ANNUAL PROGRESS REPORT

Abundance and Distribution of Northern Squawfish and Walleye in John Day Reservoir and Tailrace, 1982

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CONTENTS

TABLES

FIGURES

APPENDIX TABLES

ABSTRACT

This was the first year of a cooperative study with the U. S. Fish and Wildlife Service (USFWS) to estimate the effects of predation on juvenile salmonid survival during their seaward migration through John Day Reservoir and tailrace on the Columbia River. Two resident predators, walleye (Stizostedion vitreum vitreum) and northern squawfish (Ptychocheilus oregonensis) were collected to determine their abundance and distribution; USFWS examined their prey selection, consumption rates, and feeding periodicity.

We were able to catch walleye and northern squawfish under a wide range of sampling conditions using gill nets, trap nets, and electrofishing. Angling was only effective for sampling northern squawfish at the dams. Beach seining was ineffective for sampling either species. Electrofishing caught a larger proportion of walleye below 380 mm and northern squawfish below 300 mm than did gillnetting or trapnetting. Nearly all (99%) northern squawfish caught by angling at the dams had fork lengths greater than 299 mm.

Trends in catch per unit effort of walleye and northern squawfish indicated that movements of these species were closely related to water temperature and flow velocity. Walleye catches in littoral and backwater habitats decreased notably in June when water temperatures rose and flow velocities in deeper offshore waters decreased. Movements of northern squawfish into tailraces corresponded closely with cessation of spilling at the dams.

Schumacher-Eschmeyer and Schnabel estimates of northern squawfish abundance in the boat restricted zones of John Day and McNary dams ranged from 4,609-4,636 and 8,392-8,643, respectively. We were unable to estimate abundance of northern squawfish outside of these areas because of low numbers of recaptures. We were unable to estimate abundance of walleye anywhere because none were recaptured.

INTRODUCTION

Background

Construction of hydroelectric dams on the Columbia and Snake rivers has created a variety of hazards impeding the safe passage of downstream migrating juvenile salmonids. Since impoundment there has been a decline in the survival of juvenile salmon (Oncorhynchus spp) and steelhead trout (Salmo gairdneri) migrating to the ocean. Although injury to fish passing by dams is believed to be a serious source of juvenile salmonid mortality (Allen 1977; Ebel 1977), predation by resident fish may also contribute significantly to their mortality (Long et al. 1968; Raymond et al. 1969; 1979; Sims et al. 1976; Mullan 1980; Uremovich et al. 1982).

Impoundment of the Columbia and Snake rivers has increased the vulnerability of juvenile salmonids to predation by: (1) concentrating them in or near passage facilities at dams (Ebel 1977; Raymond 1979); (2) reducing flows and increasing turbidity of reservoirs, thus extending periods of juvenile salmonid outmigration to the ocean (Raymond 1979); and (3) increasing habitats with reduced flow favorable to establishment and expansion of exotic and native piscivorous fishes (Raymond 1979; Mullan 1980).

In 1981 the Columbia River Fisheries Council (CRFC) identified increased survival of juvenile salmonids during downstream migration as essential to meet production goals for salmon and steelhead in the Columbia and Snake rivers (CRFC 1981).

Our study was initiated as part of a cooperative effort with the U.S. Fish and Wildlife Service (USFWS) to estimate the effects of predation on juvenile salmonid survival. We will determine the distribution, local abundance, and rates of growth and mortality of two resident predators, walleye (Stizostedion vitreum vitreum) and northern squawfish (Ptychocheilus oregonensis) within John Day Reservoir and tailrace. USFWS will examine prey selection, consumption rates, and feeding periodicity of walleye and northern squawfish. John Day Reservoir and tailrace was selected as our study area because it is a rearing area for juvenile chinook salmon (Oncorhynchus tshawytscha), it is inhabited by walleye and northern squawfish, and it is an area where juvenile salmonid survival is low and residualism is high (Hjort et al. 1981).

First year study objectives were:

1. Examine the effectiveness of various gears for sampling walleye and northern squawfish.

2. Describe spatial and temporal distributions of walleye and northern squawfish.

3. Evaluate the feasibility of estimating abundances of local populations of northern squawfish and walleye in John Day Reservoir and tailrace.

Study Area

John Day Reservoir (Lake Umatilla) is approximately 77 mi (123 km) long and averages 1.1 mi (1.8 km) wide (Figure 1). At maximum pool elevation of 270 ft (82 m) above mean sea level (msl), John Day Reservoir has a surface area of 52,000 acres (20,800 ha) and a volume of 1.0 x 10^{13} ft^3 (2.9 x 10^{11} m^3). Maximum depth ranges from approximately 33 ft (10 m) in McNary Dam tailrace to 165 ft (50 m) in John Day Dam forebay.

John Day Reservoir was formed by the closure of John Day Lock and Dam in 1971. The U.S. Army Corps of Engineers operates John Day Dam to provide hydroelectric power, flood control and navigation. John Day Dam tailrace includes the upper portion of The Dalles Reservoir from river mile (RM) 191-217 (Rkm 306-347). Mean width of the tailrace is 0.6 mi (1.0 km) and mean depth is 33 ft (10 m).

The John Day and Umatilla rivers are the only major tributaries that flow into the Columbia River within the confines of our study area (Figure 1). Juvenile salmonids migrate from these rivers in spring and summer months.

METHODS AND MATERIALS

Field Sampling

The study area was divided into sections, transects, stations, and sites. A six digit code was developed to identify each sampling location and facilitate computer entry of data. Sections corresponded to areas identified and used by the Oregon Department of Fish and Wildlife Columbia River Management Program to delineate boundaries of sport fisheries (King 1981). Transects were areas within sections chosen either because they contained an assemblage of representative habitat types in close proximity to each other (primary transects) or because they occurred adjacent to or between primary transects (secondary transects). Representative habitat types were those considered to be characteristic of John Day Reservoir and tailrace and were loosely described as: (1) near-shore or offshore areas with depths less than or greater than 10 m; (2) areas with current less than or greater than 50 cm/sec; (3) backwater areas; and (4) areas at the mouths of major tributaries.

Primary transects (Table 1) were located at McNary tailrace and John Day tailrace, which represent areas influenced by spill and turbine outflow (Figures 2 and 5); at John Day forebay, which represents an area where juvenile salmonids are detained and concentrated before passage past the dam (Figure 3); and at Blalock Islands-Paterson Slough, which represents an area away from direct influence of dam operations (Figure 4). Secondary transects (Table 1), sampled primarily to examine movements of tagged fish to and from primary transects, were located in John Day Reservoir between John Day forebay and Crow Butte, and below John Day tailrace downriver to the west end of Miller Island (Figure 1).

