

Distribution and Relative Abundance of Fishes in Littoral Areas of Chief Joseph Reservoir, Columbia River

Abstract

We surveyed fish assemblages in littoral areas of Chief Joseph Reservoir of the upper Columbia River to aid in understanding this ecosystem. Fish distributions and abundances were examined during April–July 1999 in relation to environmental conditions in the reservoir. We also compared the fish assemblages in Chief Joseph Reservoir in 1999 to a past study conducted during 1974–1975, and to assemblages in other areas of the Columbia River. During 67 hr of electrofishing and 78 beach seine hauls in Chief Joseph Reservoir, 7460 fishes representing 8 families were collected. The majority of the catch was native—northern pikeminnow; reidside shiners; longnose, bridgelip, and largescale suckers; and sculpins. The most abundant introduced species was walleye, and one species, rainbow trout, was mostly of net-pen origin. Larger sizes of suckers and northern pikeminnow were most abundant in the upper reservoir, likely due to upstream spawning migrations. The lower reservoir contained greater abundances of smaller fishes, and this area had lower flows, smaller substrates, and more complex shorelines that offered these fishes refugia. Only adult suckers displayed significant differences in abundance related to substrate. The relative abundances of species appeared to have changed since the 1970s, when the dominant fishes were northern pikeminnow, peamouth, largescale suckers, and walleye. Fish assemblage differences between Chief Joseph Reservoir and lower Columbia River reservoirs were also evident due to the morphology of the reservoir, its more northerly location, and the lack of fish passage facilities at Chief Joseph Dam. Our study is one of the few descriptions of fishes in the upper Columbia River.

Introduction

Little is known about populations of wild fishes in the upper Columbia River below Grand Coulee Dam, Chief Joseph Reservoir (Figure 1). The only previous survey of fishes in this reservoir was conducted by Erickson et al. (1977) from May 1974 through August 1975. The most abundant species they collected were northern pikeminnow (*Ptychocheilus oregonensis*), largescale suckers (*Catostomus macrocheilus*), peamouth (*Mylocheilus caurinus*), and walleye (*Sander vitreus*). Although fish assemblages in the mid and lower Columbia River have been described (Gray and Dauble 1977, Poe et al. 1994, Barfoot et al. 2002), conditions in these areas differ significantly from Chief Joseph Reservoir. The majority of the Columbia River has been changed by impoundment into a series of lake-like reservoirs. Conversely, much of the Chief Joseph Reservoir has retained more riverine characteristics because of the overall steep gradient of this reservoir and its narrow canyon morphology. Additionally, unlike other

Columbia River impoundments, fish passage facilities were not constructed at Chief Joseph Dam, and therefore fish assemblages in Chief Joseph Reservoir contain only resident species.

Significant environmental changes have also occurred in Chief Joseph Reservoir since the survey during the 1970s, which may have affected fish assemblage structure. Chief Joseph Dam was completed in 1955, which changed the 83 km free-flowing reach into a river-run reservoir. In 1977, a modification of the dam raised water levels in the reservoir about 3 m (Erickson et al. 1977). This decreased the riverine portion of the upper reservoir, and increased down-river lentic habitat. Additionally, flow patterns differed between the two periods due to the construction during 1967–1984 of four dams on the Canadian portion of the Columbia River (Center for Columbia River History 2002). These were designed to provide water storage, thus allowing regulation of seasonal flows to control flooding and meet hydroelectric demands. These Canadian dams resulted in less seasonal variations in outflow from Grand Coulee Dam (Figure 2).

Our goal was to survey the fishes in Chief Joseph Reservoir to aid in understanding the upper

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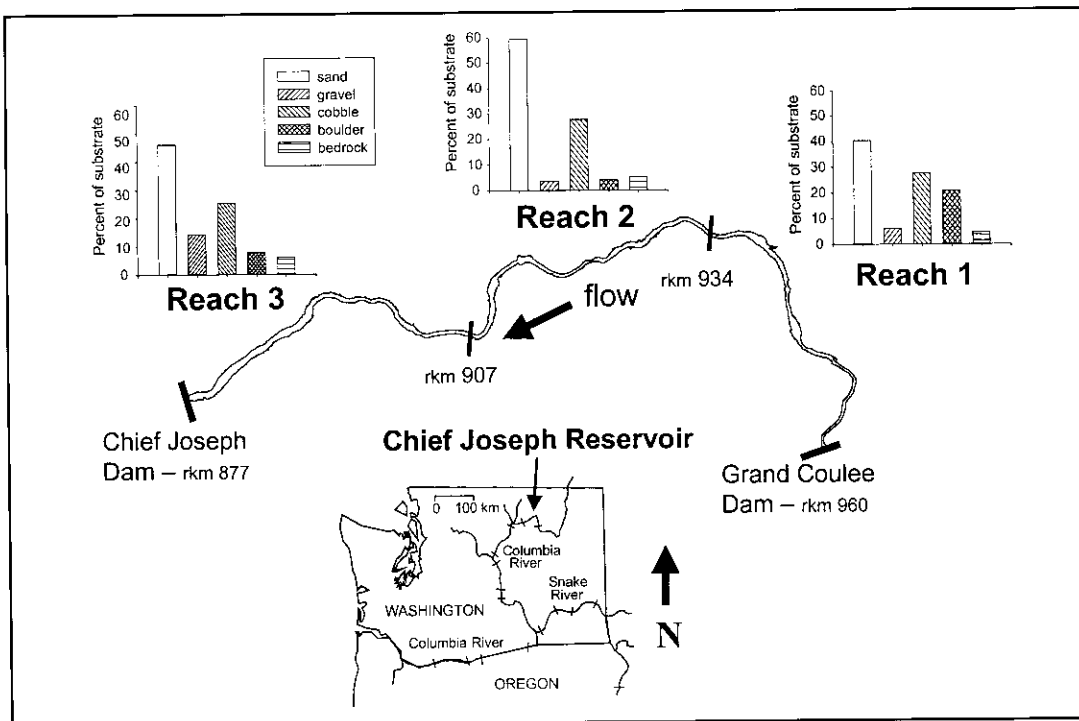


