B. Paired difference z-tests were used to evaluate the benefits of midstream Columbia River release over Tanner Creek release and to evaluate the effects of northern squawfish removal efforts on the difference between midstream and Tanner Creek releases. Similar analyses were performed on purse-seine plus beach-seine recoveries (Section la-lc) and purse-seine recoveries alone (Section 2a-2c). Recoveries in the beach seine were insufficient for a meaningful analysis (< 0.1%).

Consider the following notation:

P_{tc1} = true survival to and recovery at Jones Beach of fish released in Tanner Creek before squawfish removal on June 15.

p_{tc1} = estimate of P_{tc1} = recovery proportion at Jones Beach of fish released at Tanner Creek on June 15

Similar explanations follow for P_{tc2}, p_{tc2}, P_{mc1}, p_{mc1}, P_{mc2} and p_{mc2}

where: tc denotes Tanner Creek,
mc denotes midstream Columbia River,
1 denotes releases on June 15, before squawfish removal,
2 denotes releases on June 19, after squawfish removal.

R_{ij} = release number for group i, j

where i = tc, mcandj = 1, 2

$v(p_{ij}) = p_{ij}(1-p_{ij}) \div R_{ij}$ is the estimated variance of p_{ij}

For the three null hypotheses tested below, we assumed z (as defined below) would follow a standard normal distribution.

1) Total catch--purse seine plus beach seine.

a) The null hypothesis for testing whether recoveries of midstream Columbia-River-released fish were different than Tanner Creek-released fish for the first release pair was:

$$H_o: (P_{mc1} - P_{tc1}) = 0$$

The test statistic was:

$$z = \frac{(p_{mc1} - p_{tc1})}{\sqrt{v(p_{mc1}) + v(p_{tc1})}}$$

The relevant statistics for the first release pair were:

p_{mc1} = 525 ÷ 92240 = 0.005692

p_{tc1} = 398 ÷ 94817 = 0.004198

Then,

$$z = \frac{(0.005692 - 0.004198)}{\sqrt{\frac{0.005692(0.994308)}{92244\text{-}I} + \frac{0.004198(0.995802)}{94817}}}$$

$$= \frac{0.001494}{0.000324} = 4.6111,\ p\text{-}value < 0.0001$$

Conclusion: The recovery rate for midstream Columbia-River-released fish was significantly higher than for Tanner-Creek-released fish; the difference was 35.7%.

b) The null hypothesis for testing whether recoveries of midstream Columbia-River-released fish were different than Tanner Creek-released fish for the second release pair was:

$$H_o: (P_{mc2} - P_{tc2}) = 0$$

The test statistic was:

$$z = \frac{(p_{mc2} - p_{tc2})}{\sqrt{v(p_{mc2}) + v(p_{tc2})}}$$

The relevant statistics for the second release pair were:

P_{mc2} = 571 ÷ 94834 = 0.006021
P_{tc2} = 494 ÷ 96095 = 0.005141

Then,

$$z = \frac{(0.006021 - 0.005141)}{\sqrt{\frac{0.006021(0.993979)}{94834} + \frac{0.005141(0.994859)}{96095}}}$$

$$= \frac{0.000880}{0.000341} = 2.5806,\ p\text{-}value = 0.0099$$

Conclusion: The recovery rate for midstream Columbia-River-released fish was significantly higher than for Tanner-Creek-released fish; the difference was 17.6%.

c) The null hypothesis for testing whether northern squawfish removal had a significant benefit for midstream Columbia-River-released fish was:

$$H_o: (P_{mc1} - P_{tc1}) - (P_{mc2} - P_{tc2}) = 0$$

The test statistic was:

$$z = \frac{(p_{mc1} - p_{tc1}) - (p_{mc2} - p_{tc2})}{\sqrt{v(p_{mc1}) + v(p_{tc1}) + v(p_{mc2}) + v(p_{tc2})}}$$

The relevant statistics for the study were:

p_{mc1} = 525 ÷ 92240 = 0.005692
p_{tc1} = 398 ÷ 94817 = 0.004198
p_{mc2} = 571 ÷ 94834 = 0.006021
p_{tc2} = 494 ÷ 96095 = 0.005411

Then,

$$z = \frac{(0.005692 - 0.004198) - (0.006021 - 0.005141)}{\sqrt{\frac{0.005692(0.994308)}{92240} + \frac{0.004198(0.995802)}{94817} + \frac{0.006021(0.993979)}{94834} + \frac{0.005141(0.994859)}{96095}}}$$

$$= \frac{0.000614}{0.000470} = 1.3064 \quad p\text{-}value = 0.1914$$

Conclusion: The effect of removing northern squawfish from the migration route of Tanner-Creek-released fish was insignificant; the reduction was 50.7% ((35.7% - 17.6% ÷ 35.7) * 100).

