Development of a System-wide Predator Control Program: Fisheries Evaluation

Prepared by

Howard K. Takata
David L. Ward

Oregon Department of Fish and Wildlife
Columbia River Investigations
17330 S.E. Evelyn Street
Clackamas, Oregon 97015

January 2002

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ABSTRACT

Predator control fisheries aimed at reducing predation on juvenile salmonids by northern pikeminnow *Ptychocheilus oregonensis* were implemented for the eleventh consecutive year in the mainstem Columbia and Snake rivers. We report on (1) exploitation rates of northern pikeminnow and catch rates of incidental fishes among the three management fisheries in 2001, (2) estimated reductions in predation on juvenile salmonids since implementation of the fisheries, (3) estimated tag loss for spaghetti tags, and (4) validation of aging methodology for northern pikeminnow based on scale and opercula readings.

For the sport-reward fishery, system-wide exploitation of northern pikeminnow ≥ 250 mm fork length (FL) was a record high of 16.2%, 10.6% for northern pikeminnow 200-249 mm FL, and 15.5% for all northern pikeminnow ≥ 200 mm FL. Although northern pikeminnow were harvested by dam angling and site-specific gillnet fisheries, no fish tagged in 2001 were recovered by either of these fisheries; therefore, exploitation rates were 0%. Among reservoirs/river areas, exploitation of northern pikeminnow ≥ 200 mm by the sport-reward fishery was highest in McNary Reservoir (including the Hanford Reach) and the area downstream of Bonneville Dam. The exceptionally high exploitation rates in 2001 may be the result of low river flows that improved angler success rates, or from increased catch and effort due to an increase in rewards paid to anglers participating in the sport-reward fishery.

Incidental fish comprised 31.6% of the catch by sport-reward anglers targeting northern pikeminnow, 2.8% of the dam angling catch, and 56.6% of the site-specific gillnet catch. The proportion of the northern pikeminnow catch consisting of predator-sized (≥ 200 mm FL) fish was 82.7% in the sport-reward fishery. The incidental catch of salmonids by all fisheries combined comprised 1.0% of the total catch, a three-fold increase over previous years.

Although some modest reductions in predation have been achieved since 1999, further reductions are likely to be minimal if exploitation continues at mean 1995-2001 levels. Even if exploitation rates remain near the exceptionally high levels seen in 2001, relative predation will not decline to any significant extent. We estimate that juvenile salmonid predation will probably not change much from 76% of the pre-program level.

Within-year tag loss was estimated to be 0% for spaghetti tags. However, because an unknown proportion of harvested northern pikeminnow may not have been examined for fin marks and tag loss scars, we cannot confidently conclude that no tag loss fish were recovered. Therefore, we will need to repeat the tag loss study in 2002.

Between-reader variation in the aging of northern pikeminnow scales and opercles tended to be high with complete agreement ranging from only 22.6% for opercles to an average of 36.5% for scales. There appeared to be no clear pattern to the variation between readers. An assessment of the precision of our aging over time showed that complete agreement occurred 40.5% of the time--similar to our results in 2000. Ages assigned to opercles were the same as ages assigned to scales from the same fish only 27.7% of the time. Overall, ages for opercles tended to be greater than those for scales, suggesting that either scales underestimate ages or opercles overestimate ages of northern pikeminnow.

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* 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 abundance, consumption, and predation in Columbia River reservoirs in 1990 and 1993, Snake River reservoirs in 1991, and the unimpounded lower Columbia River downstream from Bonneville Dam in 1992 (Ward et al. 1995). From 1994 to 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 (1998) provided a comprehensive summary of NPMP evaluation from 1990 to 1996. In this report, we describe our activities and findings for 2001, and wherever possible, evaluate changes from previous years.

Our objectives in 2001 were to (1) evaluate the relative efficiency of each northern pikeminnow fishery by comparing exploitation rates and incidental catches, (2) estimate reductions in predation on juvenile salmonids since implementation of the NPMP, (3) estimate the tag loss rate for spaghetti tags, and (4) validate aging methods through collection and reading of scale and opercula samples from tagged and recaptured northern pikeminnow. The later two objectives were first implemented in 2000 based on the recommendations of an independent review of the NPMP (Hankin and Richards 2000).

METHODS

Fishery Evaluation, Predation Estimates, and Tag Loss

Field Procedures

Three northern pikeminnow fisheries were conducted in 2001. The sport-reward fishery was implemented by the Washington Department of Fish and Wildlife (WDFW) from April 30 (May 14 for areas upstream of The Dalles Dam) to October 14 throughout the lower Columbia and Snake rivers. For the second consecutive year, northern pikeminnow as small as 9 inches (230 mm) total length (TL) (approximately equivalent to 200 mm fork length) were eligible for a reward. The dam angling fishery was implemented by the Yakama Nation from April 23 to August 12 at Bonneville, The Dalles, and John Day dams (fishing primarily on the tailrace side of the dams). A site-specific gillnet fishery was also implemented by the Yakama Nation from March 26 to April 22 in Bonneville Reservoir. Both the dam angling and site-specific gillnet fisheries also targeted northern pikeminnow ≥ 230 mm TL.