Figure 1. Sample reaches in Chief Joseph Reservoir, Columbia River, Washington. Littoral substrate composition in each reach is presented. rkm = river kilometer.

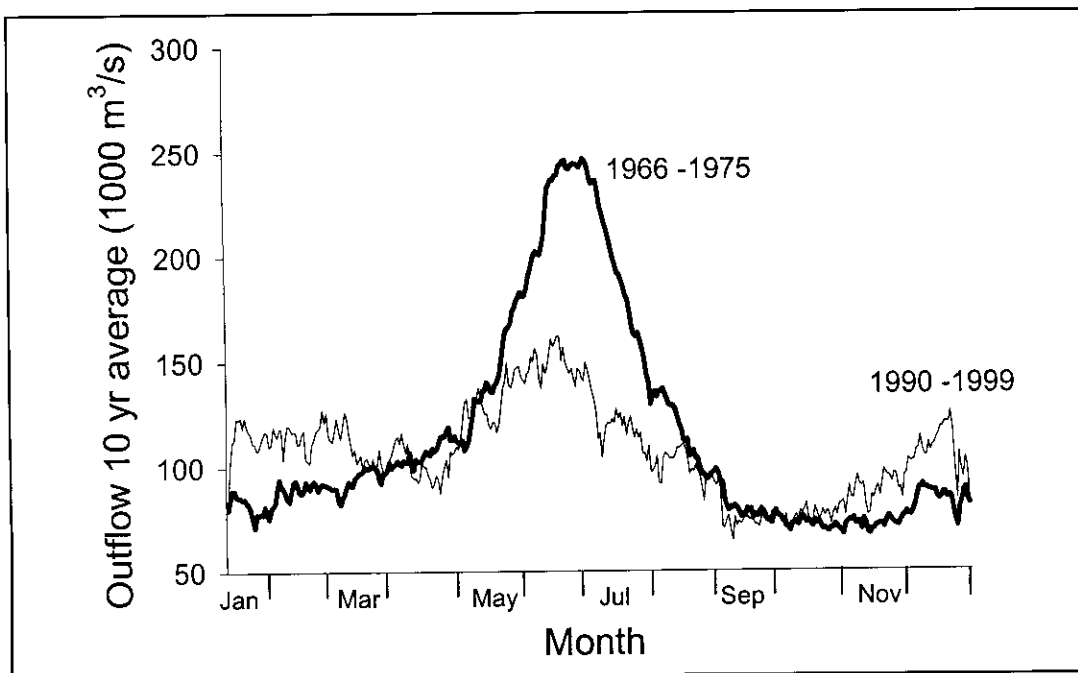


Figure 2. Ten-year daily averages (January-December) of water outflow from Grand Coulee Dam for two periods, 1966-1975 and 1990-1999 (U.S. Army Corps of Engineers and Grant County PUD 2002).

Columbia River ecosystem and as a first step in evaluations of possible impacts of hydropower operations. First, we examined fish distribution and abundance in the littoral zones of Chief Joseph Reservoir in 1999 in relation to reservoir reach, substrate, and time period (spring versus summer). Then we compared relative abundances of fishes in 1999 to the survey by Erickson et al. (1977) during 1974-75 to determine if the species structure has changed during this interval. Finally, we examined how fish species composition in Chief Joseph Reservoir differed from other areas of the Columbia River.

Methods

Habitat

To sample all habitat types in Chief Joseph Reservoir and to associate fish species with shoreline substrates, we first mapped dominant shoreline substrates along the reservoir's periphery. Substrates were assigned to one of five categories based on particle diameter: sand (< 0.25 cm), gravel (0.25 to 5.1 cm), cobble (5.1 to 25.4 cm), boulder (> 25.4 cm), and bedrock (Cummins 1962). Transition points between substrate types were identified by visual inspection and by dragging the end of a hollow metal rod over the substrate (Bramblett and White 2001). These transition points were recorded as waypoints in a global positioning system (GPS) receiver and the resulting shoreline segments were given unique identification numbers based on shoreline (north or south), reach, and substrate.