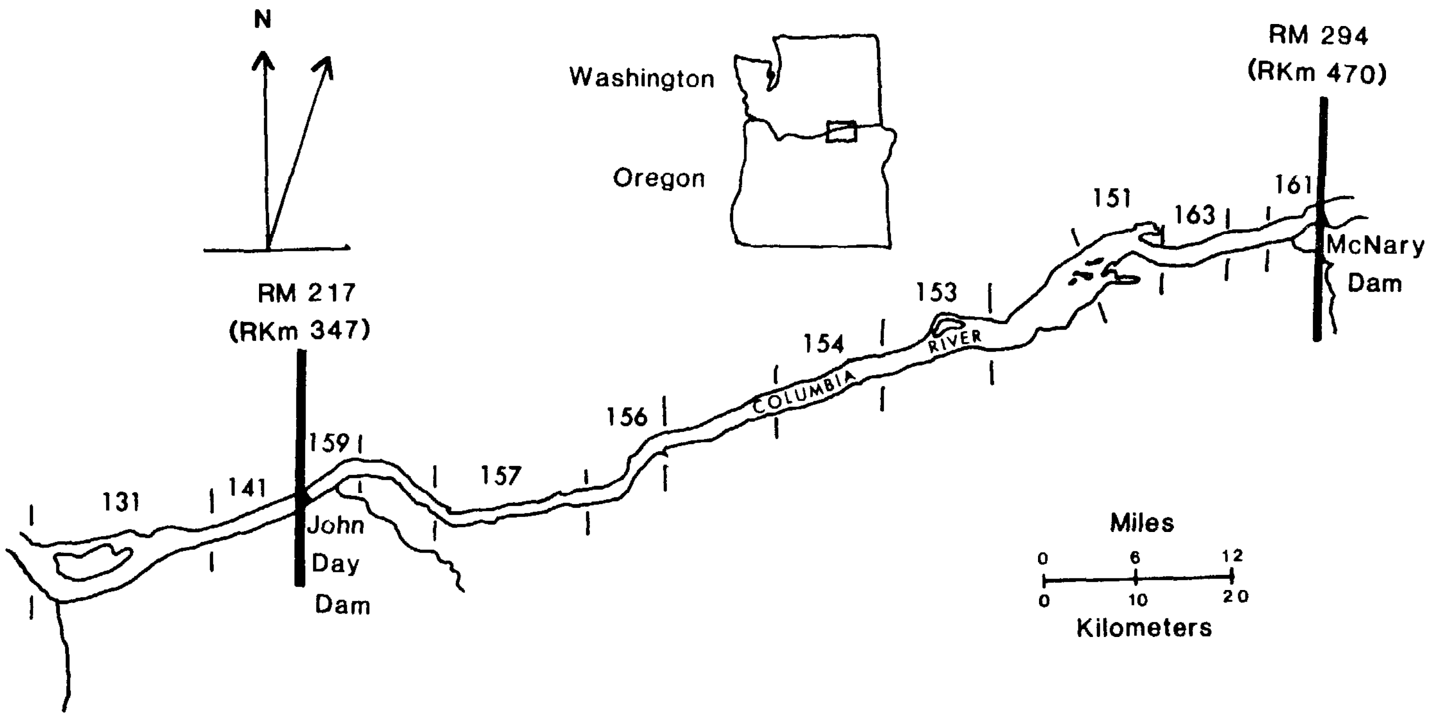

Figure 1. Locations of primary and secondary sampling transects in the John Day Reservoir and tailrace, 1982.

Table 1. Locations of primary and secondary sampling transects, John Day Reservoir and tailrace, 1982.

Transect name	Transect number	River miles (kilometers)
Miller Island	131	205-212 (328-339)
John Day Tailrace[a]	141	212-217 (339-347)
John Day Forebay[a]	159	217-221 (347-353)
Rock Creek	157	226-231 (362-370)
Arlington	156	242-249 (387-398)
Willow Creek	154	254-261 (407-417)
Crow Butte	153	263-268 (420-429)
Blalock Islands-Paterson Slough[a]	151	277-281 (443-449)
Irrigon	163	281-286 (449-457)
McNary Tailrace[a]	161	289-294 (463-470)

a Primary transects.

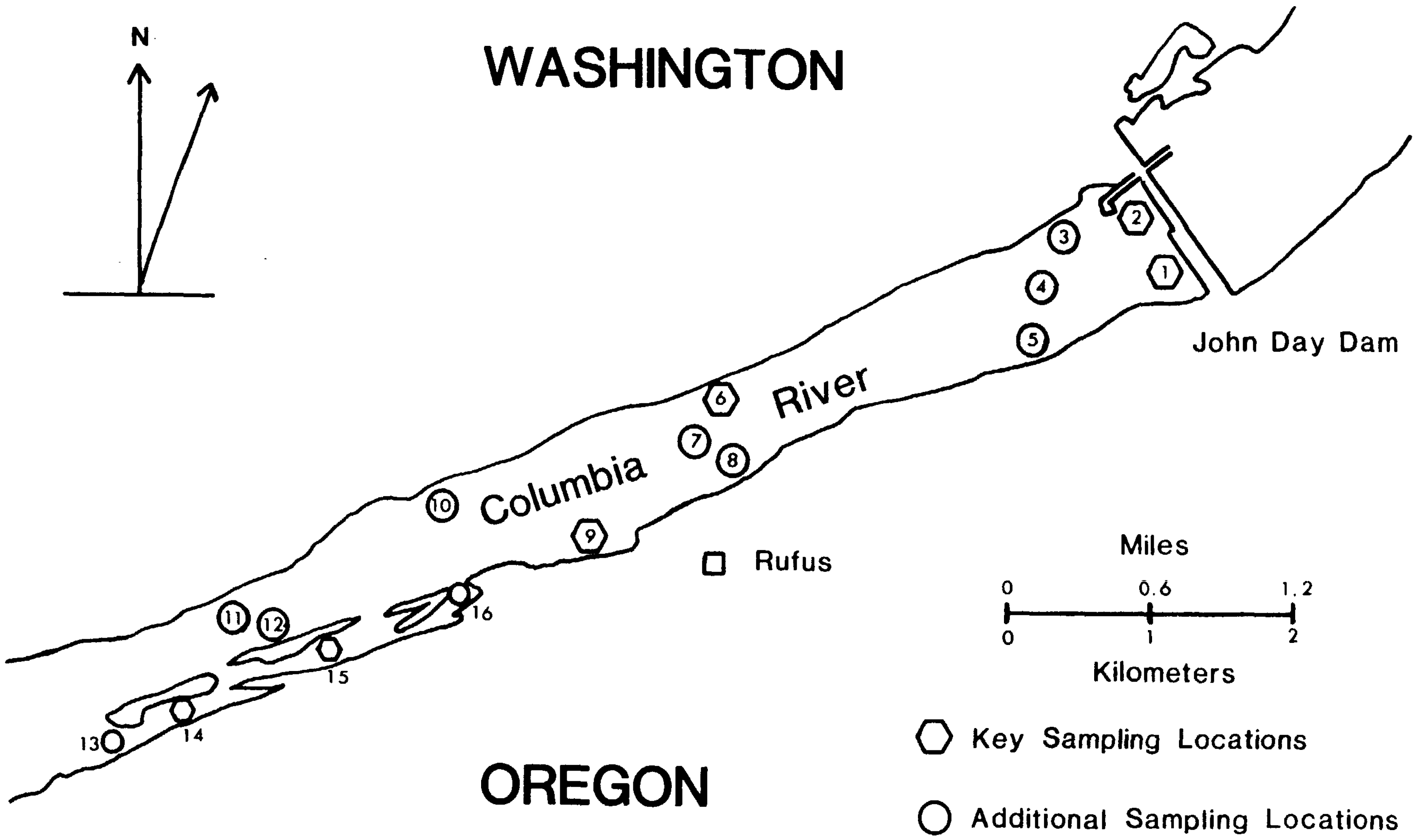

Figure 2. locations of sampling stations in the John Day Dam tailrace transect, 1982.

