‘SYSTEM-WIDE SIGNIFICANCE OF PREDATION ON JUVENILE SALMONIDS IN COLUMBIA AND SNAKE RIVER RESERVOIRS

ANNUAL REPORT 1992

Edited by:

James H. Petersen
Thomas P. Poe

U.S. Fish and Wildlife Service
National Fishery Research Center - Seattle
Columbia River Field Station
Cook, WA

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-362 1

Project Number 90-078
Contract Number DE-AI79-90BP07096

DECEMBER 1993

TABLE OF CONTENTS

Indexing juvenile Salmonid consumption by northern sguawfish in the Columbia River below Bonneville Dam and in John Day Reservoir, 1992

James H. Petersen, Sally T. Sauter, Conrad N. Frost, Steven R. Gray, and Thomas P. Poe

U.S. Fish and Wildlife Service
National Fishery Research Center -- Seattle
Columbia River Field Station
Star Route, Cook, WA 98605

ABSTRACT

Northern sguawfish (Ptvchocheilus oreaonensis) predation on juvenile salmonids was characterized during 1992 at ten locations in the Columbia River below Bonneville Dam and at three locations in John Day Reservoir. During the spring and summer, 1,487 northern sguawfish were collected in the lower Columbia River and 202 sguawfish were sampled in John Day Reservoir. Gut content data, predator weight, and water temperature were used to compute a consumption index (CI) for northern sguawfish, and overall diet was also described.

In the Columbia River below Bonneville Dam, northern sguawfish diet was primarily fish (spring 69%: summer 53%), most of which were salmonids. Salmonids were also the primary diet component in the Bonneville Dam tailrace, John Day Dam forebay and the McNary Dam tailrace. Crustaceans were the dominant diet item at the John Day mid-reservoir location, although sample sizes were small. About half of the non-salmonid preyfish were sculpins.

The consumption index (CI) of northern sguawfish was generally higher during summer than during spring. The highest CI's were observed during summer in the tailrace boat restricted zones of Bonneville Dam (CI = 7.8) and McNary Dam (CI = 4.6). At locations below Bonneville Dam, CI’s were relatively low near

Covert's Landing and Rooster Rock, higher at four locations between Blue Lake and St. Helens, and low again at three downriver sites (Kalama, Ranier, and Jones Beach). Northern squawfish catches and CI's were noticeably higher throughout the lower Columbia compared to mid-reservoir sites further upriver sampled during 1990-92. Predation may be especially intense in the free-flowing section of the Columbia River below Bonneville Dam.

Smallmouth bass (Micropterus dolomieui; N = 198) ate mostly fish - 25% salmonids, 29% sculpins, and 46% other fish. Highest catches of smallmouth bass were in the John Day Dam forebay.

ACKNOWLEDGEMENTS

Permission to sample near dams was given by the Army Corp of Engineers and sampling coordination was facilitated by the Fish Passage Center, particularly Margaret Filardo. Dave Jepsen and R. D. Nelle helped with field and laboratory work. Bill Nelson provided useful comments on an earlier draft of this report. This project was funded by the Bonneville Power Administration and administered by Bill Maslen.

INTRODUCTION

Recent studies have indicated that predation may be a significant source of mortality on outmigrating juvenile salmonids in the Columbia and Snake rivers (Petersen et al. 1991; Poe et al. 1991; Rieman et al. 1991; Vigg et al. 1991; Shively et al. 1992). Consumption of salmonids by predators may account for the majority of previously unexplained losses of juvenile salmonids in John Day Reservoir (Rieman et al. 1991). Predation has also been included as an important mortality component in river passage models that are used to develop management plans for rebuilding salmon stocks (MEG 1989; Bledsoe et al. 1990; CQS 1991; Lee 1991).

Measures to reduce predation mortality on juvenile salmonids -- predator control, improved bypass systems, barge release locations, and others -- are being implemented throughout the Columbia River Basin (NPPC 1992). Effective predation control in a large river system requires baseline data on predator abundance and consumption rates so management actions can be evaluated and modified if necessary.

In 1989, a collaborative study was initiated by the U. S. Fish and Wildlife Service (FWS) and the Oregon Department of Fish and Wildlife (ODFW) to estimate the relative magnitude of juvenile salmonid losses to predators throughout the Columbia River Basin. Emphasis has been on northern sguawfish Ptvchocheilus oreqonensis, a major predator on salmonids in several freshwater systems (Ricker 1941; Jeppson and Platts 1959; Thompson and Tufts 1967; Rieman et al. 1991). Because of the size of the Columbia River system, an indexing approach was implemented for estimating the abundance and consumption rates of northern sguawfish (Petersen et al. 1990; Vigg and Burley 1990).

The FWS has been responsible for indexing the consumption rate of salmonids by northern sguawfish, and characterizing diet and consumption rates for other piscivores. During 1990, predation was indexed in four reservoirs in the Columbia River between Bonneville Dam and Ice Harbor Dam (Petersen et al. 1990).

During 1991, predation was indexed on the lower Snake River and also in John Day Reservoir on the Columbia River (Shively et al. 1991). This report presents 1992 results of indexing northern squawfish consumption rates upon juvenile salmonids in the free-flowing stretch of the Columbia River below Bonneville Dam. John Day Reservoir was also sampled in 1992 to maintain a time series in this reservoir.

METHODS

Field Methods

Field sampling during 1992 was completed at 10 locations from Bonneville Dam tailrace to Jones Beach, Oregon and at three locations on John Day Reservoir (Figure 1; Table 1). Timing of sampling was designed to coincide with seasonal out-migration peaks of juvenile salmonids below McNary and Bonneville dams.

Twenty-four transects, each approximately 500 meters, were established at each sample location. At Bonneville Dam tailrace, McNary Dam tailrace and John Day Dam forebay locations, four of the 24 transects were within the boat restricted zone (BRZ) and 20 were outside the BRZ - ten on each side of the river for an approximate distance of 5 km.

Dam operations were adjusted by the Army Corp of Engineers to allow sampling within BRZ's around ice trash sluiceways, spillgates, and powerhouse outflows. Sampling was conducted immediately after any project operation changes, therefore gut contents of captured predators should reflect conditions of typical project operation.

Target predators -- northern squawfish, smallmouth bass _Micropterus dolomieui_, and walleye _Stizostedion vitreum_ -- were collected by boat electrofishing on established transects (15 minutes of effort per transect). On each sampling day, six transects were chosen at random at each location; two of the six random transects in forebay or tailrace locations were from the BRZs. The minimum target catch was 30 northern squawfish per day at each location (Petersen et al. 1990). Around dams the minimum target catch was split into two units: 15 per day in the BRZ and

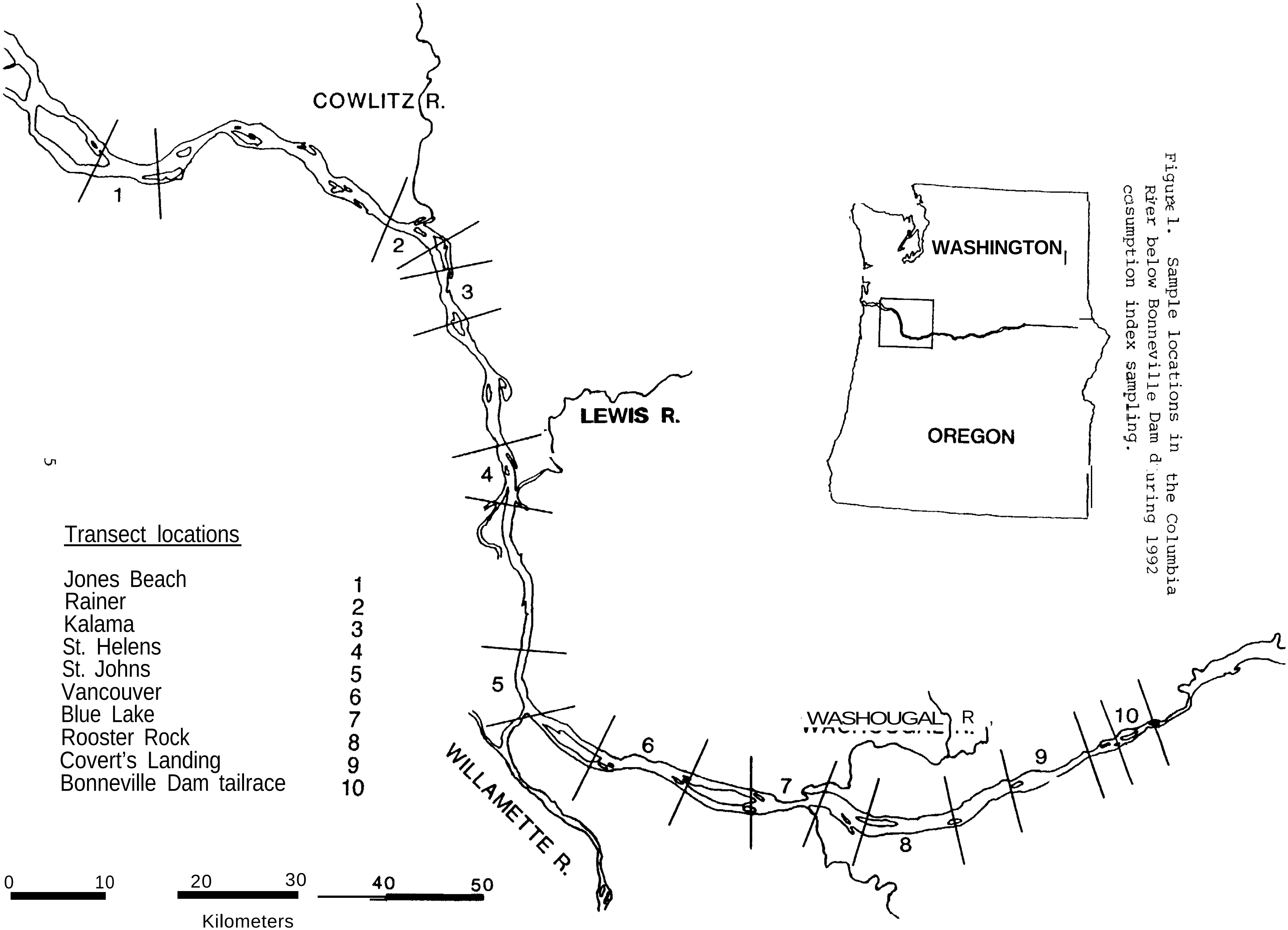

Figure 1. Sample locations in the Columbia River below Bonneville Dam during 1992 consumption index sampling.

