

Development of a Systemwide Predator Control Program: Indexing and Fisheries Evaluation

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## ABSTRACT

Predator control fisheries aimed at reducing predation on juvenile salmonids by northern pikeminnow *Ptychocheilus oregonensis* were implemented for the tenth consecutive year in the mainstem Columbia and Snake rivers. In this report, we (1) evaluate northern pikeminnow exploitation rate and catch rate of incidentally-harvested fishes among the three management fisheries in 1999, (2) estimate reductions in predation on juvenile salmonids since implementation of the fisheries, (3) compare current northern pikeminnow population parameters (relative abundance, consumption, size and age structure, growth, and fecundity) to parameters measured in 1990-1996, and (4) compare current information on abundance and consumption of smallmouth bass *Micropterus dolomieu* and walleye *Stizostedion vitreum* to information collected from 1990-1996.

Systemwide exploitation of northern pikeminnow  $\geq 250$  mm fork length was 12.5% for sport-reward, 0.0% for dam-angling (no tagged fish recovered), and 0.2% for site-specific gill-net fisheries (one tagged fish recovered). Exploitation was lowest in Lower Monumental and Little Goose reservoirs (0.0%) and highest in The Dalles Reservoir (16.1%). The dam-angling fishery had the lowest percentage (5.3%) of incidental catch relative to the total number of fish caught. Incidental catch was 31.6% in the sport-reward fishery and 63.8% in the gill-net fishery.

If exploitation rates remain similar to mean 1994-1999 levels, we estimate that potential predation by northern pikeminnow on juvenile salmonids in 2000 will be approximately 75% of predation levels prior to the implementation of removal fisheries. Further reductions in predation are unlikely unless average exploitation in future years is higher than recent levels.

Relative abundance of northern pikeminnow was lower in 1999 than mean abundance from 1994-1996. Indices of consumption and predation of northern pikeminnow were generally greater in 1999 than 1996, particularly in spring. However, predation in 1999 was less than average predation from 1994-1996 at most locations. Relative density and juvenile salmonid consumption of smallmouth bass was similar to or less than density and consumption from 1990 to 1996.

Proportional stock density of northern pikeminnow in 1999 was similar to previous years. We found no evidence that northern pikeminnow have compensated in fecundity or condition (relative weight) in response to sustained exploitation in the lower Columbia River.

Relative abundance of smallmouth bass was similar to or less than abundance from 1990 to 1996. Consumption indices for smallmouth bass were low in both spring and summer. Diet of walleye was similar to that in previous years.

## INTRODUCTION

The goal of the Northern Pikeminnow Management Program (NPMP) is to reduce mainstem mortality of juvenile salmonids attributed to predation by northern pikeminnow *Ptychocheilus oregonensis*, formerly known as northern squawfish (Nelson et al. 1998), in the lower Columbia River basin. We established baseline levels of predation and described northern pikeminnow population characteristics prior to the implementation of sustained predator control fisheries by estimating northern pikeminnow abundance, consumption, and predation in Columbia River reservoirs in 1990 (Vigg et al. 1990), Snake River reservoirs in 1991 (Ward et al. 1993), and the unimpounded lower Columbia River downstream from Bonneville Dam in 1992 (Parker et al. 1994). We sampled Columbia River impoundments again in 1993 to evaluate changes from 1990 (Zimmerman et al. 1995). From 1994-1996 we sampled in areas where sufficient numbers of northern pikeminnow could be collected to compare changes in predation among years (Zimmerman and Ward 1999). Ward (1997) provided a comprehensive summary of NPMP evaluation from 1990-1996. In this report we describe our activities and findings for 1999, and wherever possible, evaluate changes from previous years.

Our objectives in 1999 were to (1) evaluate the relative efficiency of each northern pikeminnow fishery by comparing exploitation rate and incidental catch, (2) estimate reductions in predation on juvenile salmonids since the implementation of the NPMP, and (3) update information on population dynamics of northern pikeminnow, smallmouth bass *Micropterus dolomieu* and walleye *Stizostedion vitreum*, including relative abundance, consumption, diet, year-class strength, size structure, relative weight, and fecundity.

## METHODS

### Fishery Evaluation and Loss Estimates

#### Field Procedures

Three northern pikeminnow fisheries were conducted in 1999. The sport-reward fishery was implemented by the Washington Department of Fish and Wildlife (WDFW) from May 3 to October 10 throughout the lower Columbia and Snake rivers. The dam-angling fishery was implemented by the Columbia River Inter-Tribal Fish Commission (CRITFC), Confederated Tribes of the Warm Springs Reservation of Oregon (CTWS), Confederated Tribes of the Umatilla Indian Reservation, and the Confederated Tribes and Bands of the Yakama Indian Nation (YIN) from June 7 to October 22 at Bonneville, The Dalles, John Day, and McNary dams. A site-specific gill-net fishery was implemented by CRITFC, YIN, and CTWS from May 3 to June 22 downstream from Bonneville Dam and in Bonneville and The Dalles reservoirs.

We tagged and released northern pikeminnow to estimate exploitation rates for each fishery. We used electrofishing boats and sinking gill nets to collect northern pikeminnow from April 5-June 24. We allocated equal sampling effort in all river kilometers (Rkm) from Rkm 79 through Priest Rapids Dam tailrace (Rkm 637) on the lower Columbia River, and on the Snake River from Rkm 82 through Rkm 248 (detailed methods are given in Friesen and Ward 1999).

Northern pikeminnow were tagged with a serially-numbered spaghetti tag. To account for potential growth during the fishery season, we tagged all northern pikeminnow greater than 240 mm fork length. Tags were recovered from each fishery from May 3 to October 22.

## Data Analysis

We used mark-and-recapture data to compare exploitation rates of northern pikeminnow  $\geq 250$  mm fork length among fisheries and reservoirs in 1999. Weekly estimates of exploitation for each fishery were calculated by dividing the number of tagged northern pikeminnow recovered by the number of tagged fish at large and summed to yield total exploitation rates (Beamesderfer et al. 1987). We assumed a 4.2 % rate of tag loss (Friesen and Ward 1999).

We used two methods to calculate 95% confidence intervals for the number of tagged fish recovered each week. We calculated confidence intervals for variables distributed in a Poisson distribution from Ricker (1975) for weeks when tagging and fishing occurred simultaneously. After tagging was complete, we calculated confidence intervals using the formula

$$m \pm 1.96 \sqrt{m/n} \quad (\text{if } mn > 30),$$

where

$n$  = the number of sampling periods (weeks) remaining, and  
 $m$  = the mean number of tagged fish recovered per week (Elliott 1977).

We summed estimates for each week to give overall confidence limits.

We compared incidental catch among fisheries for 1999 by determining the percent of the total catch composed of fish other than northern pikeminnow  $\geq 250$  mm fork length.

We used the “Loss Estimate Spreadsheet Model” (Friesen and Ward 1999) to estimate predation on juvenile salmonids relative to predation prior to implementation of the NPMP. The model incorporates age-specific exploitation rates on northern pikeminnow and resulting changes in age structure to estimate changes in predation. We used a 10-year “average” age structure (based on catch curves) for a pre-exploitation base, and assumed constant recruitment. Age-specific consumption was incorporated; however, potential changes in consumption, growth, and fecundity due to removals were not considered likely. The model therefore estimates changes in potential predation related directly to removals. This in effect allowed us to estimate the effects of removals if all variables except exploitation were held constant.

We estimated the potential relative predation in 1999 based on observed exploitation rates, and the eventual minimum potential predation assuming continuing exploitation at mean 1994-1999 levels. Because inputs to the model included three potential relationships between age of northern pikeminnow and consumption, and three estimates of exploitation (point estimate plus confidence limits), we computed nine estimates of relative predation for each year (Friesen and Ward 1999). We report the maximum, median, and minimum estimates.

## **Biological Evaluation**

### **Field Procedures**

To evaluate changes in relative abundance and consumption of northern pikeminnow, smallmouth bass, and walleye, we used boat electrofishing to collect biological data in spring (April 27 - June 3) and summer (June 29 - August 6) in the following areas: downstream from Bonneville Dam (Rkm 117-121, Rkm 171-177, and Rkm 178-183), Bonneville Dam tailrace, Bonneville Reservoir, John Day Dam tailrace, John Day Reservoir, Little Goose Dam tailrace, Lower Granite Dam tailrace, and upper Lower Granite Reservoir (Rkm 221-229). Sampling methods and gear specifications have been previously described (Ward et al. 1995; Zimmerman and Ward 1999). Digestive tract contents from northern pikeminnow and walleye  $\geq 250$  mm fork length, and from smallmouth bass  $\geq 200$  mm fork length were preserved using methods described by Ward et al. (1995).

We collected biological data from all northern pikeminnow collected by electrofishing and from subsamples of fish harvested by the sport-reward fishery to evaluate changes in population structure, growth, and reproduction. We determined fork length (mm), total body weight (g), sex (male, female or undetermined), and maturity (undeveloped or immature, developing, ripe, or spent), and collected gonad (ripe females only) and scale samples. Fork length data for northern pikeminnow harvested by the sport-reward fishery were provided by WDFW, and data on fork lengths of fish caught in the dam angling and site-specific gillnet fisheries were provided by CRITFC. We also collected scale samples from smallmouth bass and walleye.

### **Laboratory Procedures**

We examined digestive tract contents of northern pikeminnow, smallmouth bass, and walleye to measure relative consumption rates of juvenile salmonids. Details of laboratory methods are given in Ward et al. (1995). We collected scale samples from northern pikeminnow downstream from Bonneville Dam, and in Bonneville, John Day, and Lower Granite reservoirs. Methods of age determination were described by Parker et al. (1995). We estimated fecundity of ripe female northern pikeminnow using procedures described by Parker et al. (1995).

### **Data Analysis**

We used catch per unit effort of standardized electrofishing runs as an index of density for northern pikeminnow and smallmouth bass. We calculated indices of northern pikeminnow abundance as the product of the density index and reservoir or area-specific surface area (Ward et al. 1995). We compared density and abundance indices of northern pikeminnow in 1999 with those from 1990-1996.

The following formulas were developed as consumption indexes (CI) for northern pikeminnow (Ward et al. 1995) and smallmouth bass (Ward and Zimmerman 1999):

$$CI_{NPM} = 0.0209 \cdot T^{1.60} \cdot MW^{0.27} \cdot (S \cdot GW^{-0.61}),$$

and

$$CI_{SMB} = 0.0407 \cdot e^{(0.15)(T)} \cdot MW^{0.23} \cdot (S \cdot GW^{-0.29}),$$

where

$CI_{NPM}$  = consumption index for northern pikeminnow,

$CI_{SMB}$  = consumption index for smallmouth bass,

T = water temperature (°C),

MW = mean predator weight (g),

S = mean number of salmonids per predator, and

GW = mean gut weight (g) per predator.

The consumption index is not a rigorous estimate of the number of juvenile salmonids eaten per day by an average predator; however, it is linearly related to the consumption rate of northern pikeminnow (Ward et al. 1995) and smallmouth bass (Ward and Zimmerman 1999). Spring (April-June) and summer (June-August) consumption indices were compared with those from 1990-1996 for all sampling areas. We calculated and compared smallmouth bass CI's between two size groups:  $\geq 150$  mm and  $\geq 200$  mm fork length.

We used the product of abundance and consumption indices to calculate predation indices for northern pikeminnow for spring and summer periods, and compared northern pikeminnow predation among years for reservoirs and areas where data had been collected each year. We plotted the daily juvenile salmonid passage index at lower Columbia and Snake River dams to compare timing of consumption index sampling with concentrations of juvenile salmonids present in each area.

We used the method of El-Zarka (1959) to index year-class strengths of northern pikeminnow cohorts (1985-1995) based on their relative abundance in standardized electrofishing catches downstream from Bonneville Dam and in Bonneville Reservoir. Because the relative abundances of year classes in electrofishing catches were biased by exploitation rates that varied among years (Friesen and Ward 1999), we limited our comparisons to abundance of northern pikeminnow large enough to be effectively sampled and small enough to be excluded from the NPMP (ages 3-5).

Because fishery exploitation rates are greater on larger pikeminnow than on smaller pikeminnow (Zimmerman et al. 1995), sustained fisheries should decrease the abundance of large fish relative to the abundance of smaller fish. We used proportional stock density (PSD; Anderson 1980), where  $PSD = 100 \cdot (\text{number of fish at least quality length} / \text{number of fish at least stock length})$  to compare size structure of northern pikeminnow populations among years in the Columbia River downstream from Bonneville Dam, and in Bonneville and John Day reservoirs. Stock and quality sizes for northern pikeminnow have been defined as 250 and 380 mm fork length, respectively (Beamesderfer and Rieman 1988; Parker et al. 1995).



We used mean relative weight ( $W_r$ ) to compare condition of northern pikeminnow in 1999 with previous years (Anderson and Gutreuter 1983). We used the standard weight ( $W_s$ ) equation for northern pikeminnow developed by Parker et al. (1995),  $\log_{10}(W_s) = -4.886 + 2.986[\log_{10}(\text{fork length})]$ , in calculations ( $W_r = 100[\text{weight}]/W_s$ ). We calculated  $W_r$  for male and female pikeminnow downstream from Bonneville Dam and in Bonneville Reservoir.

We calculated mean fecundity (number of developed eggs per female) and mean relative fecundity (number of developed eggs per gram of body weight) of northern pikeminnow from the Columbia River downstream from Bonneville Dam, and from Bonneville and John Day reservoirs.