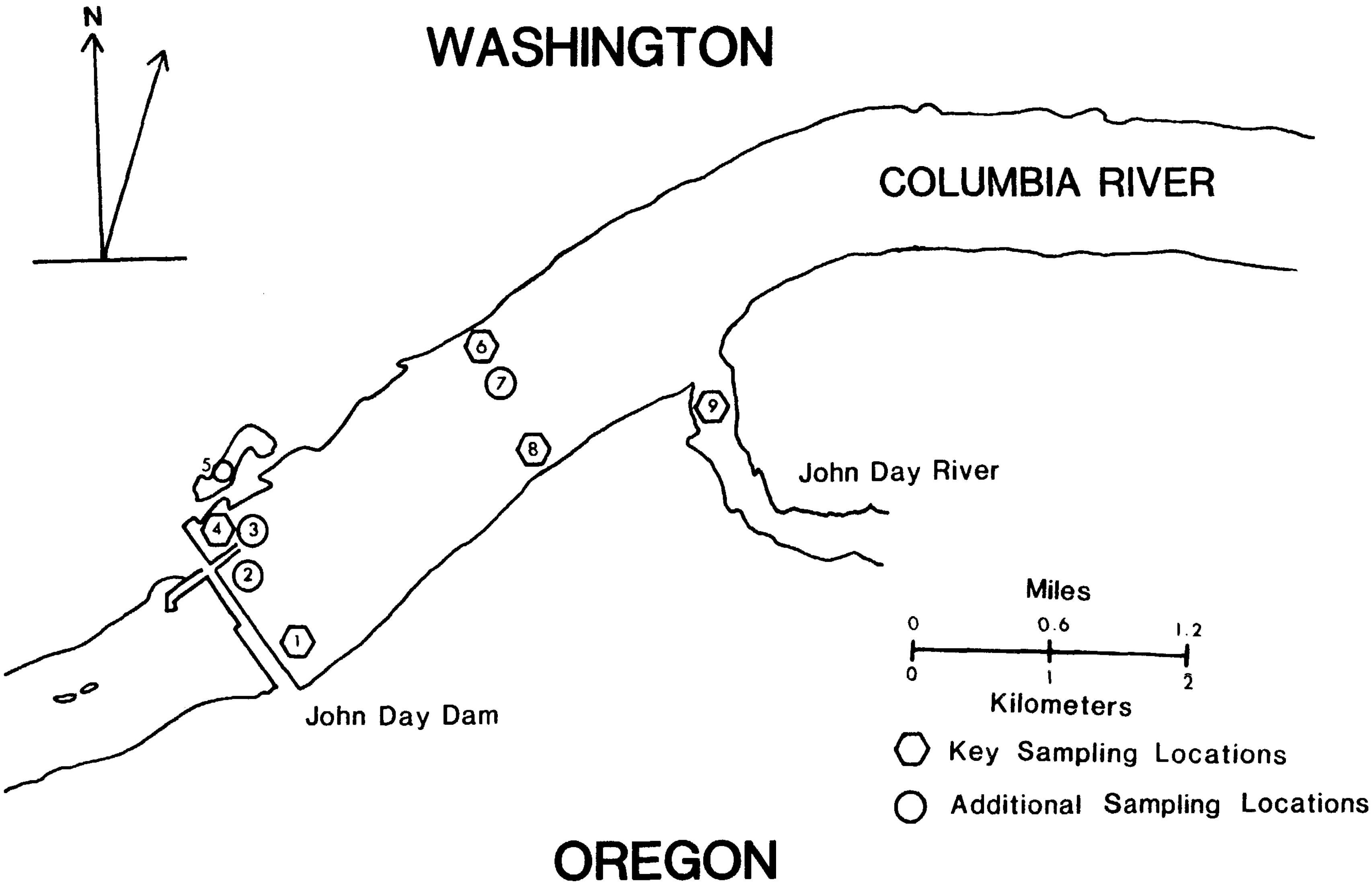

Figure 3. Locations of sampling stations in the John Day Dam forebay transect, 1982.

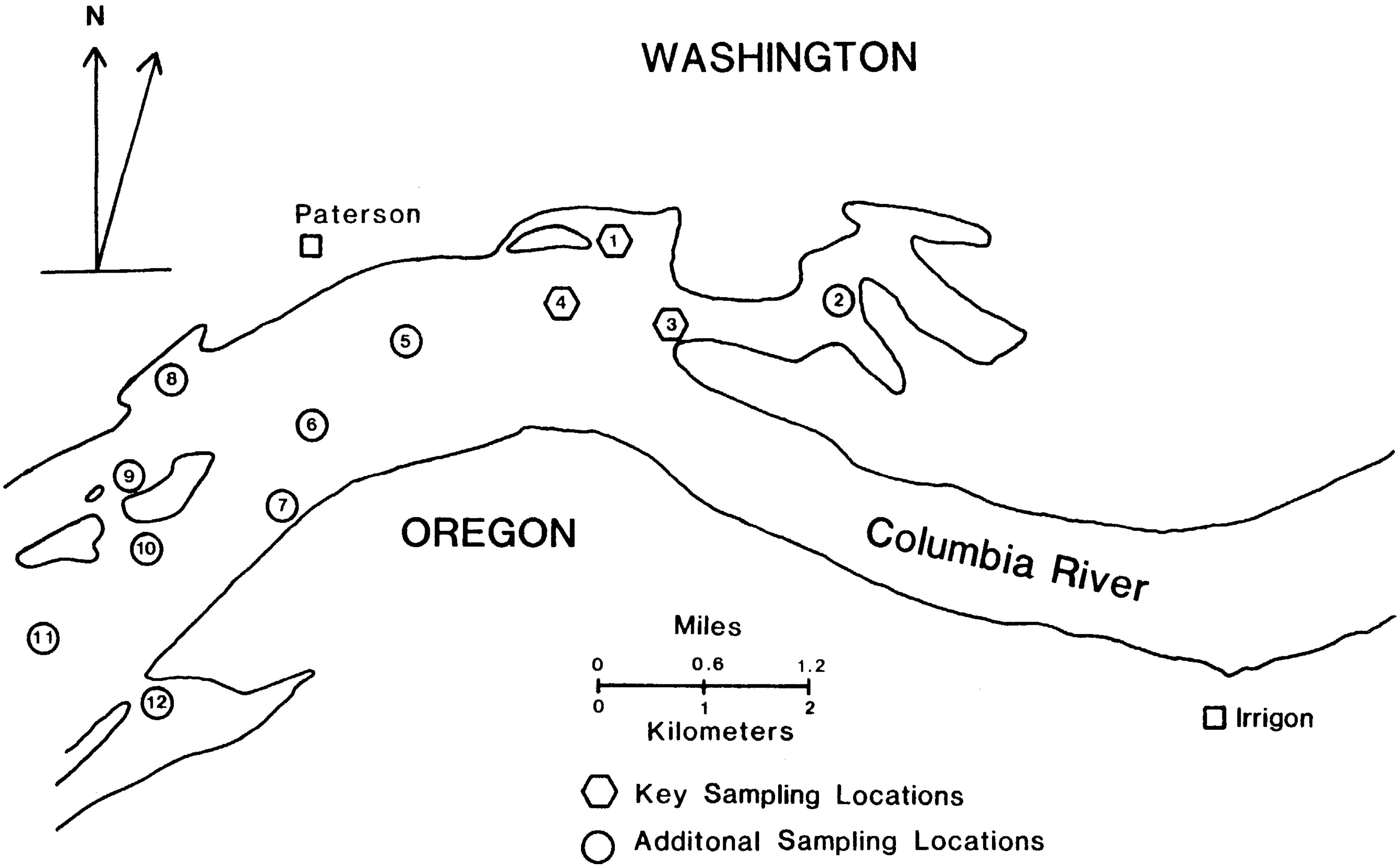

Figure 4. Locations of sampling stations in the Blalock Islands-Paterson Slough transect, 1982.

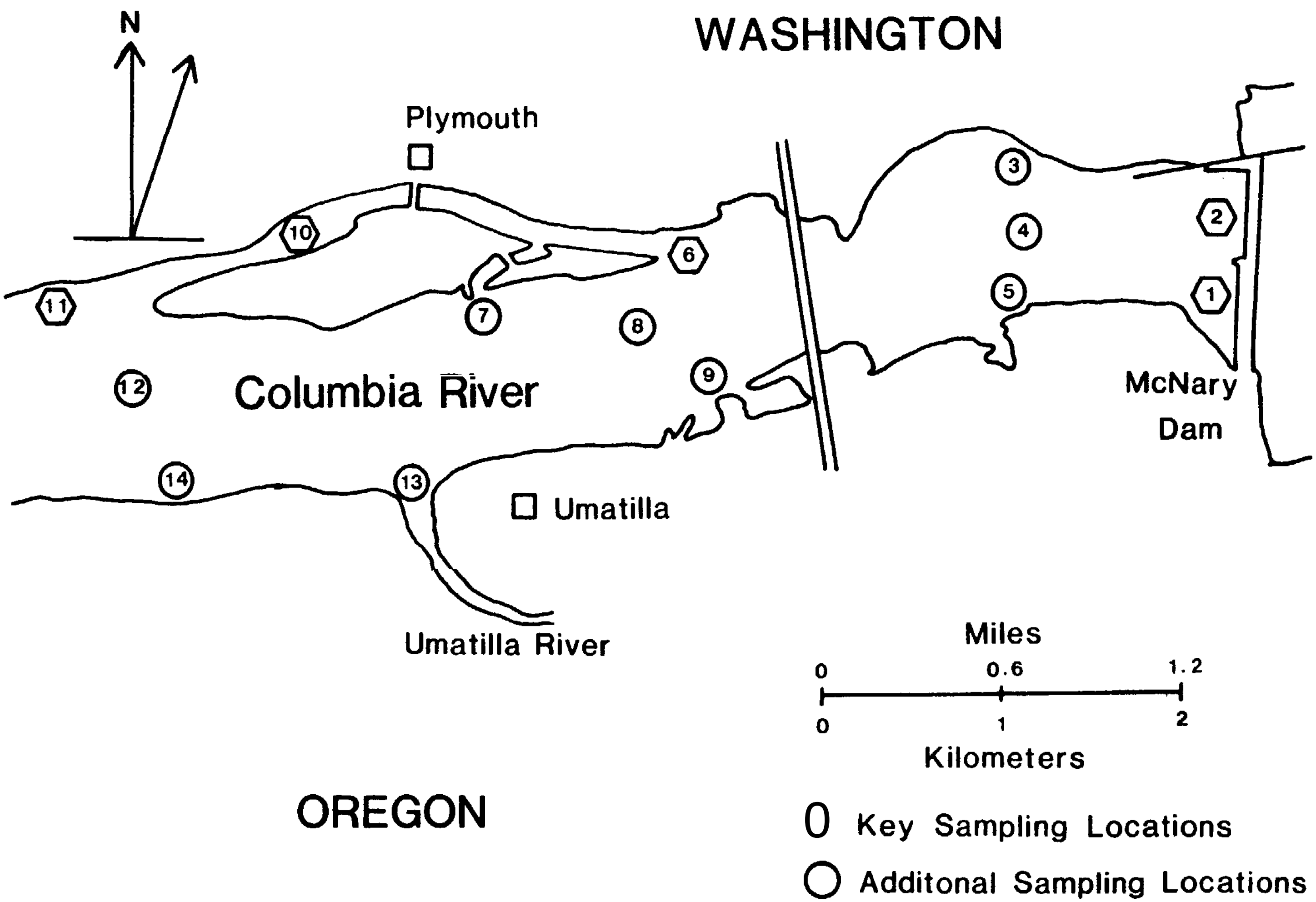

Figure 5. Locations of sampling stations in the McNary Dam tailrace transect, 1982.

