REPORT Z.

Feasibility of Various Techniques for Removal of
Northern Squawfish at Bonneville Dam,
Columbia River

Prepared by

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ABSTRACT

During 1991, the National Marine Fisheries Service evaluated a variety of techniques to remove northern squawfish, Ptychocheilus oregonensis, from the Columbia River at Bonneville Dam. Purse seining and electrofishing with permanently installed electrical arrays were tested, as well as a portable electrofisher deployed by a boom truck, a boat electrofishing unit used in combination with a beach seine, and a continuous multi-lure longline device. None of these removal techniques proved effective. However, the late starting date, other removal programs in progress, and the high rate of water spill may have influenced the results.

INTRODUCTION

Northern squawfish, Ptychocheilus oregonensis, have been identified as major predators of juvenile salmonids (Oncorhynchus spp.) in the Columbia River, accounting for most previously unexplained reservoir mortality (Uremovich et al. 1980, Poe et al. 1991, Rieman et al. 1991). Predation rates are especially high around dams, where predators concentrate and where disoriented juvenile salmonids are particularly vulnerable (Beamesderfer and Rieman 1991, Rieman et al. 1991, Vigg et al. 1991). In John Day Reservoir, Rieman et al. (1991) estimated that predators, primarily northern squawfish, consumed 14% of the juvenile salmonids entering the reservoir during April-August 1983-1986. At Bonneville Dam, Uremovich et al. (1980) estimated that 3.8 million or 11% of the downstream migrant salmonids entering Bonneville Reservoir were eaten by northern squawfish in the 1980 season. Investigators from the Coastal Zone and Estuarine Studies Division (CZES) of the National Marine Fisheries Service (NMFS) estimated the adult population of northern squawfish in the forebay of Bonneville Dam First Powerhouse to be 58,000 in 1989, based on studies concluded that year.[1]

To address this problem, the Bonneville Power Administration (BPA) is funding a "system-wide predator control program" with the Oregon Department of Fish and Wildlife (ODFW) as lead agency. One category of this program is harvest technology development, which involves designing and evaluating new techniques for northern squawfish removal. As part of the harvest technology program, NMFS tested three general techniques in the area of Bonneville Dam First Powerhouse from 17 July to 20 August, 1991 (Figure Z-1). The following

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[1] Benjamin Sandford, NMFS, CZES, 2725 Montlake Blvd. East, Seattle, WA 98112. Pers. commun., January 1991.

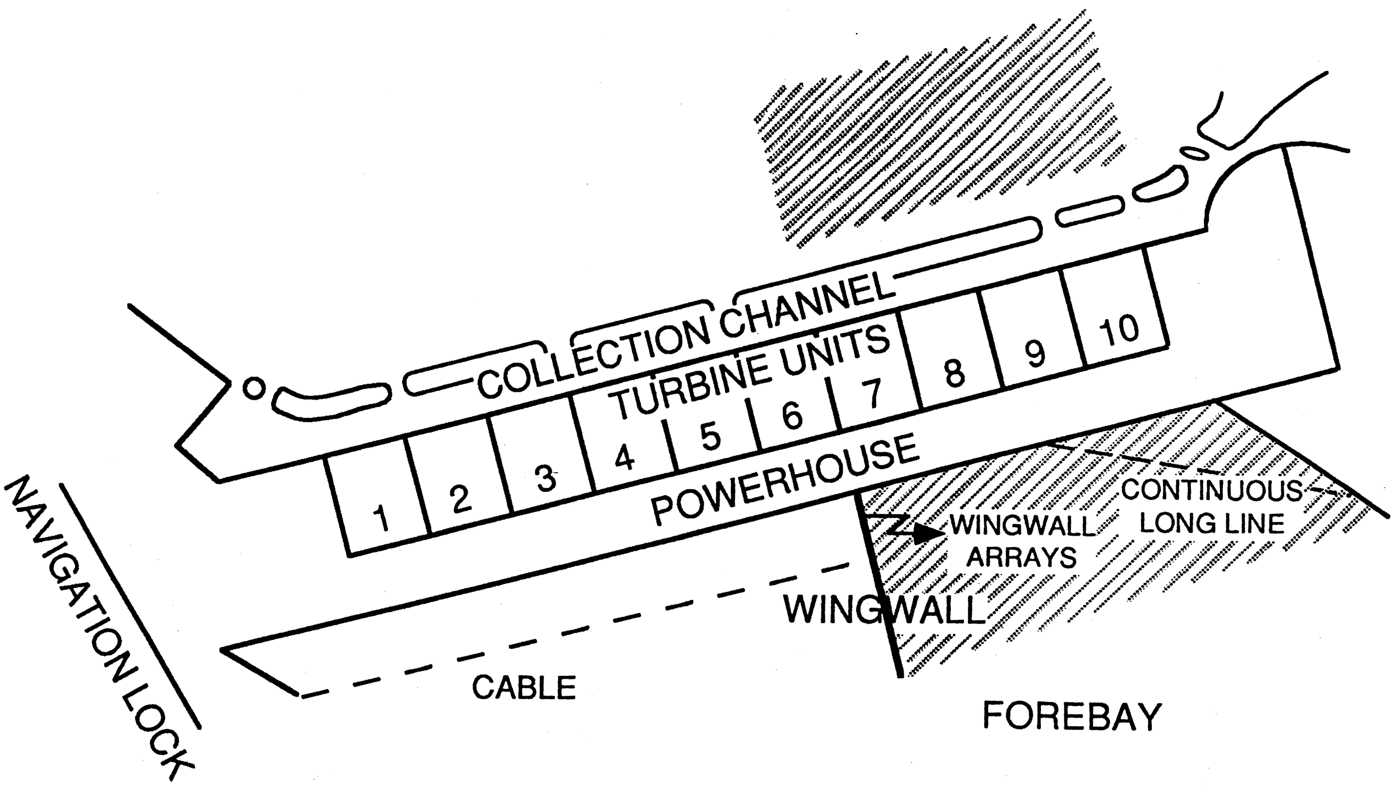

Figure Z-1. Bonneville Dam First Powerhouse showing location of wingwall arrays, piernose arrays (Turbine Unit 10) continuous multi-lure longline, and main areas for purse seining (shaded area).

harvest techniques were used: 1) electrofishing gear, both permanently installed and portable, 2) continuous multi-lure longline gear, and 3) purse seining.

ELECTROFISHING GEAR

Methods and Materials

An electrofishing system, designed and constructed by Smith-Root, Inc.[2] for the forebay of Bonneville Dam First Powerhouse, was tested. The system consisted of three main components; a 60 kW diesel-powered alternator, a control and power distribution panel box, and various electrode arrays (specifications given in Appendix Table Z-1).

A voltage selector switch on the alternator allowed voltage adjustment for maximum effectiveness with changing water conditions and electrode arrays. The available voltages were 208, 240, and 480 V, supplied in three-phase configuration, with the neutral connection isolated from the safety ground system. The control box provided on-off power switching with remote capability, metered output voltage from 0 to 500 V, and individual phase currents from 0 to 500 A. Power distribution was accomplished with three connectors, each providing the three phase voltages and a safety ground connection to the output arrays. A combination of any three arrays could be on at one time.

Each output array was constructed with a safety-grounded supporting structure and three rows of cable electrodes, each connected to one of the output phase voltages. This provided a very intense field between electrode rows with a somewhat weaker field extending outward from the sides of the array. Three output arrays were suspended along the wingwall in the center of the First

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[2] Reference to trade names does not imply endorsement by the National Marine Fisheries Service.

Powerhouse and two arrays were suspended between piernoses in Unit 10, Slots B and C (Appendix Figures Z-1 and Z-2).

A portable electrode array, deployed by either a boom truck or the Corps of Engineers (COE) gantry crane, was also tested. This was designed to produce a large local field when used alone, or to increase the affected area when used with the other electrode arrays. The three electrode array types are shown in Figure Z-2.

Installation of the electrofishing gear was not completed until 17 July. Testing began immediately and continued at various times each day into August (Table Z-1). Daily testing was usually conducted at dusk or dawn, when northern squawfish concentrations were highest. Catch data were recorded in number of fish per hour; however, this included the time needed to set up or move the electrode arrays and the time between shocks, while waiting for dispersed northern squawfish concentrations to return. Duration of the actual shock time was usually 2 to 3 minutes, unless juvenile or adult chinook salmon, O. tshawytscha, were stunned. Although the piernose electrode arrays could be moved to other locations, they were cumbersome, and the activity associated with moving them dispersed any northern squawfish in the area. The portable electrode array was less cumbersome, easily moved, and did not seem to frighten northern squawfish from the immediate area.

A steel net-frame with a 7.6-cm stretch-mesh fyke net was constructed to fit between piernoses and collect stunned fish swept into the ice-trash sluiceway. The frame was lowered and raised with a small crane. A long-handled dipnet was also used.