We tagged and released northern pikeminnow ≥ 200 mm fork length (FL) to estimate exploitation rates for each fishery. We used electrofishing boats and bottom gillnets to collect northern pikeminnow from April 4 to June 14. A detailed description of sampling gears and methods is given in Parker et al. (1995). With few exceptions, we allocated equal sampling effort in all sampled river kilometers (RKm). On the Columbia River, we sampled from RKm 78 (near Clatskanine, Oregon) upstream to RKm 634 (Priest Rapids Dam). In 2001, we sampled only about half of John Day Reservoir due to historically low numbers of tagged fish in that reservoir. In addition, approximately 18 river kilometers in various areas of the Columbia could not be sampled due to high winds. On the Snake River, we only sampled above Lower Granite Dam from RKm 190 (approximately 20 kilometers downstream of Lewiston, Idaho) to RKm 246 (near the mouth of the Grande Ronde River). Sampling in Lower Monumental and Little Goose reservoirs was discontinued in 2001 due to historically low numbers of tagged fish in those reservoirs. Northern pikeminnow ≥ 200 mm FL were tagged with a serially-numbered spaghetti tag. To evaluate tag loss, we clipped the right ventral fin on all tagged fish.

Data Analysis

We used mark-and-recapture data to compare exploitation rates of northern pikeminnow ≥ 200 mm FL among fisheries and reservoirs in 2001. Weekly estimates of exploitation for each fishery were calculated by dividing the number of tagged northern pikeminnow recovered (including fish tagged in 2001 that had lost their tags) by the number of tagged fish at large and summed to yield total exploitation rates (Beamesderfer et al. 1987).

We calculated 95% confidence intervals for each weekly exploitation estimate. 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 weekly confidence intervals using the formula

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

where

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

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

We compared incidental catch among fisheries by calculating the percent of the total catch comprised of fish other than northern pikeminnow ≥ 200 mm FL. We also estimated the proportion of predator-sized northern pikeminnow (≥ 200 mm FL) relative to the total northern pikeminnow catch, and the catch rate of salmonids in each fishery.

We used the model of 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 2001 based on observed exploitation rates, and the eventual minimum potential predation assuming continuing exploitation at mean 1995-2001 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.

To estimate tag loss, we used the formula

$$L = [m / (m + r)] * 100,$$

where

L = percent tag loss,
m = number of northern pikeminnow recaptured with missing tags and right ventral fin clips, and
r = number of northern pikeminnow recaptured with year 2001 tags intact.

Age Validation

Field and Laboratory Procedures

We collected scale samples from all northern pikeminnow that we tagged in 2001. In addition, WDFW personnel collected scale and opercle samples from each tagged northern pikeminnow recaptured in the sport-reward fishery. Scales were cleaned, mounted on cards, and pressed onto acetate sheets for viewing on a microfiche reader. Methods of age determination were described by Parker et al. (1995). Scales were read independently by two people and we kept track of the number of times that the readers disagreed on an age. Age differences were resolved by the two readers re-viewing the scale in question together until they agreed on a final age.

Opercula were placed in a bowl of water and heated in a microwave oven at high temperature for approximately 5 minutes to soften the tissue and skin covering the opercular bone. The skin and any remaining tissue was then removed using a pair of tweezers and/or toothbrush. A thickened “ridge” radiating from the focus on the concave side of each opercle was ground down with a small handheld grinder to enhance viewing of potential annuli near the focus. The opercle was then examined under a digital video microscope at 10x magnification using light transmitted from either above or below the opercle (whichever gave the best view of the annuli on a particular sample). Opercular images from the microscope were viewed on a computer monitor. Each opercle sample was read independently by the same two readers that had aged the corresponding scale samples. Again, we kept track of aging discrepancies between readers and differences were resolved in a manner similar to that for the scales to obtain a final opercle age.

Data Analysis

In a continuation of an age validation study initiated in 2000 (Takata and Ward 2001), we looked at between-reader variation in ages assigned to both scales and opercles from northern pikeminnow. An aging discrepancy was calculated as

$$d = a_2 - a_1,$$

where

d = age discrepancy,
a_1 = age assigned to a scale or opercle by Reader 1, and
a_2 = age assigned to a scale or opercle by Reader 2.

This indicated both the magnitude and direction of the discrepancy (-2 years, - 1 year, 0 years, + 1 year, etc). We then calculated the percentage of samples in each discrepancy category as a measure of between-reader variation.

We also assessed the precision of our aging over time. We compared final ages (agreed upon by both readers) assigned to scales collected at the time of recapture to those for scales collected from the same fish at the time of tagging. We used the formula

$$D = (A_R - A_T) - (Y_R - Y_T),$$

where

D = age discrepancy,
A_R = final age assigned to a scale at recapture,
A_T = final age assigned to a scale at tagging,
Y_R = recapture year, and
Y_T = tagging year

to calculate aging discrepancies. We then calculated the percent of samples in each discrepancy category as we had done for the between-reader assessment.