Station boundaries were associated with those of loosely defined habitats. Sites were point sampling locations within stations.

Sampling for walleye and northern squawfish was conducted from May through December 1982. Initial efforts (in May and June) focused on reconnaissance and exploratory sampling with gill nets, an electrofishing boat, and hook and line in primary transects to locate concentrations of walleye and northern squawfish. Key sampling locations (Figures 2-5) were identified and characterized with respect to depth, flow, and bottom contour.

In early July sampling efforts were concentrated in secondary transects to establish sampling locations for monitoring movements of tagged fish. Sampling was conducted for 2 days in each of seven secondary transects using gill nets and boat electrofishing. Since the area over which a population estimate applied was defined by the area over which tagged fish were recovered, it was necessary to determine the extent of movement into adjacent areas of fish tagged and released in primary sampling transects.

Sampling within primary transects was resumed in mid-July (when spilling at John Day and McNary dams stopped and allowed sampling near the dams) and continued through early September. Key sampling locations (Figures 2-5) were sampled once every 2 weeks with gill nets, trap nets, a beach seine, an electrofishing boat, and hook and line to examine temporal changes in distribution and evaluate relative gear efficiencies for capturing northern squawfish and walleye. Additional sampling was conducted from mid-September through early October in the boat restricted zones of John Day and McNary dams to maximize the numbers of northern squawfish tagged, released, and recaptured.

Secondary transects were again sampled in mid-October to detect movements of fish tagged and released in primary transects and examine seasonal changes in abundance and distribution of walleye and northern squawfish. Gillnetting and boat electrofishing were conducted for 2 days in each of the seven transects.

Finally, for 1 week in November and December primary transects were sampled with gill nets, a boat electrofisher, and hook and line to examine seasonal changes in abundance and distribution of walleye and northern squawfish and determine when they are recruited to our gear.

Sampling gear deployed in 1982 included surface and bottom gill nets, an electrofishing boat, trap nets, a beach seine, and hook and line. Gill nets measured 36.6-m long x 2.4-m deep. Each half consisted of three 6.1-m long monofilament nylon panels of 3.2-cm, 4.4-cm and 5.1-cm bar mesh (2.7 kg tensile strength). Mesh sizes were chosen to select for walleye (Hamley and Regier 1973) and northern squawfish (Hansen 1972) with fork lengths of at least 250 mm; these fish were expected to be piscivorous. Surface and bottom nets were set in areas of low flow, parallel or perpendicular to shore or underwater structures in depths of 0.3 to 30.0 m. Nets were tended by two-person crews for 0.3 to 3.0 hours; duration of sets decreased as water temperatures increased to minimize mortality. Samplinq was primarily conducted after sunset. Surface gill nets were also fished in high flow areas with depths of 2.0 to 6.0 m by drifting them perpendicular to direction of flow for 5 to 20 minutes.

The electrofishing boat was equipped with a 5,000-watt Ag-tronic alternator and a variable voltage pulsator (VVP) unit which provided an output capacity of 0-700 volts AC or 0-1,000 volts DC. Electrofishing runs were made parallel to shore in depths less than 3 m and along John Day and McNary dams in depths up to 50 m. The crew consisted of an operator and one or two dipnetters. Duration of each run (shocking time) ranged from 5 to 45 minutes. VVP settings ranged from 540-840 volts DC and from 3-5 amps at 60 pulses per second. Sampling was primarily conducted after sunset.

Trap nets were designed after those used by Crowe (1950) in Lake Erie and had a 2.7-m deep x 1.8-m wide x 2.4-m long multifilament nylon capture box of 1.9-cm bar mesh. Two 2.7-m deep x 7.6-m long wings and a 2.7-m deep x 60-m long lead of 5.1-cm bar mesh directed fish to 3.8-m long outer and inner hearts with 0.9-m wide fyke openings of 3.8-cm bar mesh. Fish were funneled from the inner heart to the capture box through a 17.8-cm opening. Trap nets were set with leads perpendicular to shore over substrates with gently sloping contours and in depths ranging from 2-5 m. Nets were checked and reset by two- or three-person crews at approximately 24-hour intervals over periods of 2-6 days.

The beach seine was made of multifilament nylon and was 61-m long x 4.6-m deep with 5.1-cm bar mesh. Seine hauls were made with a boat and a three-person crew in areas along shore with depths of 4 m or less and smooth, gradually sloping bottoms.

Angling gear was 2.6-m long fishing rods and medium-weight spinning reels. Baits used were artificial lures (primarily Rapalas) and dead juvenile salmonids fished on #2/0 barbless treble hooks. Angling was conducted from John Day and McNary dams, from shore, and from boats in depths up to 15 m. Sampling was conducted for 0.5 to 3.0 hours during daylight and nighttime hours.

Catches were identified to species and enumerated. Fish other than northern squawfish and walleye were released. Information on fork length (mm), weight (g), and sex (of mortalities and ripe fish) was collected from walleye and northern squawfish. Walleye and northern squawfish with lengths greater than 249 mm were marked with serially numbered T-anchor tags inserted in the dorsal musculature posterior to and left of the dorsal fin. Newly tagged fish were marked with a left opercle punch to evaluate tag loss.

Data Analysis

Primary and secondary transects were grouped into three areas to facilitate data analyses. John Day tailrace included transects 131 and 141 (Table 1). John Day pool included transects 151, 153-4, 156-7, 159 and 163 (Table 1). McNary tailrace included transect 161 (Table 1). Boat restricted zones in John Day tailrace and forebay and in McNary tailrace were treated as separate areas when estimating northern squawfish abundance to determine their numbers at the dam.

Four periods were delineated so that sampling effort was fairly evenly distributed among them. These were May 24-July 16, July 17-September 11, September 12-October 19 and October 20-December 31.

Catch-per-unit effort (CPUE) and size composition of walleye and northern squawfish caught in gill nets and trap nets and by electrofishing and angling were examined. Units of effort of our gear were net hour (gillnetting), net day (trapnetting), quarter-hour of current-on time (electrofishing) and angler hour (angling). Seasonal trends in CPUE of walleye and northern squawfish were examined by area and period.

Estimates were made of northern squawfish abundance in the boat restricted zones of John Day and McNary tailraces using Schnabel and Schumacher-Eschmeyer multiple mark and recapture methods (Ricker 1975) (Appendix A). Mark and recapture samples were grouped by 2-week periods. Fish recaptured in the same period in which they were marked were not treated as recaptures. Schnabel and Schumacher-Eschmeyer estimates were compared to determine which was most appropriate for our study.

Low numbers of recaptures precluded estimation of northern squawfish abundance in areas away from the dams (Appendix A, Table A-1). No estimates of walleye abundance were made because no marked walleye were recaptured (Appendix A, Table A-2).

Three important requirements of the Schnabel and Schumacher-Eschmeyer abundance estimators are that fish retain their marks, that a closed population is being studied and that all individuals in the catchable population are equally vulnerable to capture.

The requirement that fish retain their marks was addressed by using an opercle punch to identify a recaptured fish that had lost its tag (RLT). However, since the opercle punch was not unique for each fish, we could not determine the period in which an RLT was tagged. To determine the number of RLT's to include in estimates of population abundance, we apportioned them so that in each period the proportion of RLT's which were assumed to have been tagged in that period was equal to the proportion of recaptures-with-tags which were known to have been tagged in that period. This procedure assumed a constant rate of tag loss throughout the season; an assumption examined in Appendix B (Table B-1).

The requirement that a closed population is being studied was examined by determining the extent of movements of tagged fish to and from primary transects. Population estimates were made over the shortest time frame possible to minimize effects of movements.