In addition, an electrofishing boat was used on one occasion to evaluate its usefulness in combination with a beach seine. This was done in the tailrace of the

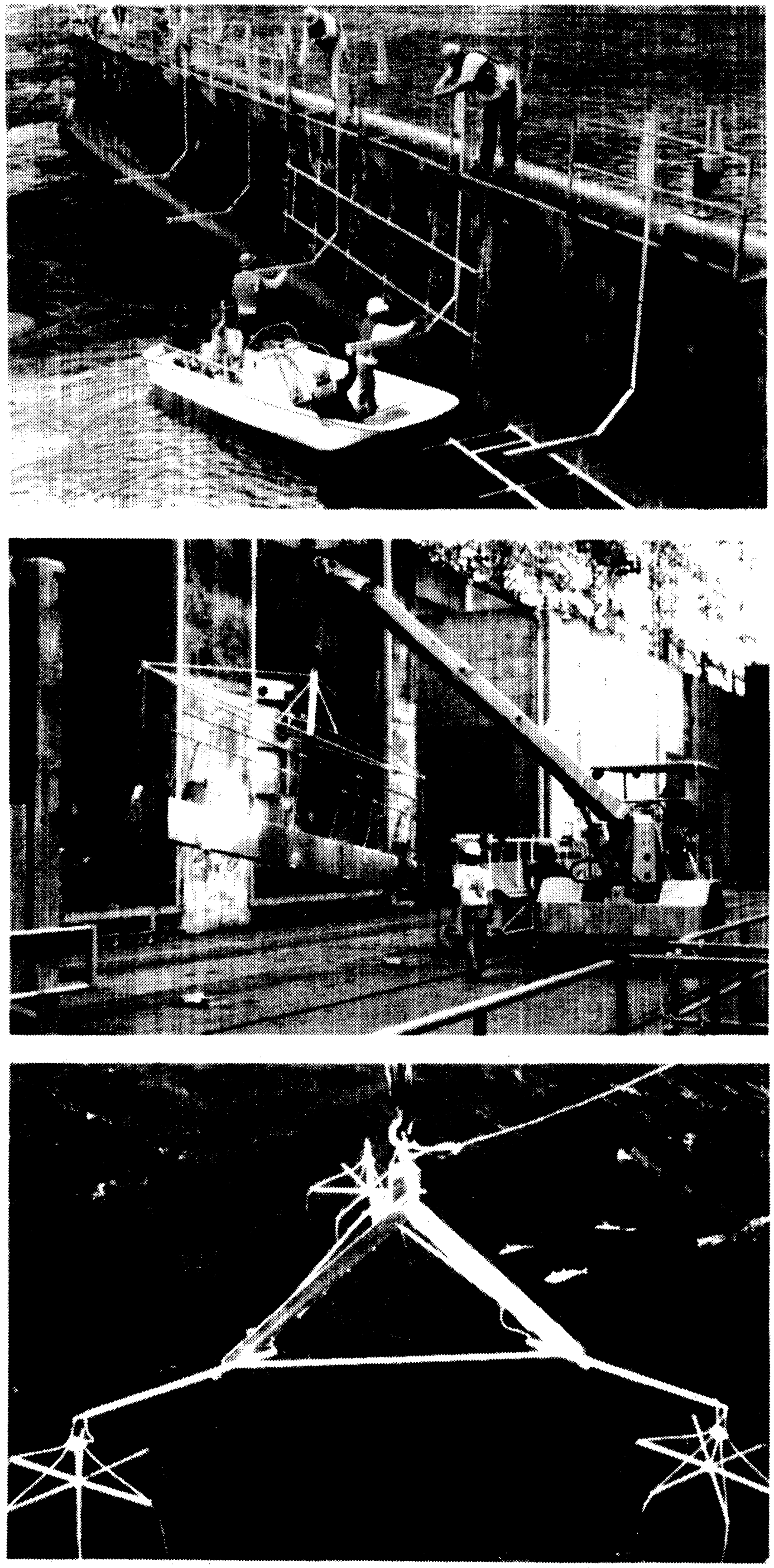


Figure Z-2. Electrofishing gear tested for harvesting northern squawfish at Bonneville Dam First Powerhouse, summer 1991. Top, wingwall electrode array; middle, piernose electrode array; bottom, portable electrode array.

Table Z-1. Sampling information for permanently installed electrofishing gear used at Bonneville Dam First Powerhouse, 1991.

Date	Time	Area	Gear
7/17	1445-1505	North of wingwall	Wingwall arrays
	2041-2045		
7/18	2131-2151	10B and 10C	Piernose arrays
7/19	1830-2115	10B and 10C	Piernose arrays
7/20	1900-2140	North of wingwall	Wingwall arrays
7/21	0620-0920	North of wingwall	Wingwall arrays
7/23	0616-0829	10B and 10C	Piernose arrays
7/24	0446-0514	10B and 10C	Piernose arrays
7/25	0547-0805	Most of powerhouse forebay	Portable array
7/29	2000-2152	1B, 3B-4B, 6A-9C	Portable array
7/30	2100-2215	1B, 1C, and 3A	Portable array
7/31	2030-2120	1C, 3A, 6B,and 6C	Portable array
8/01	2100-2200	10B and 10C	Piernose arrays
8/20	1830-1930	North of wingwall	Wingwall arrays

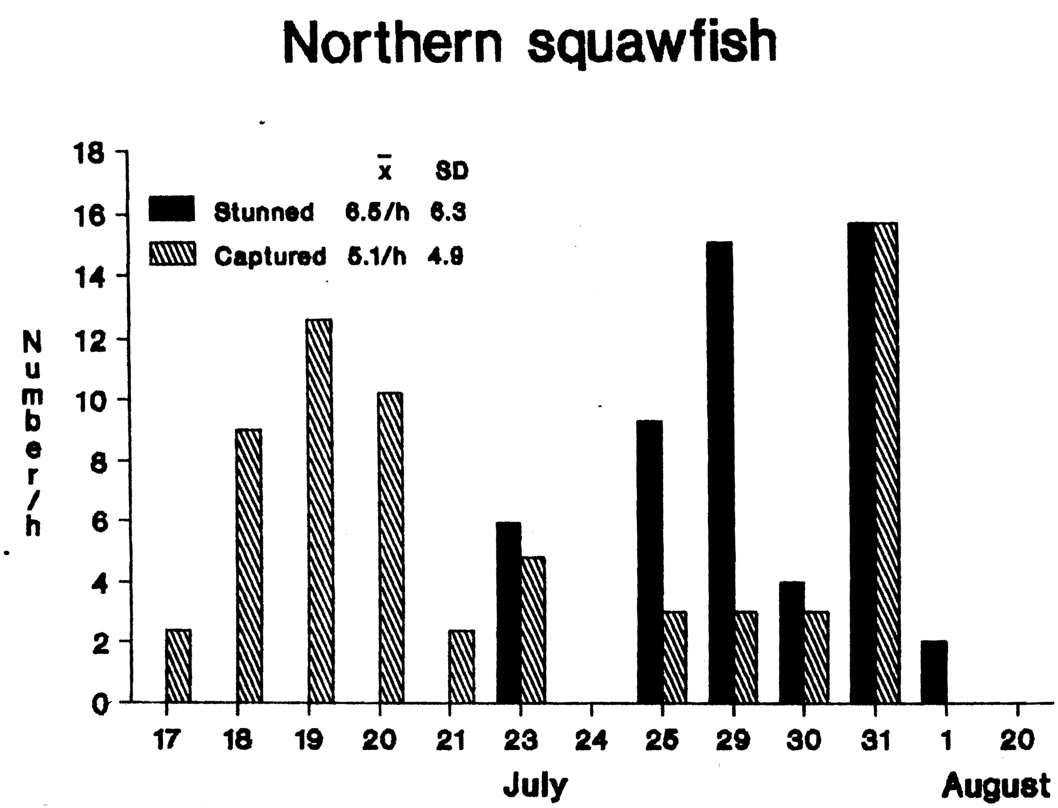
First Powerhouse. A 7.6-cm mesh trap-net lead or a 10.2-cm mesh commercial salmon gill-net was used as a beach seine, anchored on shore and held in the current by a seine skiff. A U.S. Fish and Wildlife Service (USFWS) boat and crew electrofished from upstream to the net opening. The net was then brought to shore by the seine skiff. This method was tested at several points along the north shore of Bradford Island and along the Oregon shore near the navigation locks.

Results and Discussion

The number of northern squawfish stunned and collected with the permanently installed electrofishing gear was low throughout the sampling period (17 July-20 August). Average catch was 8.9 fish per day or 5.1 fish per hour (Figure Z-3), with 116 total northern squawfish stunned and captured.

On the first day of testing, an estimated 300-400 northern squawfish were stunned with the first electrofishing effort. However, the electrical current was maintained for only 30 seconds. Later tests showed that 2 to 3 minutes were needed to stun northern squawfish effectively. Also, because of the limited hydraulic capacity of the ice-trash sluiceway, high forebay levels flooded the upper (north) end of the sluiceway. As a result, flow was not strong enough to pull stunned northern squawfish into the fyke net. Because they had not been sufficiently stunned, a majority of these fish recovered and swam away. In subsequent tests, the ice-trash sluiceway gates south of Unit 10 were readjusted to increase flow into the area where the fyke net was deployed. However, concentrations of northern squawfish similar to those on the first day of testing were not observed again.