Finally, to evaluate the potential use of opercula for aging northern pikeminnow, we compared the final age assigned to an opercle with the final age assigned to a scale collected from the same fish at the same time. We calculated discrepancies using the formula

$$D = A_O - A_S,$$

where

D = age discrepancy,
A_O = final age assigned to an opercle at recapture, and
A_S = final age assigned to a scale at recapture.

We also directly compared opercle ages to corresponding scale ages from the same fish.

RESULTS

Fishery Evaluation, Predation Estimates, and Tag Loss

We tagged and released 786 northern pikeminnow throughout the lower Columbia and Snake rivers in 2001. Eighty-five of these fish were 200 to 249 mm FL and 701 were ≥ 250 mm FL. A total of 110 northern pikeminnow tagged in 2001 were recaptured in 2001; all in the sport-reward fishery. Of these recaptures, 8 were 200-249 mm and 102 were ≥ 250 mm.

A total of 244,168 northern pikeminnow ≥ 200 mm FL were harvested by the management fisheries in 2001. System-wide exploitation of northern pikeminnow

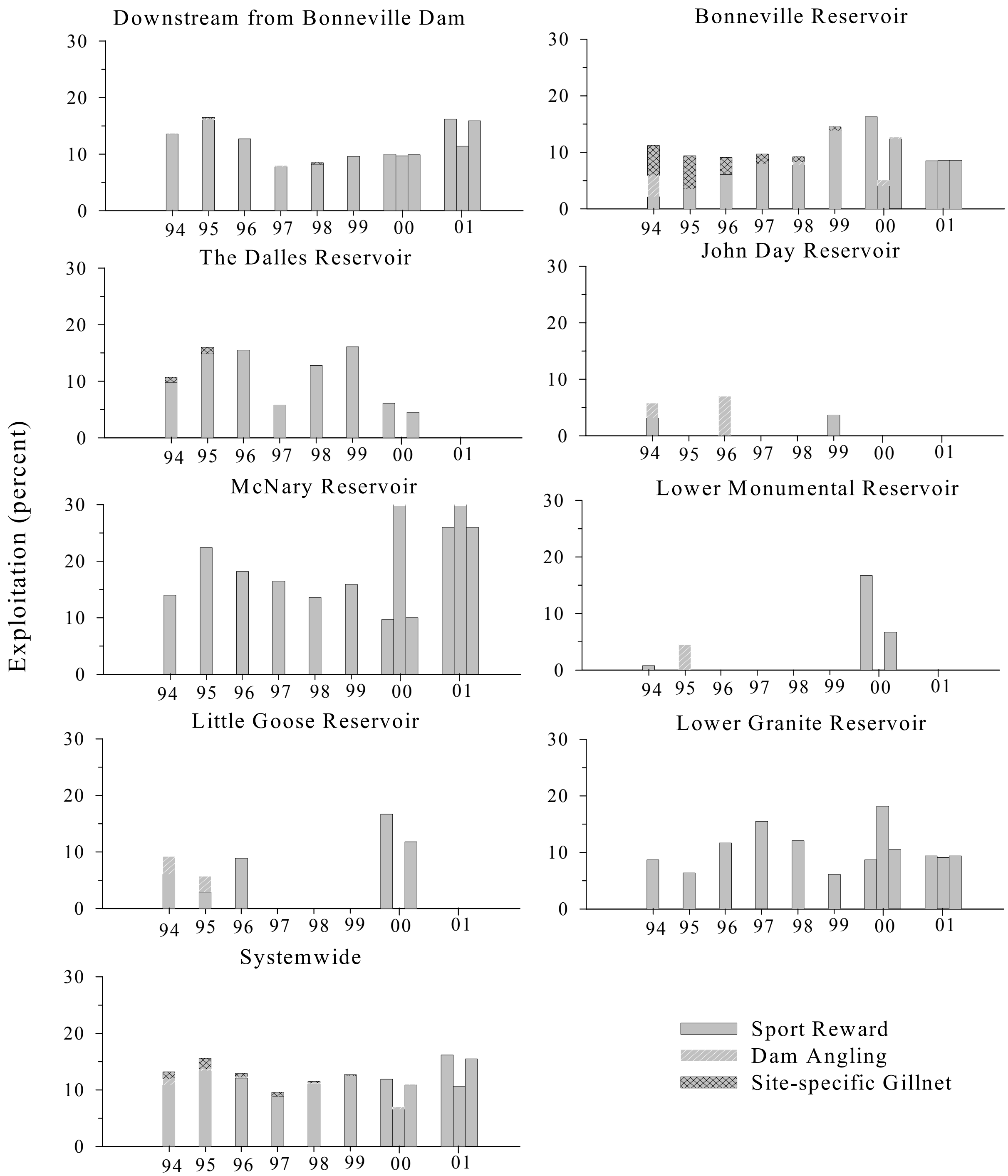

Figure 1. Exploitation of northern pikeminnow ≥ 250 mm fork length (FL) by reservoir/area and fishery, 1994-2001. For 2000 and 2001, vertical bars, from left to right, show exploitation for northern pikeminnow ≥ 250 mm FL, 200-249 mm FL, and ≥ 200 mm FL. In McNary Reservoir, 2001 sport-reward exploitation for northern pikeminnow 200-249 mm was 100%.