Table 1. Sampling locations and dates for northern squawfish consumption indexing during 1992.

Location	River Kilometer (RKM)	Dates Sampled Spring	Summer
Jones Beach	71 - 77	5/27-5/28	7/28-7/29
Rainer	106 - 111	5/21-5/22	7/23-7/24
Kalama	117 - 121	5/21-5/22	7/23-7/24
St. Helens	135 - 142	5/19-5/20	7/21-7/22
St. Johns	159 - 164	5/19-5/20	7/21-7/21
Vancouver	171 - 177	5/14-5/15	7/13-7/14
Blue Lake	190 - 196	5/14-5/15	7/13-7/14
Rooster Rock	204 - 210	5/12-5/13	7/09-7/10
Covert's Landing	220 - 225	5/07-5/08	7/06-7/07
Bonneville Dam Tailrace	225 - 233	5/05-5/06	6/29-6/30
John Day Forebay	347 - 353	5/12-5/13	7/09-7/10
John Day Mid-Reservoir	387 - 395	5/07-5/08	7/06-7/07
McNary Dam Tailrace	459 - 468	5/05-5/06	6/29-6/30

15 per day outside the BRZ. Additional, discretionary transects were sampled to maximize catch of northern squawfish. Sampling commenced 90 minutes before sunrise at all locations.

To prevent regurgitation of digestive tract contents, northern squawfish were killed soon after capture with a lethal dose of tricaine methanesulfonate (MS-222). Digestive tract contents from northern squawfish over 200 mm fork length (FL) were taken by pinching off the anterior and posterior portions of the digestive tract, then removing and placing the entire tract in a plastic bag. This technique also permitted the collection of coded-wire-tags (CWTs) from consumed fish. Northern squawfish ≤ 200 mm FL were collected whole. Field data collected on northern squawfish included: fork length (FL, nearest mm), weight (nearest 5 or 10 grams, depending upon fish size), sex, and stage of maturity.

Smallmouth bass and walleye were retained alive in livewells with aerated and circulating water until collection of digestive tract contents could be completed. These predators were anesthetized with MS-222, measured (FL), and weighed (nearest 5 or 10 grams); stomach samples were collected from smallmouth bass and walleye ≥ 150 mm FL with a modified Seaburg stomach sampler (Seaburg 1957). All digestive tract contents and whole samples were kept frozen until laboratory analysis.

Laboratory Methods

Northern Squawfish

Frozen digestive tract samples were checked for coded wire tags (CWTs) with an electronic sensor, and thawed for analysis. Digestive tracts were stripped of their contents, which were divided into major prey groups, (fish, crustacean, mollusk, insect, plant, other). Each prey group was blotted on tissue paper, weighed to the nearest 0.01 g, and returned along with the digestive tract to its original bag.

Hard parts (bones, exoskeletons, and shells) were isolated by digesting the contents of the sample bags and pouring the resulting slurry through a 425 micron (#40) sieve. Samples were digested enzymatically using a solution of porcine pancreatase (8x U.S.P.) and sodium sulfide nonahydrate mixed 2% w/w and 1% w/w, respectively, in warm tap water (Petersen et. al. 1990). The enzyme solution was poured into the sample bags and the bags were shaken to ensure contact of all the contents with the enzyme. The samples were incubated at 45-50°C for 24 hr. After digestion samples without CWTs were poured directly through sieves. Hard matter caught in the sieves was rinsed with hot tap water. If hot water did not clear away fat sufficiently, the hard parts (bones) were soaked in lye and re-rinsed.

Preyfish were characterized and enumerated by separating, identifying to species, and pairing diagnostic bones (dentaries, cleithra and opercula) with dissecting microscopes and forceps. Diagnostic bones and other hard parts were preserved in labeled vials of 95% ethanol.

Bags containing CWTs were flagged when they were checked during thawing. After blotting and weighing, flagged samples were rechecked for CWTs along with the blotting paper and tools used in analysis to preclude loss of the tags, CWTs were removed from flagged samples before sieve rinsing. CWTs in the slurry of bones and digested soft parts were found by probing the bag contents with magnetized steel rods. The tags were placed in labeled vials for later identification.

Smallmouth Bass / Walleye

Smallmouth bass and walleye stomach samples often contained relatively undigested fish, which were measured as soon as the samples were thawed. Fork lengths of undigested fish were obtained if possible; if not, then standard or nape lengths. The preyfish were returned to the sample bags and, along with the samples containing fish that were macerated or too digested to measure, were processed in the same manner as northern sguawfish gut contents.

Consumption Index

Detailed methods and index derivation for the northern sguawfish CI were presented in Petersen et al. (1990); an abbreviated description of the CI is presented here for completeness.

The estimated number of salmonids consumed per day by an individual predator, p, can be expressed as:

$$C_p = \sum_{i=1}^{n} 1 / (\text{Evacuation time for prey item } i)$$

or,

$$C_p = \sum_{i=1}^{n} 1 / D90_i \qquad (1)$$

where C_p is consumption rate (number of salmonids . individual northern squawfish^{-1} $\cdot$ day-'), $D90_i$ is number of days to 90% digestion for salmonid prey item i, and n is total number of salmonids found in the digestive tract. Using 90% digestion time, rather than l00%, avoids the problem of non-digestible prey parts that may remain in the digestive tract for extended periods. Equation (1) is equivalent to:

$$C_p = \sum_{i=1}^{n} (24 / T90_i) \qquad (2)$$

where $T90_i$ is number of hours to 90% digestion for the ith salmonid prey item. $T90_i$ was calculated by Beyer et al. (1988) and modified by Rieman et al. (1988) to:

$$T90_i = 1147 * M_i^{0.61} * T^{-1.60} * W_p^{-0.27} \qquad (3)$$

where M_i is meal size (g) at time of ingestion of salmonid prey item i, T is water temperature (°C), and W_p is predator weight (g). Substituting equation 3 into 2 and rearranging gives:

$$C_p = 0.0209 * T^{1.60} * W_p^{0.27} * \sum_{i=1}^{n} M_i^{-0.61} \qquad (4) .$$

Equation 4 provides an estimate of daily salmonid consumption per northern squawfish, but still requires estimation of meal size (M_i) through intensive analysis of gut contents and complicated data analysis. The following formula was chosen as a CI, based upon simplicity of data required and percent variance explained:

$$CI = 0.0209 * T^{1.60} * MW^{0.27} * [MTsal * MGutwgt^{-0.61}] \qquad (5)$$

where T is water temperature, MW is mean predator weight (g), MTsal is mean number of salmonids per predator, and MGutwgt is mean weight (g) of gut contents. All variables in CI are averaged over all predators in a sample: CI is the consumption index for a collection (sample) of predators.

The CI for northern squawfish, as derived above, is not meant to be a rigorous method for estimating the number of juvenile salmonids eaten per day by an average predator. The CI is based upon the simple idea of meal turnover times and does not consider such aspects of consumption as die1 feeding pattern and evacuation rate of prey. In an analysis of data from John Day Reservoir (Petersen et al. 1990) the consumption rate of northern squawfish (CR - juvenile salmonids$\cdot$predator$^{-1}\cdot$day^{-1}) was related to CI by:

$$\log_{10}(CR) = 1.17 * \log_{10}(CI) - 0.41 \qquad \underline{N} = 86 \qquad r^2 = 0.89 .$$

Distribution characteristics of the northern squawfish CI were computed by a bootstrap resampling technique (Efron and Tibshirani 1986; Petersen et al. 1990). For each sample of **N** predators, a computer program randomly selected **N** individual predator records and calculated a new CI. Five hundred CI's were computed for each CI distribution; preliminary studies showed that variances and confidence bounds were stable with 500 samples. The number of predators per bootstrap sample was set to the original sample size (N), or 60 if **N** was greater than 60.

RESULTS

Catch

During 1992 sampling, 1,911 target predators were captured (Table 2) in the lower Columbia River downstream of Bonneville Dam and in John Day Reservoir, including 1,689 northern squawfish (89%), 198 smallmouth bass (10%), and 24 walleye (1%). Non-target piscivores were also collected, including yellow perch Perca flavescens (N = 14), black bullhead Ictalurus melas (N = 2) and largemouth bass Micropterus salmoides (N = 2). Incidentally collected fish species commonly observed included suckers Catostomus spp., carp Cvprinus carpio, and peamouth Mvlocheilus caurinus. Starry flounder Platichthvs stellatus, a euryhaline marine species, were encountered in the lower river downstream of Covert's Landing (220-225 Rkm). Juvenile and adult salmon Onchorvnchus spp., steelhead Onchorvnchus mvkiss, and white sturgeon Acioenser transmontanus were occasionally shocked during sampling. When this occurred, electroshocking was delayed long enough to allow these fish to swim or drift out of the current field.

Catches of northern squawfish were generally higher in the free-flowing, lower river sites compared to John Day Reservoir sites (Table 2). Northern squawfish captured from the lower Columbia River accounted for 88% of the northern squawfish catch for 1992. Highest catches for northern squawfish occurred in the Bonneville Dam tailrace where 20% of all northern squawfish were collected. Overall catch was higher during the summer sampling period compared to the spring sampling period (Table 2).

Sex and gonad maturity were determined on northern squawfish when possible. Seventy-five percent of captured northern squawfish were sexed, 82% were females and 18% were males. During the spring sampling period, 74% of northern squawfish had developing gonads, 8% were immature and 18% could not be staged. During the summer, 5% of northern squawfish had developing gonads, 15% were ripe, 46% were spent, 5% were immature and 29% could not be staged.