The permanent electrofishing gear proved to be efficient in stunning adult American shad, Alosa sapidissima. Eight hundred and ninety-nine American shad



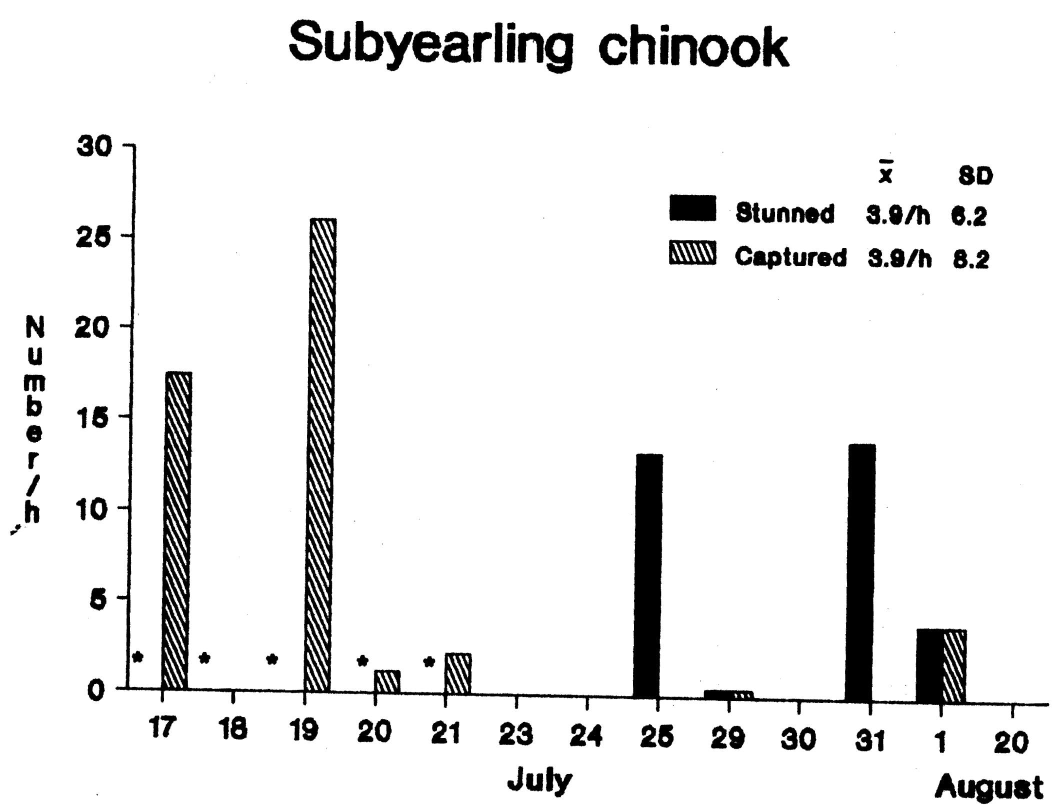


Figure Z-3. The number of northern squawfish and subyearling chinook salmon stunned and captured per hour after electrofishing with permanently installed electrofishing gear at Bonneville Dam First Powerhouse forebay, 17 July to 20 August 1991. Asterisks denote dates where the numbers of stunned fish were not recorded. Means and standard deviations are for the number captured per hour.

were captured in the ice-trash sluiceway fyke-net during the first week of electrofishing. Because of the large number of adult American shad and the small number of northern squawfish stunned, capture methods were changed after the first week. The fyke-net frame was held above the surface with a crane and not set into a fishing position until a sizeable number of stunned northern squawfish were observed. This allowed time for American shad and juvenile salmonids to be swept into the ice-trash sluiceway, where they could get out of the electrical current quickly. An estimated 7,000 to 10,000 adult American shad were electrofished and passed into the ice-trash sluiceway during our efforts.

The numbers of subyearling chinook salmon that were stunned and recovered ranged from 0 to 72 per day (Figure Z-3). Whenever they were observed, the power was shut off and they swam away. The number of smolts captured was usually low, averaging 6.9 per day. Two adult salmonids were observed during electrofishing, but swam away after the power was shut off. One disadvantage of using the fyke net was that subyearling chinook salmon that might have recovered were caught and died before they could be released. It appeared that most stunned fish--northern squawfish as well as adult and juvenile salmonids--recovered if not captured in the fyke net.

Beginning on 20 July, a portable electrode array deployed by a boom truck was tested. This increased mobility, but hindered the capture of stunned northern squawfish because it was difficult to alter the ice-trash sluiceway gate settings. A long-handled dipnet was used in some places to capture stunned fish; however, many northern squawfish escaped before they could be dipnetted. The portable electrode array was also deployed from the COE gantry crane on 25 July, with testing conducted from 0700 to 0800 h across the face of the First Powerhouse. This proved to be the easiest method for using the portable electrode array;

however, few northern squawfish were observed or captured, perhaps due to the time of day.

The feasibility of using a seine net to capture northern squawfish stunned by an electrofishing boat was evaluated in the boat-restricted zone at Bonneville Dam on 18 June. Only 15 to 20 northern squawfish were captured, but few had been observed in the area and the work was done mainly to ascertain the practicality of using this type of gear around tailraces or other areas of high flow where northern squawfish congregate. Attempts were made at both hanging the net between two boats or anchoring one end to the beach (as a beach seine); the latter proved to be much more workable. Because of high flows in the tailrace, it was difficult to maintain the net in a fishing position without having it become entangled around itself or around the boat (especially when two boats were used). The general consensus reached by participants was that the method could be used successfully in areas of low to moderate flow, using a net with larger-size mesh, larger corks, and a heavier leadline.

Permanently installed electrofishing gear at Bonneville Dam was unsuccessful in removing northern squawfish. However, the late starting date for evaluating this equipment, high spill levels during the test period, and the possible success of concurrent predator removal programs (sport bounty and dam angling) may have affected test results. During 1989, large numbers of northern squawfish were observed along the north side of the wingwall at the First Powerhouse. During 1991, very few northern squawfish were observed along the wingwall--the area where our electrical arrays were concentrated. Uremovich et al. (1980) found an inverse relationship between spill and northern squawfish abundance in the forebay at Bonneville Dam First Powerhouse. During 1991, Bonneville Dam spill levels were much higher than in 1989 (Figure Z-4), and this may have reduced the

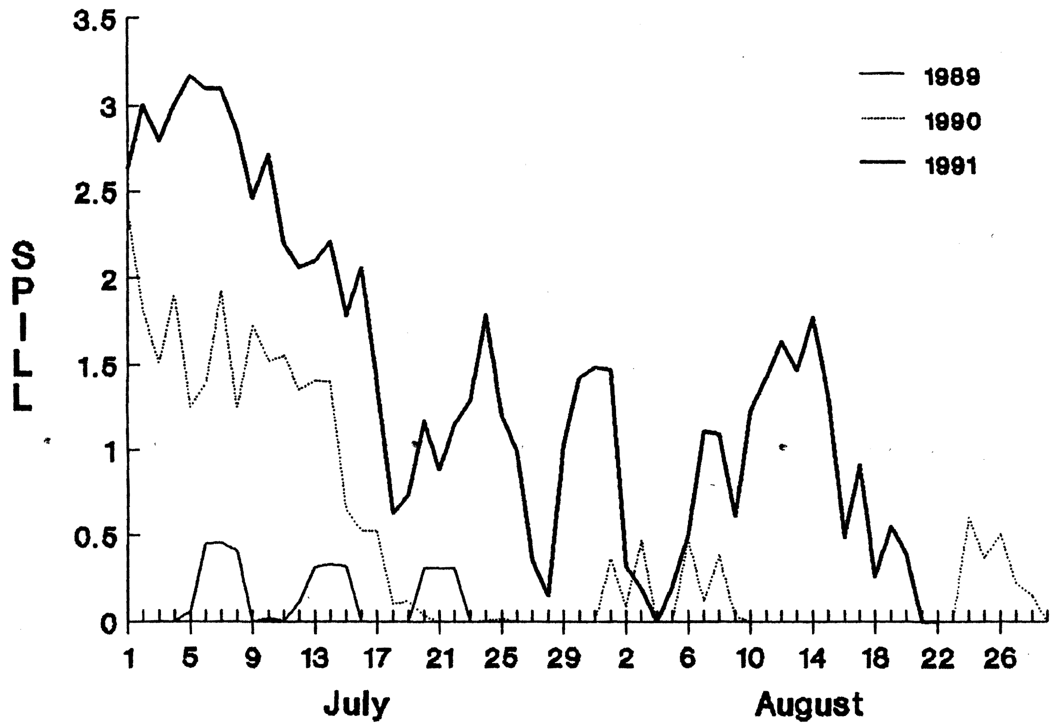


Figure Z-4. Spill (m^3/second in thousands) at Bonneville Dam, July-August 1989-1991.

local northern squawfish population. Also, reducing First Powerhouse flows for purse seining may have changed northern squawfish distribution in the forebay, since flows were reduced during their peak abundance periods.

Alternatively, we may have conditioned northern squawfish to avoid areas directly adjacent to the dam near permanently installed electrofishing gear. After the first evening of electrofishing, large concentrations of northern squawfish were not observed again in areas close enough to electrofish. Unfortunately, the confounding effects of the other removal programs and powerhouse flow manipulations made this hypothesis difficult to test.

Uremovich et al. (1980) were unsuccessful at removing northern squawfish using an electrode array mounted on a collapsible box-net lowered between piernoses at Bonneville Dam. They attributed this lack of success to an inability to fish far enough away from the First Powerhouse to reach areas where northern squawfish congregate. With the wingwall and portable array, we were able to effectively electrofish 6 to 30 m away from the powerhouse. However, we were still unable to reach areas in the forebay with the largest concentrations of northern squawfish.

CONTINUOUS MULTI-LURE LONGLINE GEAR

Methods and Materials

A hand-cranked, continuous multi-lure longline was tested in the forebay of the First Powerhouse at Bonneville Dam. It stretched from the piernose in Slot 8C to the north side of the forebay--a distance of about 80 m (Figure Z-1). A lure was attached every 2.7 m with a commercial snap-line swivel. The longline was then cranked to the opposite side of the forebay and northern squawfish and lures were removed as they came out of the water. When the last lure came out of the water, the operation was reversed. As many as 25 lures could be fished simultaneously using this method. A variety of lures were tested including plastic jigs (assorted colors and sizes), spinners, and diving plugs. Both continuous cranking and letting the lures fish for various lengths of time were tested.

Results and Discussion

Tests of continuous multi-lure longlining at Bonneville Dam First Powerhouse were conducted from 27 July to 28 August. Fifty-four northern squawfish were captured (Figure Z-5). The catch averaged 2.9 northern squawfish per hour. One steelhead, O. mykiss, smolt was also captured. White plastic jigs were the most effective lure for squawfish. Generally, the first set of lures through the water caught the highest number of northern squawfish, then the fish appeared to become "hook shy" and the catch declined with subsequent passes. For this reason, most efforts were only 1 or 2 hours in duration. Letting the gear fish for longer periods before retrieving (up to 0.5 hour) did not increase catches.