The requirement that all fish within the size range collected were equally vulnerable to capture was examined by grouping fish into 20-mm length intervals and using chi-square statistics to test if there was a common ratio of recaptures to marked fish at large for all length intervals (Youngs and Robson 1978). When chi-square tests indicated significant departures among length intervals from this common ratio, a Bonferroni-style confidence interval (Neu et al. 1974) was constructed around the observed ratio for each length interval to determine which intervals were different.

RESULTS

Catch Characteristics

We caught 175 walleye and 667 northern squawfish using gill nets, trap nets, and electrofishing (CPUE in Tables 2 and 3, respectively). We caught 2,131 northern squawfish by angling (CPUE in Table 4). Four walleye were caught by angling in John Day tailrace away from the dam; one in the early summer period (5/24-7/16) with 5 hours of effort, two in the late summer period (7/17-9/11) with 27 hours of effort and one in the fall period (9/12-10/19) with 11 hours of effort. One northern squawfish but no walleye were caught in 20 beach seine hauls, of which 10 were made in John Day tailrace, two in John Day pool, and eight in McNary tailrace.

Fork lengths of walleye in samples ranged from 140-779 mm (Figure 6). Approximately 83% of walleye in trap-net samples, 95% of walleye in gill-net samples, and 52% of walleye in electrofishing samples had fork lengths greater than 379 mm (Figure 6).

Fork lengths of northern squawfish in samples ranged from 100-539 mm (Figure 7). Approximately 90% of northern squawfish in trap-net samples, 83% of northern squawfish in gill-net samples, 68% of northern squawfish in electrofishing samples, and 99% of northern squawfish in angling samples had fork lengths greater than 299 mm.

Distribution

CPUE by gear for walleye and northern squawfish proved to be a good index of their temporal and spatial distribution. CPUE of walleye in gill nets was generally greatest in the early summer and fall periods (Table 2). The highest catch of walleye per net hour was in McNary tailrace.

CPUE of walleye in trap nets was comparable at all times of the year in McNary and John Day tailraces, but decreased dramatically in the fall and winter (10/20-12/31) periods in John Day pool (Table 2). The highest catch of walleye per net day was in John Day pool.

CPUE of walleye by electrofishing was greatest in the early summer period (Table 2). The highest catches of walleye per quarter hour current-on time were in John Day tailrace.

Table 2. CPUE of walleye and sampling effort (f) in littoral and backwater habitats by gear, period and location, John Day Reservoir and tailrace, May-December 1982.

	Location					
	McNary tailrace		John Day pool		John Day tailrace	
Gear/Period	CPUE	f[a]	CPUE	f	CPUE	f
Gill net						
5/24-7/16	2.5	26.2	0.3	18.2	0.2	15.7
7/17-9/11	0.0	8.9	0.1	22.9	0.1	17.8
9/12-10/19	0.3	5.9	0.1	16.4	0.7	12.3
10/20-12/31	0.0	9.4	T[b]	37.8	0.0	23.1
Trap net						
5/24-7/16	--	0.0	1.9	3.2	--	0.0
7/17-9/11	1.1	6.2	2.0	5.1	0.1	15.2
9/12-10/19	0.9	8.1	0.2	5.6	0.2	5.5
10/20-12/31	0.8	1.8	0.0	1.8	0.0	1.8
Electrofishing						
5/24-7/16	1.0	9.2	0.2	6.4	1.7	8.8
7/17-9/11	0.2	8.8	0.1	10.0	0.0	16.4
9/12-10/19	0.0	4.8	0.1	[illegible]	0.6	3.2
10/20-12/31	0.0	3.1	0.0	11.2	0.5	7.2

a Effort for gill nets = net hour; trap nets = net day; electrofishing = quarter-hour of current-on time.

b T ≤ 0.05.

Table 3. CPUE of northern squawfish and sampling effort (f) in littoral and backwater habitats by gear, period and location, John Day Reservoir and tailrace, May-December 1982.

	Location					
	McNary tailrace		John Day pool		John Day tailrace	
Gear/Period	CPUE	f[a]	CPUE	f	CPUE	f
Gill net						
5/24-7/16	2.8	26.2	0.3	18.2	0.7	15.7
7/17-9/11	2.7	8.9	0.8	22.9	1.3	17.8
9/12-10/19	0.7	5.9	1.0	16.4	2.7	12.3
10/20-12/31	0.1	9.4	0.5	37.8	1.1	23.1
Trap net						
	--					0.0
7/17-9/11	0.8	[illegible]	[illegible]	[illegible]	0.7	15.2
9/12-10/19	1.7	8.1	1.1	5.6	1.4	5.5
10/20-12/31	2.2	1.8	1.7	1.8	0.0	1.8
Electrofishing						
5/24-7/16	1.1	9.2	0.7	5.6	0.4	8.8
7/17-9/11	0.3	8.8	3.3	6.4	2.6	16.4
9/12-10/19	0.0	4.8	0.6	10.0	0.9	3.2
10/20-12/31	0.0	3.2		11.2	0.4	7.2

a Effort for gill nets = net hour; trap nets = net day; electrofishing = quarter-hour of current-on time.

Table 4. CPUE of northern squawfish by angling and angling hours (f) in the boat restricted zones of John Day tailrace and forebay and McNary tailrace, May-December 1982.

	Location					
	McNary tailrace		John Day pool		John Day tailrace	
Gear/Period	CPUE	f	CPUE	f	CPUE	f
5/24-7/16	5.2	54.8	2.9	19.6	1.6	10.5
7/17-9/11	9.1	110.4	1.1	53.0	5.6	69.4
9/12-10/19	6.5	77.7	3.1	19.1	2.4	14.9
10/20-12/31	2.5	8.1	3.9	8.0		8.0

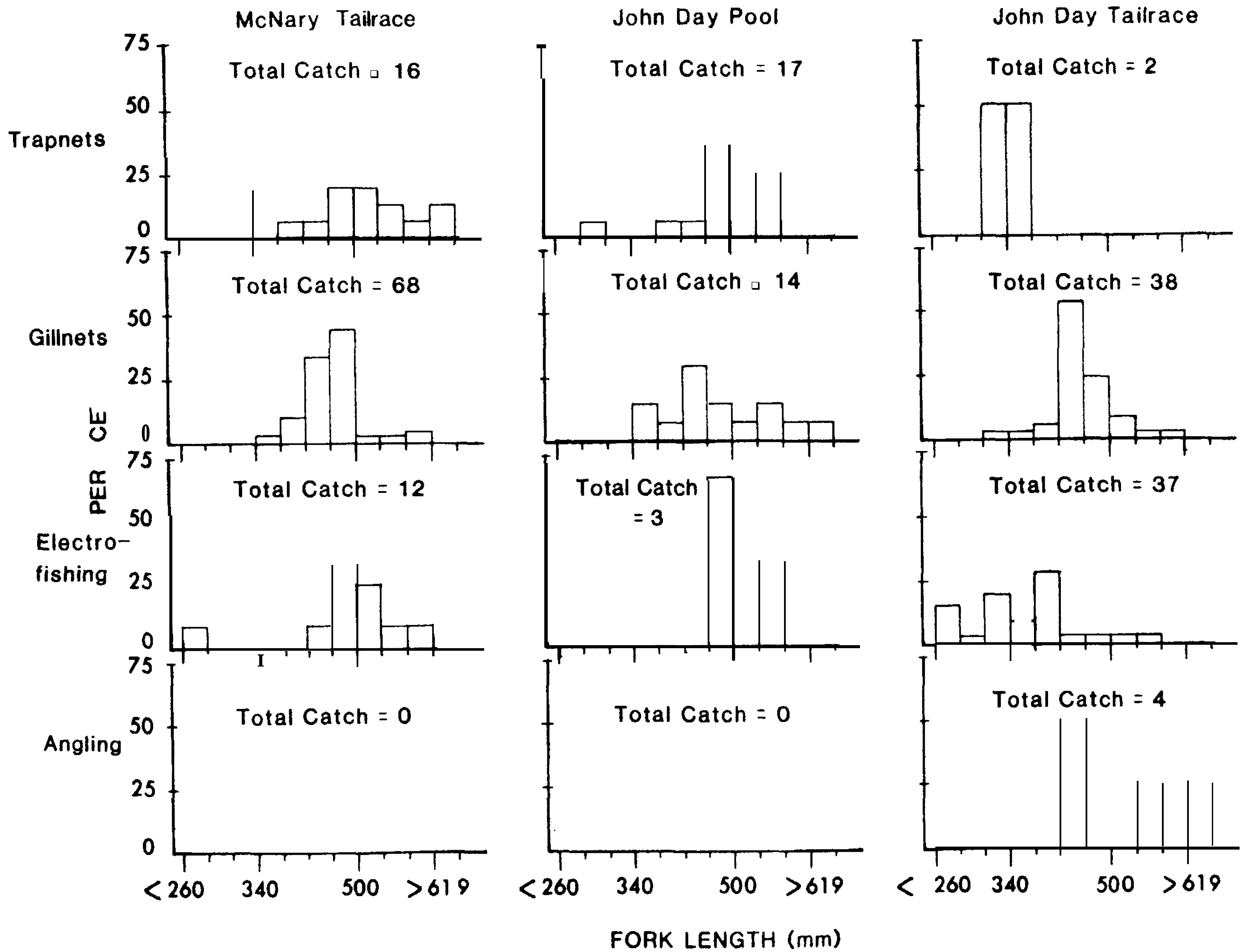

Figure 6. Percentage catch of walleye by length interval, gear type, and sampling location, John Day Reservoir and tailrace, May-December 1982.