## RESULTS

### Fishery Evaluation and Loss Estimates

We tagged and released 750 northern pikeminnow throughout the lower Columbia and Snake rivers in 1999. A total of 84 tagged fish were recaptured in the three fisheries: 83 in the sport-reward fishery, none in the dam-angling fishery, and one in the site-specific gill-net fishery. A total of 119,280 northern pikeminnow  $\geq 250$  mm were harvested in 1999: 114,687 in the sport reward fishery, 3,737 in the dam angling fishery, and 1,891 in the gill-net fishery. Total exploitation of northern pikeminnow in 1999 was 12.7%, which exceeded the 1992-1998 average of 11.8 % (Figure 1; **Appendix A**). Exploitation of northern pikeminnow in the sport-reward fishery was 12.5%; the second-highest rate observed since the program's inception. This year's sport-reward exploitation in Bonneville and The Dalles reservoirs was the highest since 1991, whereas exploitation upstream of Lower Granite Dam was lower than all previous years. The 95% confidence intervals around the system-wide exploitation estimate were 7.5 and 22.8% for all fisheries combined (Figure 1).

We did not sample the catch of northern pikeminnow in each fishery in 1999 to estimate mean size of harvested fish. The WDFW reported a mean fork length of 326 mm

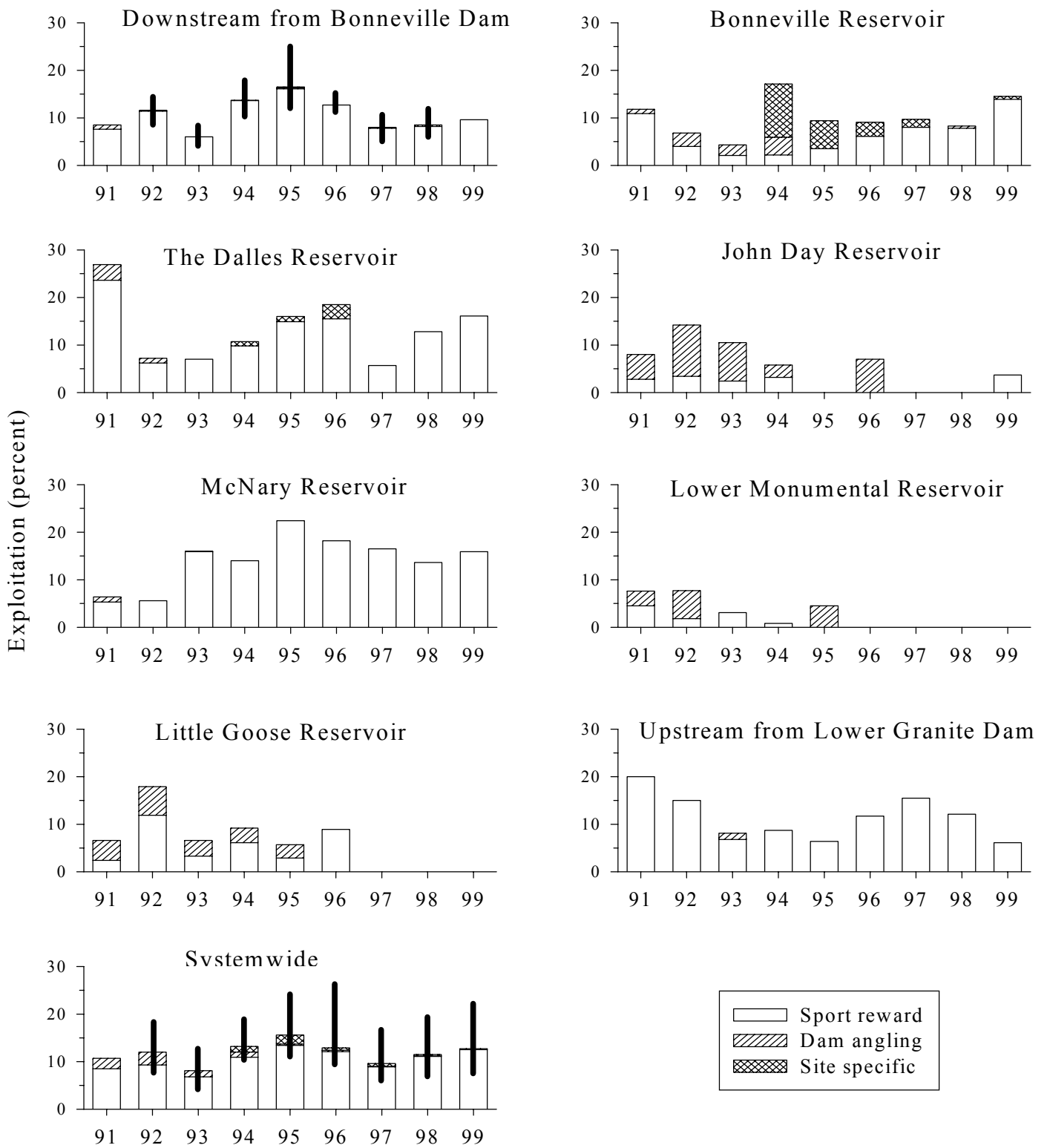


Figure 1. Exploitation of northern pikeminnow  $\geq 250$  mm fork length by fishery and area, 1991-99. Vertical bars are 95% confidence intervals for all fisheries combined downstream from Bonneville Dam and system-wide.

(N=79,084) for northern pikeminnow  $\geq 250$  mm fork length at all check stations (Fox et al. 2000). This was very similar to the means of 332 mm in 1996, 329 mm in 1997, and 325 mm in 1998. A representative sample of northern pikeminnow was not available for the dam-angling fishery. Mean size among 1,405 northern pikeminnow harvested primarily in Bonneville Reservoir by the site-specific fishery was 390 mm (Roy Beaty, CRITFC, personal communication). This was less than the mean of 412 mm for fish harvested by gill nets in Bonneville Reservoir from 1994-1996.

Incidental catch among all fisheries in 1999 was 56,817, or 32.0% of all captured fish. The incidental catch rate was 31.6% in the sport-reward fishery, 5.3% in the dam-angling fishery, and 63.8% in the gill-net fishery (Table 1). The proportion of predator-sized ( $\geq 250$  mm fork length) northern pikeminnow relative to the total number of northern pikeminnow harvested was highest in the dam-angling fishery (99.9%) and lowest in the sport-reward fishery (80.1%).

Salmonids made up only 0.5% of the total catch and 1.7% of the incidental catch for all fisheries combined in 1999. The combined incidental catch for all fisheries was primarily composed of cyprinids (including northern pikeminnow  $< 250$  mm), averaging 67% of non-targeted fish from 1995 to 1999 for all fisheries combined (Figure 2). Predator species other than northern pikeminnow (mostly smallmouth bass, channel catfish, and walleye) averaged 11.9%, catostomids averaged 9.0%, and white sturgeon averaged 6.2% of incidental catch from 1995 to 1999.

Results from the “Loss Estimate Spreadsheet Model” indicated that potential predation by northern pikeminnow on juvenile salmonids in 1999 ranges from 63% to 88% of pre-program levels, with a median estimate of 75% (Figure 3). Continued exploitation at mean 1994-99 levels will probably not result in further reductions in predation.

### **Biological Evaluation**

Timing of predator sampling near Columbia and Snake River dams generally coincided with peaks in juvenile salmonid passage indices (**Appendix B**). However, we were unable to sample within the boat-restricted zone at most of the dams because of high spill levels in 1999. Density indices for northern pikeminnow in 1999 were among the lowest measured since 1990 (**Appendix Table C-2**). Catch of northern pikeminnow at Snake River sites in spring was zero in Little Goose Dam tailrace, four in Lower Granite Dam tailrace, and 16 upstream of Lower Granite Dam. Compared to mean abundance from 1994-1996, relative abundance of northern pikeminnow in 1999 was 24% lower downstream from Bonneville Dam (excluding the tailrace BRZ), 49% lower in Bonneville Reservoir (excluding the tailrace BRZ), and 53% lower in John Day Reservoir forebay and tailrace outside the BRZ (Figure 4; **Appendix Table C-3**).

The frequency of occurrence of salmonids among northern pikeminnow was slightly (3.8%) greater in 1999 than 1996 (**Appendix Table E-1**). In 1999, spring consumption index values were greater than the 1994-1996 mean values in Bonneville Dam tailrace, the mid-

Table 1. Number of northern pikeminnow and incidentally-caught fish by species or family in each fishery in 1999. Sport reward catches of salmonids and northern pikeminnow  $\geq 250$  mm are

estimates based upon returning and non-returning anglers. Sport reward catches of all other taxa are by returning anglers only.

Species or family	Sport Reward	Dam Angling	Gill Net
Northern pikeminnow			
≥250 mm fork length	115,093	3,737	1,891
<250 mm fork length	28,541	5	20
White sturgeon <sup>a</sup>	3,048	113	1,042
American shad <sup>a</sup>	376	4	286
Salmonidae <sup>a</sup>			
Chinook (adult)	59	0	60
Chinook (juvenile)	176	-- <sup>b</sup>	-- <sup>b</sup>
Sockeye (adult)	0	0	3
Sockeye (juvenile)	0	-- <sup>b</sup>	-- <sup>b</sup>
Steelhead (adult)	81	0	23
Steelhead (juvenile)	355	-- <sup>b</sup>	-- <sup>b</sup>
Unknown salmon	0	1	3
Other	171	39	
Cyprinidae (minnows)	12,799	2	93
Catostomidae (suckers)	71	0	1,539
Channel catfish <sup>a</sup>	1,039	21 <sup>c</sup>	9 <sup>c</sup>
Smallmouth bass <sup>a</sup>	4,354	57 <sup>d</sup>	62 <sup>d</sup>
Walleye <sup>a</sup>	431	4	65
Other/unidentified	1,780	1	83
Total (all species)	168,374	3,946	5,218
Percent incidental catch	31.6	5.3	63.8

<sup>a</sup> Salmonidae = *Oncorhynchus*, *Salmo*, *Salvelinus*, and *Prosopium* spp. White sturgeon = *Acipenser transmontanus*, American shad = *Alosa sapidissima*, channel catfish = *Ictalurus punctatus*, smallmouth bass = *Micropterus dolomieu*, walleye = *Stizostedion vitreum*.

<sup>b</sup> Juvenile salmonids were not identified to species. One was captured by dam angling and seven were captured by gill net. All are listed under "Other".

<sup>c</sup> Includes all Ictalurid species.

<sup>d</sup> Includes all *Micropterus* species.

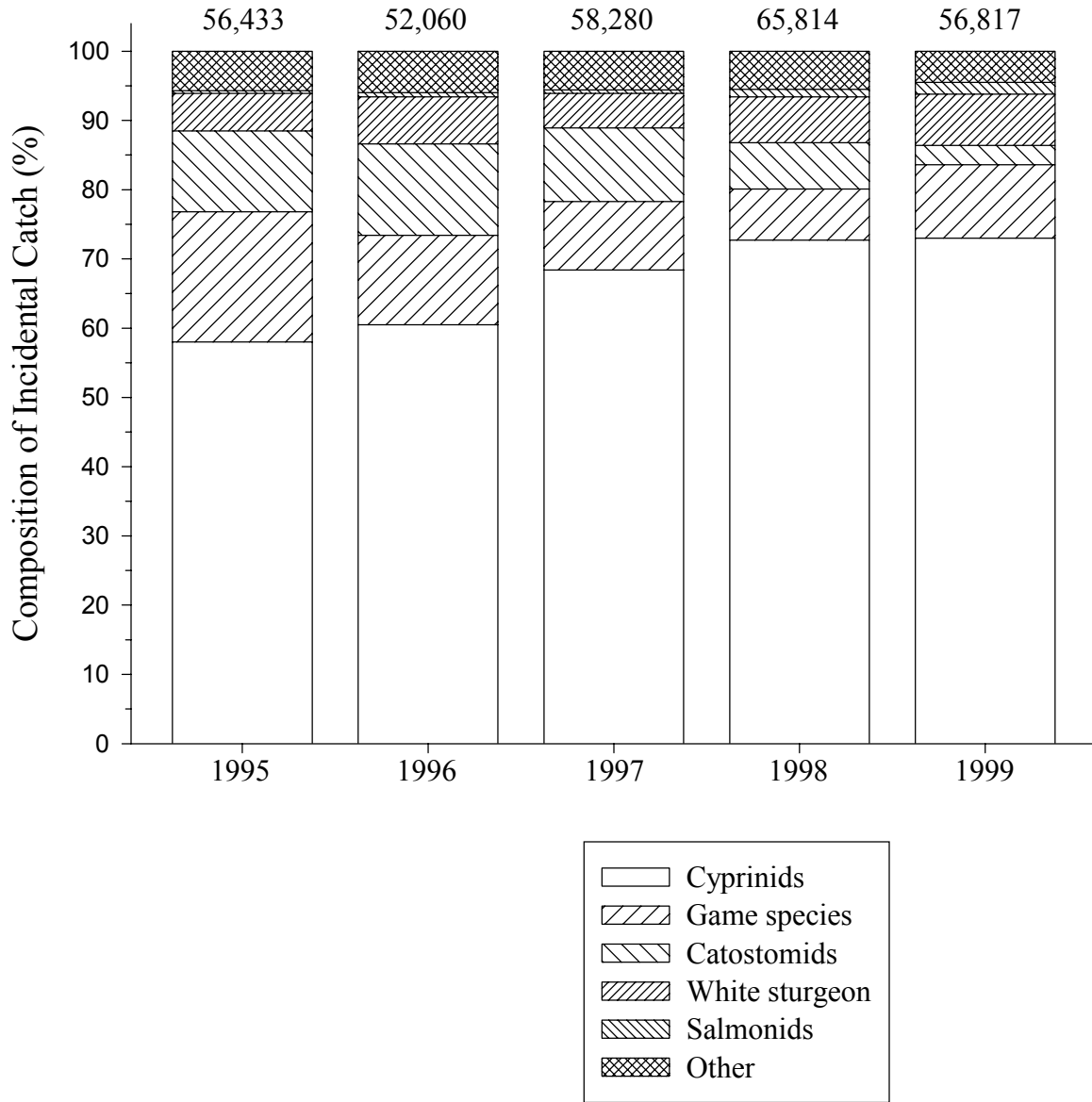


Figure 2. Taxonomic composition (percent) of incidentally-caught fish in all fisheries combined from 1995 to 1999. Figures above bars are total number of incidentally-caught fish. Cyprinids include northern pikeminnow <250 mm fork length. Game species include smallmouth bass, channel catfish, and walleye caught in the sport reward fishery, and *Micropterus* species, Ictalurid species, and walleye caught in the dam angling and gill-net fisheries.