Although this multi-lure longline gear did catch northern squawfish, it appeared less effective than traditional hook and line methods. A minimum of two people were required to operate this gear, and the catch per fisherman never exceeded that of dam anglers using a hook and line. Catch rates with hook and line were provided by dam anglers involved in the Columbia River Inter-Tribal Fish Commission removal program.[3] An advantage of fishing with hook and line was that fishermen could move to more productive areas when catch declined.

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[3] Blaine Parker, Columbia River Inter-Tribal Fish Commission. Pers. commun., July 1992.

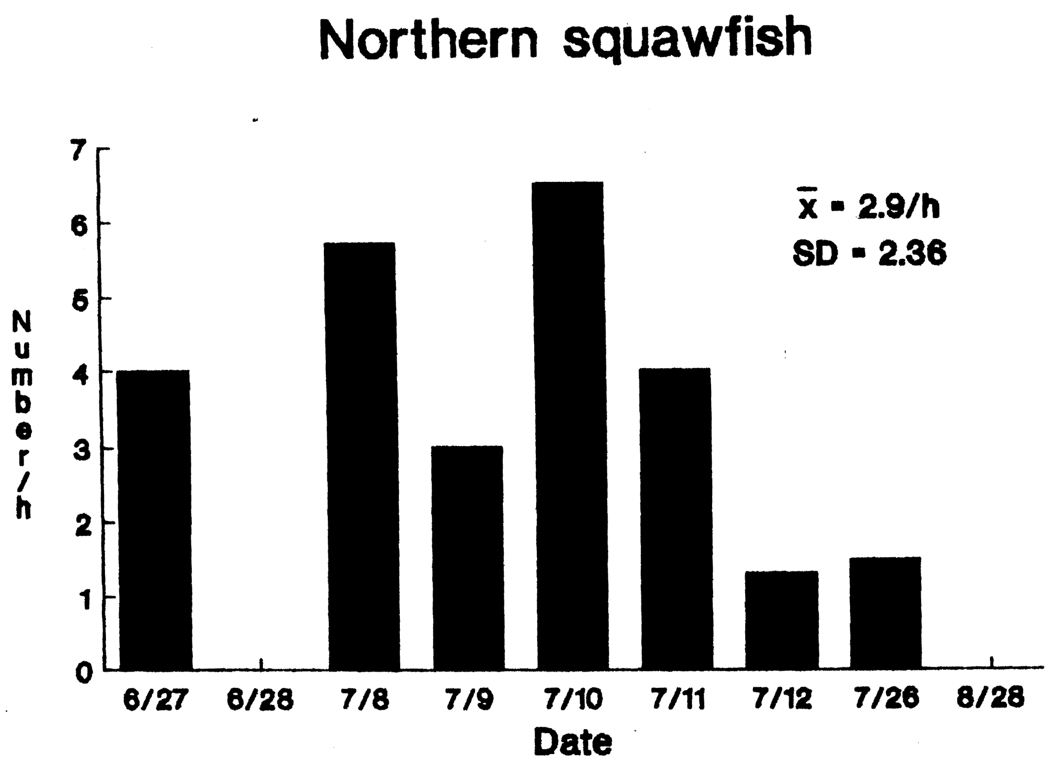

Figure Z-5. The number of northern squawfish captured per hour with continuous multi-lure longline at Bonneville Dam forebay, summer 1991.

PURSE SEINING

Background

Purse seines have been used to capture northern squawfish on numerous occasions in the Columbia and Snake Rivers (Mathews et al. 1991). The majority of those seining efforts were relatively unsuccessful. However, in the tailraces of Little Goose and McNary Dams, purse seine catches of northern squawfish were occasionally large, at several hundred fish per set (Raymond et al. 1975; Sims et al. 1976; unpublished data, NMFS, Rufus, OR). These successful efforts provided the impetus for renewed attempts at improving catch efficiency and finding locations that would provide consistently large catches. Bonneville Dam First Powerhouse was selected for this research because of the large numbers of northern squawfish concentrated in the forebay near the surface during July and August. To seine safely in areas adjacent to the powerhouse, a partial turbine shut-down is required; therefore, purse seining had to be tested in both the forebay and tailrace simultaneously.

Methods and Materials

Operating Conditions at Bonneville Dam First Powerhouse

Turbine Units 3 through 10 were shut down to create flow conditions suitable for seining while Turbine Units 1 and 2 remained in operation. To provide clearance for boats in the forebay, the large trashrack cleaning cable was lowered to the bottom of the reservoir by the COE. This cable is used to deploy the trashrack rake and is usually suspended about 3 m above the water surface, extending from the end of the wing wall to the north shoreline. To further restrict flows in the tailrace, the following fish-ladder entrances were closed: orifice Gates

58, 62, and on two occasions Gate 34, plus sluice Gate 64 and weir Gate 65 (Figure Z-6). These entrances are located between the middle and the north side of the powerhouse (Turbine Units 1 and 2 are on the south side of the dam). In addition, monofilament lines were removed to allow boat access. These are normally suspended across the tailrace to exclude predaceous birds from the outfall areas of the juvenile salmonid bypass and turbine boils.

Dates and Times of Seining

Dates and times for purse seining were chosen to minimize impacts on returning adult salmonids while fully utilizing times when northern squawfish would be concentrated near the dam. Delays in adult salmonid passage were expected as a result of the 80% shutdown of the powerhouse. The week of 22-29 July was chosen for seining because of the expected low number of adult salmonids (Appendix Table Z-2). Evening hours (1900-2230 h) were selected because passage of adult salmonids over the dam generally peaks at midday and declines shortly thereafter (Appendix Table Z-3). Evening hours are also the peak of northern squawfish activity.

Purse Seines

A special purse seine with adjustable depth and length was designed for use in moderate current and at multiple locations in the Columbia and Snake Rivers. The seine was constructed to allow alteration of the length (from 91 to 183 m) and depth (from 5 to 15 m, in 1.5-m increments). The bunt section of webbing was 14 m long with 5.1-cm stretch mesh. Other webbing, except for the leadline panel, was 6.4-cm stretch mesh. Nylon twine of 1.2-mm diameter (#12) was used for all webbing. The corkline web panel was 3 m deep with a zipper along the bottom. The middle three webbing panels were 3, 1.5, and 6 m deep, each having zippers

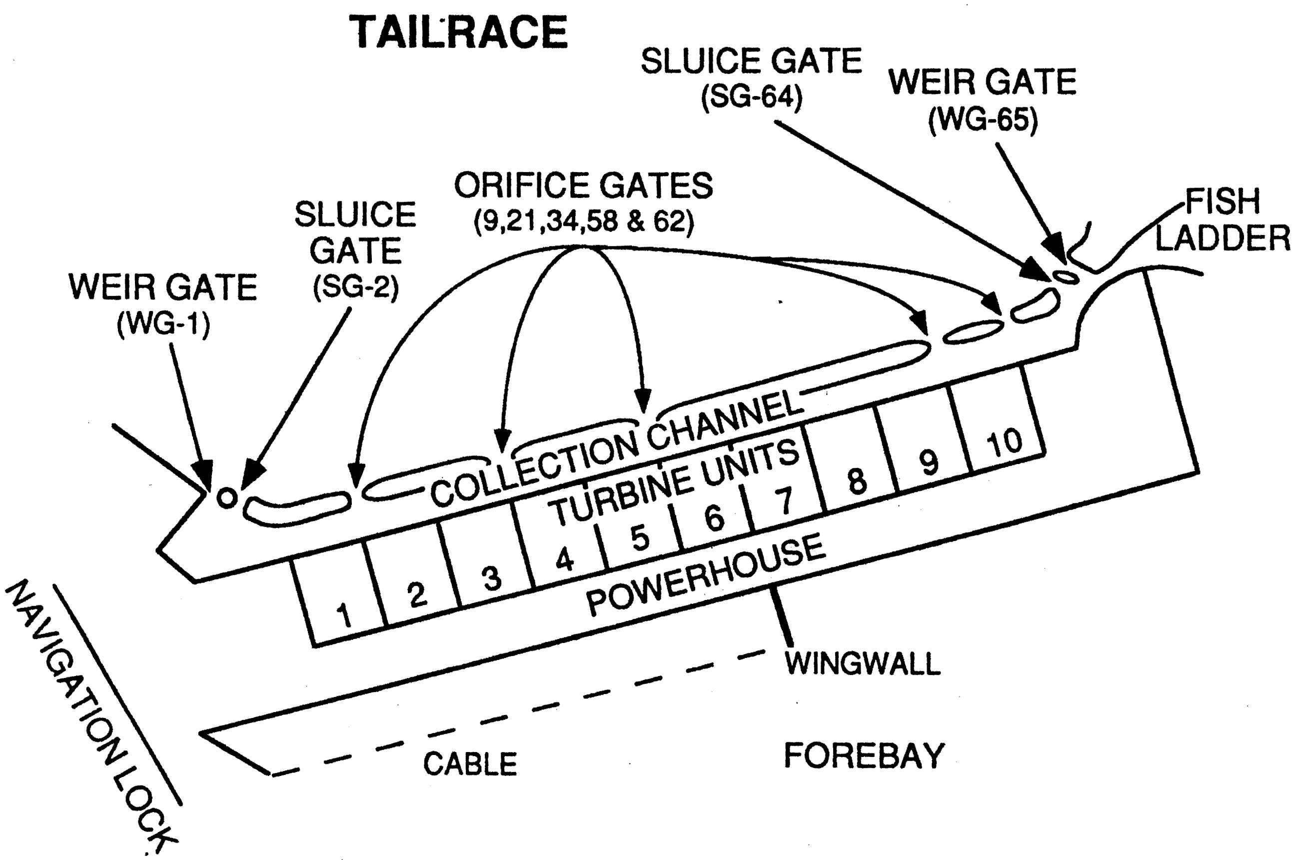

Figure Z-6. Location of adult fish attraction/collection system, forebay wingwall, and trashrack cleaning cable at Bonneville Dam First Powerhouse.

on both edges for inclusion or exclusion from the seine, depending on depth requirements. The leadline panel was 1.5 m deep and constructed of heavier 3-mm polyethylene web. It had 8.9-cm stretch-mesh openings with a zipper at the top of the panel. The leadline was hung 10% shorter than the corkline to provide a forward curl when under tow. Purse lines were 1.6-cm diameter solid-core braided nylon. Each end of the seine net was tapered, using breast lines one-half the length of the hanging web. For additional construction details refer to Appendix Figure Z-3. This seine net was used in the forebay with the middle (1.5-m) section of webbing excluded, for overall dimensions of 183 m long by 13.5 m deep.