≥ 200 mm by all fisheries combined was 15.5% (95% confidence interval of 10.0% to 25.0%). Reservoir/area-specific exploitation rates ranged from a high of 26.0% in McNary Reservoir to a low of 0.0% in The Dalles and John Day reservoirs. The system-wide exploitation rate on northern pikeminnow 200-249 mm by all fisheries was 10.6% (confidence interval not available due to mn < 30), and ranged from 100% in McNary Reservoir to 0.0% in The Dalles and John Day reservoirs. For northern pikeminnow ≥ 250 mm, all fisheries combined had a system-wide exploitation rate of 16.2% (95% confidence interval of 10.3% to 23.1%), ranging from 26.0% in McNary Reservoir to 0.0% in The Dalles and John Day reservoirs (Figure 1; Appendix Table A-1).

The sport-reward fishery harvested 240,894 northern pikeminnow ≥ 200 mm FL. Based on sampled catch proportions, an estimated 138,273 of these fish were ≥ 250 mm FL and 102,621 were in the 200-249 mm FL range. Mean fork length of northern pikeminnow harvested in the sport-reward fishery was 276 mm (M. Wachtel, WDFW, personal communication). Because all tag recoveries occurred in the sport-reward fishery, exploitation estimates for this fishery are the same as that for all fisheries combined (Figure 1; Appendix Table A-2). The Dalles and John Day reservoirs were the only reservoirs in which northern pikeminnow were tagged in 2001 but no tagged fish were recaptured by the sport-reward fishery.

Although 2,751 northern pikeminnow ≥ 200 mm FL were harvested in the dam angling fishery in 2001, none of these fish were tagged. Thus, exploitation for this fishery was calculated as 0.0% (Figure 1; Appendix Table A-3). Northern pikeminnow were not measured in the dam angling fishery in 2001 (G. Lee, Yakama Nation, personal communication); therefore, catch proportions for fish ≥ 250 mm and those in the 200-249 mm size class, as well as the mean size of harvested fish, were unknown.

A total of 523 northern pikeminnow ≥ 200 mm FL were harvested by the site-specific gillnet fishery in 2001; however, none of these fish were tagged. Therefore, exploitation for this fishery was also calculated as 0% (Figure 1; Appendix Table A-4). Northern pikeminnow were not measured in the gillnet fishery in 2001 (G. Lee, Yakama Nation, personal communication); therefore, catch proportions for fish ≥ 250 mm and those in the 200-249 mm size class, as well as the mean size of harvested fish, were unknown.

System-wide weekly exploitation rates for the management fisheries are shown in Appendix Tables A-5 through A-7. In addition, Appendix Table A-8 shows the week-by-week exploitation rates for northern pikeminnow 200-249 mm in McNary Reservoir, where total exploitation on these fish was unusually high at 100%.

In 2001, the three management fisheries reported a total incidental catch of 109,975 fish, including northern pikeminnow < 200 mm FL (Table 1). The incidental

Table 1. Catch of northern pikeminnow and incidental fishes in each fishery in 2001. Northern pikeminnow < 200 mm fork length (FL) are considered incidental catch. Sport-reward catches of incidentals are estimates based upon exit surveys of anglers who targeted northern pikeminnow.

Species or family	Sport-reward	Dam angling	Gillnet
Northern pikeminnow			
≥ 200 mm FL	240,894	2,751	523
< 200 mm FL	50,202	[a]	[a]
Salmonidae			
Chinook (adult/jack)	131	0	[a]
Coho (adult/jack)	6	0	[a]
Sockeye (adult)	7	0	[a]
Steelhead (adult)	187	0	[a]
Cutthroat trout	57	0	[a]
Juvenile salmon/steelhead	679	0	[a]
All other salmonids[b]	2,375	0	[a]
White sturgeon	4,461	23	106
Walleye	364	[a]	[a]
Smallmouth bass	6,020	[a]	[a]
Yellow perch	1,094	[a]	[a]
American shad	413	[a]	[a]
Cyprinidae[c]	26,169	[a]	[a]
Catostomidae	2,831	[a]	[a]
Ictaluridae	4,642	[a]	[a]
Centrarchidae[d]	271	[a]	[a]
Other/unidentified	10,677	56	576
Total (all species)	350,108	2,830	1,205
Percent incidental catch	31.6	2.8	56.6