2) Purse seine recoveries.

a) The null hypothesis for testing whether recoveries of midstream Columbia-River-released fish were different than Tanner-Creek-released fish for the first release pair was:

$$H_o: (P_{mc1} - P_{tc1}) = 0; \ z = 4.2475; \ \text{p-value} < 0.0001$$

b) The null hypothesis for testing whether recoveries of midstream Columbia-River-released fish were different than Tanner-Creek-released fish for the second release pair was:

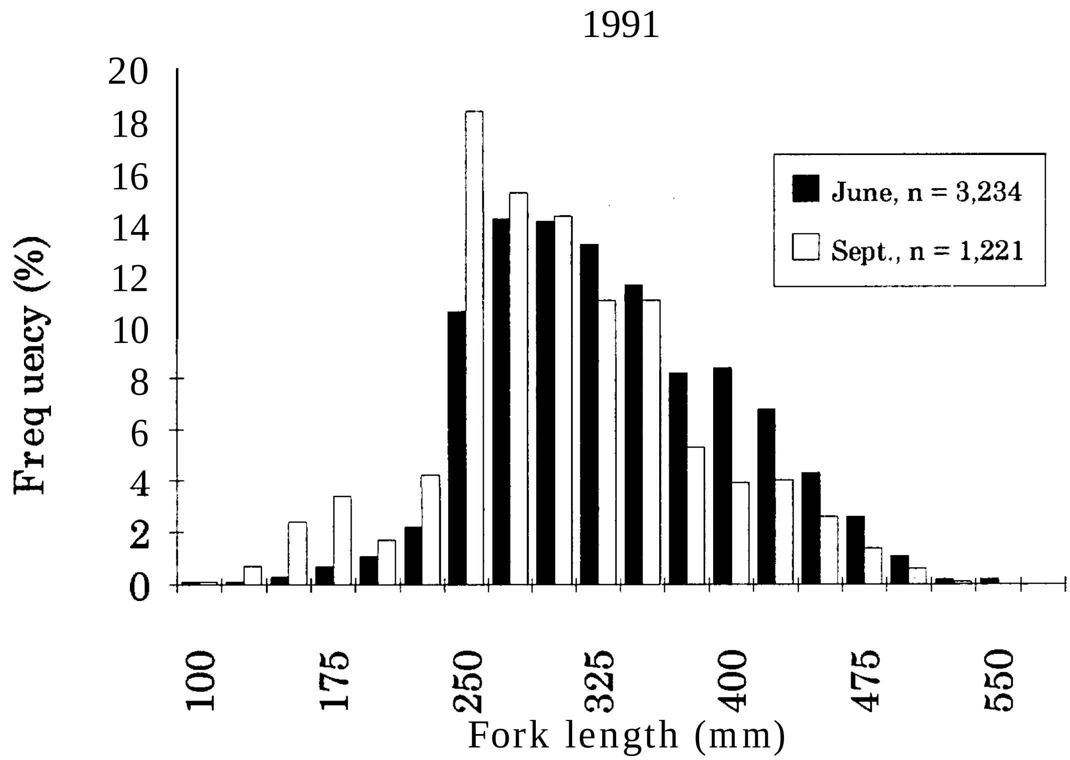
$$H_o: (P_{mc2} - P_{tc2}) = 0; \ z = 2.9475; \ \text{p-value} = 0.0030$$