The initial research design called for NMFS to seine the forebay while UW researchers concurrently seined the tailrace. UW researchers proposed to also fish in the tailrace, using a purse seine net specially designed to catch northern squawfish (Mathews et al. 1991). However, due to unanticipated delays, UW personnel and equipment were not available. On short notice, NMFS adapted purse seine nets and vessels normally used to sample juvenile salmonids (Ledgerwood et al. 1990) to fish in the tailrace. On the first night, a seine measuring 229 m long by 9.8 m deep, constructed with 1.9-cm stretch-mesh webbing was used. This net proved too deep for the tailrace (minimum depths about 7.5 m). On the second night, a smaller seine was used. This measured 137 m long by 5.2 m deep, and was constructed with 1.9-cm stretch-mesh webbing. The shorter net was better suited to the confined area of the tailrace, away from the discharge current of Turbine Units 1 and 2.

Fishing Procedures and Fish Processing

Purse seines were set off the seiner with the assistance of a seine skiff. The nets were set in two configurations, opening toward and away from the dam.

Generally, sets were made as near as possible to the powerhouse. After a net was deployed (requiring about 3 minutes) it was immediately closed by returning the skiff end of the net to the seiner (Figure Z-7). Hydraulic capstans were used to purse the bottom of the net closed (requiring from 15 to 30 minutes). The vessel fishing the special northern squawfish seine was equipped with an overhead power block to retrieve webbing from the water. The block required about 15 minutes to retrieve webbing. The webbing of the juvenile salmonid net was pulled in by hand, requiring about 10 minutes. The retrieval action crowded captured fish toward the bunt. Non-target fish were counted and released without processing, and, if possible, were released from the net prior to complete retrieval of gear. Numbers of American shad were estimated. Captured northern squawfish were counted, measured, marked, and released for indexing.[4] Northern squawfish in excess of marking requirements were killed.

Results

The purse seine harvest of northern squawfish was low; only 134 were captured in 17 purse seine sets made from 23 to 28 July (Table Z-2). Eight sets were made in the tailrace using the 137-m juvenile salmonid seine[5] and 52 northern squawfish were caught. Neither set configuration was superior. Six sets were made in the forebay, using the 183-m northern squawfish seine and catching a total of 79 northern squawfish. In addition, on 27 and 28 July, three sets were made in the forebay using the 137-m seine and three northern squawfish were

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[4] Marking of northern squawfish performed by ODFW personnel, David Ward, project leader.

[5] The 229-m juvenile salmonid seine was fished on 22 July (one set), but the set was aborted due to entanglement with the river bottom.

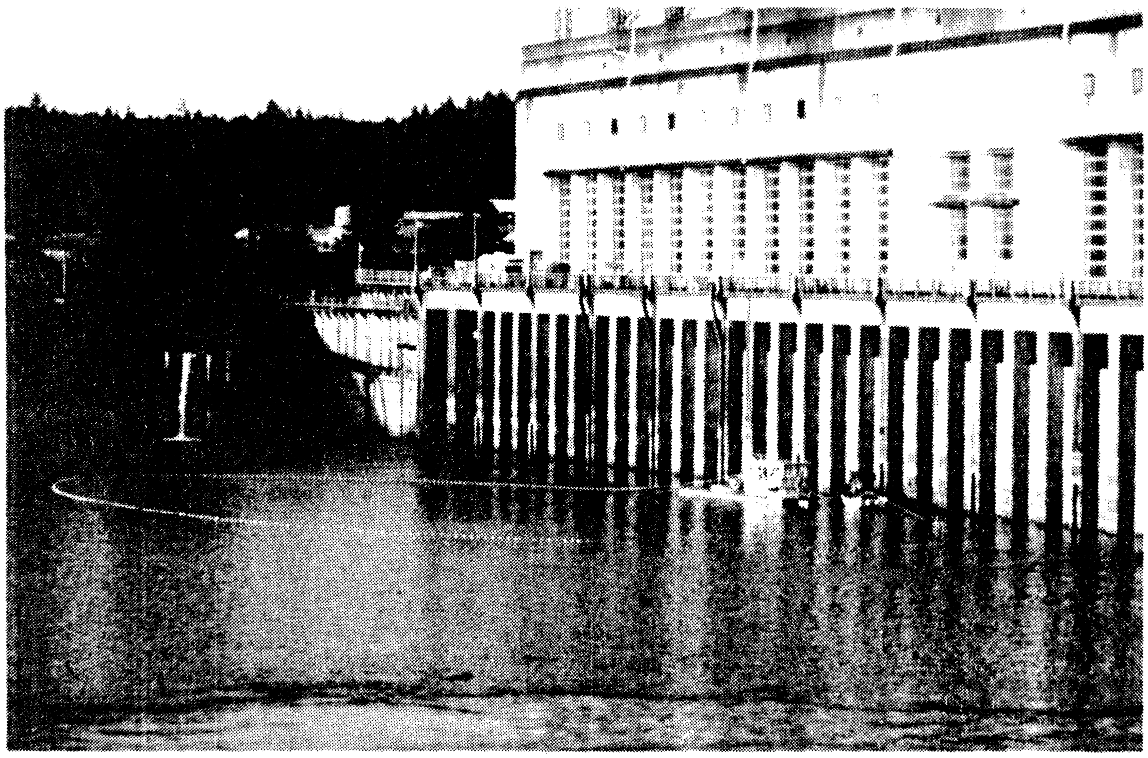

Figure Z-7. Purse seine boat in tailrace of Bonneville Dam First Powerhouse.

Table Z-2. Purse seine catches of northern squawfish at Bonneville Dam First Powerhouse, 1991.

Date (July)	Time of set	Set configuration[a]	Seine dimensions	Northern squawfish
		Tailrace		
22	2041	Away, 3 m	229 m x 9.8 m	--[b]
23	1918	Away, 3 m	137 m x 5 m	0
23	1953	Toward, 3 m	137 m x 5 m	12
24	1906	Toward, 3 m	137 m x 5 m	--[c]
24	2010	Toward, 3 m	137 m x 5 m	3
25	1908	Toward, 3 m	137 m x 5 m	21
25	1951	Toward, 3 m	137 m x 5 m	6
25	2020	Toward, 3 m	137 m x 5 m	3[d]
26	2000	Away, 3 m	137 m x 5 m	1
26	2040	Toward, 3 m	137 m x 5 m	6
			TOTAL	52
		Forebay		
22	1900	Away, 3 m	183 m x 13.5 m	--[b]
23	1900	Away, 3 m	183 m x 13.5 m	20
24	1900	Away, 3 m	183 m x 13.5 m	15
25	1900	Away, 150 m	183 m x 13.5 m	25
26	2000	Away, 3 m	183 m x 13.5 m	8
27	2103	--	137 m x 5 m	--[c]
27	2200	Away, 3 m	137 m x 5 m	1
27	2110	Away, 3 m	183 m x 13.5 m	3
28	2108	Away, 3 m	137 m x 5 m	1
28	2142	Away, 40 m	137 m x 5 m	1[d]
28	2100	Away, 3 m	183 m x 13.5 m	8
			TOTAL	82

[a] Purse seine set configuration code: 'away' = net opening away from the face of the dam; 'toward' = net opening toward the dam; and the approximate distance the net was deployed from the dam (m).
[b] Submerged debris entangled the net and compromised set.
[c] Difficulties with fishing gear compromised set.
[d] Currents created by operation of Turbine Units 1 and 2 pulled corkline under surface allowing some fish to escape.

caught. All sets in the forebay were made with the net opening away from the dam to allow seiners to be towed clear from possible entanglement with debris.

Incidental catches of American shad were substantial, and estimates occasionally approached 5,000 fish per set. When large numbers of American shad were captured, most were allowed to escape over the corkline; possibly some target fish escaped as well. Four adult and 92 juvenile salmonids[6] were captured--these fish were generally released prior to complete retrieval of the net. Complete catch results are presented in Appendix Table Z-4. Poor catches of northern squawfish and concerns about possible disruption of upstream passage of adult salmonids prompted termination of seining. The termination after 28 July concluded seine testing one day earlier than originally proposed.

Discussion

Several factors may have reduced purse seine catches of northern squawfish. These fish may have sounded or left the areas adjacent to turbines that were shut down. They may have avoided the area because of boat engine noise. The largest single catch of northern squawfish (25 fish) occurred in a set about 150 m upstream from the dam, where the seine was in contact with the bottom during pursing. Modification of purse seining equipment to rapidly close the bottom of the net may improve catch results if fish are escaping by sounding.

Although large numbers of northern squawfish were observed in the forebay during late July 1989, other removal efforts underway in 1991 may have altered population distribution in the immediate vicinity of the First Powerhouse. However, preliminary catch data[7] from angling efforts in the vicinity of

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[6] No juvenile salmonids were captured in the larger-mesh 183 m long squawfish seine.
[7] Kathy McRae, Columbia River Inter-Tribal Fish Commission. Pers. commun., November 1991.