Mean forklength of northern squawfish collected throughout

Table 2. Number of major predators collected during consumption indexing sampling in 1992. N =Total number, M=males, F=females, U=unidentified sex, SMB=Smallmouth Bass, WAL=Walleye, YLP=Yellow Perch. Northern squawfish catch is all predators, including those <250 mm FL. See Table 1 for description of locations.

Location	Northern Squawfish				SMB	WAL	YLP
	N	M	F	U	N	N	N
Spring							
Lower River							
Jones Beach	56	13	13	30	0	0	0
Rainer	75	9	35	31	0	0	0
Kalama	47	4	30	13	2	0	0
St. Helens	67	5	55	7	0	1	0
St. Johns	71	6	57	8	0	2	0
Vancouver	97	22	60	15	17	4	1
Blue Lake	71	3	56	12	6	3	0
Rooster Rock	37	9	22	6	0	2	0
Covert's Landing	34	4	26	4	0	0	0
Bonneville Dam Tailrace	127	12	79	36	6	3	0
John Day Reservoir							
John Day Dam Forebay	38	12	26	0	46	0	0
John Day Mid-Reservoir	8	2	6	0	19	0	0
McNary Dam Tailrace	44	7	38	0	1	7	0
Spring Total	772	107	503	162	97	22	1
Summer							
Lower River							
Jones Beach	59	5	26	27	0	0	0
Rainer	106	9	46	51	1	0	0
Kalama	79	0	28	51	1	0	1
St. Helens	89	5	64	20	0	0	2
St. Johns	82	2	52	28	1	0	9
Vancouver	47	5	28	14	13	1	0
Blue Lake	72	19	24	29	16	0	0
Rooster Rock	38	12	10	16	7	0	0
Covert's Landing	17	1	6	10	6	0	1
Bonneville Dam Tailrace	216	45	155	16	5	1	0
John Day Reservoir							
John Day Dam Forebay	29	8	21	0	36	0	0
John Day Mid-Reservoir	13	4	8	1	7	0	0
McNary Dam Tailrace	70	4	65	1	8	0	0
Summer Total	917	119	533	264	101	2	13

the John Day Reservoir ($\bar{X}$=410 mm FL, range 113 - 520 mm) were significantly larger (t-test; P<0.001) than fish collected in the lower river ($\bar{X}$=320 mm FL, range 83 - 548 mm). Average forklength for northern sguawfish was 388 mm for females (**N** = 1,036) and 304 mm for males (**N** = 226); weights ranged from 44 g to 2,550 g ($\bar{X}$=638 g, **N** = 1,502).

Smallmouth bass was the second most abundant predator (Table 2), with 117 (59%) collected in John Day Reservoir and 81 (41%) from the lower river. Highest catches for smallmouth bass occurred in the John Day Dam forebay location (**N** = 82). Forklengths of all smallmouth bass ranged from 140 mm to 436 mm ($\bar{X}$=256 mm, **N** = 198) and weights ranged from 30 g to 1,470 g ($\bar{X}$=312 g).

Diet of Northern Sguawfish

The gut contents of 1,484 sguawfish were examined in the laboratory. The diet of smaller sguawfish (< 250 mm FL: **N** = 270) was mostly insects and small crustaceans (primarily corophium sp.). The diet of the larger fish (≥ 250 mm FL: **N** = 1,214) was dominated by fish and crustaceans (69.7% and 14.6%, respectively, over all areas and seasons: Table 3).

Lower Columbia - In the spring, northern squawfish diet was primarily fish (46-78%) at the nine downstream locations (Table 3). The majority (> 60%) of fish in the diet were salmonids, except at Jones Beach (33% salmonids). During summer, diet was largely fish between Jones Beach and Blue Lake (44-62%, except Vancouver 28%), but crustaceans were more important at the other locations (Table 3). Over 75% of the ingested preyfish at St. Johns, Vancouver, and Blue Lake were salmonids. Insects also formed a substantial part of the diet during summer in all but one of the Lower Columbia locations. The mean weight of gut contents decreased slightly between spring (8.4 g) and summer (5.1 g), while the percentage of empty digestive tracts did not change appreciably between seasons (Table 3).

Bonneville Dam Tailrace - The diet of sguawfish in the two areas within this location, BRZ and non-BRZ, was markedly

Table 3. Gut content of northern squaufish collected at locations in the lower Columbia River and John Day Reservoir (Mid-Colum.) during 1992. Gut contents (%) are the mean percentages of individual northern squaufish. Crust.=crustacean; Moll.=mollusk; BRZ=boat restricted zone.

LOCATION	N	Mean gut wt (g)	% emty guts	GUT CONTENTS (%) Fish	Crust.	Moll.	Insect	Plant	Other
SPRING SEASON									
Lower Columbia									
Jones Beach	25	10.83	36.0	63.9	22.1	0.8	7.0	0.0	6.2
Ranier	44	8.12	40.9	77.6	7.7	2.9	0.0	11.0	0.9
Kalama	33	5.96	51.5	46.2	51.9	1.0	0.0	1.8	0.0
St. Helens	57	10.35	40.4	75.5	14.5	3.0	3'0 29	5.9	0.2
St. Johns	60	6.09	45.0	67.7	12.1	[illegible]	[illegible]	11.1	3.0
Vancouver	71	7.15	38.0	70.8	13.6	0.0	4.5	6.2	4.7
Blue Lake	61	7.42	41.0	77.8	5.6	0.0	0.0	13.9	2.8
Rooster Rock	33	8.55	51.5	47.1	46.6	4.5	9.1 0.0	0.0	6.3
Coverts Landing	32	14.87	31.3	72.7	9.1			4.6	0.0
All Lower Columbia sites total:	416	8.41	41.59	69.34	16.56	1.32	2.93	7.23	2.22
Bonneville Tailrace									
Non-BRZ	22	7.07	54.5	59.7	10.0	10.0	20.3	0.0	0.0
BRZ	77	12.76	33.8	86.3	5.9	2.0	3.9	0.0	2.0
John Day Reservoir									
John Day Forebay	37	13.23	27.0	72.3	9.2	0.0	3.7	11.1	3.7
John Day Mid-res.	8	16.51	25.0	15.0	50.7	17.7	11.8	0.0	4.8
McNary Tailrace-									
Non-BRZ	9	3.90	66.7	9.9	70.5	0.0	0.0	0.0	19.6
BRZ	35	21.52	20.0	96.4	0.0	0.0	3.6	0.0	0.0
SUMNER SEASON									
Lower Columbia									
Jones Beach	40	2.91	40.0	58.0	12.5	4.2	16.7	4.2	4.5
Ranier	47	3.16	42.6	57.9	5.5	10.0	8.7	9.8	7.0
Kalama	30	3.65	43.3	52.7	23.5	0.6	11.8	0.2	11.8
St. Helens	56	9.39	26.8	61.6	27.8	[illegible]		0.0	7.6
St. Johns	59	5.26	44.1	60.5	18.3	0.0	2:::	0.0	0.0
Vancouver	21	6.16	28.6	28.2	45.2	0.0	20.0	6.7	0.0
Blue Lake	35	5.57	34.3	43.5	33.0	0.0	14.9	8.7	0.0
Rooster Rock	19	2.52	68.4	5.6	61.1	0.0	33.3	0.0	0.0
Coverts Landing	5	0.00	100.0				-		
All Lower Columbia sites total:	312	5.07	40.4	52.85	23.61	2.28	13.33	3.59	4.33
Bonneville Tailrace									
Non-BRZ	43	5.19	48.8	49.5	22.0	8.4	11.0	0.0	9.1
BRZ	147	17.42	19.7	90.8	4.1	0.0	2.5	2.6	0.0
John Day Reservoir									
John Day Forebay	27	3.28	37.0	29.4		0.0	59.5	0.0	5.9
John Day Mid-res.	13	3.43	46.2	0.0	5:::	0.0	28.6	14.3	0.0
NcNary Tailrace-									
Non-BRZ	1	0.00	100.0						
BRZ	67	12.58	32.8	98.2	1.8	0.0	0.0	0.0	0.0

different. The diet within the BRZ was principally fish (86% in spring, 91% in summer), while the share of fish in the non-BRZ was 50-60%. Northern squawfish collected in the non-BRZ contained substantial amounts of crustaceans, mollusks, and insects. The ratio of mean weight of gut contents in Bonneville Dam tailrace BRZ to non-BRZ samples was 1.8 in spring and 3.4 in summer (Table 3). Overall, the highest ratio of salmonids per squawfish (3.5) was found in squawfish from the Bonneville Dam tailrace BRZ collected during summer (Table 4).

John Day Reservoir - The percent of fish in northern squawfish from John Day Dam forebay declined from 72% in spring to 29% in summer (Table 3); the ingested preyfish in the forebay were exclusively salmonids. At the John Day mid-reservoir location, over 50% of the northern squawfish diet was crustaceans, with the remainder of the diet being mainly mollusks, fish, insects, and plants. No salmonids were found in northern squawfish from the mid-reservoir, although sample sizes were relatively small (spring N = 8; summer **N** = 13). In the McNary Dam tailrace BRZ, gut contents were almost entirely fish; salmonids comprised all but one of 162 enumerated preyfish (Table 4). The number of salmonids per squawfish in the BRZ nearly doubled from spring to summer.

Fish formed a very large part of the diet in the **BRZs** of John Day Dam forebay and McNary Dam tailrace; the mean weight percent of fish in gut contents over both seasons being 91.9%. The occurrence of salmonid preyfish in northern squawfish was higher in BRZs (2.28 **salmonids·fish**$^{-1}$) than at other areas (0.46 **salmonids·fish**$^{-1}$; Table 4). Fish eaten within the BRZs were almost exclusively salmonids. The percentage of salmonids among enumerated preyfish from BRZ and all other areas was 99.5% and 71.2%, respectively.