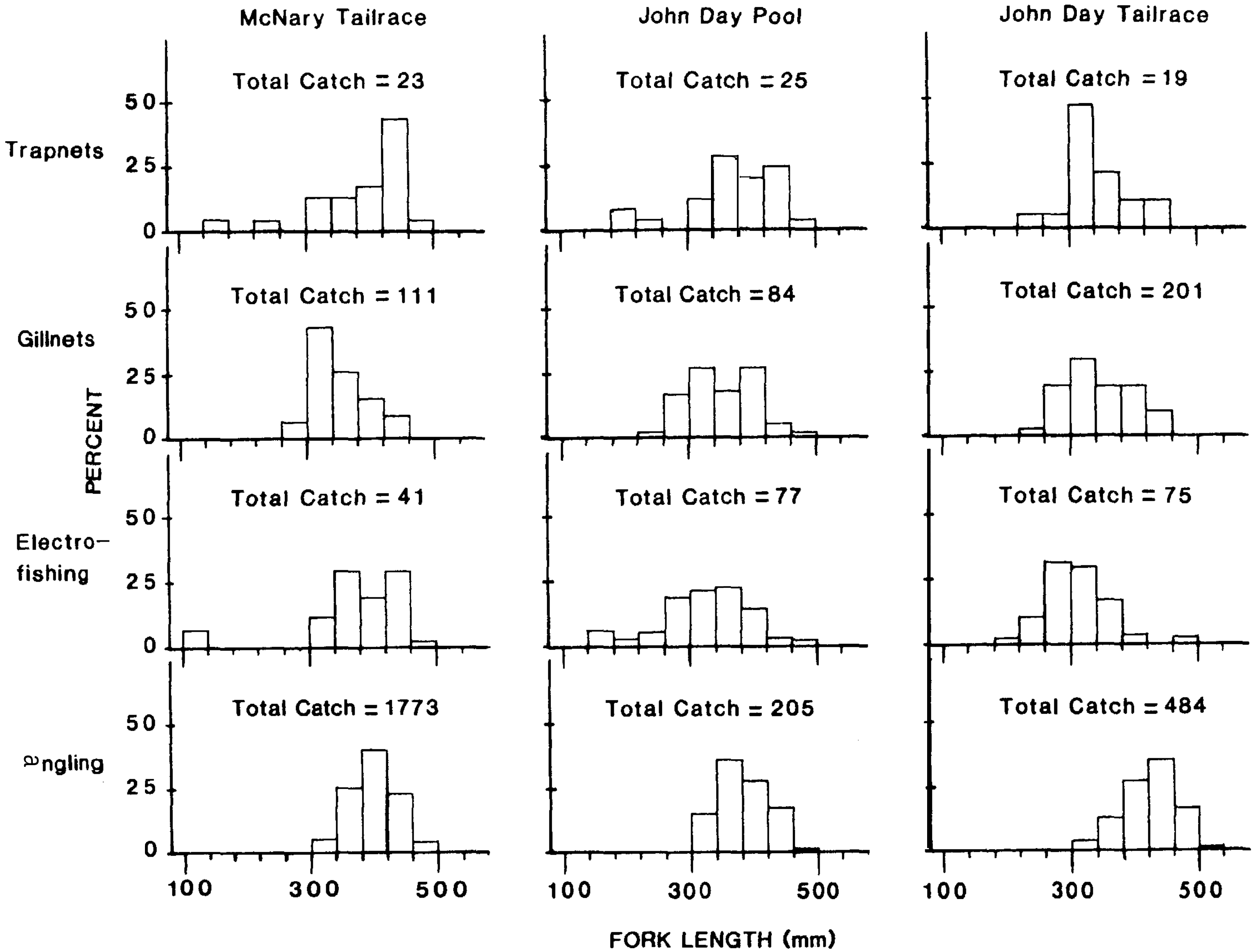

Figure 7 Percentage catch of northern squawfish by length interval, gear type, and sampling location, John Day Reservoir and tailrace, May-December 1982.

CPUE of northern squawfish in gill nets was comparable at all times of the year in John Day pool and John Day tailrace but decreased notably in the fall and winter periods in McNary tailrace. The highest catches of northern squawfish per net hour were in McNary tailrace in the early and late summer periods and in John Day tailrace in the fall period (Table 3).

CPUE of northern squawfish in trap nets increased over the season in McNary and John Day tailraces but decreased in John Day pool (Table 3). The highest catches per net day were in McNary tailrace in the winter period and in John Day pool in the early and late summer periods.

CPUE of northern squawfish by electrofishing varied. The highest catch per quarter hour current-on time was in the fall period in John Day pool (Table 3).

Finally, CPUE of northern squawfish by angling in the boat restricted zones John Day and McNary dams was highest in the late summer and fall periods in McNary and John Day tailraces and in the fall and winter periods in John Day forebay (Table 4). Effort was notably higher in the late summer period than in the other periods at all three locations.

Population Abundance

Schnabel and Schumacher-Eschmeyer estimates of northern squawfish abundance (Table 5) differed in John Day tailrace boat restricted zone (BRZ) by less than 1% and in McNary tailrace BRZ by less than 3%. Computations for these estimates are presented in Appendix A (Tables A-3 and A-4).

None of the 406 northern squawfish marked and released in the John Day tailrace BRZ were recaptured outside of the BRZ during the period over which the abundance estimates were calculated. Nor were any of the 399 northern squawfish marked and released in areas adjacent to the John Day tailrace BRZ recaptured within the BRZ during this time.

One of the 1,331 northern squawfish marked and released in the McNary tailrace BRZ was recaptured outside of the BRZ during the period over which the abundance estimates were made. Similarly, one of 257 northern squawfish marked and released in areas adjacent to the McNary tailrace BRZ was recaptured within the BRZ during this time.

The number of northern squawfish recaptured in the John Day tailrace BRZ was not large enough to test whether there was a common ratio of recaptures to marked fish at large among length intervals. The fifteen recaptures were distributed over four periods and had fork lengths ranging from 340-499 mm.

Ratios of recaptures to marks at large for northern squawfish in the McNary tailrace BRZ were not consistent among length classes ($X2 = 74.0$, $p < 0.01$) (Appendix B, Table B-2). Bonferroni-style confidence intervals indicated that observed ratios were significantly ($p < 0.05$) less than expected for northern squawfish in the 360-379 mm length class-during the last three periods over which abundance estimates were made (Appendix B, Table B-3).

Table 5. Abundance estimates (N) of northern squawfish in the boat restricted zones (BRZ) of John Day and McNary tailraces and their 95% confidence intervals (in parentheses).

Location/Method	Periods included	N
John Day tailrace-BRZ		
Schnabel	7/17-10/29	4636 (2992-8832)
Schumacher-Eschmeyer	7/17-10/19	4609 (3455-6922)
McNary tailrace-BRZ		
Schnabel	7/17-10/19	8643 (7237-10511)
Schumacher-Eschmeyer	7/17-10/19	8392 (6682-11278)

DISCUSSION

Since 1982 was the first year of our efforts to determine the distribution and abundance of walleye and northern squawfish in the John Day pool and tailrace, our first objective was to evaluate several types of gear to determine which ones were most likely to provide adequate samples of walleye and northern squawfish. A variety of gears were needed to provide sampling capability in different habitats (described under Methods) and under various conditions of water depth, water temperature, and wave action.