Bonneville Dam during summer 1991 do not suggest a significant decrease in numbers of northern squawfish during the week of purse seining (Figure Z-8).

Of paramount concern during this study were possible impacts on upstream passage of adult salmonids due to reduced river flows through the tailrace. This was a result of the partial shutdown of the First Powerhouse, which was necessary for seining. On a daily basis, we examined the counts of adult salmonids obtained from the Washington shore and Bradford Island counting stations (Table Z-3). Although there were large daily variations, no apparent impacts on migration could be detected.

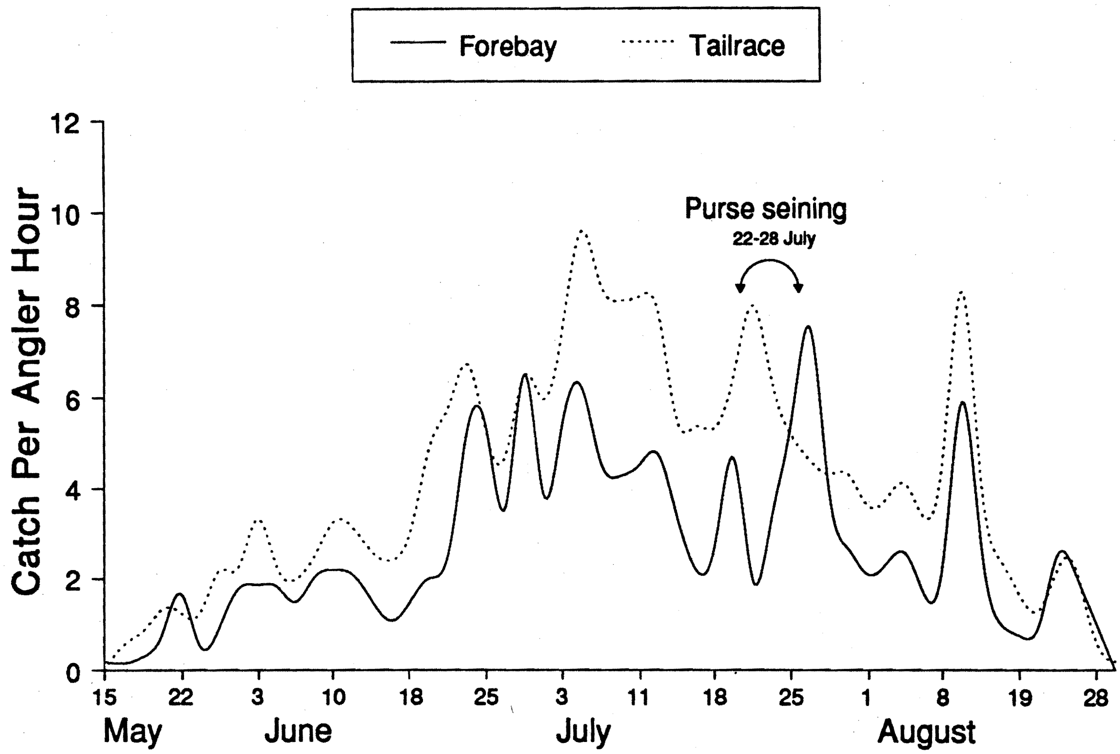

Figure Z-8. Average catch per hour of northern squawfish by angling in vicinity of Bonneville Dam First Powerhouse, comparing temporal catch distribution to period of purse seine effort; Kathy McRae, Columbia River Inter-Tribal Fish Commission, personal communication.

Table Z-3. Combined adult salmon counts for Bradford Island and Washington shore monitoring stations at Bonneville Dam during periods just prior to and during squawfish seining at the First Powerhouse.

	Time															
	0500 to 0550	0600 to 0650	0700 to 0750	0800 to 0850	0900 to 0950	1000 to 1050	1100 to 1150	1200 to 1250	1300 to 1350	1400 to 1450	1500 to 1550	1600 to 1650	1700 to 1750	1800 to 1850	1900 to 1950	2000 to 2050
	Number of adults passing[a]															
20 July																
Bradford	35	22	21	32	48	25	31	44	33	35	34	49	42	77	34	26
Washington	199	315	125	106	125	112	123	156	70	92	98	159	142	126	45	21
21 July																
Bradford	27	23	23	38	31	22	21	41	25	50	59	63	84	64	47	18
Washington	44	177	101	142	189	160	227	165	98	148	166	143	138	123	69	26
22 July[b]																
Bradford	29	36	16	27	39	18	43	31	24	41	36	63	54	32	39	33
Washington	125	188	78	158	150	79	85	38	116	105	56	94	120	126	68	118
23 July[b]																
Bradford	15	30	15	35	39	13	48	46	36	67	68	31	50	49	49	30
Washington	161	254	94	57	91	85	144	160	105	101	92	113	122	63	42	24
24 July[b]																
Bradford	31	31	12	21	25	37	39	59	69	87	93	102	111	120	51	22
Washington	198	139	100	65	84	136	125	144	110	120	256	235	168	125	81	15
25 July[b]																
Bradford	10	11	15	6	19	36	28	24	31	28	67	80	69	74	52	19
Washington	163	290	117	66	176	121	166	198	176	132	257	172	150	71	36	14
26 July[c]																
Bradford	8	28	27	25	19	28	13	27	30	62	32	45	69	55	25	18
Washington	129	341	102	59	63	108	136	101	157	165	127	125	78	77	36	25
27 July[d]																
Bradford	6	13	8	5	9	10	21	34	45	36	52	55	112	88	56	38
Washington	195	107	101	123	186	139	143	209	134	107	122	128	73	88	65	46
28 July[e]																
Bradford	11	23	34	48	23	38	54	19	48	50	92	81	81	163	86	57
Washington	134	64	15	73	40	78	85	83	122	112	102	90	97	70	50	21
29 July																
Bradford	33	59	49	57	93	50	57	64	69	51	51	71	86	84	50	32
Washington	58	45	40	97	142	115	193	197	227	295	235	258	159	193	82	37
30 July																
Bradford	19	25	9	22	27	32	58	70	46	49	65	63	76	107	54	31
Washington	92	124	93	143	197	228	278	223	230	174	188	212	130	203	124	69

[a] Combined counts include adult chinook salmon and jacks, sockeye salmon, and steelhead.
[b] Shut-down of First Powerhouse Turbine Units 3-10 from 1900 to 2100 h.
[c] Shut-down of First Powerhouse Turbine Units 3-10 from 2000 to 2100 h.
[d] Shut-down of First Powerhouse Turbine Units 3-10 from 2100 to 2230 h.
[e] Shut-down of First Powerhouse Turbine Units 3-10 from 2100 to 2200 h.

CONCLUSIONS: ALL TECHNIQUES

None of the northern squawfish removal techniques evaluated at Bonneville Dam during 1991 proved effective; however, the late starting date, other northern squawfish removal programs in progress, and the high rate of water spill may have influenced results. Electrofishing with both permanently installed and portable electrode arrays may still prove effective if northern squawfish congregate near the First Powerhouse as they have in past years. Continuous multi-lure longlining is too labor-intensive and ineffective to warrant further testing.

Purse seine catches of northern squawfish were also considerably lower than expected, based on numbers of northern squawfish observed in the surface waters around the dam. Altered powerhouse operating conditions required for seining may have caused the poor catch, since northern squawfish may have left the immediate area after turbines were shut down. It is also possible that northern squawfish eluded the net by sounding before the seine could be pursed.

Incidental catches of adult salmonids by purse seine were low (four), and except for American shad, other incidental catches were low. Reduction in passage of adult salmonids during the seining period was not discernible.

Because of the small numbers of northern squawfish captured using all techniques tested, no analysis of catch per unit effort (CPUE) versus cost was done.