The reservoir was also divided into three reaches of approximately equal length (Figure 1). Reach 1 extended from the Grand Coulee Dam tailrace to rkm 934, Reach 2 extended from rkm 934 to rkm 907, and Reach 3 extended from rkm 907 to the Chief Joseph Dam forebay. Reach 1 was more riverine and had the highest percentage of boulder substrate of all reaches (21%), the least sand (41%), and an intermediate amount of cobble (28%; Figure 1). Reach 2 was almost exclusively sand (59%) and cobble (28%). The lowest section of Chief Joseph Reservoir, Reach 3, was composed primarily of sand (46%), gravel (14%), and cobble (26%).

Lastly, we divided our sampling efforts into two periods, April-May (spring) and June-July

(summer), to examine seasonal effects on species abundances. Mean daily temperatures increased steadily from 5° to 10°C during the first sampling period, and increased from 10° to 16°C during June-July (U.S. Army Corps of Engineers and Grant County PUD 2002).

Sampling

We used a stratified random sampling design with reach and shoreline substrate as strata. Sampling was conducted on nine consecutive nights twice each month from April through July 1999. Sampling began about one hour before sunset and continued until approximately 0300 hours. Boat electrofishing, the primary method of fish collection, was conducted during each night of sampling. Shoreline electrofishing sites were randomly selected each month to sample 4-6 sites per substrate type in each reach. Sampling was conducted without replacement within each month, but all sites became eligible for sampling at the start of the next month.

An electrofishing boat delivered 2-3 A of current to the water with 30 Hz pulsed DC at 400-425 V, and a current field width of about 5 m. Shoreline segments were electrofished by starting at the upstream end and proceeding downstream as near shore as possible. Sites were located with a GPS on the night of sampling and reflective markers were used to identify the upstream and downstream boundaries prior to sampling. The entire length of shoreline segments < 1000 m were electrofished. Segments > 1000 m long were divided for subsampling. Segments 1000-1500 m long were divided in two, and segments 1500-2500 m long were divided into three sections; we randomly chose and electrofished one site from each of these. Segments >2500 m were divided into 500 m sections and we randomly sampled three sites from these. Stunned fish were immediately netted and placed in a live-well.

Beach seining was conducted on two randomly selected nights during each 9-d sample period. Five beach seine sites on sand, gravel, or cobble substrate were selected each night based on proximity to the electrofishing sites sampled that evening. Square sets were made with a 5-mm stretch-mesh seine (30.5 m x 2.4 m) set parallel to the shoreline. Bridal lines (6.1 m

long) connected to each of the brails were used to pull the net to shore.

Fish Identification

Fish were lightly anesthetized in tricaine methanesulfonate (MS-222, 100 mg/l) and generally identified to species with the exception of sculpins (*Cottus* spp.), which were left at genera. Also, bridgelip suckers (*C. columbianus*) and largescale suckers < 150 mm fork length (FL) were difficult to differentiate and were not identified to species. Fish < 300 mm FL were measured to the nearest 1 mm, and fish > 300 mm FL were measured to the nearest 5 mm. After examination, fish were placed in fresh water to recover for at least 15 min before release back in the reservoir.

Data Analysis

Numbers of fishes collected were adjusted to account for level of effort per shoreline substrate type, which was necessary because sampling was not completely random. If a substrate type was sampled more or less than its actual occurrence in reservoir shorelines, and a species preferred this substrate type, then the percent abundance of this species would be increased or decreased over the actual value as an artifact of the stratified random sampling plan. For example, adjusted number of carp collected during beach seining = actual number of carp collected at sand sites x (% sand substrate in reservoir shorelines (as determined from the shoreline substrate survey) / % sand sites sampled) + similarly adjusted numbers for other shoreline substrate types.

For the most abundant taxa collected by each gear type in 1999, we used analysis of variance (ANOVA) to test for significant effects of reach, substrate, and sampling period (spring versus summer) on unadjusted catch-per-unit-effort (CPUE). A unit of effort for beach seining was one haul, while for electrofishing, a unit of effort was 10 min of current on time. Values were transformed to $\ln(\text{CPUE} + 1)$ for statistical comparisons. Where applicable, we also divided taxa into size groups for analysis. If the overall model was significant ($P < 0.05$), Tukey's studentized range test was used to examine if there were significant differences between mean transformed CPUE values.

Results

Fish Assemblage Structure

During the study, 7460 fishes representing 8 families and 21 taxa were collected during 67 hr of electrofishing and 78 beach seine hauls (Table 1). Eight species were introduced. Based on body shapes and fin condition, we determined that rainbow trout (*Oncorhynchus mykiss*) probably originated from net-pen operations in Chief Joseph and Grand Coulee reservoirs. The origin of the few chinook salmon (*O. tshawytscha*) is unknown: this species is not currently stocked in Chief Joseph and Grand Coulee reservoirs. The most abundant taxa were northern pikeminnow, redbreasted shiner (*Richardsonius balteatus*), longnose sucker (*Catostomus*), bridgelip sucker, largescale sucker, rainbow trout, walleye, and sculpins. Length frequency distributions of the most abundant species collected, longnose sucker (*Catostomus catostomus*), indicated the presence of three size classes (< 150 mm, 150-299 mm, and >299 mm FL), which were separated for analysis. We examined the catch of these species in relation to reach, substrate, and sampling period for both gear types.