We were able to catch walleye and northern squawfish under a wide range of sampling conditions by gillnetting, trapnetting, and electrofishing. Gillnetting enabled sampling of deep water areas (>2 m) while electrofishing enabled sampling of near-shore, shallow water areas (<2m). Both of these gears required constant tending. Trapnetting enabled-sampling for extended time periods without constant tending, and was especially useful in areas such as Blalock Islands where inclement weather limited the number of sampling trips.

CPUE was highly variable over time and location for all three gear types (Tables 2 and 3). Some of the variability in CPUE likely resulted from alterations in our sampling approach made to improve overall sampling efficiency and changes in gear from those borrowed early in the study to those designed and purchased specifically to meet our sampling needs.

Angling was useful for sampling northern squawfish at dams (Table 4), but was not useful either for sampling northern squawfish away from dams or for sampling walleye anywhere. We angled only near the water surface at dams. If walleye occur in significant numbers at dams they are likely distributed deeper in the water column than we effectively sampled. While both species can be caught by angling away from dams, effort required for marking and recapturing fish would be cost prohibitive. However, a survey of sport anglers could be used to gather recapture and harvest data, thereby making use of a relatively large amount of angling effort at a comparatively low cost.

Beach seining was ineffective in 1982 and will not be used for sampling in 1983. Only one northern squawfish was captured in 20 seine hauls.

Improvements in sampling equipment and design and deployment techniques together with increased familiarity with areas to be sampled can be expected to-result in increased sampling efficiency in 1983. Trap nets have been redesigned and increased in size. They will be capable of sampling to depths of 4.5 m rather than 1.8 m. Improvements in the electrical system of our electrofishing boat are being made, including relocation of the anode with respect to the work area of samplers. In addition to stationary gillnetting, we will employ drift gillnetting in 1983 as a technique for sampling offshore in deep areas with high flow.

Sample sizes of fishes caught were too small to allow adequate evaluation of size selectivity, or selectivity for tagged or untagged fish during 1982. These gear selectivity evaluations will be made in 1983.

A high proportion (83-95%) of walleye and northern squawfish in trap-net and gill-net catches had fork lengths greater than 379 mm and 299 mm, respectively. Nearly all (99%) northern squawfish caught by angling at dams were over 299 mm. However, catches of walleye over 379 mm or northern squawfish over 299 mm using electrofishing were only slightly higher (52-68%) than catches of fishes below these lengths. These data indicate that larger numbers of smaller fish were caught by electrofishing. This may be due either to a size selectivity difference between electrofishing and the other gears or to a difference in distributional patterns of smaller fish with respect to habitats sampled with electrofishing versus habitats sampled with the other gears.

Seasonal trends in CPUE of walleye and northern squawfish by trap nets, gill nets, and electrofishing reflected their abundance in littoral and backwater habitats; we were unable to sample deeper offshore habitats because of high flow. Seasonal trends in CPUE of northern squawfish by angling reflected their abundance at spillways and near powerhouses of McNary and John Day dams, especially after stoppage of spilling.

Trends in CPUE of walleye suggested that they used littoral and backwater habitats early in the summer (May and June), moved to deeper water habitats later in the summer (July-September) and returned to littoral and backwater habitats in the fall (in October). We were unable to determine where walleye were distributed when they were not in littoral and backwater habitats.

Trends in CPUE of northern squawfish suggested that they used littoral and backwater habitats throughout the year. CPUE of northern squawfish by angling at the dam indicated that in late summer (July and August) large numbers of northern squawfish were concentrated in the tailraces.

Movements of walleye and northern squawfish appeared to be closely related to water temperature and flow velocity. Walleye catches in littoral and backwater habitats decreased notably after June when water temperatures in shallower waters rose and flow velocities in deeper offshore waters decreased. Movements of northern squawfish into the tailraces corresponded closely with cessation of spill at the dams. Hjort et al. (1981) concluded that flow velocity was an important factor affecting fish distribution during their study of resident fish in John Day Reservoir. They also observed higher CPUE of walleye in backwater areas during spring and fall than during summer. In a study at Bonneville Dam, Uremovich et al. (1982) found that CPUE of northern squawfish by angling in the tailrace and forebay was highest during July and August, after cessation of spill.

Schnabel and Schumacher-Eschmeyer estimates of northern squawfish abundance were similar to each other for the boat retricted zones (BRZ) of John Day and McNary tailraces. Schaefer (1951) stated that Schnabel estimates are more appropriate than Schumacher-Eschmeyer estimates when less than 25% of the estimated population is tagged. We tagged approximately 9% (406/4,636) and 15% (1,330/8,643) of the estimated number of northern squawfish in the BRZ's of John Day and McNary tailraces, respectively. By Schaefer's criteria, our Schnabel estimates are probably most appropriate.

Estimates of northern squawfish abundance in McNary tailrace BRZ may not reflect their abundance throughout the BRZ. Most of the fish were captured and released at the mouth of the adult fishway. If these fish did not mix freely with others in the BRZ, then estimates may be of the abundance of this localized population. In 1983 we will randomly distribute sampling effort within the BRZ and will radiotelemetrically monitor movements of northern squawfish captured and released in the BRZ to define the area over which abundance estimates apply.

Loss of tags by northern squawfish marked throughout the season was high (32%). Although use of secondary marks enabled the identification of recaptures, it was necessary to assume that proportions of recaptures without tags that were marked in the same period in which they were recaptured were equal to observed proportions for recaptures with tags. This assumption introduced another source of error to our population abundance estimates. In 1983 we will replace the T-anchor tags with more persistant spaghetti tags inserted through the dorsal musculature and tied over the back with an overhand knot.

Comparisons between tagging and recapture locations of northern squawfish in the boat restricted zones of John Day and McNary tailraces suggest that movements to and from the BRZ's during the period when abundance estimates were made were minimal. Our radiotelemetry study of northern squawfish movements in McNary tailrace BRZ in 1983 should better describe movement patterns.

Bonferroni-style confidence intervals (Neu et al. 1974) indicated that in the final 6 weeks of the season (8/28-10/8) significantly ($p < 0.05$) fewer northern squawfish in the 360-379 mm length group were recaptured in the McNary tailrace BRZ than was expected if all length groups were sampled equally within a period. These significant differences could have resulted from gear selectivity, differential growth rates among length groups or dilution of tagged fish in that length group by an influx of untagged fish of those lengths. Stratification of the catchable population into length groups with approximately equal vulnerability to capture and calculation of individual abundance estimates for each group would be appropriate. However, inadequate numbers of recaptures precluded stratification of northern squawfish samples by length.

Based upon 1982 catch rates using gill nets, trap nets, and eiectrofishing, we expect to capture enough northern squawfish in 1983 to estimate their abundance in the John Day and McNary tailraces and their boat restricted zones if sampling effort in 1983 is approximately twice that expended in 198.2. However, because 1982 catch rates of walleye using gill nets, trap nets, and electrofishing decreased notably in late summer (7/17-9/11) (Table 2), we expect to be able to estimate their abundance only in the tailraces in 1983 and only if sampling effort to mark walleye is concentrated early in the year (April-June) and an angler survey to supplement recoveries of marked walleye is conducted later in the year (June-August).

Smallmouth bass will be included with walleye and northern squawfish as a target species in 1983. Preliminary findings by USFWS (Gray et al. 1983) suggest that smallmouth bass may be as important a predator of juvenile anadromous salmonids as walleye because they appear to be more abundant in the reservoir than walleye.

Sampling in 1983 will be concentrated in four primary transects throughout the season to maximize tagging and recapturing of walleye, northern squawfish, and smallmouth bass. Effort spent sampling secondary transects in 1982 was unproductive and will be drastically reduced to enable more intense sampling of primary transects in 1983.

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APPENDIX A

Catch Data and Computations for Estimation of Population Abundances

Chapman's modification of Schnabel's method and Schumacher-Eschmeyer's method (kicker 1975) were used to calculate estimates (N) of northern squawfish abundance in the boat restricted zones of John Day (Table A-3) and McNary (Table A-4) tailraces.

The formula used to calculate the modified Schnabel estimate was:

$$N = \frac{\Sigma CM}{(\Sigma R)+1}$$

Confidence limits for N were calculated by considering ΣR as a Poisson variable and using Appendix II in Ricker (1975).