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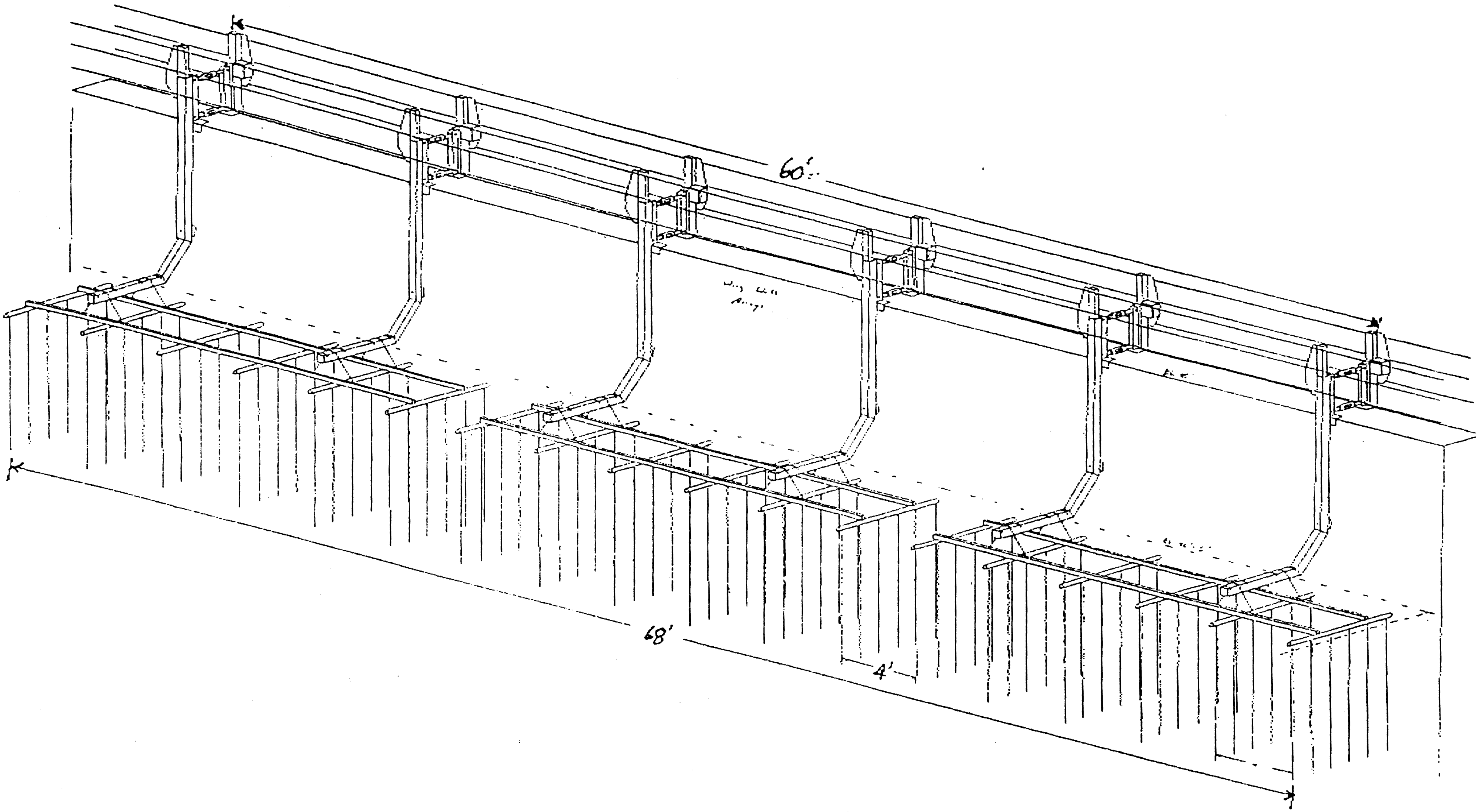
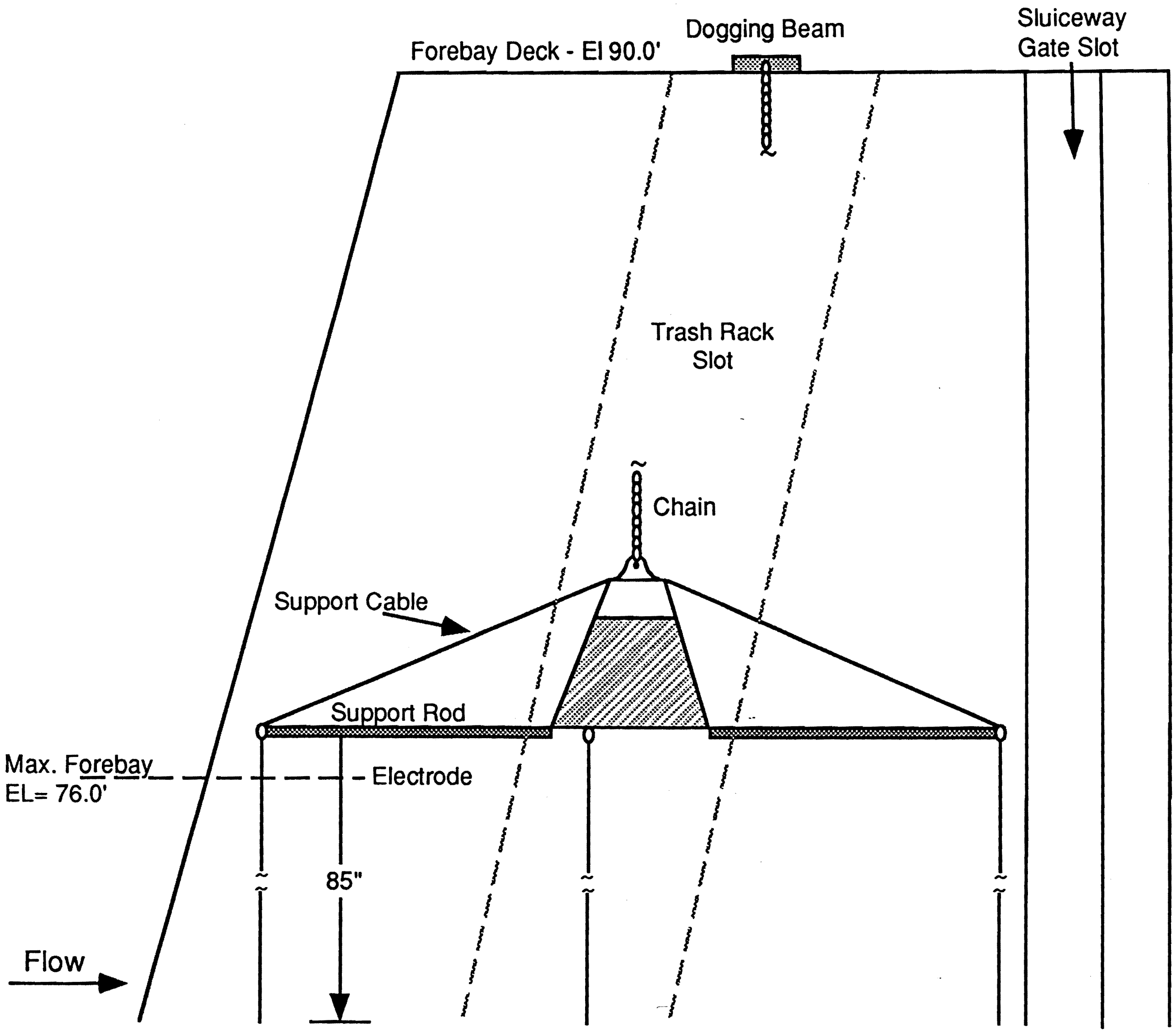
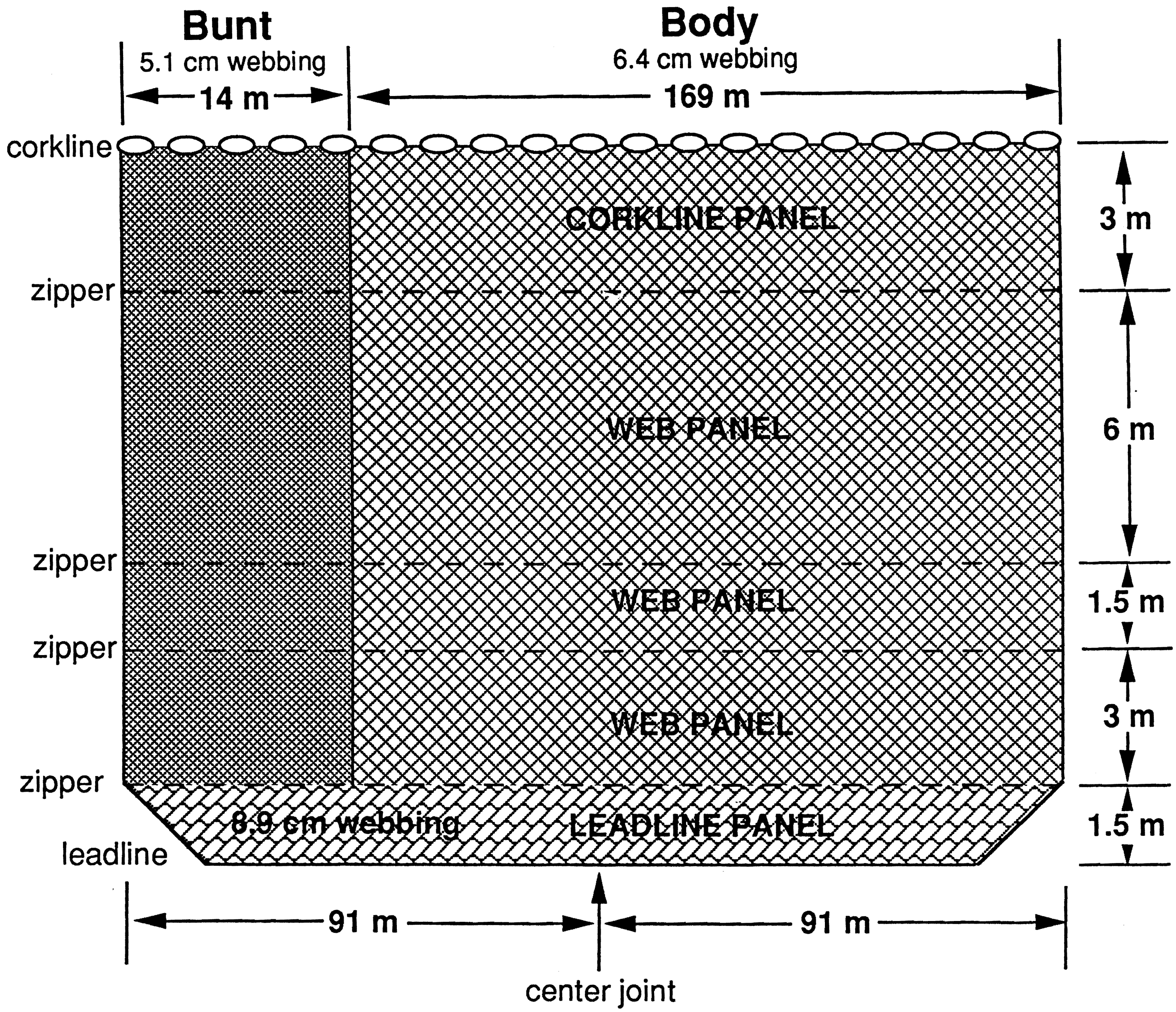
APPENDIX FIGURES



Appendix Figure Z-1. View of three wingwall arrays used for electrofishing northern squawfish at Bonneville Dam First Powerhouse.