Only 122 non-salmonid fish were counted in the gut contents, of which nearly half were sculpins. Other fish found in descending order of abundance were: threespine stickleback (Gasterosteus aculeatus), peamouth (Mylocheilus caurinus), redside shiner (Richardsonius balteatus), northern squawfish,

Table 4. Prey fish consumed by northern squawfish (SQF) collected et locations in the lower Columbia River and John Day Reservoir (Mid-Columbia) during 1992. FL=forklength; Mean Fish Wt.=mean prey fish mass (g) per predator; % molts = percent of the total number of fish consumed that were smolts.

PREDATORS			PREY FISH CONSUMED					
RESERVOIR Location	N	Mean FL (mm)	Mean Fish ut. (9)	Total # Smolts	# Smolts Per SQF	% Smolts	Total # Other Fish	% Other Fish
SPRING SEASON								
Lower Colunbia								
Jones Beach	25	266	19.90	2	0.080	33.3	4	66.7
Ranier	44	292	14.67	17	0.386	68.0	8	32.0
Kalama	33	343	15.18	9	0.273	81.8	2	18.2
St. Helens	57	363	21.74	29	0.509	90.6	3	9.4
St. Johns	60	361	14.72	27	0.450	90.0	3	10.0
Vancouver	71	320	13.06	62	0.873	92.5	5	7.5
Blue Lake	61	352	14.87	53	0.869	94.6	3	5.4
Rooster Rock	33	361	28.31	8	0.242	61.5	5	38.5
Coverts Landing	32	380	22.93	27	0.844	100.0	0	0.0
ALL lower Columbia sites total:	416	373	17.21	234	0.563	87.6	33	12.4
Bonneville Tailrace								
Non-BRZ	22	322	20.23	8	0.364	100.0	0	0.0
BRZ	77	377	22.11	61	0.792	96.8	2	3.2
John Day Reservoir								
John Day Forebay	37	396	23.90	42	1.135	100.0	0	0.0
John Day Mid-res.	8	382	10.76	0	0.000	0.0	1	100.0
McNary Tailrace-								
Non-BRZ	9	397	5.90	0	0.000	0.0	1	100.0
BRZ	35	430	27.88	33	0.943	97.1	1	2.9
SUMMER SEASON								
Lower Columbia								
Jones Beach	40	298	5.11	2	0.050	7.7	24	92.3
Ranier	47	259	7.86	7	0.149	36.8	12	63.2
Kalama	30	268	6.72	0	0.000	0.0	11	100.0
St. Helens	56	310	9.78	18	0.321	45.0	22	55.0
St. Johns	59	306	9.56	22	0.373	78.6	6	21.4
Vancouver	21	276	9.82	11	0.524	84.6	2	15.4
Blue Lake	35	265	11.19	31	0.886	96.9	1	3.1
Rooster Rock	19	276	3.56	0	0.000	0.0	2	100.0
Coverts Landing	5	253	0.00	0	0.000	-	0	0.0
All lower Columbia sites total:	312	349	21.00	91	0.292	53.2	80	46.8
Bonneville Tailrace								
Non-BRZ	43	313	14.95	25	0.581	92.6	2	7.4
BRZ	147	381	23.07	520	3.537	99.8	1	0.2
John Day Reservoir								
John Day Forebay	27	381	12.98	6	0.222	100.0	0	0.0
John Day Mid-res.	13	389	0.00	0	0.000	0.0	1	100.0
McNary Tailrace-								
Non-BRZ	1	221	0.00	0	0.000	.	0	0.0
BRZ	67	438	18.52	129	1.925	100.0	0	0.0

chiselmouth (Acrocheilus alutaceus), and single specimens of a few species. Lamprey (Entosphenus tridentatus) teeth were found in 14 samples.

Diet of smallmouth bass

Of 198 smallmouth bass collected, 47 had empty stomachs while many samples had nothing more than traces of insects or crustaceans. Smallmouth bass stomachs contained 89 preyfish: 22 salmonids, 26 sculpins, 31 preyfish were other species (northern squawfish, sucker, peamouth, Micronterus sp., carp, and red-sided shiner, in descending order of abundance), and ten preyfish could not be identified. More salmonids (73%) and sculpins (69%) were collected during spring than during summer (27% and 31%, respectively). More smallmouth bass (N = 82) were caught in the John Day Dam forebay than at any other location. The preyfish over both seasons from that location included: 7 salmonids, 9 sculpins, and 8 unidentified species.

Northern Squawfish Consumption Index

At locations along the lower Columbia River (below Bonneville Dam), consumption indices (CI) ranged from 0 to 1.6 during the spring season and from 0 to 3.2 during summer (Table 5). The CI's varied considerably among sites during the summer (CV = 120%) and moderately (CV = 55%) in the spring. During the spring, CI's in the lower Columbia River ranged from 0.2 to 1.6 with the highest indices being at the Blue Lake and Vancouver locations. During summer, CI's were relatively high at four locations between St. Helens and Blue Lake (1.0 - 3.2: Table 5), and lower at the other sample locations (<0.7; Table 5).

Northern squawfish consumption in the Bonneville Dam tailrace was much higher within the BRZ (spring = 1.0; summer = 7.8) than at non-BRZ sites (spring = 0.5; summer = 2.1; Table 5). During the summer sampling period, northern squawfish catch and CI within the Bonneville Dam tailrace BRZ were more than double those at any other location in the lower river.

During spring, John Day Reservoir CI values ranged from 0 to

Table 5. Northern Squawfish consumption indices (CI) at locations in the lower Columbia river and John Day Reservoir (Mid-Columbia) during 1992. Note that a CI of 0.0 means no juvenile salmon were found in the predator digestive tracts. CI is the consumption index for the original sample (N). Mean CI, standard deviation (SO), coefficient of variation (CV%) and quartiles are given for the 500 bootstrap samples. BRZ=boat restricted zone.

RESERVOIR Locat ion	N	CI	Bootstrap Summary Mean	so	CV(%)	Quartiles 25th	25th
SPRING SEASON							
Lower Colunbia							
Jones Beach	25	0.1	0.2	0.1	77.3	0.1	0.2
Ranier	44	0.7	0.7	0.1	18.4	0.6	0.8
Kalama	33	0.6	0.6	0.2	35.2	0.5	0.7
St. Helens	57	0.8	0.8	0.1	15.0	0.7	0.8
St. Johns	60	0.9	0.9	0.2	22.3	0.8	1.1
Vancouver	71	1.3	1.3	0.3	20.5	1.1	1.5
Blue Lake	61	1.6	1.6	0.3	17.1	1.4	1.8
Rooster Rock	33	0.4	0.4	0.1	38.1	0.3	0.5
Coverts Landing	32	1.0	1.0	0.2	22.8	0.8	1.2
Bonneville Tailrace							
Non-BRZ	22	0.5	0.5	0.2	42.1	0.4	0.7
BRZ	77	1.0	1.0	0.1	13.7	0.9	1.1
John Day Reservoir							
John Day Forebay	37	1.9	1.9	0.4	20.4	1.6	2.1
John Day Mid-res.	8	0.0	0.0	0.0			
McNary Tailrace-							
Non-BRZ	9	0.0	0.0	0.0			
BRZ	35	0.9	0.9	0.1	11.2	0.9	1.0
SUMMER SEASON							
Lower Columbia							
Jones Beach	40	0.2	0.2	0.1	68.0	0.1	0.3
Ranier	47	0.6	0.6	0.4	63.8	0.3	0.8
Kalama	30	0.0	0.0	0.0		0.0	0.0
St. Helens	56	1.0	1.0	0.3	24.9	0.9	1.2
St. Johns	59	1.5	1.5	0.4	29.7	1.2	1.8
Vancouver	21	1.7	1.7	1.2	67.7	0.9	2.4
Blue Lake	35	3.2	3.1	1.1	33.9	2.4	3.8
Rooster Rock	19	0.0	0.0	0.0		0.0	0.0
Coverts Landing	5	0.0	0.0	0.0		0.0	0.0
Bonneville Tailrace							
Non-BRZ	43	2.1	2.1	0.9	42.3	1.4	2.7
BRZ	147	7.8	7.8	0.8	9.8	7.3	8.3
John Day Reservoir							
John Day Forebay	27	0.7	0.7	0.3	35.2	0.5	0.9
John Day Mid-res.	13	0.0	0.0	0.0		0.0	0.0
McNary Tai lrace-							
Non-BRZ	1	0.0	0.0	0.0		0.0	0.0
BRZ	67	4.6	4.5	0.4	9.8	4.2	4.8

1.9 while summer CI's were from 0 to 4.6 (Table 5). Both northern squawfish catch and CI's were higher near the dams than at the mid-reservoir locations, where the CI was zero. The highest catch and CI in John Day Reservoir occurred in the McNary Dam tailrace BRZ during the summer.

DISCUSSION

Catch

During 1992, catches of northern squawfish at lower Columbia River sites were higher than catches at the John Day mid-reservoir location (Table 2) and at mid-reservoir locations sampled in previous years (Petersen et al. 1990; Shively et al. 1991). Relatively high catches of northern squawfish observed in the lower Columbia River, compared to mid-reservoir locations, may have been caused by differences in morphology and substrate, and how these relate to electroshock efficiency or size structure of the population.

The large numbers of northern squawfish collected in the lower Columbia River may be related to a gently-sloping littoral zone with many obstructions to river flow. Nearshore areas in several reservoirs have steep grades with large cobble-rock substrate. Large numbers of northern squawfish were also associated with jetty pilings at lower river sites, perhaps congregating near flow shears and avoiding high velocity water (see also Faler et al. 1988). Backeddies created by jettys may have attracted northern squawfish (and some preyfish) since less energy would be required in these calm areas.

Electroshock efficiency may have been higher in the broad littoral zones in the lower Columbia River, where water-depth is fairly consistent. Water-depth influences the range of electroshocking gear by affecting current density. Current is dispersed over a greater area in deep water, decreasing the effective sampling field. Bottom substrate conductivity also alters current density and effective range. Gravel, rock and sand bottoms conduct less electricity than substrates with fine particulates and large amounts of organic debris (Reynolds 1983).