The formulae used to calculate the Schumacher-Eschmeyer estimate and its variance were:

$$1/N = \frac{\Sigma MR}{\Sigma CM^2}$$

$$S^2 = \frac{\Sigma R^2/C - \Sigma MR/\Sigma CM^2}{n-1}$$

where n is the number of periods in which fish were marked. Confidence limits for 1/N were calculated as:

$$1/N \pm t_{(n-1,p)} \sqrt{\frac{S^2}{\Sigma CM^2}}$$

Table A-1. Catch of northern squawfish in locations other than the boat restricted zones of John Day and McNary tailraces, May-December 1982.

Location	Catch	Marks released	Recaptures	Mortalities	Others[a]
John Day tailrace[b]	246	240	1	5	0
John Day forebay-boat restricted zone	165	159	2	2	2
John Day pool[c]	131	123	1	7	0
McNary tailrace[b]	145	134	3	3	5

a Unmarked fish unintentionally released.
b Excluding the boat restricted zone.
c Excluding John Day forebay boat restricted zone.

Table A-2. Catch of walleye by location in John Day Reservoir and tailrace, May-October 1982.

Location	Catch	Marks released	Recaptures	Mortalities
John Day tailrace	58	49	0	9
John Day pool	29	21	0	8
McNary tailrace	88	63	0	25

Table A-3. Computations for Schnabel and Schumacher-Eschmeyer estimates of northern squawfish abundance in the boat restricted zone of John Day tailrace.

Period	C[a]	T[b]	R[c]	M[d]	CM	MR	CM2	R^2/C
7/17-7/30	88	86	0	0	0	0	0	0.0000
7/31-8/13	92	90	1	86	7912	86	680432	0.0109
8/14-8/27	43	43	0	176	7568	0	1331968	0.0000
8/28-9/10	92	87	5	219	20148	1095	4412412	0.2717
9/11-9/24	57	46	4	306	17442	1224	5337252	0.2807
9/25-10/8	60	54	5	352	21120	1760	7434240	0.4167

a C is the number of fish caught.
b T is the number of fish marked and released.
c R is the number of marked fish recaptured.
d M is the number of marked fish at large.

Table A-4. Computations for Schnabel and Schumacher-Eschmeyer estimates of northern squawfish abundance in the boat restricted zone of McNary tailrace.

Period	C[a]	T[b]	R[c]	M[d]	CM	MR	CM^2	R^2/C
7/17-7/30	338	314	0	0	0	0	0	0.0000
7/31-8/13	214	191	10	314	67196	3140	21099544	0.4673
8/14-8/27	203	108	12	505	102515	6060	51770075	0.7094
8/28-9/10	401	282	17	612	245412	10404	150192144	0.7207
9/11-9/24	300	242	32	894	268200	28608	239770800	3.4133
9/25-10/8	243	194	39	1136	276048	44304	313590528	6.2593

a C is the number of fish caught.
b T is the number of fish marked and released.
c R is the number of marked fish recaptured.
d M is the number of marked fish at large.

APPENDIX B

Data and Computations for Examining the Validity of Assumptions of the Schnabel and Schumacher-Eschmeyer Estimates

Tag loss prevented us from identifying the period in which a recapture without a tag (RLT) was marked and precluded direct testing of whether the rate of tag loss was constant throughout the season. To investigate whether observed increases over time in the proportions of RLT's to total recaptures could have occurred when the rate of tag loss was constant, we calculated expected numbers of RLT's given a constant tag loss rate and compared expected and observed values using Spearman's rank correlation and chi square goodness of fit tests (Snedecor and Cochran 1967).

Expected numbers of RLT's (E_{ij}) from a cohort (i) of fish marked in a given period (j) were calculated for each subsequent period as the number of fish in the cohort ($T_{i.}$) less expected RLT's from the previous period (E_{ik}) times the recapture rate (R) and the tag loss rate (L):

$$E_{ij} = (T_{i.} - \sum_{k=1}^{j-1} E_{ik})\, RL$$

Recapture rate was estimated as the mean proportion of recaptures to marked fish at large observed for the season. Tag loss rate was estimated as the mean proportion of RLT's to total recaptures observed for the season.

Observed numbers of northern squawfish recaptured without tags were strongly correlated to ($r = 0.93$, $p = 0.01$) but were significantly different from ($X^2 = 16.48$, $p = 0.02$) expected values (Table B-1). The positive correlation between observed and expected values suggest that the increase in the number of RLT's observed late in the season could have occurred with a constant rate of tag loss. The result of the chi-square test suggests that for some cohorts, particularly those northern squawfish tagged from September 11-24, the tag loss rate was higher than the seasonal average.

Chi-square analyses and Bonferroni-style confidence intervals used to test the assumption that all individuals in the catchable population are equally vulnerable to capture are presented in Tables B-2 and B-3, respectively.

Table B-1. Expected numbers of northern squawfish recaptured without tags in the boat restricted zone of McNary tailrace, June-September 1982.

Period	Number tagged and released	Sampling period 13	14[a]	15	16	17	18	19	20
6/5-6/18	194	2	2	2	2	2	2	2	2
6/19-7/2	73	1	1	1	1	1	1	0	0
7/3-7/16[a]	0		0	0	0	0	0	0	0
7/17-7/30	314			3	3	3	3	3	3
7/31-8/13	191				2	2	2	2	2
8/14-8/27	108					1	1	1	1
8/28-9/10	282						3	3	3
9/11-9/24	242							3	3
9/25-10/8	194								2
Total (Expected)[b]		3	3	6	8	9	12	14	16
Observed		0	0	3	6	3	10	24	16

a We did not sample in McNary Dam boat restricted zone during this period; not included in analyses.

b Chi-square value for goodness of fit test of observed vs. expected is $X^2 = 16.48$; df = 7 and corresponding $p = 0.0211$.
The coefficient for Spear-man rank correlation between observed and expected is $r = 0.93$; corresponding $z = 2.47$ and $p = 0.0135$.

Table B-2. Chi-square analyses by period of whether there is a common ratio of recaptures (r) to marked fish at large (m) among length intervals for northern squawfish in the boat restricted zone of McNary tailrace.

		Length interval (mm)							
Period		<360	360-379	**380-399**	**400-419**	**420-439**	>440	**x2**	**pa**
6/19-7/2	r	2	0	1	7	4	2	10.6	0.06
	m	13	30	40	33	30	34		
7/17-7/30	r	0	2	3	3	7	4	7.7	0.18
	m	25	41	50	51	38	45		
7/31-8/13	r	0		2	6	5	7	14.7	0.19
	m	96	9:	109	107	76	75		
8/14-8/27	r	2	2	6	5	1	3	3.9	0.56
	m	139	126	148	149	103	98		
8/28-9/10	r	0	1	5	4	7		16.7	0.01
	m	160	144	172	168	109	10:		
9/11-9/24	r	8	3	8	11	9	8	6.5	0.26
	m	200	201	230	205	152	130		
9/25-10/8	r	3	2	8	10	11	8	14.0	0.02
	m	240	243	276	258	183	153		
								74.1	<0.01

a P is the probability level of the corresponding X2 statistic.

Table B-3. Observed (0) and expected (E) ratios of recaptures in a given length interval and period to total recaptures in the same period for northern squawfish in the boat restricted zone of McNary tailrace.

Period		Length interval (mm)					
		<360	360-379	380-399	400-419	420-439	>440
6/19-7/2	E	0.08	0.15	**0.21**	0.20	**0.17**	**0.18**
	0	0.12	0.00[a]	**0.06**	0.44	0.25	0.12
7/17-7/30	E	0.09	0.16	0.20	0.20	0.17	0.18
	0	0.00[a]	0.10	0.16	0.16	0.37	0.21
7/31-8/13	E	**0.16**	0.17	**0.19**	0.19	0.14	0.14
	0	0.00[a]	0.05	**0.10**	0.28	0.24	0.33
8/14-8/27	E	0.18	**0.16**	0.20	0.20	0.13	0.13
	0	0.10	**0.10**	0.32	0.26	0.05	0.16
8/28-9/10	E	0.18	0.16	0.20	0.19	0.13	0.13
	0	0.00[a]	0.04[b]	0.21	0.17	0.29[c]	0.29[c]
9/11-9/24	E	**0.18**	0.18	0.20	0.18	0.14	0.12
	0	**0.17**	0.06[b]	0.17	0.23	0.19	0.17
9/25-10/8	E	0.17	**0.15**	0.20	**0.19**	0.14	0.12
	0	0.07	0.05[b]	**0.19**	0.24	0.26	**0.19**

a Zero values precluded construction of Bonferroni-style confidence intervals.
b Observed value was significantly ($p<0.05$) less than expected value.
c Observed value was significantly ($p\leq0.05$) greater than expected value.