[a] Catch unknown. Counts included in “Other/unidentified”.
[b] Includes juveniles and adults of *Oncorhynchus* spp., *Salvelinus* spp., and mountain whitefish *Prosopium williamsoni*.
[c] Excluding northern pikeminnow.
[d] Excluding smallmouth bass.

catch rate for all fisheries combined was 31.1%. The most common incidental fishes were northern pikeminnow < 200 mm, other cyprinids, and unidentified fishes. The incidental catch rate was 31.6% for anglers who targeted northern pikeminnow in the sport-reward fishery, 2.8% in the dam angling fishery, and 56.6% in the site-specific gillnet fishery. For the sport-reward fishery, the proportion of the northern pikeminnow catch consisting of predator-sized (≥ 200 mm) fish was 82.7%. The proportions for the dam angling and site-specific gillnet fisheries are unknown (G. Lee, Yakama Nation, personal communication). In the sport-reward fishery, 1.0%

of the total catch consisted of salmonids. Salmonids made up 4.3% of the total catch in the site-specific gillnet fishery. No salmonids were caught in the dam angling fishery. For all fisheries combined, salmonids made up 1.0% of the total catch.

Modeling results indicate that potential predation by northern pikeminnow on juvenile salmonids in 2001 ranged from 63% to 88% of pre-program levels, with a median estimate of 76% (Figure 2). Continued harvest at mean 1995-2001 exploitation levels will result in minimal additional reductions in predation.

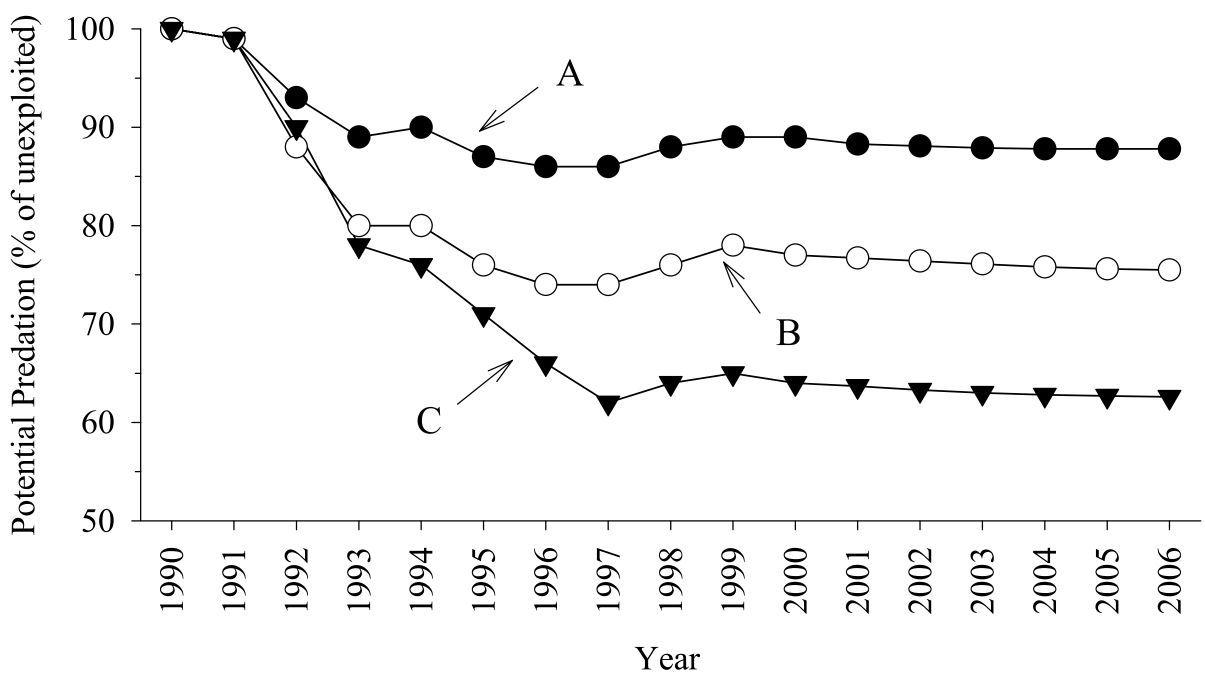

Figure 2. Maximum (A), median (B), and minimum (C) estimates of potential predation on juvenile salmonids by northern pikeminnow relative to predation prior to implementation of the Northern Pikeminnow Management Program. Trends after 2001 indicate predicted predation in future years if exploitation is maintained at mean 1995-2001 levels.

No northern pikeminnow with a right ventral fin clip and a missing tag were reported recovered in any of the management fisheries. Thus, within-year tag loss was calculated as 0% for northern pikeminnow tagged with spaghetti tags in 2001.

Age Validation

We aged a total of 302 scale and opercle samples from tagged and recaptured northern pikeminnow in 2001. Ninety-nine of these fish were tagged in 2001 and 13 were tagged in 2000.