Electrofishing

Reach and sampling period (spring versus summer) affected CPUE of most fishes, and distribution patterns were species-specific. Northern pikeminnow were collected in significantly ($P < 0.01$) greater numbers in Reach 3 than Reaches 1 and 2 during both time periods (Figure 3). In contrast, rainbow trout were more abundant during spring in Reach 1 ($P < 0.01$). Catches of walleye were significantly higher during spring in all reaches, while sculpins were significantly ($P < 0.01$) more abundant during summer in Reaches 2 and 3 (Figure 3).

Larger sizes (>299 mm FL) of all three species of suckers were collected in significantly ($P < 0.01$) greater numbers in Reach 1 (Figures 4 and 5). There was no significant effect of period on the abundance of large longnose suckers, while largescale suckers were more numerous in spring, and bridgelip suckers more commonly collected during summer. Both groups of smaller (< 300 mm FL) longnose suckers were significantly ($P < 0.01$) more abundant in summer, with abundances

TABLE 1. Adjusted numbers of fishes collected by electroshocking (ES), and beach seining (BS) in Chief Joseph Reservoir during April 4-July 28, 1999, and percent (%) catch for both gears combined. Numbers are adjusted to account for level of effort per shoreline substrate type. ¹ = introduced species. ² = primarily net pen origin.

		ES	BS
Actual number of fish collected:		5403	2057
Adjusted number of fish collected:		5671	2026
Number of hours sampled (ES) or hauls (BS):		67	78
Common name	Latin name	% Catch	Adjusted numbers
Carps and minnows—Cyprinidae			
Carp ¹	<i>Cyprinus carpio</i>	1	82
Peamouth	<i>Mylocheilus caurinus</i>	<1	0
Northern pikeminnow	<i>Ptychocheilus oregonensis</i>	5	251
Redside shiner	<i>Richardsonius balteatus</i>	15	183
Tench ¹	<i>Tinca tinca</i>	<1	32
Unidentified		<1	16
Suckers—Catostomidae			
Longnose sucker	<i>Catostomus catostomus</i>	21	1520
Bridgelip sucker	<i>C. columbianus</i>	6	488
Largescale sucker	<i>C. macrocheilus</i>	6	409
Unidentified		10	465
Bullhead catfishes—Ictaluridae			
Brown bullhead ¹	<i>Ameiurus nebulosus</i>	<1	1
Trouts—Salmonidae			
Rainbow trout ²	<i>Oncorhynchus mykiss</i>	15	1070
Kokanee	<i>O. nerka</i>	2	156
Chinook salmon	<i>O. tshawytscha</i>	<1	3
Mountain whitefish	<i>Prosopium williamsoni</i>	1	7
Brown trout	<i>Salmo trutta</i>	<1	34
Bull trout	<i>Salvelinus confluentus</i>	<1	1
Brook trout ¹	<i>Salvelinus fontinalis</i>	<1	21
Unidentified		1	27
Cods—Gadidae			
Burbot	<i>Lota lota</i>	1	52
Sunfishes—Centrarchidae			
Smallmouth bass ¹	<i>Micropterus dolomieu</i>	1	72
Perches—Percidae			
Yellow perch ¹	<i>Perca flavescens</i>	1	58
Walleye ¹	<i>Sander vitreus</i>	7	477
Sculpins—Cottidae			
Unidentified	<i>Cottus</i> spp.	9	246

increasing from Reach 1 to Reach 3 (Figure 5). There were no significant effects of reach or period on the distribution of unidentified suckers < 150 mm FL (Figure 4).

Overall, there were few significant effects of substrate. However, substrate did significantly affect some sucker distributions, with bridgelip and largescale suckers less abundant over sand