Uniform water-depths and sandy bottom substrate may have increased the catch of northern squawfish on the lower river by increasing electroshocking performance.

The average size of northern squawfish caught in the lower Columbia River was less than squawfish caught in John Day Reservoir, primarily because of the large number of northern squawfish (200 mm FL collected below Bonneville Dam. The increased abundance of small northern squawfish in the lower river may have been related to the broader littoral zone.

Northern Squawfish Consumption Indices

As in previous years, consumption indices (CI's) for northern squawfish were highest near hydroelectric projects, especially in dam tailraces during the summer. In the Bonneville Dam tailrace BRZ, summer CI's were higher during 1992 (7.8) than was observed during summer 1990 (4.6; Petersen et al. 1991), although CI's measured in this BRZ during spring 1990 and 1992 showed the opposite pattern (2.5 vs. 1.0, respectively). Individual northern squawfish from the Bonneville Dam tailrace BRZ contained as many as 18 salmonids during 1992. Over three years, spring CI's at McNary Dam BRZ have been 2.4 (1990), 1.5 (1991) I and 0.9 (1992) while summer CI's were 11.2 (1990), 2.8 (1991) I and 4.6 (1992) (Petersen et al. 1990; Shively et al. 1991, this report). Consumption of salmonids varied between consecutive years by +64% to -75% at this location. Sample sizes of northern squawfish in the John Day Dam forebay were often below our target minimum, making interannual comparison of consumption rates at this location more equivocal.

Consumption rate of salmonids by northern squawfish appears to be particularly high in the free-flowing river below Bonneville Dam, especially compared to mid-reservoir locations sampled during the spring outmigration period. During spring 1992, the mean CI at the nine lower Columbia River sample locations was 0.8 (range 0.2 - 1.6). By comparison, the mean CI at "mid-reservoir" locations between Bonneville Dam and Ice Harbor Dam (lower Snake River) was 0.1 (range 0.0 - 0.5; Petersen et al. 1990; Shively et al. 1991). Spring consumption indices were zero at the four mid-reservoir locations in the lower Snake River during 1991 (Shively et al. 1991).

Consumption of salmonids by northern squawfish during the summer was highly variable among the nine sites in the lower Columbia River (mean 0.9; range 0.0 to 3.1). Summer consumption indices were also variable at mid-reservoir locations between Bonneville Dam and Ice Harbor Dam (mean 0.8; range 0.0 - 1.6; Petersen et al. 1990; Shively et al. 1991). Summer CI's were not estimated in the lower Snake River since few salmonids migrate through the Snake after May.

Variability in consumption indices among sample locations may be caused by different water flow patterns in various river sections, prey density differences between upper and lower river areas, or by sampling problems. At sample locations in the lower river, the majority of predators was frequently collected from only a few transects. Wing-dams (groins), points, jettys, and other obstructions are common in the lower river, creating backeddies where predators often congregated. Northern squawfish were frequently caught in calm microhabitats such as the backeddy just behind a piling, although water velocity just a meter or two away was often quite high. In-river obstructions and the generally shallow depth of the river below Bonneville Dam may also make salmonids more vulnerable to predators.

Higher prey densities below Bonneville Dam might explain some of the relatively high CI's observed in this river reach. All migrating salmonids must pass through the lower river, including wild fish, most hatchery-reared fish, and fish transported from Lower Granite, Little Goose, or McNary dams, which are released just below Bonneville Dam. Combined salmonid numbers from these sources would likely cause densities to be somewhat higher in the lower river than within Bonneville or The Dalles reservoir, for example, where summer consumption indices were zero. A generally higher prey density throughout the lower river cannot explain the complex spatial pattern of northern squawfish CI's below Bonneville Dam.

Sample timing and sample size are also considerations when making spatial or temporal comparisons among consumption indices. Sample timing throughout the river system was based on hatchery release dates and historic passage of juvenile salmonids. Spring and summer sampling at John Day Reservoir locations during 1992 coincided well with peak passage over McNary Dam (Figure 2). Only summer sampling at the John Day Dam forebay was poorly timed, occurring just after the high passage indices at McNary Dam (Figure 2). Spring sampling in Bonneville Dam tailrace fell between two major pulses of outmigrants over Bonneville Dam (likely hatchery releases), while summer sampling in the Bonneville Dam tailrace occurred during peak passage (Figure 2). We did not show sample times in Figure 2 for the lower Columbia River locations since lower river sites are distant from Bonneville Dam, and timing of downstream passage might not coincide with Bonneville Dam passage.

Sample size was not a problem in the lower river during 1992 since catches were generally above our target minimum (30 northern squawfish). Collecting adequate numbers of northern sguawfish to make consumption estimates has, however, been an occasional problem during sampling further upriver, especially at mid-reservoir locations (Petersen et al. 1990; Shively et al. 1991).

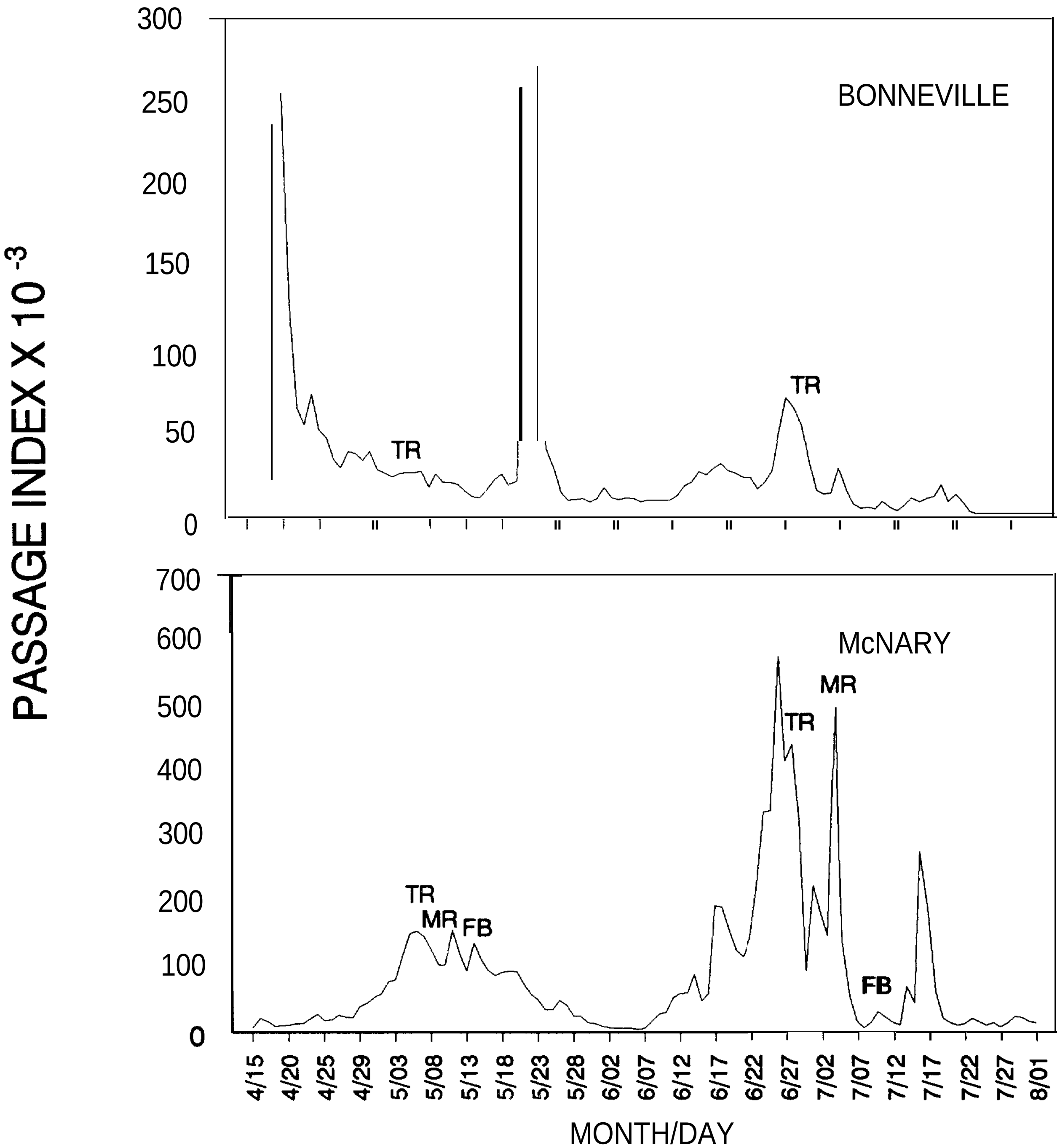

Figure 2 Timing of Consumption Index sampling during 1992 with respect to juvenile salmonid passage indices at mainstem dams. Approximate sample times for tailrace (TR), and immediate downstream mid-reservoir (MR), and forebay (FB) locations are shown in panals. The MR locator in the McNary panal, for example, actually represents sampling within the John Day mid-reservoir. Passage data from the Fish Passage Center 1992 Biweekly Reports.

LITERATURE CITED

Beyer, J. M., G. Lucchetti, and G. Gray. 1988. Digestive tract evacuation in northern sguawfish (Ptvchocheilus oreaonensis). Canadian Journal of Fisheries and Aquatic Science 45:548-553.

Bledsoe, L. J., S. Vigg, and J. H. Petersen. 1990. Simulation estimates of salmonid predation loss to northern sguawfish in a Columbia River reservoir. Pages 206-220. In: Nigro et al. 1990.

CQS (Center for Quantitative Science, University of Washington). 1991. Columbia River Passage Model, Documentation for CRiSP.l, DRAFT (August 16, 1991). Bonneville Power Administration, Portland, OR.

Efron, B. and R. Tibshirani, 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science, 1:54-77.

Jeppson, P. W. and W. S. Platts. 1959. Ecology and control of Columbia squawfish in northern Idaho lakes. Transactions of the American Fisheries Society 88:197-202.