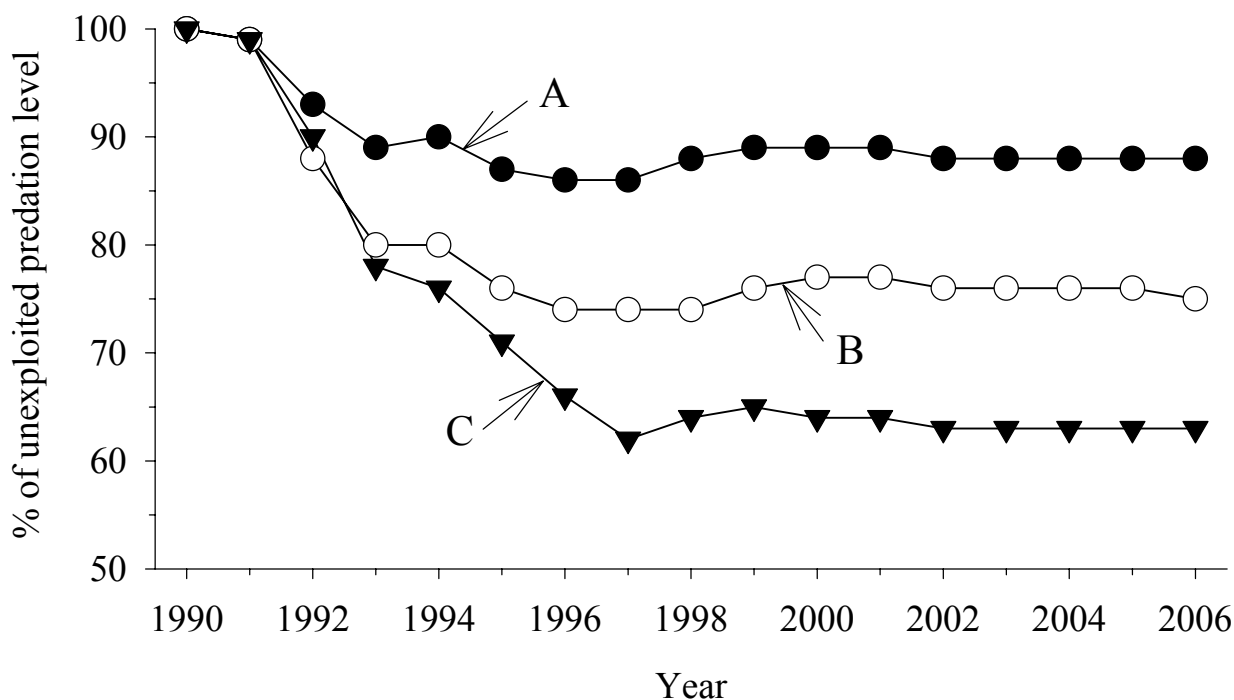


Figure 3. Maximum (A), median (B), and minimum (C) estimates of potential predation on juvenile salmonids by northern pikeminnow relative to predation prior to implementation of the northern pikeminnow management program. Trends after 2000 indicate predation in future years if exploitation is maintained at mean 1994-99 levels.

reservoir of Bonneville Reservoir, John Day Dam tailrace, and the upper portion of Lower Granite Reservoir (**Appendix Table C-4**). Consumption indices in spring were similar or lower than 1994-1996 means in the remaining locations. Summer consumption indices were equal to or lower than 1994-1996 means at all locations (**Appendix Table C-5**).

Predation indices in spring were greater in 1999 than 1996 except in Bonneville Dam tailrace (Figure 5; **Appendix Table C-6**). Predation in spring 1999 was generally lower than the mean index values from 1994-1996. In summer, the sum of predation index values downstream from Bonneville Dam in 1999 was greater than 1996, but less than mean predation from 1994-1996 (Figure 6; **Appendix Table C-7**). Predation indices at impounded sites upstream from Bonneville Dam were mostly negligible in summer 1999.

Year-class strengths of northern pikeminnow downstream from Bonneville Dam were highest in 1985 and 1991, and lowest in 1987 (Figure 7). In Bonneville Reservoir, strong year classes occurred in 1985, 1987, and 1991, and year-class strength was lowest in 1988. Estimates of PSD and  $W_r$  (Table 2) and fecundity (Table 3) of northern pikeminnow in 1999 were within the ranges of estimates in previous years.

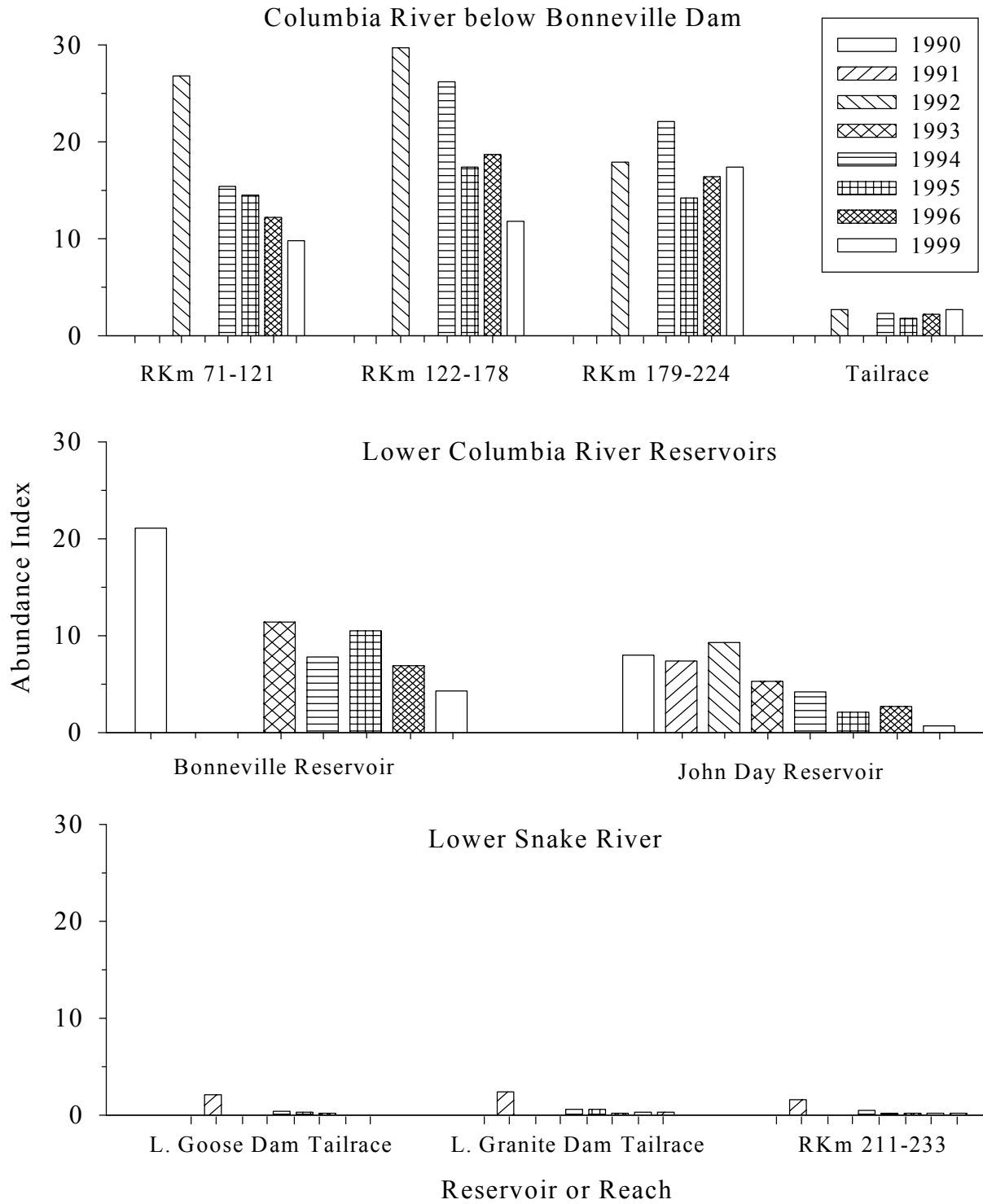


Figure 4. Index of northern pikeminnow abundance from 1990-96 and 1999 for sampling locations in the lower Columbia and Snake rivers. RKm = river kilometer.

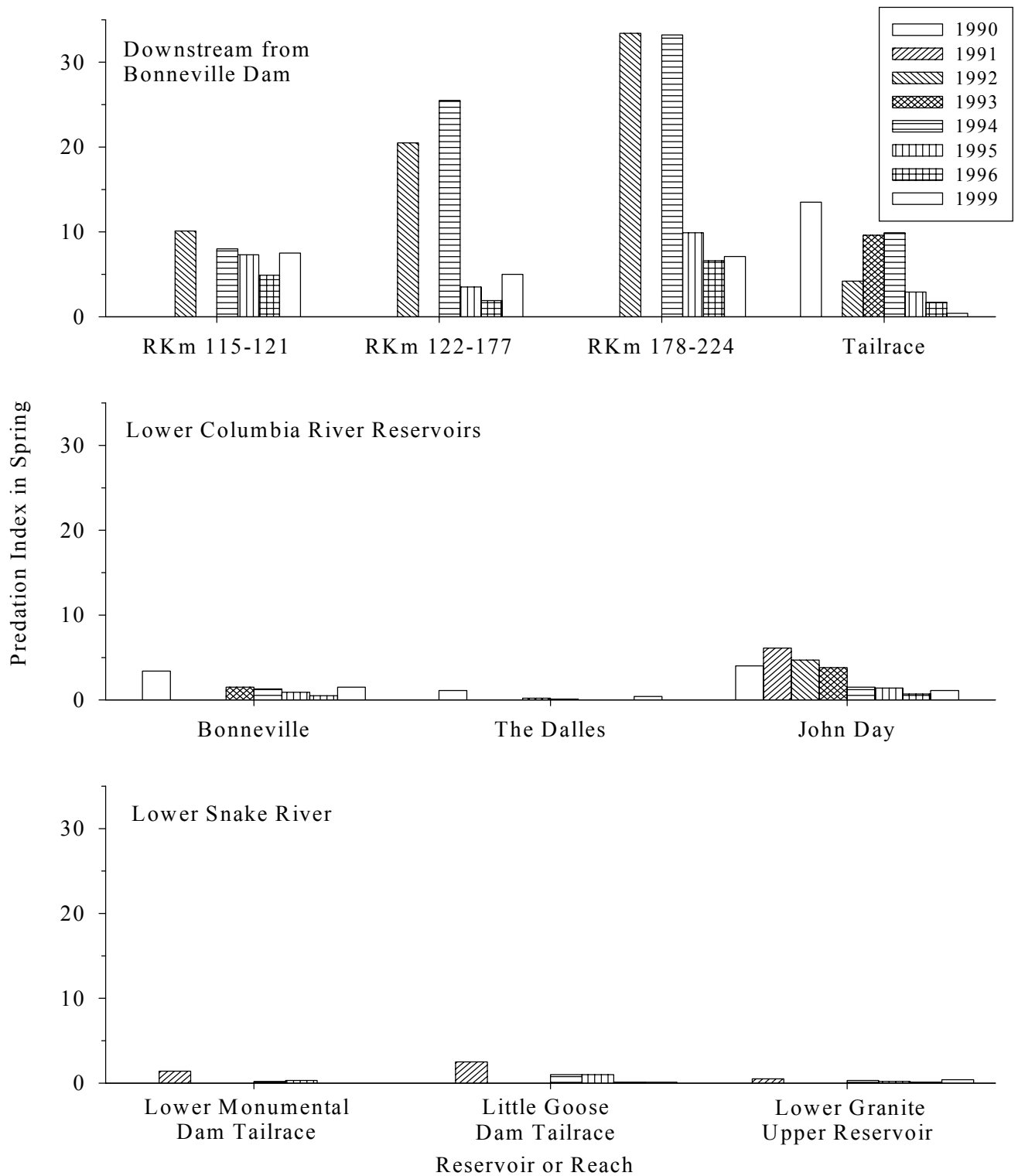


Figure 5. Index of predation by northern pikeminnow during spring in 1990-1996 and 1999 for sampling locations in the lower Columbia and Snake rivers. RKm = river kilometer.