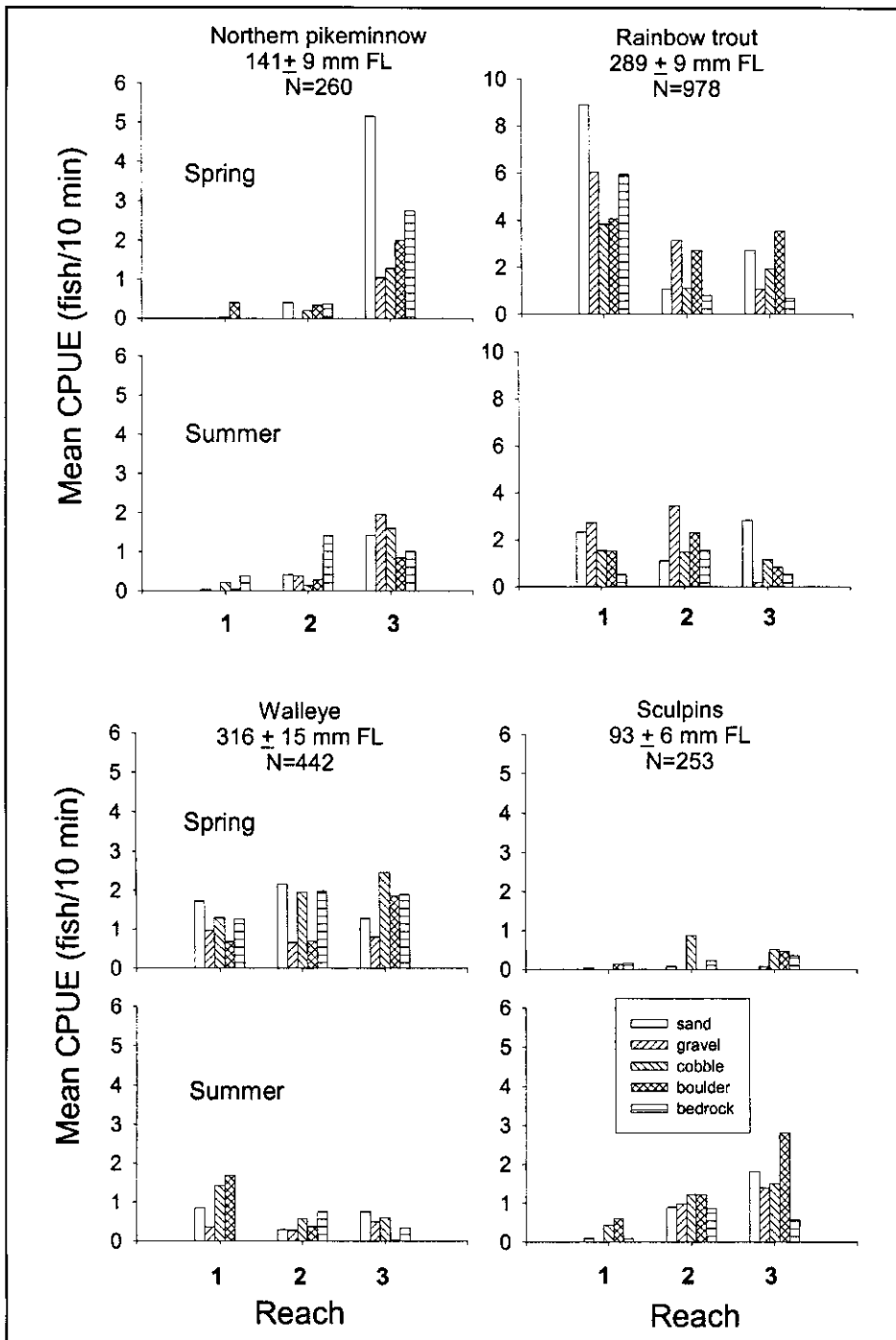


Figure 3. Mean catch per unit effort (CPUE) of four taxa collected by boat electroshocking in three reaches of Chief Joseph Reservoir during two sample periods, April-May (spring) and June-July (summer), and over five substrates. CPUE is measured as fish collected per 10 minutes of current on time. Mean fork length (FL) \pm one standard error of each taxon is presented. N = number of fish. Note different vertical axes scales.