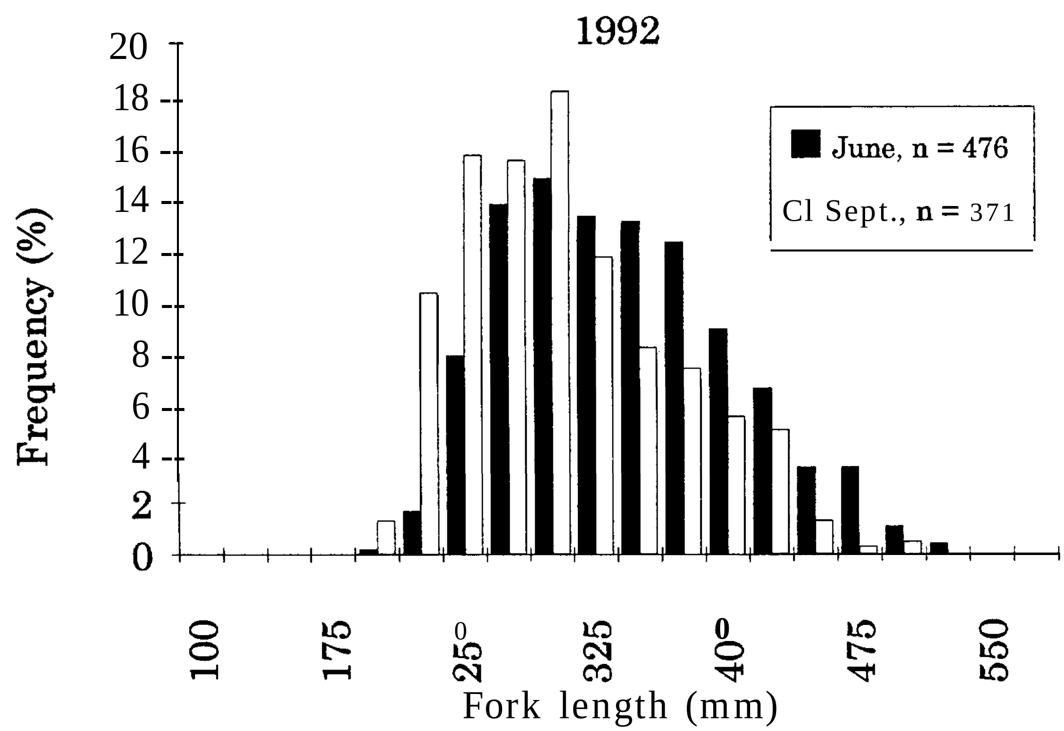
c) The null hypothesis for testing whether northern squawfish removal had a significant benefit for midstream Columbia-River-released fish was:

$$H_o: (P_{mc1} - P_{tc1}) - (P_{mc2} - P_{tc2}) = 0; \ z = 0.8125; \ \text{p-value} = 0.4165$$

APPENDIX E

Length-Frequency Distributions for Northern Squawfish Sampled in the Bonneville Dam Tailrace Area by ODFW, 1991 and 1992





Appendix Figure E-1.--Fork length frequency of northern squawfish captured in the Bonneville Dam tailrace area comparing June and September, 1991 and 1992. Sport reward fishery; data provided by David Ward, ODFW, Clackamas, Or.

REPORT F

Northern Squawfish Sport Reward Payments

Prepared by

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Pacific States Marine Fisheries Commission
Gladstone, Oregon

1992 Annual Report

CONTENTS

INTRODUCTION

During 1992, the voucher payment project of the Squawfish Management Program paid a total of $537,840 to anglers for 179,280 fish in the sport reward fishery. A total amount of $52,108.50 was paid (for compensation of effort and for fish caught) to three fishers under contract in the commercial longline fishery.

SPORT REWARD FISHERY

A total of $537,840 was paid for 179,280 fish documented in 16,578 sport reward vouchers in the 1992 program (Table 1). Sport anglers received a $3 reward for each squawfish over 11 inches long as documented on a sport reward voucher issued by Washington Department of Wildlife check station staff. The anglers mailed their vouchers to our office for processing of payment. The first vouchers were received in May; the first payments were not processed until June. Payment activity was highest during June and July, with about 74% of total dollars paid during that time period.

Table 1. Total number of vouchers received, total numbers of fish represented by those vouchers, total funds paid in rewards, and average number of fish per voucher by month in the 1992 sport reward fishery.

Month	# Vouchers	# Fish	$ Total	# Fish /Voucher
June	4,398	54,357	$163,071	12.36
July	5,900	78,527	$235,581	13.31
August	3,006	24,852	$74,556	8.27
September	2,252	16,227	$48,681	7.21
October	804	4,168	$12,504	5.18
November	218	1,149	$3,447	5.27
TOTAL	16,578	179,280	$537,840	10.81

In general, processing proceeded smoothly. Initially, voucher processing time took about 10 days. The Pacific States Marine Fisheries Commission (PSMFC) then mailed checks to anglers and submitted bills to the Oregon Department of Fish and Wildlife (ODFW) for reimbursement, a process which took three to five weeks to be completed. Due to the high volume of payments being sent to anglers, PSMFC could not afford to continue mailing payments before reimbursement was received from ODFW. PSMFC began holding checks, in some cases up to five weeks after processing, until funds for those checks were received from ODFW. This caused quite a few disgruntled anglers, who expected payment within two to three weeks. To speed processing, PSMFC was able to reduce initial voucher processing time to within three days of receipt. Anglers were notified, both at check stations and on the voucher payment message line, that processing took from four to six weeks.