For scales collected at tagging, complete agreement (i.e. zero discrepancy) on ages assigned by the two readers was 35.4%, with 75.6% agreement within ± one year (Figure 3). For scales collected at recapture, complete agreement was slightly higher at 37.6%. Agreement within ± one year for this group of scales was also higher at 78.2%. Complete agreement was lowest for opercles collected at recapture at 22.6%. The readers agreed within ± one year 62.8% of the time. Reader 1 tended to age a little higher than Reader 2 on scales collected at recapture, while Reader 2 tended to age higher on scales collected at tagging and on opercles collected at recapture (Figure 3). The largest age discrepancy between the two readers was 5 years.

When final ages assigned to scales collected at tagging in 2000 were compared to final ages assigned to scales collected at recapture in 2001 for the same fish, the ages agreed only 15.4% of the time (Figure 4). However, agreement within ± one year occurred with 69.2% of the samples. Ages assigned to scales collected at recapture were usually the same or actually younger than ages assigned to scales from the same fish at tagging even though a year had elapsed between tagging and recapture.

When final ages assigned to scales collected at tagging in 2001 were compared to final ages assigned to scales collected at recapture in 2001 for the same fish, complete agreement was higher at 40.5% (Figure 4). Agreement within ± one year was also higher at 78.5%. However, when there was a discrepancy, ages assigned to scales collected at recapture were actually younger than ages assigned to scales from the same fish at tagging.

Final ages assigned to scales matched exactly with final ages assigned to opercles from the same fish 27.7% of the time (Figure 5). Agreement within ± one year was 66.0%. The majority (54.2%) of the samples had an opercle age that was greater than the scale age. Scale ages ranged from 3 to 13 years while opercle ages ranged from 4 to 17 years. Ages for opercles tended to be greater than scale ages throughout the entire range of age classes in the sample (Figure 5).