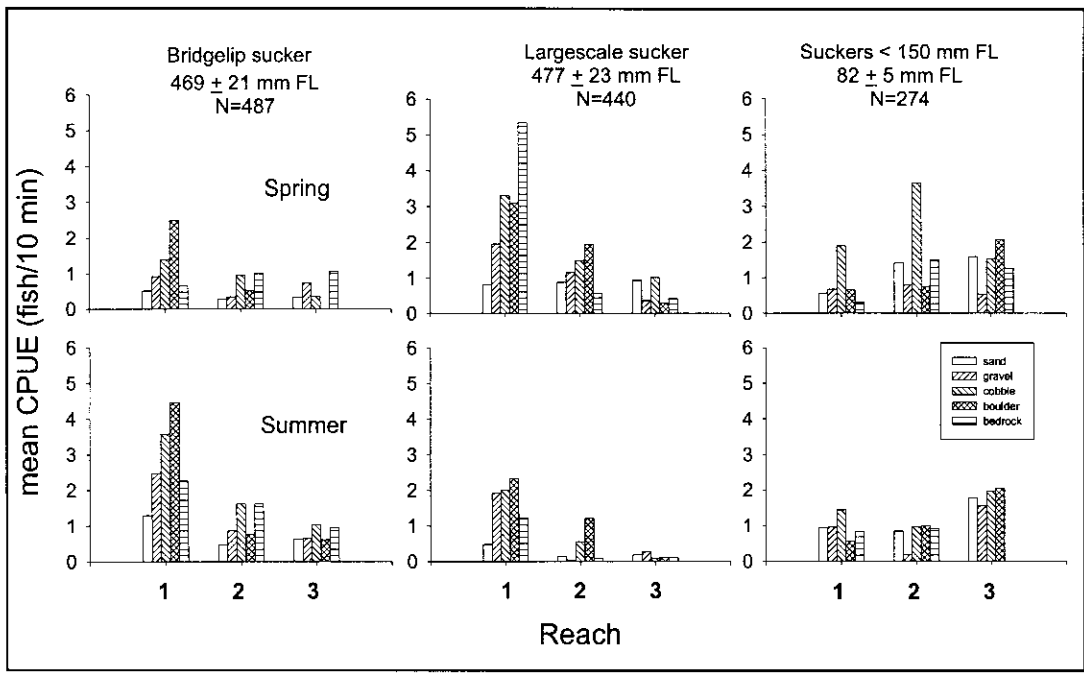


Figure 4. Mean catch per unit effort (CPUE) of three taxa collected by boat electroshocking in three reaches of Chief Joseph Reservoir during two sample periods, April-May (spring) and June-July (summer), and over five substrates. CPUE is measured as fish collected per 10 minutes of current on time. Mean fork length (FL) ± one standard error of each taxon is presented. N = number of fish.

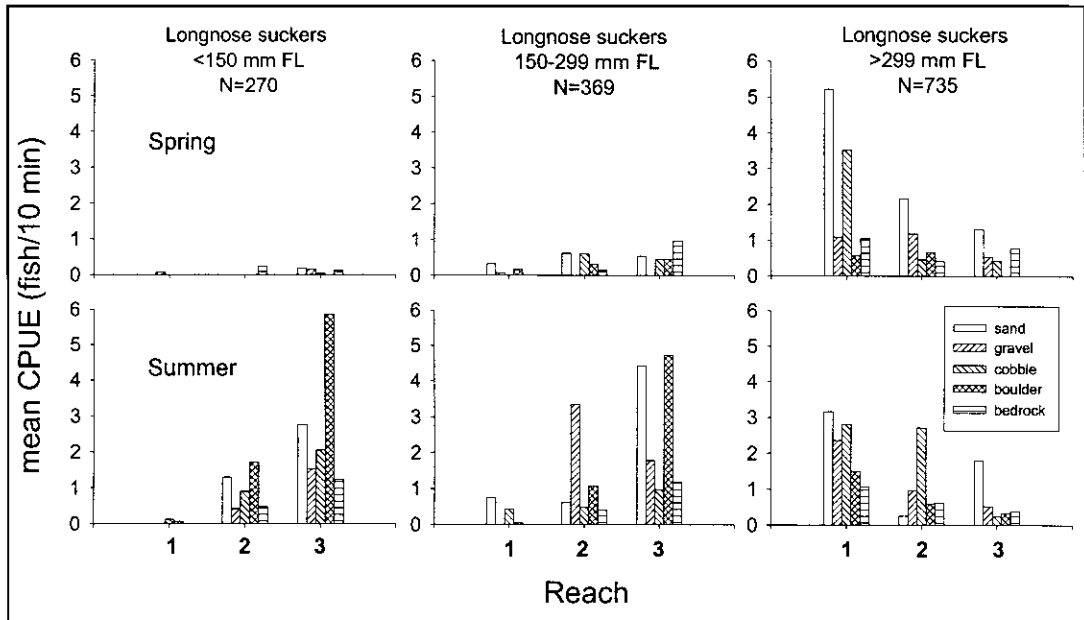


Figure 5. Mean catch per unit effort (CPUE) of three sizes of longnose suckers collected by boat electroshocking in three reaches of Chief Joseph Reservoir during two sample periods, April-May (spring) and June-July (summer), and over five substrates. CPUE is measured as fish collected per 10 minutes of current on time. FL = Fork length. N = number of fish.

than other substrate types, and conversely, longnose suckers more abundant over sand in some locations (Figures 4 and 5). Substrate significantly ($P < 0.01$) affected distributions of 150-299 mm FL longnose suckers, but there were no clear trends, with preferred substrate types differing in each reach (Figure 5).

Beach Seine

There were no significant effects of reach, period, or substrate on catches of northern pikeminnow, suckers, or sculpins in beach seine hauls (Figure 6). Redside shiners were significantly more abundant in Reach 3 ($P < 0.01$).