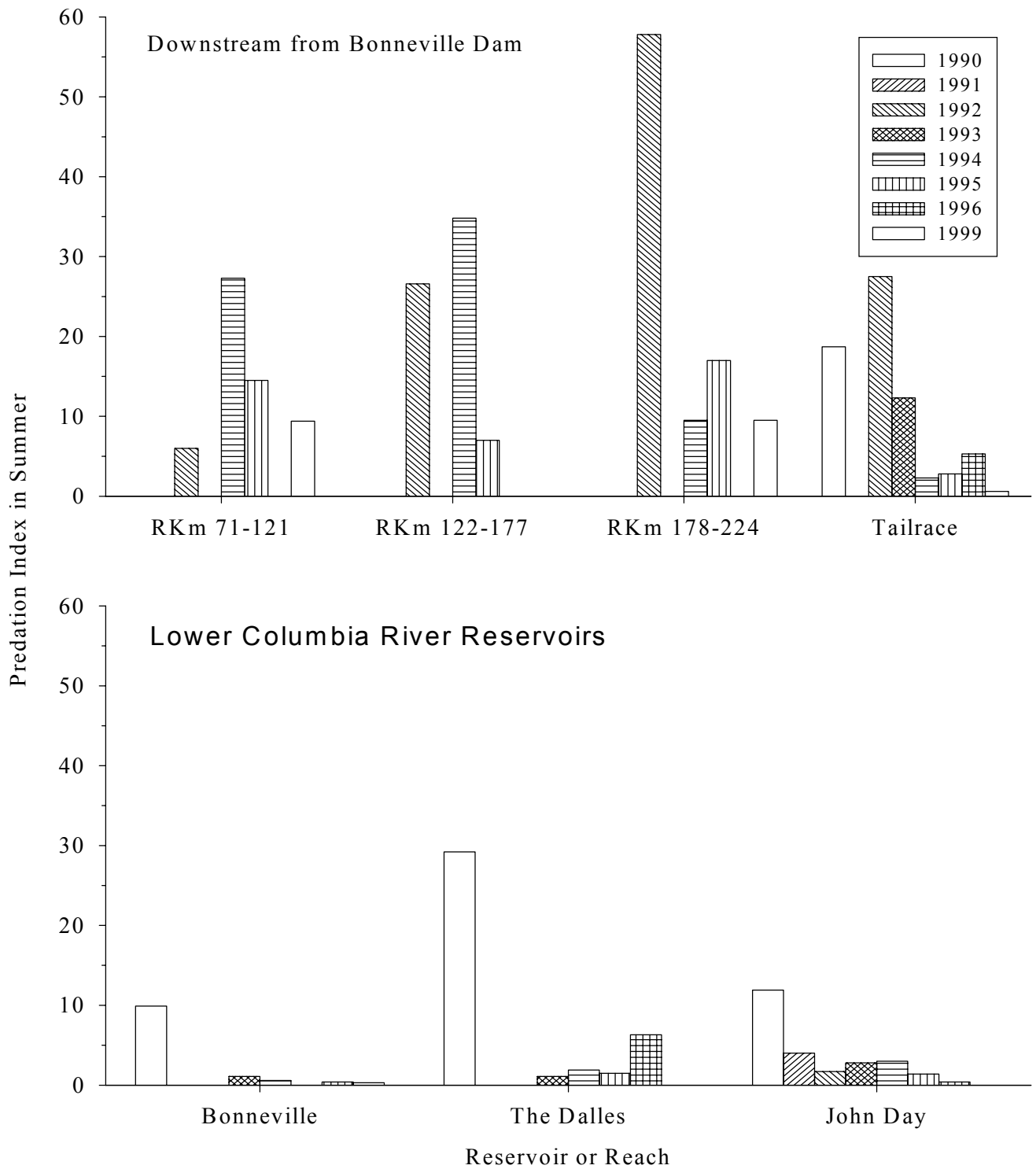


Figure 6. Index of predation by northern pikeminnow during summer in 1990-1996 and 1999 for sampling locations in the lower Columbia River. Predation indices for The Dalles Reservoir excludes the mid-reservoir and forebay. RKm = river kilometer.

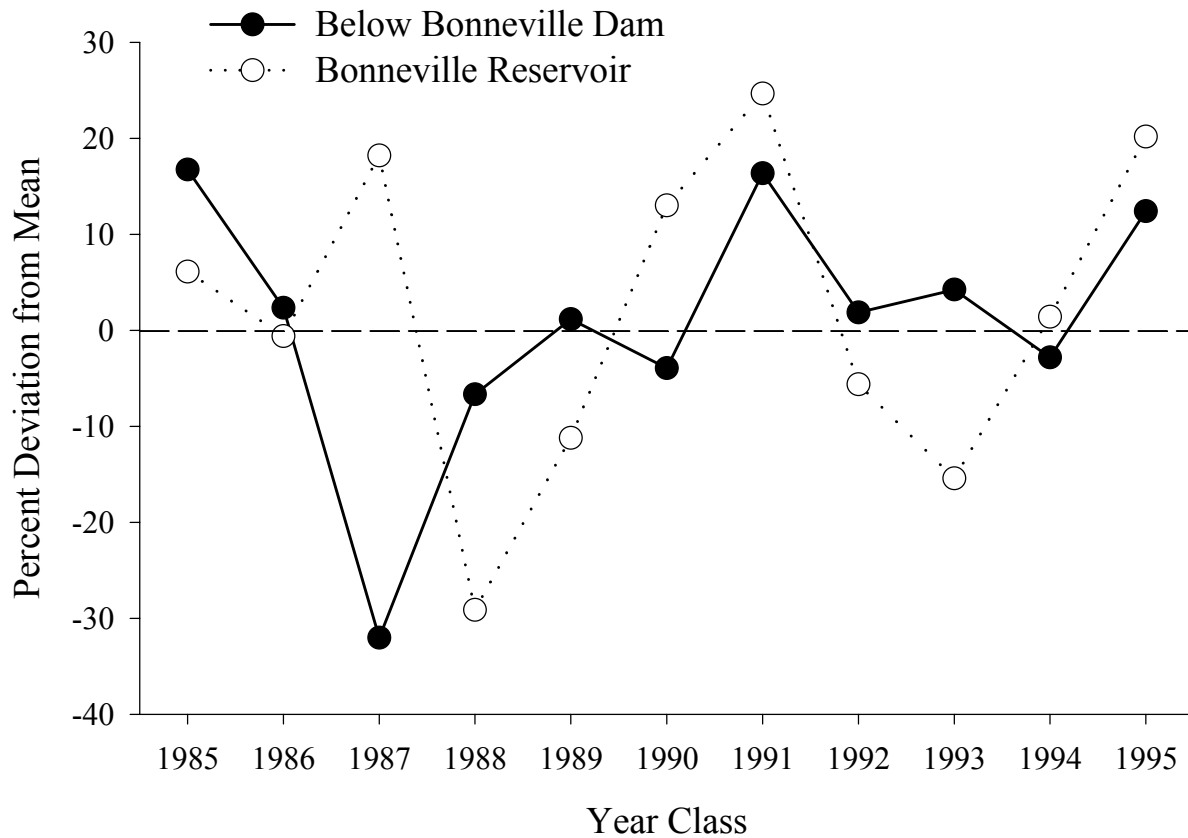


Figure 7. Index of relative year-class strength of northern pikeminnow in the Columbia River downstream from Bonneville Dam and Bonneville Reservoir from 1985 to 1995.

Relative density of smallmouth bass in 1999 was generally similar or less than density from 1990 to 1996 (**Appendix Tables D-1 and D-2**). Consumption indices for smallmouth bass were very low at all locations in both spring and summer (**Appendix Tables D-3 and D-4**). Consumption indices for smallmouth bass  $\geq 150$  mm were not statistically different from those computed for bass  $\geq 200$  mm during spring ( $P=0.79$ ) and summer ( $P=0.90$ ). The frequency of occurrence of salmonids among smallmouth bass in 1999 was similar to 1996 (**Appendix Table E-1**).

Table 2. Proportional stock density (PSD), mean relative weight ( $W_r$ ), and sample size (N) of northern pikeminnow downstream from Bonneville Dam and in Bonneville Reservoir in 1999 and 1990-1996.

Location, parameter	1990	1991	1992	1993	1994	1995	1996	1999
Downstream from Bonneville Dam								
PSD	--	--	0.29	--	0.33	0.41	0.33	0.39
(N)	--	--	(682)	--	(401)	(206)	(245)	(226)
Mean $W_r$ , males	--	--	88	--	93	88	87	92
(N)	--	--	(453)	--	(220)	(64)	(102)	(75)
Mean $W_r$ , females	--	--	96	--	103	99	95	104
(N)	--	--	(494)	--	(340)	(156)	(171)	(146)
Bonneville Reservoir								
PSD	0.43	--	--	0.37	0.40	0.26	0.24	0.33
(N)	(245)	--	--	(148)	(378)	(319)	(199)	(169)
Mean $W_r$ , males	85	81	--	97	99	95	92	96
(N)	(24)	(26)	--	(161)	(234)	(164)	(102)	(93)
Mean $W_r$ , females	101	83	--	106	106	103	101	105
(N)	(71)	(37)	--	(153)	(304)	(161)	(113)	(72)

The proportion of walleyes that had consumed juvenile salmonids was 19.6% in spring and 18.5% in summer (**Appendix Table E-1**). Walleye stomachs contained 50 identifiable prey fish, 21 (42.0%) of which were salmonids (**Appendix Table E-2**).

## DISCUSSION

Rieman and Beamesderfer (1990) predicted that sustained exploitation of northern pikeminnow >275 mm fork length at an annual rate of 10-20% would reduce losses of juvenile salmonids to predation by 50%. Total systemwide exploitation by the three fisheries in 1999 was 12.7%, exceeding the average rate of 11.8% from 1992-1998. As in previous years, sport-reward effort, harvest, and exploitation greatly exceeded other fisheries. The dam-angling and site-specific gill-net fisheries, while contributing less to exploitation, harvested localized concentrations of northern pikeminnow which may have aggregated to feed on juvenile salmonids (Collis et al. 1995).

Table 3. Mean fecundity (number of eggs per female), mean relative fecundity (MRF; number of eggs per gram of body weight), and sample size (N) of northern pikeminnow downstream from Bonneville Dam and in Bonneville Reservoir in 1999 and 1991-1996.

Location, parameter	1991	1992	1993	1994	1995	1996	1999
Downstream from Bonneville Dam							
Mean fecundity	37,500	25,069	22,410	26,717	18,865	24,047	22,117
MRF	40.01	38.74	37.68	37.37	31.32	40.79	38.43
(N)	(59)	(247)	(267)	(84)	(121)	(39)	(37)
Bonneville Reservoir							
Mean fecundity	31,225	33,640	30,444	29,313	18,550	26,413	20,768
MRF	45.17	35.96	32.15	32.43	22.27	33.90	24.13
(N)	(37)	(105)	(101)	(100)	(6)	(47)	(33)

If exploitation rates remain similar to mean 1994-99 levels, it is likely that no further reductions in potential predation will be realized. Predation will remain at approximately 75% of pre-program levels. Exploitation rates lower than mean 1994-99 levels will result in increases in potential predation.

Reducing the number of large northern pikeminnow may improve salmonid survival if remaining northern pikeminnow do not consume salmonids at a higher rate (Beamesderfer et al. 1996). Predation indices of northern pikeminnow in 1999 exceeded values from 1996 at many locations, but were generally similar or less than mean values from 1994-1996. Higher consumption indices for northern pikeminnow in 1999 relative to 1996 may be partially attributed to our sample timing which coincided particularly well with juvenile salmonid passage at most locations.

Consumption indices for smallmouth bass were low in 1999, and comparable to previous years. We speculated that previous indices of smallmouth bass consumption were biased low because we only sampled stomach contents of fish  $\geq 200$  mm fork length. This year we sampled smallmouth bass  $\geq 150$  mm and found that consumption indices were not significantly different between the two minimum length criteria. The incidence of juvenile salmonid predation by walleyes was greater in 1999 than previous years (Zimmerman 1999), perhaps reflecting increased abundance of juvenile salmonids when sampling was conducted. All indices for northern pikeminnow and smallmouth bass in the tailrace areas at most dams were biased low because river conditions and spill levels during 1999 prevented sampling effort in most of the boat-restricted zones.

Estimates of PSD were generally within the range from 1990-1996. Much of the variation in PSD undoubtedly resulted from fluctuating year-class strengths that influenced the number of stock-size fish (Mesa et al. 1990).

If northern pikeminnow compensate for sustained exploitation with increased growth or fecundity rates, relative benefits of the NPMP will be diminished (Beamesderfer et al. 1996). Our estimates of fecundity and relative weight of northern pikeminnow have not shown any increasing trends since 1990, and 1999 estimates were well within the ranges noted in previous years.

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## **APPENDIX A**

Exploitation of Northern Pikeminnow, 1992-1999



**Appendix Table A-1.** Total exploitation rates (%) of northern pikeminnow  $\geq 250$  mm fork length, 1992-1999.

Area or reservoir	1992	1993	1994	1995	1996	1997	1998	1999
Downstream from								
Bonneville Dam	11.7	6.0	13.8	16.5	12.7	8.0	8.4	9.6
Bonneville	6.8	4.3	11.2	9.4	9.1	9.7	9.2	14.5
The Dalles	7.2	7.0	10.7	16.0	15.5	5.8	12.8	16.1
John Day	14.2	10.5	5.8	0.0	7.0	0.0	0.0	3.7
McNary	5.6	16.0	14.0	22.4	18.2	16.5	13.6	15.9
Ice Harbor	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>
Lower Monumental	7.7	3.1	0.8	4.5	0.0	0.0	0.0	0.0
Little Goose	17.9	6.6	9.2	5.7	8.9	0.0	0.0	0.0
Lower Granite	15.0	12.5	8.7	6.4	11.7	15.5	12.1	6.1
Systemwide	12.0	8.1	13.2	15.5	12.9	9.6	11.5	12.7

<sup>a</sup> No northern pikeminnow tagged.

**Appendix Table A-2.** Exploitation rates (%) of northern pikeminnow  $\geq 250$  mm fork length for the sport-reward fishery, 1992-1999.

Area or Reservoir	1992	1993	1994	1995	1996	1997	1998	1999
Downstream from								
Bonneville Dam	11.4	6.0	13.6	16.1	12.7	7.8	8.2	9.6
Bonneville	4.0	2.1	2.2	3.5	6.1	8.0	7.8	13.9
The Dalles	6.2	7.0	9.8	14.9	15.5	5.8	12.8	16.1
John Day	3.4	2.4	3.2	0.0 <sup>a</sup>	0.0 <sup>a</sup>	0.0 <sup>a</sup>	0.0 <sup>a</sup>	3.7
McNary	5.6	15.9	14.0	22.4	18.2	16.5	13.6	15.9
Ice Harbor	-- <sup>b</sup>	-- <sup>b</sup>	-- <sup>b</sup>	-- <sup>b</sup>	-- <sup>b</sup>	-- <sup>b</sup>	-- <sup>b</sup>	-- <sup>b</sup>
Lower Monumental	1.8	3.1	0.8	0.0 <sup>a</sup>	0.0 <sup>a</sup>	0.0 <sup>a</sup>	0.0 <sup>a</sup>	0.0 <sup>a</sup>
Little Goose	11.9	3.3	6.1	2.9	8.9	0.0 <sup>a</sup>	0.0 <sup>a</sup>	0.0 <sup>a</sup>
Lower Granite	15.0	12.5	8.7	6.4	11.7	15.5	12.1	6.1
Systemwide	9.3	6.8	10.9	13.4	12.1	8.9	11.1	12.5

<sup>a</sup> Northern pikeminnow harvested, but no tags recovered.