Those vouchers that had missing or incomplete information were returned to anglers for completion. In all, 1,736 vouchers were returned. To date, 239 vouchers worth approximately $2,500 have not been resubmitted to PSMFC for payment. Table 2 outlines the reasons why vouchers were returned to anglers and the corresponding number of vouchers returned by reason.

Table 2. Summary of why 1,736 vouchers were returned to anglers by reason, number of vouchers by reason, and the percentage of the total. (Some vouchers were returned for multiple reasons.)

Reason Returned	Number Vouchers	% of Total	Reason Returned	Number Vouchers	% of Total
Name Incomplete	147	8%	Trip Form Incomplete	1,120	65%
Address Incomplete	307	18%	Annual Form Incomplete	928	53%
Social Security Number Missing	333	19%	Voucher sent w/o Questionnaire	491	28%
No Angler Signature	40	2%	# Fish not indicated	37	2%

In addition to the 239 vouchers that were not resubmitted for payment, 29 vouchers representing 166 fish ($198) were withheld from payment. These anglers did not submit an annual trip form questionnaire. All anglers in this group were notified of this missing information, and did not resubmit their vouchers for payment. Thirty checks totalling $300 were returned to PSMFC by the post office due to invalid addresses. PSMFC tried to correct address information where possible, but these anglers never submitted additional vouchers, nor did they call concerning non-payment of vouchers.

If the above totals are added to- the total number of vouchers paid, we can account for 16,846 vouchers representing approximately 182,524 fish caught, with a value of $547,572. Thus, approximately $9,732 of program dollars were never paid out for the 259 vouchers representing 3,244 fish.

Approximately 4,084 individual anglers received compensation from the sport reward program. An additional 116 individuals did not receive compensation, due to unreturned vouchers. These 116 anglers did not submit other vouchers during the 1992 season. Thus, 4,200 participating anglers can be accounted for in PSMFC's component of the program.

There were several requests by various agencies to withhold payment on anglers suspected of wrongdoing (i.e., fishing outside the program boundaries). There were 14 individuals for whom payment was withheld or delayed. A procedure was developed, with the help of the Oregon attorney general's office, whereby ODFW would send written notification to PSMFC instructing the commission to withhold or release payment for certain individuals.

A total of 41 checks for $4,074 were mailed in calendar year 1992. In February of 1993, checks for 63 vouchers and 6,254 fish ($19,362) were released to individuals for whom payments were being withheld. Thirteen vouchers for 2,249 fish ($6,747) remain unpaid.

In January, PSMFC's programmer worked on cleaning up files and readying the payment information for magnetically filing IRS 1099-MISC forms. These forms were issued to anglers who made $600 or more in income from the sport reward fishery. In all, 202 forms were filed for this group of individuals who made $287,936.

Some individuals from whom money was being withheld pending investigation received a 1099-MISC that reflected only the actual dollars paid out as of December 31, 1992. These individuals were issued subsequent payments in February of 1993, as authorized by the Oregon Department of Fish and Wildlife. These monies will be reflected in the individuals' 1993 1099-MISC forms. As stated above, 13 vouchers for 2,249 fish ($6,747) have not yet been paid for the 1992 season.

COMMERCIAL LONGLINE FISHERY

For the 14 weeks that the commercial longline fishery was open, PSMFC processed 144 vouchers totalling $52,108.50. Longliners were compensated $250 per day for a five-day work week or $312.50 per day for a four-day work week. Compensation for effort totaled $48,187.50. Reward payments for 1,307 fish caught for the season were $3,921 (Table 3).

Table 3. Total compensation for commercial longline fishery by week, effort, number of fish caught, compensation for fish, and total dollars paid.

Week Number	Compensation for Effort	Number Fish Caught	#Fish @$3 Each	Dollar Total by Week
1	$3,250.00	76	$228.00	$3,478.00
2	$3,687.50	77	$231 .OO	$3,918.50
3	$4,062.50	117	$351.00	$4,413.50
4	$2,498.00	48	$144.00	$2642.00
5	$4,751 .oo	204	$612.00	$5,363.00
6	$3,376.00	103	$309.00	$3,685.00
7	$3,437.50	124	$372.00	$3,809.50
8	$3,562.50	166	$498.00	$4,060.50
9	$4,000.00	169	$507.00	$4,507.00
10	$4,000.00	35	$105.00	$4,105.00
11	$3,750.00	32	$96.00	$3,846.00
12	$3,437.50	40	$120.00	$3,557.50
13	$4,375.00	116	$348.00	$4,723.00
TOTAL	$48,187.50	1,307	$3,921.00	$52,108.50