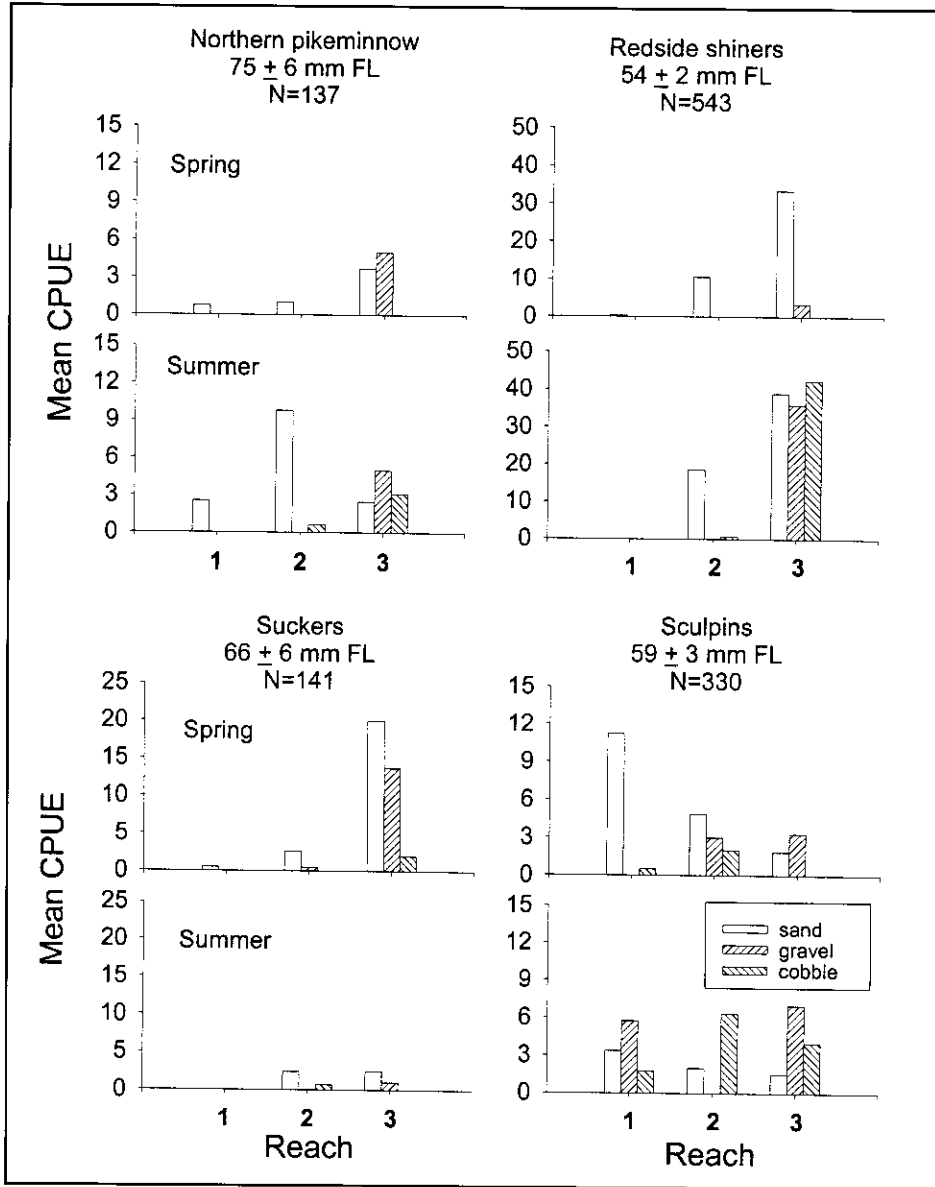


Figure 6. Mean catch per unit effort (CPUE) of four taxa collected by beach seining in three reaches of Chief Joseph Reservoir during two sample periods, April-May (spring) and June-July (summer), and over three substrates. CPUE is one beach seine haul. Mean fork length (FL) \pm one standard deviation of each taxon is presented. N = number of fish. Note different vertical axes scales.

Discussion

We observed species and size-related differences in fish abundance in Chief Joseph Reservoir that were linked to reservoir reach. Larger sizes of some species such as suckers were most abundant in the upper reservoir (Figures 4 and 5), likely due to upstream spawning migrations. For example, longnose suckers in British Columbia initiate upstream spawning migrations at 5°C and continue through about 15°C (Geen et al. 1966). Similarly, in the Hanford Reach of the central Columbia River, largescale suckers move upstream to spawn primarily during June, with peak spawning at 12-15°C (Dauble 1986). Furthermore, we collected 13 larger northern pikeminnow mostly in Reach 1 of Chief Joseph Reservoir, and spawning of this species occurs in dam tailraces at temperatures >14°C (Gadomski et al. 2001). Although the higher abundances of rainbow trout in Reach 1 were largely due to the location of net-pen facilities, upriver spawning migrations of this species have also been reported (Davies and Sloane 1987).

The lower portion of the reservoir (Reach 3) contained greater abundances of smaller fishes (Figures 3, 5, and 6). This area also had lower flows, smaller substrates, and more complex shoreline areas with woody debris that attracted small fish possibly seeking shelter from predators (Sillett and Foster 2000, Laegdsgaard and Johnson 2001). Some abundant taxa in this area, such as sculpins and redbreasted shiner, are smaller at maturity. However, rearing juveniles of some species were also common, such as immature northern pikeminnow, and during the summer, longnose suckers.

The abundance of some fishes differed seasonally. During spring, rainbow trout, walleye, and largescale suckers were more abundant than during summer, while the opposite pattern was observed for sculpins, bridgelip suckers, and smaller longnose suckers (Figures 3, 4, and 5). Seasonal changes in environmental characteristics may have caused these fishes to shift habitat use out of or into littoral areas where we sampled. For example, temperature influences movements and distributions of fishes (Hall and Werner 1977, Tufescu 1994). Temperatures in Chief Joseph Reservoir increased from 5° to 10°C during spring and from 10° to 16°C during summer, with higher temperatures in shallow shorelines due to solar heating. Higher shoreline temperatures also in-

crease the growth of instream vegetation and enhance food availability causing fish to move onshore (Hall and Werner 1977). Lastly, water flow in Chief Joseph Reservoir characteristically differs between these two periods, usually peaking during June (Figure 2).