<sup>b</sup> No northern pikeminnow tagged.

**Appendix Table A-3.** Exploitation rates (%) of northern pikeminnow  $\geq 250$  mm fork length for the dam-angling fishery, 1992-1999.

Area or Reservoir	1992	1993	1994	1995	1996	1997	1998	1999
Downstream from Bonneville Dam	0.2	0.0 <sup>b</sup>	0.1	0.2	0.0 <sup>b</sup>	0.2	0.0	0.0 <sup>b</sup>
Bonneville	2.8	2.2	3.7	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.5	0.0 <sup>b</sup>
The Dalles	1.0	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>
John Day	10.8	8.1	2.6	0.0 <sup>b</sup>	7.0	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>
McNary	0.0 <sup>b</sup>	0.1	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	-- <sup>a</sup>
Ice Harbor	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>
Lower Monumental	5.9	0.0 <sup>b</sup>	0.0 <sup>b</sup>	4.5	0.0 <sup>b</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>
Little Goose	6.0	3.3	3.1	2.8	0.0 <sup>b</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>
Lower Granite	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>
Systemwide	2.7	1.3	1.1	0.3	0.3	0.1	0.1	0.0

<sup>a</sup> No fishing effort.

<sup>b</sup> Northern pikeminnow harvested, but no tags recovered.

<sup>c</sup> No northern pikeminnow tagged.

**Appendix Table A-4.** Exploitation rates (%) of northern pikeminnow  $\geq 250$  mm fork length for the site-specific gill-net fishery, 1994-1999.

Area or Reservoir	1994	1995	1996	1997	1998	1999
Downstream from Bonneville Dam	--	0.2	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.3	-- <sup>b</sup>
Bonneville	5.3	5.9	3.0	1.7	0.9	0.6
The Dalles	0.9	1.1	0.0 <sup>b</sup>	-- <sup>b</sup>	-- <sup>b</sup>	-- <sup>b</sup>
John Day	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	-- <sup>b</sup>	-- <sup>b</sup>	-- <sup>a</sup>
McNary	0.0 <sup>b</sup>	0.0 <sup>b</sup>	0.0 <sup>b</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>
Ice Harbor	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>	-- <sup>c</sup>
Lower Monumental	0.0 <sup>b</sup>	0.0 <sup>b</sup>	-- <sup>a</sup>	-- <sup>b</sup>	-- <sup>a</sup>	-- <sup>a</sup>
Little Goose	-- <sup>a</sup>	0.0 <sup>b</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>
Lower Granite	0.0 <sup>b</sup>	0.0 <sup>b</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>	-- <sup>a</sup>
Systemwide	1.2	1.9	0.5	0.6	0.3	0.2

<sup>a</sup> No fishing effort.

<sup>b</sup> Northern pikeminnow harvested, but no tags recovered.

<sup>c</sup> No northern pikeminnow tagged.

**Appendix Table A-5.** Dates for each sampling period in 1999.

Period	Dates	Period	Dates
1	April 5 - April 11	16	July 19 - July 25
2	April 12 - April 18	17	July 26 - August 1
3	April 19 - April 25	18	August 2 - August 8
4	April 26 - May 2	19	August 9 - August 15
5	May 3 - May 9	20	August 16 - August 22
6	May 10 - May 16	21	August 23 - August 29
7	May 17 - May 23	22	August 30 - September 5
8	May 24 - May 30	23	September 6 - September 12
9	May 31 - June 6	24	September 13 - September 19
10	June 7 - June 13	25	September 20 - September 26
11	June 14 - June 20	26	September 27 - October 3
12	June 21 - June 27	27	October 4 - October 10
13	June 28 - July 4	28	October 11 - October 17
14	July 5 - July 11	29	October 18 - October 24
15	July 12 - July 18		

**Appendix Table A-6.** Exploitation of northern pikeminnow downstream from Bonneville Dam in 1999.

Time period	Tagged	Recaptures				Exploitation		
		Sport	Dam	Net	At Large	Sport	Dam	Net
1	191	--	--	--	--	--	--	--
2	33	--	--	--	191	--	--	--
3	--	--	--	--	224	--	--	--
4	--	--	--	--	224	--	--	--
5	--	--	--	--	224	--	--	--
6	3	--	--	--	224	--	--	--
7	--	1	--	--	227	0.0044	--	--
8	--	--	--	--	226	--	--	--
9	--	--	--	--	226	--	--	--
10	--	2	--	--	226	0.0088	--	--
11	--	--	--	--	224	--	--	--
12	--	1	--	--	224	0.0045	--	--
13	--	2	--	--	223	0.0090	--	--
14	--	3	--	--	221	0.0136	--	--
15	--	5	--	--	218	0.0229	--	--
16	--	1	--	--	213	0.0047	--	--
17	--	--	--	--	212	--	--	--
18	--	--	--	--	211 <sup>a</sup>	--	--	--
19	--	1	--	--	211	0.0047	--	--
20	--	2	--	--	210	0.0095	--	--
21	--	1	--	--	208	0.0048	--	--
22	--	--	--	--	207	--	--	--
23	--	--	--	--	207	--	--	--
24	--	--	--	--	207	--	--	--
25	--	1	--	--	207	0.0048	--	--
26	--	--	--	--	206	--	--	--
27	--	--	--	--	206	--	--	--
28	--	--	--	--	206	--	--	--
29	--	--	--	--	206	--	--	--
Total	227	20	0	0	--	0.0918	0.0000	0.0000
Adjusted for tag loss						0.0957	0.0000	0.0000

<sup>a</sup> A fish tagged downstream from Bonneville Reservoir was recaptured above Bonneville Dam.

**Appendix Table A-7.** Exploitation of northern pikeminnow in Bonneville Reservoir in 1999

Time period	Tagged	Recaptures				Exploitation		
		Sport	Dam	Net	At Large	Sport	Dam	Net
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	180	--	--	--	--	--	--	--
4	--	--	--	--	180	--	--	--
5	--	1	--	0	180	0.0056	--	--
6	--	1	--	0	178 <sup>a</sup>	0.0056	--	--
7	--	1	--	0	177	0.0056	--	--
8	--	2	--	1	176	0.0114	--	0.0057
9	--	0	--	0	172 <sup>b</sup>	--	--	--
10	--	1	0	0	172	0.0058	--	--
11	--	0	0	0	171	--	--	--
12	--	5	0	0	170 <sup>b</sup>	0.0294	--	--
13	--	1	0	--	164 <sup>b</sup>	0.0061	--	--
14	--	2	0	--	163	0.0123	--	--
15	--	3	0	--	160 <sup>b</sup>	0.0188	--	--
16	--	4	0	--	155 <sup>b</sup>	0.0258	--	--
17	--	0	0	--	150 <sup>a</sup>	--	--	--
18	--	1	0	--	150 <sup>b</sup>	0.0067	--	--
19	--	0	0	--	149	--	--	--
20	--	0	0	--	148	--	--	--
21	--	0	0	--	148	--	--	--
22	--	0	0	--	148	--	--	--
23	--	0	0	--	148	--	--	--
24	--	0	0	--	148	--	--	--
25	--	0	0	--	148	--	--	--
26	--	0	0	--	148	--	--	--
27	--	0	0	--	148	--	--	--
28	--	--	0	--	148	--	--	--
29	--	--	0	--	148	--	--	--
Total	180	22	0	1	--	0.1330	0.0000	0.0057
Adjusted for tag loss						0.1386	0.0000	0.0059

<sup>a</sup> A fish tagged in Bonneville Reservoir was removed by ODFW electrofishing crews.

<sup>b</sup> A fish tagged in Bonneville Reservoir was recaptured outside the reservoir.

**Appendix Table A-8.** Exploitation of northern pikeminnow in The Dalles Reservoir in 1999.

Time period	Tagged	Recaptures			At Large	Exploitation		
		Sport	Dam	Net <sup>a</sup>		Sport	Dam	Net <sup>a</sup>
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--
5	41	--	--	--	41	--	--	--
6	--	--	--	--	41	--	--	--
7	--	--	--	--	41	--	--	--
8	--	--	--	--	41	--	--	--
9	--	--	--	--	41	--	--	--
10	--	--	--	--	41	--	--	--
11	--	2	--	--	41	0.0488	--	--
12	--	--	--	--	39	--	--	--
13	--	--	--	--	39	--	--	--
14	--	2	--	--	39	0.0513	--	--
15	--	1	--	--	37	0.0270	--	--
16	--	--	--	--	36	--	--	--
17	--	1	--	--	36	0.0278	--	--
18	--	--	--	--	35	--	--	--
19	--	--	--	--	35	--	--	--
20	--	--	--	--	35	--	--	--
21	--	--	--	--	35	--	--	--
22	--	--	--	--	35	--	--	--
23	--	--	--	--	35	--	--	--
24	--	--	--	--	35	--	--	--
25	--	--	--	--	35	--	--	--
26	--	--	--	--	35	--	--	--
27	--	--	--	--	35	--	--	--
28	--	--	--	--	35	--	--	--
29	--	--	--	--	35	--	--	--
Total	41	6	0	--	--	0.1549	0.0000	--
Adjusted for tag loss						0.1614	0.0000	--

<sup>a</sup> No fishing effort.

**Appendix Table A-9.** Exploitation of northern pikeminnow in John Day Reservoir in 1999.

Time period	Tagged	Recaptures			At Large	Exploitation		
		Sport	Dam	Net <sup>a</sup>		Sport	Dam	Net <sup>a</sup>
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--
7	22	--	--	--	--	--	--	--
8	--	--	--	--	22	--	--	--
9	--	--	--	--	22	--	--	--
10	--	--	--	--	22	--	--	--
11	6	--	--	--	22	--	--	--
12	1	1	--	--	28	0.0357	--	--
13	--	--	--	--	28	--	--	--
14	--	--	--	--	28	--	--	--
15	--	--	--	--	28	--	--	--
16	--	--	--	--	28	--	--	--
17	--	--	--	--	28	--	--	--
18	--	--	--	--	27 <sup>b</sup>	--	--	--
19	--	--	--	--	27	--	--	--
20	--	--	--	--	27	--	--	--
21	--	--	--	--	27	--	--	--
22	--	--	--	--	27	--	--	--
23	--	--	--	--	27	--	--	--
24	--	--	--	--	27	--	--	--
25	--	--	--	--	27	--	--	--
26	--	--	--	--	27	--	--	--
27	--	--	--	--	27	--	--	--
28	--	--	--	--	27	--	--	--
29	--	--	--	--	27	--	--	--
Total	29	1	0	--	--	0.0357	0.0000	--
Adjusted for tag loss						0.0372	0.0000	--

<sup>a</sup> No fishing effort.

<sup>b</sup> A fish tagged in John Day Reservoir was recaptured outside the reservoir.

**Appendix Table A-10.** Exploitation of northern pikeminnow in McNary Reservoir in 1999.

Time period	Tagged	Recaptures			At Large	Exploitation		
		Sport	Dam <sup>a</sup>	Net <sup>a</sup>		Sport	Dam <sup>a</sup>	Net <sup>a</sup>
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--
6	96	--	--	--	--	--	--	--
7	--	2	--	--	96	0.0208	--	--
8	39	--	--	--	94	--	--	--
9	12	1	--	--	133	0.0075	--	--
10	--	1	--	--	144	0.0069	--	--
11	--	--	--	--	143	--	--	--
12	--	4	--	--	143	0.0280	--	--
13	--	1	--	--	139	0.0072	--	--
14	--	1	--	--	138	0.0072	--	--
15	--	5	--	--	137	0.0365	--	--
16	--	2	--	--	132	0.0152	--	--
17	--	1	--	--	130	0.0077	--	--
18	--	1	--	--	129	0.0078	--	--
19	--	--	--	--	128	--	--	--
20	--	--	--	--	128	--	--	--
21	--	--	--	--	128	--	--	--
22	--	--	--	--	128	--	--	--
23	--	--	--	--	128	--	--	--
24	--	1	--	--	128	0.0078	--	--
25	--	--	--	--	127	--	--	--
26	--	--	--	--	127	--	--	--
27	--	--	--	--	127	--	--	--
28	--	--	--	--	127	--	--	--
29	--	--	--	--	127	--	--	--
Total	147	20	--	--	--	0.1526	--	--
Adjusted for tag loss						0.1590	--	--

<sup>a</sup> No fishing effort.



**Appendix Table A-11.** Exploitation of northern pikeminnow in Lower Monumental Reservoir in 1999.

Time period	Tagged	Recaptures			At Large	Exploitation		
		Sport	Dam <sup>a</sup>	Net <sup>a</sup>		Sport	Dam <sup>a</sup>	Net <sup>a</sup>
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--
10	11	--	--	--	--	--	--	--
11	--	--	--	--	11	--	--	--
12	--	--	--	--	11	--	--	--
13	--	--	--	--	11	--	--	--
14	--	--	--	--	11	--	--	--
15	--	--	--	--	11	--	--	--
16	--	--	--	--	11	--	--	--
17	--	--	--	--	11	--	--	--
18	--	--	--	--	11	--	--	--
19	--	--	--	--	11	--	--	--
20	--	--	--	--	11	--	--	--
21	--	--	--	--	11	--	--	--
22	--	--	--	--	11	--	--	--
23	--	--	--	--	11	--	--	--
24	--	--	--	--	11	--	--	--
25	--	--	--	--	11	--	--	--
26	--	--	--	--	11	--	--	--
27	--	--	--	--	11	--	--	--
28	--	--	--	--	11	--	--	--
29	--	--	--	--	11	--	--	--
Total	20	0	--	--	--	0.0000	--	--
Adjusted for tag loss						0.0000	--	--

<sup>a</sup> No fishing effort.