Lee, D. C. 1991. A stochastic, compartmental model of the migration of juvenile anadromous salmonids in the Columbia River Basin. Ecological Modelling 54:227-245.

MEG (Monitoring and Evaluation Group). 1989. System planning model documentation. Northwest Power Planning Council, Portland, OR.

Nigro, A. A., S. Vigg and C. Burley. 1990. Development of a system-wide predator control program: Stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River Basin. Annual Progress Report, August 1988 - September 1989, Project Summary. Project Number 82-028, Bonneville Power Administration, Portland, OR.

Petersen, J. H., M. G. Mesa, J. Hall-Griswold, W. C. Schrader, G. W. Short and T. P. Poe. 1990. Magnitude and dynamics of predation on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report of Research, 1989-1990. Bonneville Power Administration, Portland, OR.

Petersen, J. H., D. B. Jepsen, R. G. Nelle, R. S. Shively R. A. Tabor and T. P. Poe. 1991. System-wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report of Research, 1990. Bonneville Power Administration, Portland, OR.

Reynolds, J.B. 1983. Electrofishing. In: L. A. Nielsen and D.L.

Johnson (eds.). Fisheries Techniques. Southern Printing Company, Inc., Blacksburg, VI.

Ricker, W.E. 1941. The consumption of young sockeye salmon by predaceous fishes. Journal of the Fisheries Research Board of Canada 5:293-313.

Rieman, B. E., R. C. Beamesderfer, S. Vigg and T. P. Poe. 1988. Predation by resident fish on juvenile salmonids in a mainstem Columbia Reservoir: Part IV. Estimated total loss and mortality of juvenile salmonids to northern sguawfish, walleye, and smallmouth bass. In: T. P. Poe and B. E. Rieman (eds.), 1988. Predation by resident fish on juvenile salmonids in John Day Reservoir, 1983-86. Final Report, (Contracts DE-A179-82BP34796 and DE-A179-82BP35097) Bonneville Power Administration, Portland, OR.

Seaburg, K. G. 1957. A stomach sampler for live fish. Progressive Fish Culturist 19:137-139.

Shively, R. S., R. A. Tabor, R. D. Nelle, D. B. Jepsen, J. H. Petersen, S. T. Sauter, and T. P. Poe. 1991. System-wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report of Research, 1991. Bonneville Power Administration, Portland, OR.

Thompson, R. B. and D. F. Tufts. 1967. Predation by Dolly Varden and northern sguawfish on hatchery-reared sockeye salmon in Lake Wenatchee, Washington. Transactions of the American Fisheries Society 96:424-427.

vigg, S., T. P. Poe, L. A. Prendergast, and H. C. Hansel. 1988. Predation by resident fish on juvenile salmonids in a mainstem Columbia River Reservoir: Part II. Consumption rates of northern sguawfish, walleye, smallmouth bass, and channel catfish. In: Poe, T. P. and B. E. Rieman (eds.), 1988. Predation by resident fish on juvenile salmonids in John Day Reservoir, 1983-86. Final Report, (Contracts DE-A179-82BP34796 and DE-A179-82BP35097) Bonneville Power Administration, Portland, OR.

vigg, S. and C. C. Burley. 1990. Report A - Developing a predation index and evaluating ways to reduce juvenile salmonid losses to predation in the Columbia River. In: A. A. Nigro (ea.), 1990. Developing a predation index and evaluating ways to reduce salmonid losses to predation in the Columbia River Basin. 1989 Annual Progress Report. Bonneville Power Administration, Portland, OR.

Reproduction and early life history of northern squawfish *Ptvchocheilus oreaonensis* in the Columbia River

Dena M. Gadomski, Alice M. Murphy, and Craig A. Barfoot

U.S. Fish and Wildlife Service

National Fishery Research Center

Columbia River Field Station

Star Route, Cook WA 98605

ABSTRACT

Little is known about northern squawfish *Ptvchocheilus oreaonensis* reproduction and early life history in the Columbia River. Our objectives were to locate spawning sites, describe larval and juvenile rearing areas, and characterize larval drift. Sampling with boat-towed plankton nets and a manually-pulled shoreline sled was conducted primarily during June-September 1992 in The Dalles Pool, the upper Bonneville Pool, and the lower Deschutes River. Sample processing has not been completed, and thus results are incomplete. However, preliminary data suggest that shallow areas of the Deschutes River are being used as northern squawfish larval and YOY juvenile rearing areas. Low numbers of larval northern squawfish were collected during plankton sampling in the Deschutes River and the upper Dalles Pool: samples have not been examined from the lower Dalles Pool and the upper Bonneville Pool. During die1 plankton sampling in the upper Dalles Pool, almost all northern squawfish/chiselmouth *Acrocheilus alutaceus* larvae (small larvae of these two species cannot be separated) were collected at night, suggesting a nocturnal pattern of abundance perhaps due to increased downriver drift at night. Further research is necessary to locate northern squawfish spawning and rearing areas, including more sampling at night and in tributaries.

ACKNOWLEDGEMENTS

J. Petersen, S. Sauter, and T. Olson helped with field work. Special thanks to G. Schultz, G. Wiebe, M. Sheer, G. Holmberg, and B. Klatte for processing samples. J. Petersen provided useful comments on the manuscript. This project was funded by the Bonneville Power Administration and administered by W. Maslen.

INTRODUCTION

Northern sguawfish _Ptvchocheilus oreaonensis_ have been identified as major predators of juvenile salmonids migrating downstream through Columbia River dams and reservoirs (Poe et al. 1991). Because of this, a variety of northern squawfish removal fisheries have been implemented. Long-term management requires basic knowledge of reproduction, early life history, and factors influencing these processes, since the strength of a year-class may be determined by the survival of egg, larval, and juvenile stages. Additionally, as part of an effort to evaluate the northern squawfish removal program, it is of value to monitor larval and juvenile sguawfish abundances as indicators of population responses since compensatory mechanisms could result in enhanced recruitment.

Little published information exists concerning northern sguawfish reproduction and early life history, particularly in the Columbia River system. Northern sguawfish are broadcast spawners with benthic adhesive eggs (Olney 1975). Squawfish form large spawning aggregations in some areas (Jeppson 1957; Casey 1962; Olney 1975). Spawning has been reported to occur on sites with rubble-cobble substrates and at a variety of water depths (Jeppson and Platts 1959; Patten and Rodman 1969; Beamesderfer 1992). Northern sguawfish spawning has not been described in the Columbia River, but high densities of larval northern sguawfish have been observed in upper littoral habitats of the John Day Pool (Hjort et al. 1981; LaBolle 1984; LaBolle et al. 1985).

In 1992 we initiated a field program to study northern squawfish reproduction and early life history in the Columbia River Basin. We sampled in the upper Bonneville Pool, the upper and lower Dalles Pool, and the Deschutes River. Our objectives were to locate spawning sites, characterize larval and juvenile rearing areas, and describe larval drift between these locations. Physical parameters were measured concurrent with sampling to determine how environmental factors may influence production and survival of eggs and larvae or affect spatial and temporal distribution patterns of larvae and juveniles. Because sample processing has not been completed, we present preliminary results from the upper Dalles Pool and from the Deschutes River.

METHODS

Sample Collection

Overview.- Sample areas were chosen based on substrate type and to compare mainstem to tributary areas. The upper Bonneville and upper Dalles Pools contain sites with large proportions of potential northern squawfish spawning habitat (gravel/rubble/cobble), identified by cartographic modeling with a geographic information system (GIS) (Gadomski and Murphy 1991). For comparison, we also sampled in the lower Dalles Pool, an area with little potential northern squawfish spawning substrate.

Samples were collected weekly from late May through mid-September 1992 at four locations: 1) the upper Dalles Pool (river miles (RM) 211.25-216.25); 2) the lower Dalles Pool (RM 194-199); 3) the upper Bonneville Pool (RM 186.25-191.25); and 4) the mouth of the Deschutes River. Because of high winds and rough water conditions, not all locations could be sampled every week. Limited sampling at the Deschutes River continued through November 1992. Sampling was conducted during daylight hours, except for some night sampling at the upper Dalles Pool for die1 comparisons. Most sampling was conducted with boat-towed plankton nets and a manually-pulled shoreline sled. Some samples were collected with dipnets or drift nets. Samples were fixed in 10% formalin buffered with sodium borate and lightly stained with phyloxine B.

Plankton Samoling.-Plankton samples were collected with 0.5 m diameter (2.5 m length, 500 μm mesh) conical plankton nets with bridleless frames (Nester 1987). A net was suspended from a winch situated on each side of a 5.8 m aluminum boat: two nets were towed simultaneously resulting in paired (port and starboard) samples. A General Oceanics Model 2030 digital flowmeter was suspended off-center in the mouth opening of each net to measure water volume filtered. Each net was held at depth by a 5 kg depressor plate. Nets were towed upriver at a wire angle of 65°. Actual distance traveled (in relation to the shoreline) varied depending on river current. Tows were stepped-oblique for a total of 9 min: initially 3 min at mid-water depth (based on water depth at the tow starting point), then 3 min at quarter-water depth, and finally 3 min at the surface. Maximum initial net depth was 12 m. In shallow water areas, tows were essentially at the surface.

Each week at the upper and lower Dalles Pool and at the upper Bonneville Pool, we conducted five or six paired plankton tows, three or four tows at fixed sites and two tows at random sites. (At the upper Dalles Pool we collected additional samples which will be described below.) Two fixed sites were sampled in the mainstem at a north shore and a mid-channel location, and one fixed site was in a backwater (Table I). In the upper Dalles Pool, an additional fixed sampling site was established on the south shore (Table 1). Mainstem fixed sites were chosen in areas previously identified as having potential northern sguawfish spawning habitat (Gadomski and Murphy 1991). In addition, we sampled two randomly chosen sites at each of the three mainstem study areas. Bach five-mile long study area was subdivided into 20 quarter-mile intervals. A random number chart was used to determine which quarter-mile would be the starting point of two paired tows. One random tow was conducted in the mid-channel, and one along either the Oregon or the Washington shore (chosen by a coin toss).