Appendix Figure Z-2. Cross section of piernose array used for electrofishing northern squawfish at Bonneville Dam First Powerhouse.



Appendix Figure Z-3. Northern squawfish purse seine designed for use around hydroelectric dams on the Snake and Columbia Rivers.

APPENDIX TABLES

Appendix Table Z-1. Specifications of electrofishing equipment used at Bonneville Dam First Powerhouse, 1991.

Alternator:

kVA: 75
kW: 60
Output current: 90 A per phase at 480 V.
RPM: 1800
Frequency: 60 Hz
Phase: 3, Wye connected without neutral
Power Factor: 0.8
Voltage: 480, 240, 208

Control:

Output: Full-cycle three-phase alternating current.
Switching: 600,000 operations at full rated current.
Metering: Individual phase currents and phase A-B Voltage. 0 to 500 VAC A.
Safety: Key operated audio alarm, front panel status indicator, remote operator switch, safety grounding system.
Power distribution: High voltage and current twist lock connectors.

Arrays:

Wingwall arrays: Made up of three sections covering 21 m total length. Each section is electrically divided into two groups of three rows; each row is energized with a different phase voltage. Rows consist of six electrodes, constructed of 216 cm long, 5-mm stainless steel cables. Electrodes are spaced at 25-cm intervals on each row; rows are spaced on 1.2-m centers. This arrangement will produce a strong electrical field between rows for the length of the array.

Piernose arrays: Consist of three rows of electrodes with each row connected to a different phase voltage. Electrodes in a row are spaced on 61-cm centers and rows are spaced 1.4 m apart.

Portable array: Consists of three Smith-Root UAA-6 arrays. One connected to each phase voltage.

Appendix Table Z-2. Daily counts of adult salmonids passing Bradford Island monitoring station at Bonneville Dam, 1990.

Date	Adult counts[a]		
	Chinook	Sockeye	Steelhead
15 July	23	85	127
16	25	46	133
17	26	35	122
18	27	73	213
19	37	47	233
20	24	31	176
21	14	31	124
22	52	65	350
23	39	27	292
24	11	19	111
25	7	9	190
26	10	2	126
27	10	4	171
28	11	13	141
29	8	7	212
30	90	10	646
31	59	7	254
01 August	38	3	355
02	8	4	119
03	30	2	443
04	56	0	570
05	91	0	475
06	21	0	381
07	21	0	381
08	52	0	620
09	30	0	373
10	35	0	384

[a]Numbers are partial daily counts. Hourly counts taken from 0600 to 1200 h.

Appendix Table Z-3. Counts of adult salmonids observed at the upstream entrance gates of the First Powerhouse and at the Bradford Island counting station at Bonneville Dam, 14-25 August 1983.[a][b]

	Average counts at entrance gates						Percent of daily entries	
Time	Weir #65	Sluice #64	Orifice[c] #62	Orifice #58	Sluice #2	Weir #1	Entrance counts[d]	Ladder counts[e]
0600	--[f]	--	--	--	--	--	--	1.2
0700	23.4	13.2	12.3	5.8	43.2	15.0	6.5	5.3
0800	30.6	31.8	14.0	8.4	58.2	24.6	9.3	3.2
0900	59.4	49.8	18.8	6.8	72.0	15.0	11.5	4.5
1000	46.2	60.0	22.9	9.0	67.8	18.0	11.8	6.4
1100	42.6	33.6	23.1	11.2	75.0	13.8	11.3	5.6
1200	36.0	29.4	24.7	6.7	65.4	24.0	10.7	7.7
1300	46.2	28.8	14.1	5.0	47.4	19.2	8.6	8.3
1400	23.4	28.2	13.8	6.7	55.8	13.8	8.2	8.9
1500	33.6	22.2	18.3	4.3	49.8	13.2	8.1	8.3
1600	32.4	30.0	13.7	3.6	48.6	15.6	8.3	7.2
1700	43.2	23.4	10.3	4.0	47.4	13.8	7.9	7.2
1800	32.4	19.8	11.3	4.6	30.0	10.8	6.0	8.9
1900	--	--	--	--	--	--	--	7.7
2000	--	--	--	--	--	--	--	6.7
2100	--	--	--	--	--	--	--	2.9

[a] Data courtesy Jim Kuski, Robert Stansell, and Bill Naga; Corps of Engineers, Bonneville Dam. Downstream passage excluded in these data.
[b] The only year these data were recorded was 1983. Data set for 14-25 August most closely corresponded to expected time period of proposed research.
[c] Orifice gates 34, 21, and 9 not represented.
[d] Entrance counts from the First Powerhouse fishways.
[e] Ladder counts from Bradford Island counting station.
[f] (--) denotes that entrance information is not available.

Appendix Table Z-4. Catch composition and set descriptions of the purse seine effort at Bonneville Dam First Powerhouse, 1991.

Date	Water temp °C	Time of set	Time of outage	Seine dimensions	Fishing location	Set configuration	Northern squawfish	Adult salmonids	Juvenile salmonids	American shad	Red-sided shiner	Peamouth
July 22	20	2041	1900	229m x 9.8m	tailrace	Away, 3m	--[a]	--	--	--	--	--
"		1900	"	183m x 13.5m	forebay	Away, 3m	--	--	--	--	--	--
23	20	1918	1900	137m x 5m	tailrace	Away, 3m	0	0	0	0	0	0
"		1953	"	137m x 5m	tailrace	Toward, 3m	12	0	1	14	0	1
"		1900	"	183m x 13.5m	forebay	Away, 3m	20	0	0	8	0	0
24	20	1906	1900	137m x 5m	tailrace	Toward, 3m	--	--	--	--	--	--
"		2010	"	137m x 5m	tailrace	Toward, 3m	3	0	0	0	0	2
"		1900	"	183m x 13.5m	forebay	Away, 3m	15	0	0	155	0	0
25	20	1908	1900	137m x 5m	tailrace	Toward, 3m	21	0	0	0	20	15
"		1951	"	137m x 5m	tailrace	Toward, 3m	6	0	0	2	0	0
"		2020	"	137m x 5m	tailrace	Toward, 3m	3	2	0	6	0	0
"		1900	"	183m x 13.5m	forebay	Away 150m	25	0	0	~4,000	0	0
26	20	2000	2000	137m x 5m	tailrace	Away, 3m	1	0	3	1	0	0
"		2040	"	137m x 5m	tailrace	Away, 3m	6	0	1	0	0	0
"		2000	"	183m x 13.5m	forebay	Away, 3m	8	1	0	~5,000	0	0
27	20	2103	2100	137m x 5m	forebay		--	--	--	--	--	--
"		2200	"	137m x 5m	forebay	Away, 3m	1	0	22	234	0	0
"		2110	"	183m x 13.5m	forebay	Away, 3m	3	0	0	10	0	0
28	20	2108	2100	137m x 5m	forebay	Away, 3m	1	0	55	25	0	0
"		2142	"	137m x 5m	forebay	Away, 40m	1	0	10	10	0	0
"		2100	"	183m x 13.5m	forebay	Away, 3m	8	1	0	~5,000	0	0

[a]"--" denotes data not available. Set compromised because of difficulties with gear.

Space before "m"

Appendix Table Z-4. Catch composition and set descriptions of the purse seine effort at Bonneville Dam First Powerhouse, 1991.

Date	Water temp °C	Time of set	Time of outage	Seine dimensions	Fishing location	Set configuration	Northern squawfish	Adult salmonids	Juvenile salmonids	American shad	Red-sided shiner	Peamouth
July 22	20	2041	1900	229 m x 9.8 m	tailrace	Away, 3 m	--[a]	--	--	--	--	--
"		1900	"	183 m x 13.5 m	forebay	Away, 3 m	--	--	--	--	--	--
23	20	1918	1900	137 m x 5 m	tailrace	Away, 3 m	0	0	0	0	0	0
"		1953	"	137 m x 5 m	tailrace	Toward, 3 m	12	0	1	14	0	1
"		1900	"	183 m x 13.5 m	forebay	Away, 3 m	20	0	0	8	0	0
24	20	1906	1900	137 m x 5 m	tailrace	Toward, 3 m	--	--	--	--	--	--
"		2010	"	137 m x 5 m	tailrace	Toward, 3 m	3	0	0	0	0	2
"		1900	"	183 m x 13.5 m	forebay	Away, 3 m	15	0	0	155	0	0
25	20	1908	1900	137 m x 5 m	tailrace	Toward, 3 m	21	0	0	0	20	15
"		1951	"	137 m x 5 m	tailrace	Toward, 3 m	6	0	0	2	0	0
"		2020	"	137 m x 5 m	tailrace	Toward, 3 m	3	2	0	6	0	0
"		1900	"	183 m x 13.5 m	forebay	Away, 150 m	25	0	0	~4,000	0	0
26	20	2000	2000	137 m x 5 m	tailrace	Away, 3 m	1	0	3	1	0	0
"		2040	"	137 m x 5 m	tailrace	Away, 3 m	6	0	1	0	0	0
"		2000	"	183 m x 13.5 m	forebay	Away, 3 m	8	1	0	~5,000	0	0
27	20	2103	2100	137 m x 5 m	forebay	--	--	--	--	--	--	--
"		2200	"	137 m x 5 m	forebay	Away, 3 m	1	0	22	234	0	0
"		2110	"	183 m x 13.5 m	forebay	Away, 3 m	3	0	0	10	0	0
28	20	2108	2100	137 m x 5 m	forebay	Away, 3 m	1	0	55	25	0	0
"		2142	"	137 m x 5 m	forebay	Away, 40 m	1	0	10	10	0	0
"		2100	"	183 m x 13.5 m	forebay	Away, 3 m	8	1	0	~5,000	0	0

[a]"--" denotes data not available. Set compromised because of difficulties with gear.