**Appendix Table A-12.** Exploitation of northern pikeminnow in Little Goose Reservoir in 1999.

Time period	Tagged	Recaptures				Exploitation		
		Sport	Dam	Net	At Large	Sport	Dam <sup>a</sup>	Net <sup>a</sup>
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--
10	27	--	--	--	27	--	--	--
11	--	--	--	--	27	--	--	--
12	--	--	--	--	27	--	--	--
13	--	--	--	--	27	--	--	--
14	--	--	--	--	27	--	--	--
15	--	--	--	--	27	--	--	--
16	--	--	--	--	27	--	--	--
17	--	--	--	--	27	--	--	--
18	--	--	--	--	27	--	--	--
19	--	--	--	--	27	--	--	--
20	--	--	--	--	27	--	--	--
21	--	--	--	--	27	--	--	--
22	--	--	--	--	27	--	--	--
23	--	--	--	--	27	--	--	--
24	--	--	--	--	27	--	--	--
25	--	--	--	--	27	--	--	--
26	--	--	--	--	27	--	--	--
27	--	--	--	--	27	--	--	--
28	--	--	--	--	27	--	--	--
29	--	--	--	--	27	--	--	--
Total	27	0	--	--	--	0.0000	--	--
Adjusted for tag loss						0.0000	--	--

<sup>a</sup> No fishing effort.

**Appendix Table A-13.** Exploitation of northern pikeminnow in Lower Granite Reservoir in 1999.

Time period	Tagged	Recaptures			At Large	Exploitation		
		Sport	Dam <sup>a</sup>	Net <sup>a</sup>		Sport	Dam <sup>a</sup>	Net <sup>a</sup>
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--
4	88	--	--	--	--	--	--	--
5	--	--	--	--	88	--	--	--
6	--	--	--	--	88	--	--	--
7	--	--	--	--	88	--	--	--
8	--	--	--	--	88	--	--	--
9	--	--	--	--	88	--	--	--
10	--	--	--	--	88	--	--	--
11	--	--	--	--	88	--	--	--
12	--	1	--	--	88	0.0114	--	--
13	--	--	--	--	87	--	--	--
14	--	--	--	--	87	--	--	--
15	--	--	--	--	87	--	--	--
16	--	1	--	--	87	0.0115	--	--
17	--	1	--	--	86	0.0116	--	--
18	--	--	--	--	85	--	--	--
19	--	--	--	--	85	--	--	--
20	--	--	--	--	85	--	--	--
21	--	--	--	--	85	--	--	--
22	--	1	--	--	85	0.0118	--	--
23	--	--	--	--	84	--	--	--
24	--	--	--	--	84	--	--	--
25	--	--	--	--	84	--	--	--
26	--	1	--	--	84	0.0119	--	--
27	--	--	--	--	83	--	--	--
28	--	--	--	--	83	--	--	--
29	--	--	--	--	83	--	--	--
Total	88	5	--	--	--	0.0582	--	--
Adjusted for tag loss						0.0606	--	--

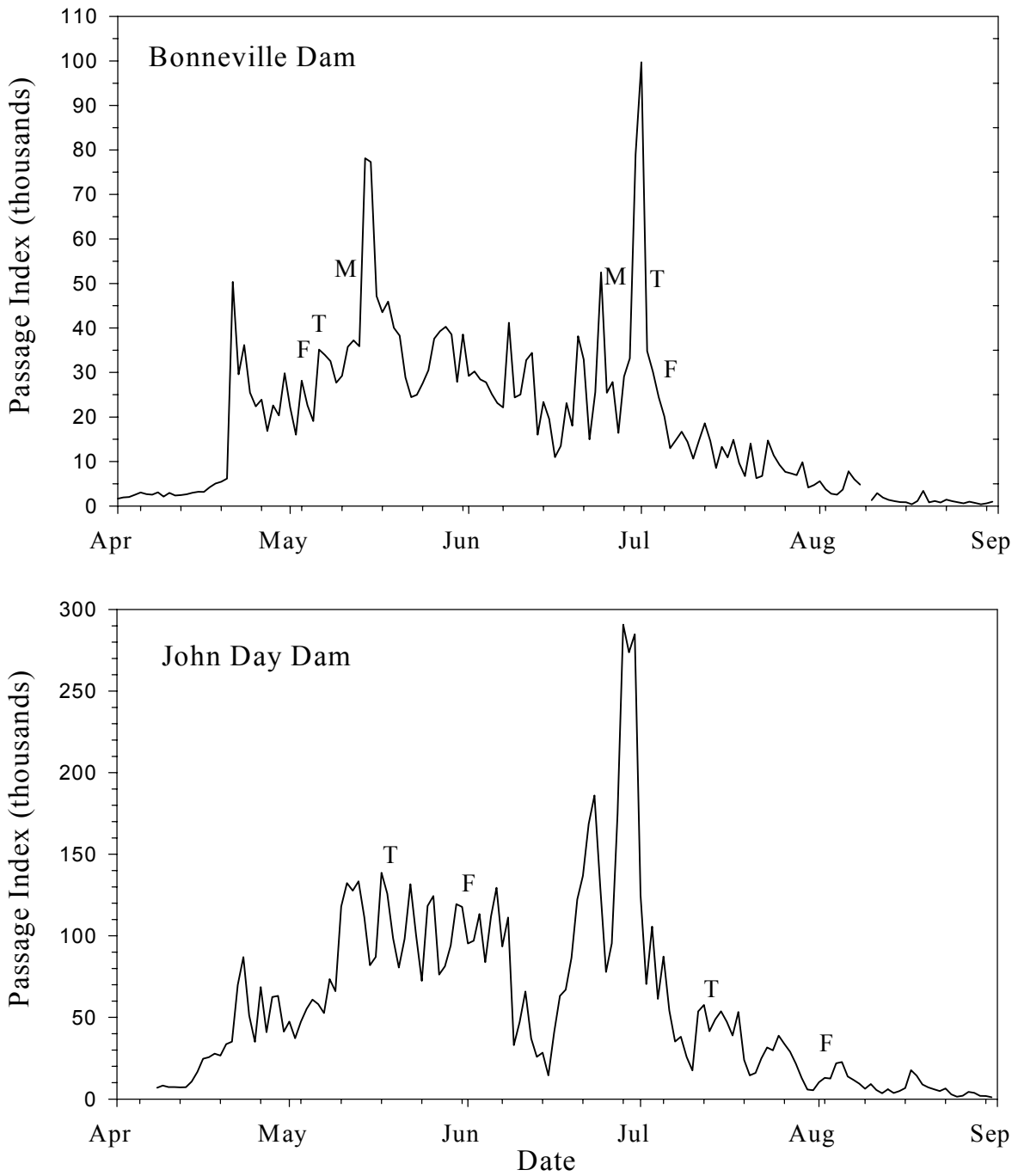
<sup>a</sup> No fishing effort.

**Appendix Table A-14.** Exploitation of northern pikeminnow systemwide in 1999.

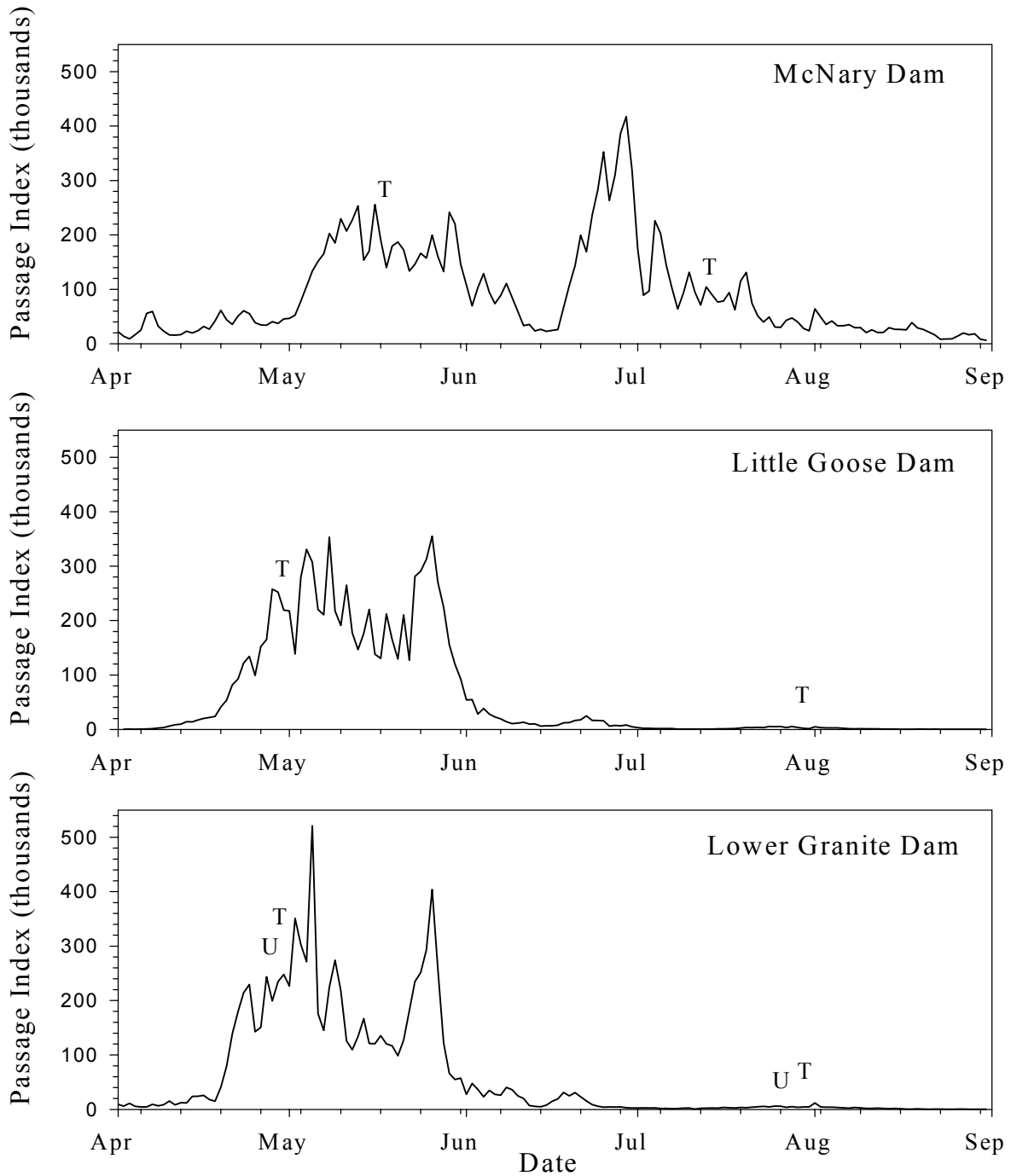
Time period	Tagged	Recaptures				Exploitation		
		Sport	Dam	Net	At Large	Sport	Dam	Net
1	191	--	--	--	--	--	--	--
2	33	--	--	--	191	--	--	--
3	180	--	--	--	224	--	--	--
4	88	--	--	--	404	--	--	--
5	41	1	--	--	492	0.0020	--	--
6	99	1	--	--	531	0.0019	--	--
7	22	4	--	--	629	0.0064	--	--
8	39	3	--	1	647	0.0046	--	0.0015
9	12	1	--	--	682	0.0015	--	--
10	38	4	--	--	693	0.0058	--	--
11	6	3	--	--	727	0.0041	--	--
12	1	13	--	--	730	0.0178	--	--
13	--	4	--	--	718	0.0056	--	--
14	--	9	--	--	714	0.0126	--	--
15	--	16	--	--	705	0.0227	--	--
16	--	8	--	--	689	0.0116	--	--
17	--	6	--	--	680	0.0088	--	--
18	--	2	--	--	674	0.0030	--	--
19	--	1	--	--	672	0.0015	--	--
20	--	2	--	--	671	0.0030	--	--
21	--	1	--	--	669	0.0015	--	--
22	--	1	--	--	668	0.0015	--	--
23	--	--	--	--	667	--	--	--
24	--	1	--	--	667	0.0015	--	--
25	--	1	--	--	666	0.0015	--	--
26	--	1	--	--	665	0.0015	--	--
27	--	--	--	--	664	--	--	--
28	--	--	--	--	664	--	--	--
29	--	--	--	--	664	--	--	--
Total	750	83	0	1	--	0.1203	--	0.0015
Adjusted for tag loss						0.1254	--	0.0016

## **APPENDIX B**

Timing of 1999 Consumption Index Sampling in Relation to Juvenile Salmonid Passage Indices  
at Lower Columbia and Snake River Dams



**Appendix Figure B-1.** Timing of consumption index sampling with respect to juvenile salmonid passage indices at Bonneville and John Day dams in 1999. Sample times for forebay (F), tailrace (T), and areas downstream from Bonneville Dam tailrace (M) are shown.



**Appendix Figure B-2.** Timing of consumption index sampling with respect to juvenile salmonid passage indices at McNary, Little Goose, and Lower Granite dams in 1999. Sample times for tailraces (T) and upper Lower Granite Reservoir (U) are shown.

## **APPENDIX C**

Electrofishing Effort, Density, Abundance, Consumption, and Predation Indices for Northern  
Pikeminnow in the Lower Columbia and Snake Rivers in 1990-1996 and 1999



**Appendix Table C-1.** Sampling effort (number of 15-minute electrofishing runs) in 1990-1996 and 1999 in the lower Columbia and Snake rivers. RKm = river kilometer, BRZ = boat restricted zone. Areas marked "ns" were not scheduled for sampling.