Two paired plankton tows were also conducted weekly in the mouth of the Deschutes River, one each on the east and west shores of the river (Table 1). Because of shallow water and limited distances, tows were at the surface and ranged in duration from about 3 to 8 min.

Additional sampling was conducted in the upper Dalles Pool to determine die1 differences in larval abundance. On six occasions, June 29-30, July 15, July 28, August 6, August 11, and

Table 1. Descriptions of fixed plankton tow sites in the upper Dalles Pool, the lower Dalles Pool, the upper Bonneville Pool, and the Deschutes River. RM = river miles. At the Deschutes River, M = the distance upriver from the confluence of the Deschutes with the Columbia River (measured in meters).

LOCATION	RM	SUBSTRATE-GRADIENT	DEPTH (M)	WATER VELOCITY (M/S)
Upper Dalles				
mainstem north shore	215.25	gravel/cobble-gentle	3-7	0.7-1.5
mainstem mid-channel	215.25	--	1-10	0.4-1.1
mainstem south shore	215.25	bedrock/boulder steep	10-21	0.2-0.9
backwater	211.75	gravel/cobble-gentle/moderate	7-9	< 0.3
Lower Dalles				
mainstem north shore	194.00	bedrock/boulder-vertical	0.6-18	0.2-0.5
mainstem mid-channel	194.00	--	8.5-82.5	O-3-0.6
backwater	197.25	bedrock/boulder-vertical	6-11	0.1-0.2
upper Bonneville				
mainstem north shore	190.00	large boulder-vertical	4-16.5	0.2-1.0
mainstem mid-channel	190.00	--	1.5-25	0.5-1.4
backwater	190.25	sand/cobble/bedrock-gentle/moderate/steep	1-13	0.1-0.3
Deschutes	M			
east shore	250	fine sediment/sand-steep	0.5-2.5	0.3-0.5
west shore	175	fine sediment/sand-gentle	0.5-2.5	0.4-0.9

August 24, paired plankton tows were conducted at the three mainstem fixed sites (Table 1) during daylight, dusk (2000-2150), and darkness (2330-0030).

Limited sampling was also conducted in the upper Dalles Pool to compare bottom to surface larval distributions. Samples were collected during daylight hours on July 15, July 21, August 11, August 24, and September 9. Two sites were sampled, off the Washington shore at RM 215.25 and at RM 215.50. These areas were shallow (3-7 m), with gravel/cobble substrates and relatively high water velocities (0.7-1.5 m/s). Sampling was conducted for 9 min at each site. The starboard plankton net was maintained with its lower edge touching the bottom, and the port plankton net was at the surface. We towed against the current at a speed where we maintained position or only slowly moved upriver.

Sled.-Shoreline locations were sampled weekly for larvae and juveniles with a manually-towed net built from a design by LaBolle et al. (1985). The net was a 1.5 m long conical design constructed of 500 pm mesh dyed brown and mounted on a frame with side skids and a front roller bar. The mouth was 1.5 m wide and could be vertically adjusted for depth, although we maintained mouth depth at 10 cm. Bridles were attached on each side of the mouth opening so the sled could be pulled by two persons.

To conduct a tow, we positioned the sled offshore in a water depth just covering the mouth opening, usually about 30 cm. Water depth and distance to shore were measured from the frame center. We waited about a minute for fish to adjust to any disturbances, and then towed the net parallel to the shore against the current at about 0.75 m/s. Tow distance was usually 50 m. The sample was then washed into the end of the net and removed through a quick-release cod end for preservation. Water volume filtered (usually 7.5 m^3) was calculated by multiplying mouth area by distance towed.

Two or three fixed sled sites were selected at each mainstem sampling location, one or two on the mainstem, and one in a backwater (Table 2). In the Deschutes River, a sled tow was conducted on each shore (Table 2), although on the east shore the

Table 2. Descriptions of sled sites in the upper Dalles Pool, the lower Dalles Pool, the upper Bonneville Pool, and the Deschutes River. RM = river miles. At the Deschutes River, M = the distance upriver from the confluence of the Deschutes with the Columbia River (measured in meters). All sled sites had gentle gradients and negligible water velocities. Vegetation was often seasonally variable.

LOCATION	RM	SUBSTRATE	VEGETATION
<u>upper Dalles</u>			
mainstem south shore	212.25	gravel/cobble	absent
mainstem island	215.50	gravel/cobble	absent
backwater	212.25	fine sediment/ cobble	light
<u>Lower Dalles</u>			
north shore Browns Island (upstream)	197.75	fine sediment	absent-heavy
north shore Browns Island (downstream)	197.75	gravel/cobble	absent-light
backwater	197.50	fine sediment	moderate
<u>upper Bonneville</u>			
mainstem south shore	190.00	fine sediment/ sand	light-heavy
backwater	190.75	fine sediment/ sand	absent-moderate
<u>Deschutes</u>	**M**		
east shore	900	fine sediment	moderate-heavy
west shore	250	fine sediment/ sand	light-heavy

distance towed was only 15 m because of uneven bottom terrain. Sled sites were chosen to represent the range of conditions found in shallow littoral areas of the study locations. Our gear type and towing methods, however, dictated that we sample areas with gentle gradients and even terrain. This type of site was rare in our sampling locations. For example, the upper Dalles Pool is characterized by steep-sided channel walls with shoreline substrates consisting primarily of basaltic cliffs and boulder fields.

Dipnet.- High abundances of larval or juvenile fishes were sometimes observed in very shallow areas of sled sample sites. These areas were not accessible to sled tows; thus, we used a l-mm mesh dipnet to capture a minimum of 30 larvae and juveniles per site. One site on the west shore of the Deschutes River could only be sampled by dipnet. This site consisted of shallow (l-20 cm) pools of water on bedrock overlain by fine sediment with moderate to heavy amounts of instream vegetation. Because dipnet sampling is non-quantitative, numbers of fish larvae and juveniles collected were summarized as percent composition of catch.

Drift Nets.- Larval drift samples were collected weekly at the east side of the Deschutes River 750 m from the confluence with the Columbia River. The substrate in this area was bedrock and boulders with little instream vegetation. Two 0.5 m diameter (2.5 m length, 500 μm mesh) conical plankton nets were attached side-by-side to shoreline vegetation in waters 0.6-0.7 m deep. Current velocity in this area was about 0.3-0.6 m/s. Nets were set for an hour during daylight. A General Oceanics Model 2030 digital flowmeter was suspended off-center in the mouth opening of each net to measure water volume filtered.

Environmental Parameters.- At each sample site we measured temperature, turbidity, and current velocity at the starting point of a tow. Water temperature was measured at the surface with a handheld thermometer and at 2 m with a Yellow Springs Instrument tele-thermometer. Turbidity was measured with a Hach model 16800 Turbidimeter. Mean water column velocity (an average of the velocity measured at 0.2 and 0.8 of the **total** depth, or at 0.6 of the depth in waters < 0.75 m) was measured with a cable-suspended Price type **"AA"** sensor connected to a Swoffer Instruments Model 2200 direct reading current velocity meter. Current velocity was not measured at all sites every week because of rough waters or time constraints.

At shoreline sites we also evaluated substrate, gradient, and vegetation. Substrate categories were based upon Platts et al. **(1983),** and ranged from fine sediment or sand to gravel/cobble, boulders, or bedrock. Gradients were classified as flat **(1-10°),** gentle **(10-20°),** steep **(20-45°)** or very steep **(45°-vertical).** Vegetation was indexed from absent (1) to heavy (4).

Sample Processing

Sorting.- Fish eggs, larvae and juveniles were sorted from samples using a magnifying lamp. Larvae and juveniles were placed in vials of 4% formalin buffered with sodium borate for later identification. Fish eggs were enumerated and preserved in 4% unbuffered formalin to prevent chorion collapse (Markle 1984). To ensure quality control, about 15% of the samples were resorted to confirm that no fish or eggs were missed in the original sort.

Composition and volume of each sample were determined. Macrophytes and large pieces of debris such as twigs and leaves were noted and removed. Relative proportions of major groups of invertebrates and plants in the remaining sample were estimated. A measurement of wet volume, determined by displacement, was made for each sample after the removal of fish, eggs, macrophytes and large debris (Kramer et al. 1972; Smith and Richardson 1977).

Larval and Juvenile Fish Identification.- Larval and juvenile fishes were identified, enumerated, and assigned developmental stages (yolk-sac larva, larva, and juvenile). Non-cyprinids were usually identified to family and cyprinids were identified to the lowest possible taxonomic level.

Larvae of northern squawfish and chiselmouth *Acrocheilus alutaceus* have not been adequately described to separate early stages (< about 12 mm standard length (SL), prior to pelvic fin formation); thus we grouped some specimens into a combined northern squawfish/chiselmouth category. Peamouth Mylocheilus caurinus larvae were separated from other cyprinids based on the presence of a median thoracic stripe of melanophores (Miura 1962; Hjort 1981 et al.), although some early yolk-sac cyprinid larvae, lacking pigmentation, were identified only to family. Identification criteria of larger northern squawfish, peamouth, and chiselmouth larvae included position of the dorsal fin relative to the pelvic and anal fins, along with other characters described in Miura (1962) and Mundy (1980).

Specimens of northern squawfish, northern squawfish/chiselmouth, and unidentified cyprinids, were measured for notochord length (NL) or standard length (SL), depending on degree of notochord flexion. Notochord length (preflexion and flexion) = snout tip to the end of the notochord, while standard length (postflexion) = snout tip to the posterior margin of the hypural bones (Ahlstrom and Moser 1976). Fork length (FL) was also measured when fins were adequately developed.

PRELIMINARY RESULTS

Overview.- Due to time constraints, sample processing has not been completed. Larval and juvenile fish catch results are presented for all samples from the upper Dalles Pool. Results are presented for the Deschutes River for all plankton tow and drift net samples, and for sled and dipnet samples collected from July 27 through Oct. 19, 1992. Larval and juvenile fishes collected at the lower Dalles Pool and upper Bonneville Pool have not been examined. Complete larval and juvenile fish abundance data and results of physical parameter measurements will be presented in later reports.