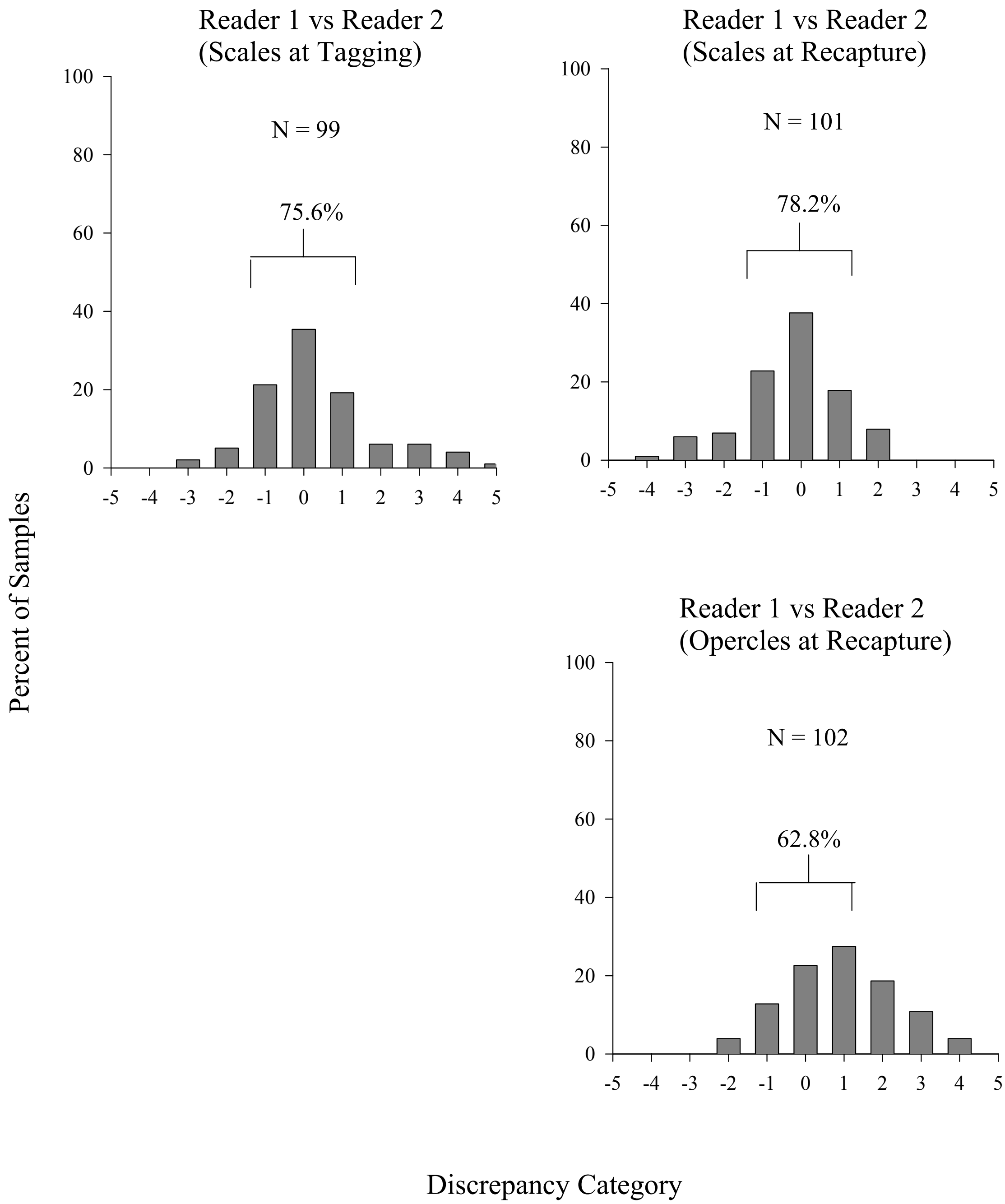

Figure 3. Distribution of reader aging discrepancies for northern pikeminnow scales and opercles collected at tagging and recapture in 2001. A potential aging discrepancy is defined as the Reader 1 age subtracted from the Reader 2 age.

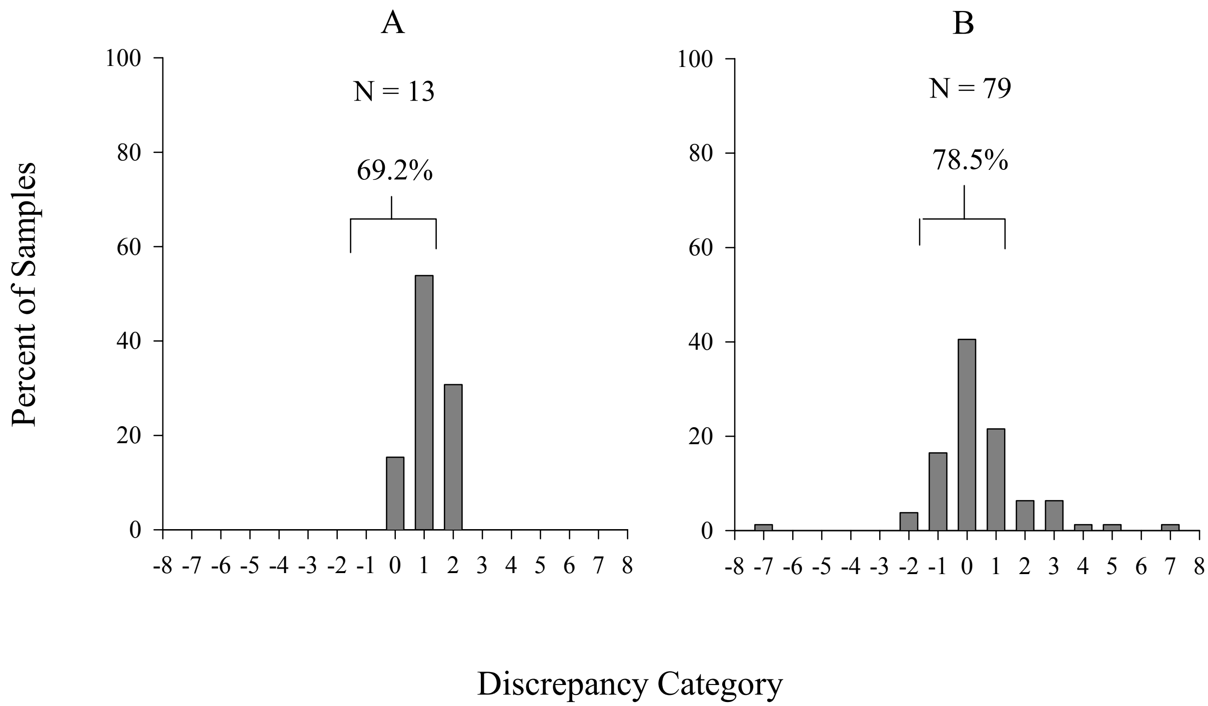

Figure 4. Panel A shows aging discrepancies for scales taken from fish during tagging in 2000 and at recapture in 2001. Panel B shows aging discrepancies for scales taken from fish during tagging in 2001 and at recapture in 2001. A potential discrepancy is defined as the difference between recapture age minus tagging age and recapture year minus tagging year.