Location, area	Effort (number of electrofishing runs)							
	1990	1991	1992	1993	1994	1995	1996	1999
Below								
Bonneville Dam								
RKm 114-121	ns	ns	68	ns	36	45	43	44
RKm 172-178	ns	ns	65	ns	33	36	35	47
RKm 190-197	ns	ns	64	ns	43	40	40	40
Tailrace	26	ns	37	16	27	16	24	29
Tailrace BRZ	13	ns	23	9	8	8	7	0
Bonneville Reservoir								
Forebay	47	ns	ns	35	97	79	80	62
Mid-reservoir	52	ns	ns	28	84	45	57	57
Tailrace	37	ns	ns	25	60	80	69	71
Tailrace BRZ	15	ns	ns	6	8	0	0	0
The Dalles Reservoir								
Forebay	62	ns	ns	31	92	62	59	ns
Tailrace	45	ns	ns	21	40	27	28	71
Tailrace BRZ	11	ns	ns	5	8	8	3	0
John Day Reservoir								
Forebay	56	61	68	44	91	75	75	52
Mid-reservoir	61	58	62	43	43	94	94	0
Tailrace	39	44	47	37	60	80	80	62
Tailrace BRZ	16	15	17	9	14	0	0	0
Lower Monumental Res.								
Tailrace	ns	40	ns	ns	39	38	24	11
Tailrace BRZ	ns	16	ns	ns	5	8	8	3
Little Goose Reservoir								
Tailrace	ns	40	ns	ns	31	32	33	28
Tailrace BRZ	ns	17	ns	ns	8	8	4	1
Lower Granite Reservoir								
Upper reservoir	ns	55	ns	ns	85	89	89	75

**Appendix Table C-2.** Relative density (CPUE) of northern pikeminnow  $\geq 250$  mm fork length in the lower Columbia and Snake rivers in 1990-1996 and 1999. RKm = river kilometer, BRZ = boat restricted zone. Areas marked "ns" were not scheduled for sampling.

Location, area	Density index (CPUE)							
	1990	1991	1992	1993	1994	1995	1996	1999
Below								
Bonneville Dam								
RKm 114-121	ns	ns	1.3	ns	1.0	0.9	0.8	0.6
RKm 172-178	ns	ns	1.6	ns	2.1	1.4	1.5	0.9
RKm 190-197	ns	ns	2.4	ns	1.7	1.1	1.3	1.4
Tailrace	5.8	ns	3.4	9.6	2.9	2.2	2.8	3.5
Tailrace BRZ	13.7	ns	12.9	14.5	18.9	4.6	5.8	--
Bonneville Reservoir								
Forebay	5.7	ns	ns	2.2	2.4	2.4	1.3	1.0
Mid-reservoir	2.1	ns	ns	1.2	0.7	1.0	0.7	0.3
Tailrace	0.5	ns	ns	1.1	0.6	1.1	0.8	0.8
Tailrace BRZ	5.5	ns	ns	1.5	6.8	--	--	--
The Dalles Reservoir								
Forebay	1.1	ns	ns	1.2	0.6	0.6	0.4	ns
Tailrace	2.8	ns	ns	0.7	0.7	1.6	3.7	0.8
Tailrace BRZ	21.5	ns	ns	10.8	5.8	3.5	1.0	--
John Day Reservoir								
Forebay	0.7	0.7	1.3	0.6	0.7	0.3	0.3	0.2
Mid-reservoir	0.3	0.2	0.3	0.2	0.1	0.1	0.1	--
Tailrace	0.8	0.8	0.1	0.5	0.3	0.3	0.5	0.2
Tailrace BRZ	14.7	17.9	9.2	13.3	2.4	--	--	--
Lower Monumental Res.								
Tailrace	ns	1.5	ns	ns	0.3	0.1	0.2	0
Tailrace BRZ	ns	16.3	ns	ns	1.2	3.9	1.0	0
Little Goose Reservoir								
Tailrace	ns	1.6	ns	ns	0.4	0.1	0.3	0.3
Tailrace BRZ	ns	28.3	ns	ns	6.4	10.3	1.0	0
Lower Granite Reservoir								
Upper reservoir	ns	1.9	ns	ns	0.5	0.2	0.3	0.2

**Appendix Table C-3.** Abundance index values for northern pikeminnow  $\geq 250$  mm fork length in the lower Columbia and Snake rivers in 1990-1996 and 1999. RKm = river kilometer, BRZ = boat restricted zone. Areas marked "ns" were not scheduled for sampling.

Location, area	Abundance Index							
	1990	1991	1992	1993	1994	1995	1996	1999
Below								
Bonneville Dam								
RKm 71-121	ns	ns	26.8	ns	15.4	14.5	12.2	9.8
RKm 122-177	ns	ns	19.7	ns	26.2	17.4	18.7	11.8
RKm 178-224	ns	ns	17.9	ns	22.1	14.2	16.4	17.4
Tailrace	4.5	ns	2.7	7.6	2.3	1.8	2.2	2.7
Tailrace BRZ	3.0	ns	2.8	3.1	4.1	1.0	1.3	--
Bonneville Reservoir								
Forebay	5.5	ns	ns	2.1	2.3	2.3	1.3	1.0
Mid-reservoir	15.2	ns	ns	8.5	5.0	7.4	4.9	2.2
Tailrace	0.4	ns	ns	0.8	0.5	0.8	0.7	1.1
Tailrace BRZ	0.9	ns	ns	0.2	1.1	--	--	--
The Dalles Reservoir								
Forebay	1.4	ns	ns	1.6	0.7	0.5	0.6	ns
Tailrace	2.7	ns	ns	0.7	0.6	1.5	3.6	0.8
Tailrace BRZ	4.4	ns	ns	2.2	1.1	0.7	0.7	--
John Day Reservoir								
Forebay	1.4	1.3	2.5	1.2	1.4	0.5	0.6	0.3
Mid-reservoir	5.2	4.7	6.6	3.2	2.3	1.0	1.1	--
Tailrace	1.4	1.4	0.2	0.9	0.5	0.6	1.0	0.4
Tailrace BRZ	1.6	1.9	1.0	1.4	0.3	--	--	--
Lower Monumental Res.								
Tailrace	ns	1.3	ns	ns	0.3	0.1	0.1	0
Tailrace BRZ	ns	0.8	ns	ns	0.1	0.2	0.1	0
Little Goose Reservoir								
Tailrace	ns	0.7	ns	ns	0.2	<0.1	0.1	0.1
Tailrace BRZ	ns	1.7	ns	ns	0.4	0.6	0.1	0
Lower Granite Reservoir								
Upper reservoir	ns	1.6	ns	ns	0.5	0.2	0.2	0.2

**Appendix Table C-4.** Indices of northern pikeminnow consumption of juvenile salmonids from 1990-1996 and 1999 during spring. RKm = river kilometer, BRZ = boat-restricted zone. Parentheses indicate number of digestive tracts examined.

Reservoir or reach, area	Consumption index							
	1990	1991	1992	1993	1994	1995	1996	1999
Below								
Bonneville Dam								
RKm 114-121	--	--	0.5(102)	--	0.5(14)	0.5(25)	0.4(23)	0.8(21)
RKm 172-178	--	--	1.0(189)	--	1.1(34)	0.2(28)	0.1(43)	0.4(23)
RKm 190-197	--	--	1.1(126)	--	1.5(42)	0.7(25)	0.4(33)	0.4(22)
Tailrace	1.2(61)	--	0.5(22)	0.8(75)	3.2(57)	0.8(25)	0.4(29)	0.1(24)
Tailrace BRZ	2.7(86)	--	1.0(77)	1.1(63)	0.6(95)	1.7(17)	0.6(8)	--
Bonneville								
Forebay	0.6(153)	--	--	0.7(20)	0.2(116)	0.3(88)	0.0(59)	0.0(17)
Mid-reservoir	0.0(39)	--	--	0.0(14)	0.2(34)	0.0(26)	0.1(17)	0.6(9)
Tailrace	0.3(7)	--	--	0.0(18)	0.0(19)	0.2(22)	0.0(35)	0.2(43)
Tailrace BRZ	2.3(41)	--	--	--	--	--	--	--
The Dalles								
Forebay	0.8(38)	--	--	0.1(19)	0.1(22)	0.0(22)	0.0(15)	--
Tailrace	0.7(27)	--	--	0.0(8)	--	--	--	0.5(6)
Tailrace BRZ	0.9(50)	--	--	0.0(1)	--	--	--	--
John Day								
Forebay	1.5(38)	1.9(23)	1.9(38)	1.5(11)	1.0(11)	1.7(7)	0.7(4)	1.2(7)
Mid-reservoir	0.0(6)	0.5(6)	0.0(8)	0.0(2)	0.0(3)	0.0(1)	0.0(3)	--
Tailrace	1.5(17)	0.9(23)	0.0(9)	2.0(24)	0.3(13)	0.8(13)	0.5(14)	1.7(8)
Tailrace BRZ	2.5(60)	1.5(55)	0.9(35)	--	0.7(8)	--	--	--
Lower Monumental								
Tailrace	--	0.6(58)	--	--	0.7(9)	0.0(2)	0.0(2)	--
Tailrace BRZ	--	0.7(127)	--	--	--	1.3(7)	0.0(1)	--
Little Goose								
Tailrace	--	0.7(68)	--	--	1.9(12)	1.4(2)	0.7(7)	0.9(4)
Tailrace BRZ	--	1.2(126)	--	--	1.5(25)	1.6(63)	--	--
Lower Granite								
Upper reservoir	--	0.3(127)	--	--	0.6(41)	1.2(16)	0.2(23)	1.9(16)

**Appendix Table C-5.** Indices of northern pikeminnow consumption of juvenile salmonids from 1990-1996 and 1999 during summer. Rkm = river kilometer, BRZ = boat-restricted zone.

Reservoir or reach, area	Consumption index							
	1990	1991	1992	1993	1994	1995	1996	1999
<b>Below</b>								
<b>Bonneville Dam</b>								
RKm 114-121	--	--	0.3(117)	--	1.8(22)	1.5(14)	0.0(9)	1.0(6)
RKm 172-178	--	--	1.3(136)	--	1.5(32)	0.4(22)	0.0(9)	0.0(21)
RKm 190-197	--	--	1.9(59)	--	0.4(32)	1.2(20)	0.0(20)	0.5(33)
Tailrace	0.5(45)	--	2.1(43)	1.2(81)	0.4(24)	0.9(11)	0.6(38)	0.2(77)
Tailrace BRZ	5.5(109)	--	7.8(147)	1.0(131)	2.1(56)	1.3(16)	3.1(33)	--
<b>Bonneville</b>								
Forebay	1.8(139)	--	--	0.5(95)	0.3(111)	0.0(96)	0.3(44)	0.0(45)
Mid-reservoir	0.0(42)	--	--	0.0(31)	0.0(24)	0.0(19)	0.0(21)	0.0(7)
Tailrace	0.0(4)	--	--	0.0(14)	0.0(15)	0.8(67)	0.0(23)	0.3(45)
Tailrace BRZ	0.8(61)	--	--	1.0(23)	3.2(54)	--	--	--
<b>The Dalles</b>								
Forebay	1.0(61)	--	--	0.0(28)	0.0(27)	0.0(15)	0.0(8)	--
Tailrace	0.0(46)	--	--	0.0(9)	0.8(27)	0.0(41)	0.7(92)	0.0(39)
Tailrace BRZ	6.4(50)	--	--	0.5(117)	1.2(43)	2.2(28)	5.4(3)	--
<b>John Day</b>								
Forebay	2.4(16)	3.1(17)	0.7(27)	0.6(40)	1.2(57)	2.0(13)	0.4(13)	0.0(1)
Mid-reservoir	0.9(7)	0.0(3)	0.0(13)	0.6(10)	0.6(5)	0.0(4)	0.0(0)	--
Tailrace	2.6(25)	0.0(19)	0.0(1)	0.0(11)	0.0(4)	0.6(13)	0.3(19)	0.0(7)
Tailrace BRZ	11.7(50)	2.8(77)	4.6(67)	0.6(119)	1.9(31)	--	--	--

**Appendix Table C-6.** Indices of northern pikeminnow predation of juvenile salmonids from 1990-1996 and 1999 during spring. RKm = river kilometer, BRZ = boat-restricted zone.

Reservoir or reach, area	Predation index							
	1990	1991	1992	1993	1994	1995	1996	1999
Below								
Bonneville Dam								
RKm 71-121	--	--	10.1	--	8.0	7.3	4.9	7.5
RKm 122-177	--	--	20.5	--	25.5	3.5	1.9	5.0
RKm 178-224	--	--	33.4	--	33.2	9.9	6.6	7.1
Tailrace	5.5	--	1.4	6.1	7.4	1.4	0.9	0.4
Tailrace BRZ	8.0	--	2.8	3.5	2.5	1.7	0.8	--
Bonneville								
Forebay	3.3	--	--	1.5	0.3	0.7	0.0	0.0
Mid-reservoir	0.0	--	--	0.0	1.0	0.0	0.5	1.3
Tailrace	0.1	--	--	0.0	0.0	0.2	0.0	0.2
Tailrace BRZ	2.0	--	--	--	--	1.5	--	--
The Dalles								
Forebay	1.1	--	--	0.2	0.1	0.0	0.0	--
Tailrace	1.9	--	--	0.0	--	--	--	0.4
Tailrace BRZ	3.9	--	--	0.0	--	--	--	--
John Day								
Forebay	2.1	2.4	4.7	1.9	1.3	0.9	0.4	0.4
Mid-reservoir	0.0	2.4	0.0	0.0	0.0	0.0	0.0	--
Tailrace	1.9	1.3	1.9	1.7	0.2	0.5	0.3	0.7
Tailrace BRZ	3.9	2.9	0.9	--	0.2	--	--	--
Lower Monumental								
Tailrace	--	0.8	--	--	0.2	0.0	0.0	--
Tailrace BRZ	--	0.6	--	--	--	0.3	0.0	--
Little Goose								
Tailrace	--	0.5	--	--	0.4	<0.1	0.1	0.1
Tailrace BRZ	--	2.0	--	--	0.6	1.0	--	--
Lower Granite								
Upper reservoir	--	0.5	--	--	0.3	0.2	0.1	0.4

**Appendix Table C-7.** Indices of northern pikeminnow predation of juvenile salmonids from 1990-1996 and 1999 during summer. RKm = river kilometer, BRZ = boat-restricted zone.