Upper Dalles Pool.- Results for fixed and random plankton tow sampling in the upper Dalles Pool were pooled. During plankton tows in the mainstem, a total of 1,862 larvae were collected in 18,198 m^3 of water filtered (a density of 10.2 larvae per 100 m^3). In the backwater area, larvae were somewhat less abundant: 258 larvae were collected in 3331 m^3 of water (7.8 larvae per 100 m^3). Sculpin (Cottidae, probably Cottus asper) larvae dominated the samples. Two northern sguawfish/chiselmouth larvae were collected, both in the mainstem.

Die1 plankton net sampling resulted in higher total fish abundances during daylight hours; densities during day, dusk, and night were 3.7, 3.0, and 2.7 larval and juvenile fishes per 100 m^3 of water filtered, respectively. Total numbers of larvae and juveniles collected during day, dusk, and night were 161, 146, and 118, respectively. More juveniles were captured during dusk and night than day, possibly due to less net avoidance. At all time periods, the most abundant larvae were sculpins. Larval shad were most abundant during daylight hours. One northern sguawfish juvenile and 8 northern sguawfish/chiselmouth larvae were collected. All 9 specimens were captured in late June or mid-July during dusk and night, suggesting a nocturnal pattern of abundance.

No larval or juvenile fishes were collected during surface and benthic plankton tow sampling in the upper Dalles Pool.

Few larvae and juveniles (N = 21) were collected in shoreline areas of the upper Dalles Pool with the sled in 644 m^3 of water filtered. One northern sguawfish juvenile and one sguawfish/chiselmouth larva were captured at the mainstem island site.

Deschutes River.- In Deschutes River plankton tows, only sucker larvae (Catostomidae) were collected: 44 larvae were captured in 4153 m^3 of water filtered. In all drift net samples (5107 m^3 of water filtered), a total of 6 sucker larvae, one sucker juvenile, and one sculpin juvenile were collected.

Deschutes River sled tow and dipnet results are only reported for sampling conducted during July 27 - Oct. 19 for sleds, and July 27 - Aug. 28 for dipnets. Many more fishes were captured in shoreline sled tows in the Deschutes River than in the upper Dalles Pool. In the Deschutes, 349 larvae and juveniles were collected in 80.25 m^3 of water filtered (a density of 440 fish per 100 m^3) versus a density of only 3.3 larvae and juveniles per 100 m^3 of water in the upper Dalles Pool. In the Deschutes River, all collected larvae and juveniles were cyprinids or catostomids. Northern sguawfish juveniles were the most abundant taxon in Deschutes River sled samples (40% of the catch), with a mean density of 360 per 100 m^3 of water. In dipnet samples, 13% of all fish captured were sguawfish juveniles. Fish length information is not presented in this report, but all northern sguawfish juveniles collected were probably young-of-the-year (YOY). More juveniles than larvae were captured, but it is likely that samples collected earlier in the season (June and July), which have not yet been examined, will contain more larvae.

DISCUSSION

Results presented in this report are incomplete. Due to report deadlines, we have not examined samples from the lower Dalles Pool and the upper Bonneville Pool, and from June and July in the Deschutes River. Conclusions concerning northern sguawfish reproduction and early life history would thus be premature at this time.

Few northern squawfish/chiselmouth larvae and sguawfish juveniles were collected in plankton tows at the upper Dalles Pool. Although we sampled weekly, possibly our timing did not coincide with northern sguawfish larval drift. Nesler et al. (1988) reported that newly-hatched Colorado sguawfish Ptvchocheilus lucius larvae move rapidly down the Yampa River, being present in a 6-km river reach for only about l-2 d. It is also possible, however, that the upper Dalles Pool is not heavily utilized by northern sguawfish for spawning, or that 1992 was a year with reduced spawning activity.

It is noteworthy that more northern squawfish/chiselmouth larvae were collected during dusk and night sampling than during the day. Larval fishes have commonly been reported to drift downriver at night (Gale and Mohr 1978; Brown and Armstrong 1985;

Carter et al. 1986). In die1 drift-net sampling conducted by Tyus and Haines (1991) from 1979 to 1988, Colorado sguawfish larvae were most abundant during early morning hours (G. Bruce Haines, U.S. Fish and Wildlife Service, Vernal, Utah; personal communication). More die1 sampling is necessary to confirm the observed nocturnal pattern of northern sguawfish larval abundance. In 1993 we plan to continue conducting nighttime plankton tows in the upper Dalles Pool, and begin night sampling in other mainstem and tributary locations.

We collected very few larvae and juveniles during sled sampling in the upper Dalles Pool. We sampled with essentially the same gear as LaBolle et al. (1985) used in upper littoral habitats of the John Day Pool during 1981-1982. LaBolle et al., however, reported very high catches of larvae. Thus, gear effectiveness probably was not a factor in our low catches: these areas do not appear to be utilized for larval rearing by northern squawfish.

In contrast, we collected a fairly high overall density of larvae and juveniles (440 fish/100 m^3) in sled tows in the Deschutes River. The most abundant taxon in sled samples was northern sguawfish YOY juveniles. Because these samples were collected later in the season (July 27. - Oct. 19), earlier samples likely contain more northern sguawfish larvae. Although data suggest that shallow areas of the Deschutes River are being utilized as larval and YOY juvenile rearing areas, we do not know whether sguawfish spawned in the Deschutes River or whether larvae or juveniles migrated into the Deschutes from the mainstem Columbia River. In 1993, more sampling will be conducted to further investigate this question.

REFERENCES

Ahlstrom, E.H., and H.G. Moser. 1976. Eggs and larvae of fishes and their role in systematic investigations and in fisheries. Rev. Trav. Inst. Peches Marit. 40:379-398.

Beamesderfer, R. C. 1992. Reproduction and early life history of northern sguawfish, Ptvchocheilus oreaonensis, in Idaho's St. Joe River. Environmental Biology of Fishes 35:231-241.

Brown, A. V., and M. L. Armstrong. 1985. Propensity to drift downstream among various species of fish. Journal of Freshwater Ecology 3:3-17.

Carter, J. G., V. A. Lamarra, and R. J. Ryel. 1986. Drift of larval fishes in the upper Colorado River. Journal of Freshwater Ecology. 3:567-577.

Casey, 0. E. 1962. The life history of the northern sguawfish in Cascade Reservoir. Master's Thesis. University of Idaho, Moscow.

Gadomski, D.M., and A.M. Murphy. 1991. Reproduction and early life history of northern sguawfish Ptvchocheilus oreaonensis in the Columbia River. pp. 89-100 in T.P. Poe, editor. Significance of selective predation and development of prey protection measures for juvenile salmonids in Columbia and Snake River reservoirs. Annual report by the U.S. Fish and Wildlife Service to the Bonneville Power Administration, Portland, OR.

Gale, W.F., and H.W. Mohr, Jr. 1978. Larval fish drift in a large river with a comparison of sampling methods. Transactions of the American Fisheries Society. 107:46-55.

Hjort, R. C., B. C. Mundy, and P. L. Hulett. 1981. Habitat requirements for resident fishes in the reservoirs of the lower Columbia River. Army Corps of Engineers,, Final Report Contract No. DACW57-79-C-0067.

Jeppson, P. 1957. The control of sguawfish by use of dynamite, spot treatment, and reduction of lake levels. The Progressive Fish-Culturist 19:168-171.

Jeppson, P. W., and W. S. Platts. 1959. Ecology and control of the Columbia River sguawfish in northern Idaho lakes. Transactions of the American Fisheries Society 88:197-202.

Kramer, D., M.J. Kalin, E.G. Stevens, J.R. Thrailkill, and J.R. Zweifel. 1972. Collecting and processing data on fish eggs and larvae in the California current region. NOAA Technical Report NMFS Circ-370.

LaBolle, L.D. 1984. Importance of the upper littoral zone as rearing area for larval and juvenile fishes in a Columbia River impoundment. Master's Thesis. Oregon State University, Corvallis.

LaBolle, L. D., H. W. Li, and B. C. Mundy. 1985. Comparison of two samplers for quantitatively collecting larval fishes in upper littoral habitats. Journal of Fish Biology 26:139-146.

Markle, D.F. 1984. Phosphate buffered formalin for long term preservation of formalin fixed ichthyoplankton. Copeia 2:535-528.

Miura, T. 1962. Early life history and possible interaction of five inshore species of fish in Nicola Lake, British Columbia. PhD Thesis. University of British Columbia.

Mundy, B.C. 1980. A draft laboratory reference for the identification of larval and juvenile fishes from the Columbia River between the John Day and McNary Dams. Army Corps of Engineers, Fourth Quarterly Report, Contract No. DACW57-79-C-0067.

Nesler, T. P., R. T. Muth, and A. F. Wasowicz. 1988. Evidence for baseline flow spikes as spawning cues for Colorado squawfish in the Yampa River, Colorado. American Fisheries Society Symposium 5:68-79.

Nester, R.T. 1987. Horizontal ichthyoplankton tow-net system with unobstructed net opening. North American Journal of Fisheries Management 7:148-150.

Olney, F. E. 1975. Life history and ecology of the northern squawfish Ptvchocheilus oreaonenesis (Richardson) in Lake Washington. Master's Thesis. University of Washington, Seattle.

Patten, B. G., and D. T. Rodman. 1969. Reproductive behavior of northern sguawfish, Ptvchocheilus oreaonenesis. Transactions of the American Fisheries Society 198:108-111.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating steam, riparian, and biotic conditions. U.S. Forest Service General Technical Report INT - 138.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.

Smith, P.E., and S.L. Richardson. 1977. Standard techniques for pelagic fish egg and larva surveys. FAO Fisheries Technical Paper No. 175.

Tyus, H. M., and G. B. Haines. 1991. Distribution, habitat use, and growth of age-0 Colorado squawfish in the Green River Basin, Colorado and Utah. Transactions of the American Fisheries Society 120:79-89.