The only fishes in Chief Joseph Reservoir that displayed significant differences in abundance related to substrate were adult suckers. Bridgelip and largescale suckers were more abundant over rock substrates, while longnose suckers were more abundant over sand. This distribution pattern may be due to foraging behavior rather than spawning preferences, since all three species spawn primarily over gravel substrate (McCart and Aspinwall 1970, Dion et al. 1994). In the Hanford Reach of the middle Columbia River, both bridgelip and largescale sucker diets are dominated by algal periphyton, which they graze from cobble and other rock substrates (Dauble 1980, 1986), while longnose suckers feed selectively on cladocerans (*Daphnia* spp.) and chironomids, if available, in addition to algae (Brown and Graham 1954, Barton 1980).

The relative abundances of fish species in Chief Joseph Reservoir appeared to have changed since the 1970s. Although different gears and sampling designs were used, the magnitude of change for some species was large, suggesting actual assemblage differences. Erickson et al. (1977) sampled in the reservoir from May 1974 through August 1975 primarily using gillnets and beach seines. The most abundant species they collected were northern pikeminnow (34% of the catch), largescale sucker (16%), peamouth (12%), and walleye (8%), with speckled dace (*Rhinichthys osculus*), bridgelip sucker, mountain whitefish (*Prosopium williamsoni*), yellow perch (*Perca flavescens*), and prickly sculpin (*Cottus asper*) each composing 3-5% of the catch. In contrast, the most abundant species during our study were redbreasted shiner, longnose sucker, and rainbow trout (Table 1), yet each was only 1-2% of the catch in 1974-1975. The most notable decrease from the mid-1970s to 1999 was the proportion of two native cyprinids, peamouth and northern pikeminnow. However, it must be noted that because of differences in sampling methodology and effort, we cannot determine if absolute abundances of these fishes declined.

It is difficult to explain precisely why fish species assemblages differed between these two

periods. The more stable conditions in Chief Joseph Reservoir (i.e., water levels) in the 1990s may have resulted in a more productive environment with greater benthic invertebrate prey densities (Wydoski and Bennett 1981, Cushman 1985, Geist et al. 1996). Some fishes may have experienced increased recruitment during the 1990s because water level fluctuations affect shoreline habitat structure such as vegetation abundance and are detrimental to growth and survival of age-0 fish in nursery areas (Sheidegger and Bain 1995). Additionally, the increased numbers of rainbow trout during the 1990s from net pen production may have changed the species composition in Chief Joseph Reservoir, due both to direct predation on native fishes, and competition for fish and invertebrate food sources (Beauchamp 1990, Lynott et al. 1995).

Fish assemblages in Chief Joseph Reservoir also varied from other Columbia River reservoirs, in part because of habitat differences due to impoundment. After impoundment, Chief Joseph remained a relatively fast-flowing system with few large backwater areas (Erickson et al. 1977). Conversely, many other reservoirs became more lake-like, resulting in a shift from fish assemblages composed primarily of native riverine species to those with an abundance of introduced taxa adapted to lentic conditions (Li et al. 1987, Poe et al. 1994). Similarly to Chief Joseph Reservoir, one of the few free-flowing areas of the Columbia River, the Hanford Reach, has low numbers of introduced fishes, about 1% (Gray and Dauble 1977, Li et al. 1987). Furthermore, the redbreasted sunfish, a native cyprinid found in lotic systems, is abundant in both the Hanford Reach and Chief Joseph Reservoir, but is rarely collected in Columbia River impoundments (Gray and Dauble 1977, 2001; Barfoot et al. 2002). Finally, Chief Joseph Reservoir differs from others in the Columbia River system because there are no fish passage facilities at Chief Joseph and Grand Coulee dams. This prevents upriver migration of fishes such as species of salmon from lower reservoirs.

The location of Chief Joseph Reservoir also affected fish assemblage structure. Li et al. (1987)

presented a diagram of native fishes along a river continuum in the Pacific Northwest. They found that as the gradient increased and water temperatures decreased, largescale and bridgelip suckers were gradually replaced by mountain (*C. platyrhynchus*) and longnose suckers. Our results corroborate this model, since longnose suckers were common in Chief Joseph Reservoir, while they have not been reported farther downstream in the Columbia River (Gray and Dauble 1977, Barfoot et al. 2002). Our catch of burbot (*Lota lota*) also reflects the more northerly location of Chief Joseph Reservoir, since this species is rare in the mid and lower Columbia River (Bonar et al. 2000).

Our results are one of the few descriptions of fish assemblages in the upper Columbia River and will aid in understanding this ecosystem. The fish composition in Chief Joseph Reservoir is unique for a variety of reasons. Chief Joseph Reservoir differs from other reservoirs in the Columbia River system because all species are resident. Assemblage differences between Chief Joseph Reservoir and lower Columbia River reservoirs were also evident most likely due to the morphology of the reservoir and its more northerly location. Information we collected on fish distribution and abundance in relation to environmental conditions will be useful in examining possible effects of hydropower operations on fish assemblage structure in Chief Joseph Reservoir.

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