Reservoir or reach, area	Predation index							
	1990	1991	1992	1993	1994	1995	1996	1999
Below								
Bonneville Dam								
RKm 71-121	--	--	6.0	--	27.3	14.5	0.0	9.4
RKm 122-177	--	--	26.6	--	34.8	7.0	0.0	0.0
RKm 178-224	--	--	37.8	--	9.5	17.0	0.0	9.5
Tailrace	2.3	--	5.7	9.1	1.0	1.6	1.3	0.6
Tailrace BRZ	16.4	--	21.8	3.2	1.3	1.2	4.0	--
Bonneville								
Forebay	9.9	--	--	1.1	0.6	0.0	0.4	0.0
Mid-reservoir	0.0	--	--	0.0	0.0	0.0	0.0	0.0
Tailrace	0.0	--	--	0.0	0.0	0.6	0.0	0.3
Tailrace BRZ	0.7	--	--	0.2	3.5	--	--	--
The Dalles								
Forebay	1.4	--	--	0.0	0.0	0.0	0.0	--
Tailrace	0.0	--	--	0.0	0.5	0.0	2.5	0.0
Tailrace BRZ	27.8	--	--	1.1	1.4	1.5	3.8	--
John Day								
Forebay	3.4	4.0	1.7	0.8	1.6	1.0	0.2	0.0
Mid-reservoir	4.7	--	0.0	2.0	1.4	0.0	0.0	--
Tailrace	3.8	--	0.0	0.0	0.0	0.4	0.2	0.0
Tailrace BRZ	18.6	5.4	4.6	0.9	0.5	--	--	--

## **APPENDIX D**

Relative Density and Consumption Indices for Smallmouth Bass in the  
Lower Columbia and Snake Rivers in 1990-1996 and 1999



**Appendix Table D-1.** Relative density of smallmouth bass 200 mm fork length and larger in the lower Columbia and Snake rivers during spring, 1990-1996 and 1999. Relative density = mean transformed catch ( $\log_{10}(\text{catch}+1)$ ) per 15-minute electrofishing run.

Reservoir or reach, area	Relative density							
	1990	1991	1992	1993	1994	1995	1996	1999
Below Bonneville Dam								
RKm 71-121	--	--	0.0	--	0.0	<0.1	0.0	0.0
RKm 122-177	--	--	0.2	--	0.2	0.5	0.3	0.1
RKm 178-224	--	--	0.1	--	0.1	0.4	0.1	<0.1
Tailrace	--	--	0.1	--	0.1	0.4	0.1	0.1
Bonneville								
Forebay	<0.1	<0.1	--	0.1	<0.1	0.1	0.1	0.1
Mid-reservoir	0.3	<0.1	--	0.1	0.3	0.3	0.2	0.1
Tailrace	0.3	0.3	--	0.7	0.5	0.4	0.6	0.4
John Day								
Forebay	0.5	0.3	0.4	--	0.3	0.4	0.3	0.1
Mid-reservoir	0.5	0.6	0.2	--	0.3	0.4	0.5	--
Tailrace	<0.1	0.1	0.2	--	0.1	0.1	<0.1	<0.1
Lower Granite								
Upper reservoir	0.6	--	--	--	0.6	0.3	0.4	0.3

**Appendix Table D-2.** Relative density of smallmouth bass 200 mm fork length and larger in the lower Columbia and Snake rivers during summer, 1990-1996 and 1999. Relative density = mean transformed catch ( $\log_{10}(\text{catch}+1)$ ) per 15-minute electrofishing run.

Reservoir or reach, area	Relative density							
	1990	1991	1992	1993	1994	1995	1996	1999
Below Bonneville Dam								
RKm 71-121	--	--	<0.1	--	0.1	<0.1	<0.1	0.0
RKm 122-177	--	--	0.1	--	0.2	0.2	0.1	0.1
RKm 178-224	--	--	0.1	--	0.1	0.2	0.1	0.1
Tailrace	--	--	0.2	--	0.1	0.2	0.1	0.2
Bonneville								
Forebay	0.1	0.0	--	0.1	<0.1	0.1	<0.1	0.2
Mid-reservoir	0.1	0.1	--	0.2	0.2	0.1	0.1	0.1
Tailrace	0.2	0.4	--	0.4	0.4	0.5	0.2	0.4
John Day								
Forebay	0.4	0.3	0.3	0.4	0.5	0.4	0.3	0.4
Mid-reservoir	0.2	0.1	0.3	0.4	0.2	0.6	0.4	--
Tailrace	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1
Lower Granite								
Upper reservoir	--	0.6	--	--	0.3	0.4	0.1	0.0

**Appendix Table D-3.** . Indices of smallmouth bass ( $\geq 200$  mm fork length) consumption of juvenile salmonids from 1990-1996 and 1999 during spring. RKm = river kilometer, BRZ = boat-restricted zone. Parentheses indicate number of digestive tracts examined.

Reservoir or reach, area	Consumption index							
	1990	1991	1992	1993	1994	1995	1996	1999
Below								
Bonneville Dam								
RKm 114-121	--	--	0.0(1)	--	0.0(0)	0.0(2)	--	--
RKm 172-178	--	--	0.1(12)	--	0.0(23)	0.1(47)	0.0(27)	0.0(4)
RKm 190-197	--	--	0.0(0)	--	0.3(10)	0.0(33)	0.0(11)	0.0(1)
Tailrace	--	--	0.0(4)	--	0.0(7)	0.0(26)	0.0(6)	0.0(3)
Bonneville								
Forebay	0.0(0)	--	--	0.0(2)	0.0(5)	0.1(12)	0.0(11)	0.0(6)
Mid-reservoir	0.0(0)	--	--	0.0(1)	0.0(47)	0.1(30)	0.0(17)	0.0(4)
Tailrace	0.0(10)	--	--	0.0(21)	0.0(58)	0.0(99)	0.0(123)	<0.1(46)
John Day								
Forebay	0.1(6)	0.0(41)	0.1(39)	0.0(37)	0.1(75)	0.0(76)	0.0(23)	0.1(13)
Mid-reservoir	0.0(17)	0.0(33)	0.0(14)	0.0(27)	0.0(45)	0.0(127)	0.0(72)	--
Tailrace	0.0(0)	0.0(4)	0.0(1)	0.0(3)	0.0(27)	0.0(11)	0.0(6)	0.0(5)
Lower Granite								
Upper reservoir	--	0.1(57)	--	--	0.2(48)	0.1(94)	<0.1(83)	0.1(68)

**Appendix Table D-4.** Indices of smallmouth bass ( $\geq 200$  mm fork length) consumption of juvenile salmonids from 1990-1996 and 1999 during summer. Rkm = river kilometer, BRZ = boat-restricted zone.

Reservoir or reach, area	Consumption index							
	1990	1991	1992	1993	1994	1995	1996	1999
<b>Below</b>								
<b>Bonneville Dam</b>								
Rkm 114-121	--	--	0.0(0)	--	0.0(6)	0.0(2)	0.0(1)	--
Rkm 172-178	--	--	0.0(7)	--	0.2(22)	0.3(18)	0.0(5)	0.0(8)
Rkm 190-197	--	--	0.4(13)	--	0.3(9)	0.8(17)	0.0(7)	0.0(11)
Tailrace	--	--	0.0(2)	--	0.0(14)	0.0(8)	0.0(5)	0.0(13)
<b>Bonneville</b>								
Forebay	0.0(0)	--	--	0.0(2)	0.4(8)	0.0(13)	0.0(8)	0.2(28)
Mid-reservoir	0.0(3)	--	--	0.0(14)	0.0(32)	0.0(9)	0.0(13)	0.0(17)
Tailrace	0.0(3)	--	--	0.0(36)	0.1(77)	0.1(97)	0.0(25)	0.0(89)
<b>John Day</b>								
Forebay	0.3(10)	0.5(43)	0.2(35)	0.7(55)	0.2(137)	0.3(92)	0.1(36)	0.2(50)
Mid-reservoir	0.3(13)	0.0(40)	0.0(4)	0.1(65)	0.0(35)	0.0(182)	0.0(67)	--
Tailrace	0.0(10)	0.1(13)	0.0(6)	0.0(23)	0.0(19)	0.0(22)	0.0(9)	0.0(9)

## **APPENDIX E**

Digestive Tract Contents and Comparison of Fish Diets of Northern Pikeminnow,  
Smallmouth Bass, and Walleye in 1999

We examined digestive tract contents of 487 northern pikeminnow, 554 smallmouth bass, and 73 walleye captured during 1999 index sampling (**Appendix Table E-1**). The systemwide frequency of occurrence (%FO) of salmonids *Oncorhynchus* spp. in predator digestive tracts was 10.7% for northern pikeminnow, 2.9% for smallmouth bass, and 19.2% for walleye, representing increases of 3.8%, 1.1%, and 14.0%, respectively, from 1996 (Friesen et al. 1997). As in other years, salmonids appeared more frequently in predator digestive tracts during spring (Friesen et al. 1997; Zimmerman 1999). We observed the greatest seasonal difference in northern pikeminnow, where %FO of salmonids was 20.5% in spring and 3.8% in summer for all areas combined. Spatial differences were uncertain due to small sample sizes in some areas; however, %FO of salmonids was generally greatest for northern pikeminnow in the lower Snake River (42.3%, n = 26), for smallmouth bass in the lower Snake River (6.7%, n = 150), and for walleye in lower Columbia River impoundments (19.0%, n = 63).

The composition of prey fish families found in northern pikeminnow, smallmouth bass, and walleye digestive tracts during 1999 was similar to previous years (Zimmerman 1999). Salmonids constituted the majority of prey fish consumed by northern pikeminnow, whereas sculpins *Cottus* spp. were consumed most frequently by smallmouth bass (**Appendix Table E-2**). Walleye utilized other fish families, primarily cyprinids and catostomids, more frequently than northern pikeminnow or smallmouth bass. The proportion of identifiable fish as salmonids in predator digestive tracts was higher in 1999 than in 1996 for all areas and predator species. Total number of prey fish per predator (all areas combined) was 0.86 for walleye, 0.40 for smallmouth bass, and 0.33 for northern pikeminnow. Values for 1996 were 0.59, 0.23, and 0.18, respectively (Friesen et al 1997). Observed increases in %FO of salmonids, proportion of diet as salmonids, and number of prey per predator from 1996 to 1999 may be partially attributed to increased abundance of salmonids during sampling periods. Field sampling in 1999 coincided with peaks in juvenile salmonid passage at dams, particularly during spring (**Appendix B**).

**Appendix Table E-1.** Number of northern pikeminnow, smallmouth bass, and walleye digestive tracts examined (N) from the lower Columbia and Snake rivers in 1999 that contained food, fish, and juvenile salmonids (Sal).

Period: Reservoir or area	Northern pikeminnow				Smallmouth bass				Walleye			
	N	Food	Fish	Sal	N	Food	Fish	Sal	N	Food	Fish	Sal
<b>Spring:</b>												
Below Bonneville												
Dam tailrace	66	33	27	17	5	3	1	0	2	2	2	2
Bonneville Dam												
tailrace	24	10	8	2	3	3	2	0	2	2	2	0
Bonneville	69	27	8	3	56	48	18	1	2	1	1	0
The Dalles	6	4	4	2	31	23	4	0	20	17	10	4
John Day	15	6	6	6	18	14	4	0	19	13	12	3
Lower Mon.	0	--	--	--	40	36	18	1	1	1	1	0
Little Goose	4	1	1	1	30	23	15	1	0	--	--	--
Lower Granite	16	11	10	10	68	57	31	7	0	--	--	--
Total	200	92	64	41	251	207	93	10	46	36	28	9
<b>Summer:</b>												
Below Bonneville												
Dam tailrace	60	35	14	7	19	15	5	0	2	1	1	0
Bonneville Dam												
tailrace	77	29	12	2	13	11	10	0	3	2	2	0
Bonneville	97	37	5	2	134	109	31	1	4	2	1	0
The Dalles	39	4	1	0	66	52	15	0	10	8	8	2
John Day	8	3	1	0	59	49	25	4	8	7	7	3
Lower Mon.	0	--	--	--	0	--	--	--	0	--	--	--
Little Goose	5	4	0	0	0	--	--	--	0	--	--	--
Lower Granite	1	1	0	0	12	8	3	1	0	--	--	--
Total	287	113	33	11	303	244	89	6	27	20	19	5

**Appendix Table E-2.** Sample size and percentage of salmonids, cottids, and other fish families in northern pikeminnow, smallmouth bass, and walleye digestive tracts that contained identifiable fish in three reaches of the lower Columbia and Snake rivers, 1999. DBD = downstream from Bonneville Dam, COL = lower Columbia River reservoirs, and SNK = lower Snake River reservoirs.

Sample size, family	Northern pikeminnow			Smallmouth bass			Walleye		
	DBD	COL	SNK	DBD	COL	SNK	DBD	COL	SNK
Digestive tracts	227	234	26	40	364	150	9	63	1
Total fish	71	31	57	29	122	73	11	51	1
Identifiable fish	53	24	51	23	71	45	11	39	0
% Salmonidae	67.9	79.2	100.0	8.7	12.7	22.2	36.4	43.6	0.0
% Cottidae	24.5	16.7	0.0	91.3	63.4	48.9	36.4	15.4	0.0
% Other taxa	7.6	4.2	0.0	0.0	23.9	28.8	27.3	41.1	0.0
% Cyprinidae	5.7	4.2	0.0	0.0	2.8	2.2	27.3	15.4	0.0
% Catostomidae	0.0	0.0	0.0	0.0	14.1	2.2	0.0	20.5	0.0
% Ictaluridae	0.0	0.0	0.0	0.0	2.8	8.9	0.0	2.6	0.0
% Percopsidae	0.0	0.0	0.0	0.0	2.8	0.0	0.0	2.6	0.0
% Gasterosteidae	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0
% Centrarchidae	1.9	0.0	0.0	0.0	1.4	13.3	0.0	0.0	0.0
% Percidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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