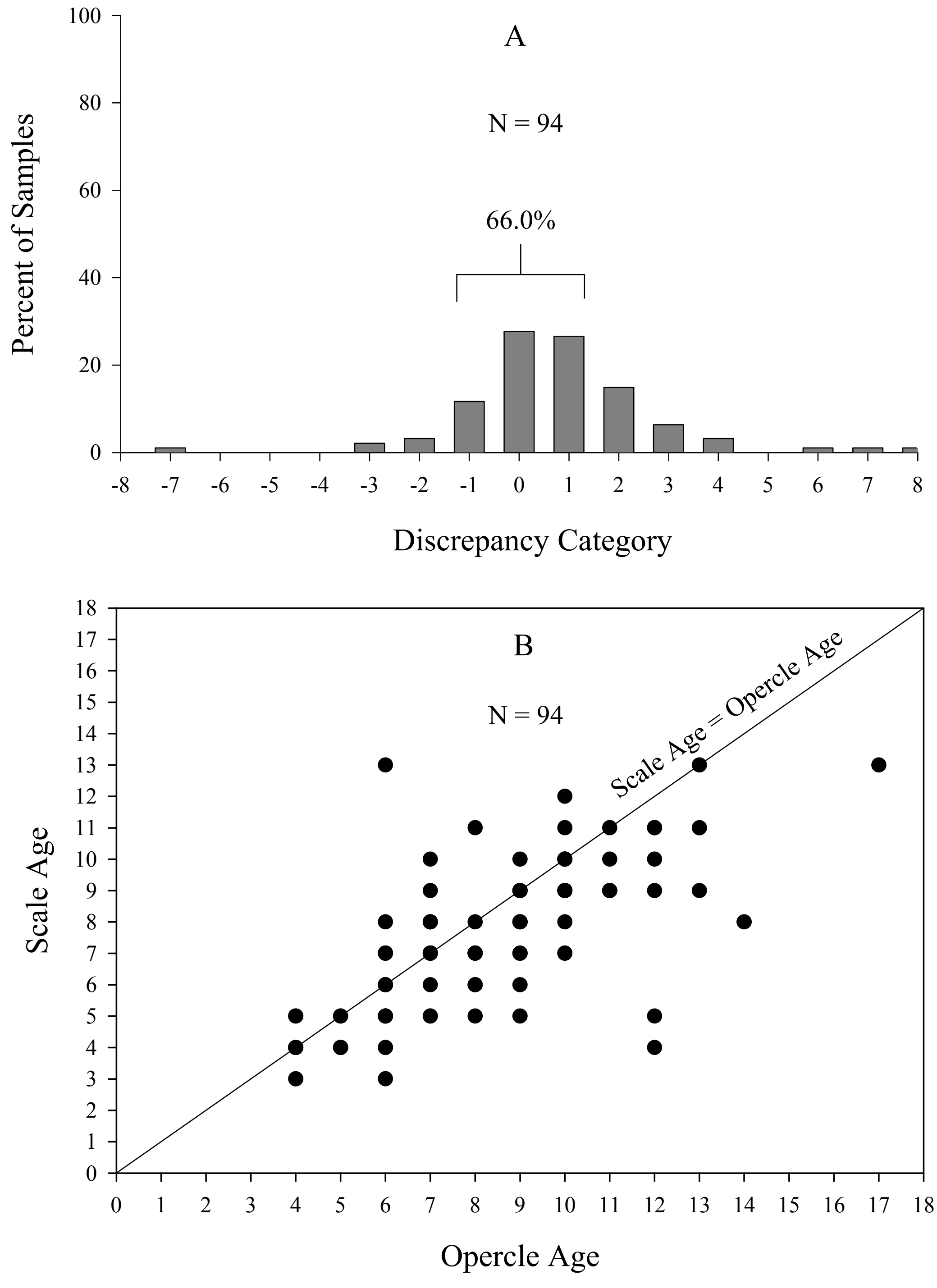

Figure 5. Comparison of ages assigned to scales and opercles from northern pikeminnow recaptured in 2001. Panel A shows aging discrepancies between scales and opercles taken from the same fish. A potential discrepancy is defined as the scale age subtracted from the opercle age Panel B shows scale ages plotted against corresponding opercle ages.

DISCUSSION

At 16.2%, system-wide exploitation of northern pikeminnow ≥ 250 mm by the management fisheries in 2001 was the highest since inception of the program in 1991. It far exceeded the 11.7% mean exploitation rate for the 5-year period 1996-2000. The exploitation rates for northern pikeminnow 200-249 mm (10.6%) and for all northern pikeminnow ≥ 200 mm (15.5%) also increased from rates for these fish in 2000 (the first year northern pikeminnow 200-249 mm FL were targeted) (Figure 1).

There are two possible explanations for the exceptionally high exploitation rates observed in 2001. One factor that may have contributed to high exploitation is river level/flow. The mean river stage at the gauging station below Bonneville Dam (USGS site number 14128870) during the sport-reward season (May through September, 2001) was the lowest in the past decade (U.S. Geological Service unpublished data). Using mean stage (ft) as an index of river level/flow and sport-reward exploitation data from 1995 through 2001, there was a significant inverse relationship ($r^2 = 0.76$; $P < .05$) between the sport-reward exploitation rate on northern pikeminnow ≥ 250 mm and mean stage during the season (Figure 6). Low river levels may concentrate northern pikeminnow in certain areas (e.g. dam tailrace reaches or tributary mouths), possibly improving angling success rates in those areas. Concentrations of fish would also increase the likelihood of catching a tagged fish, thereby potentially increasing exploitation rates.

The second factor that may have contributed to higher exploitation rates in 2001 was the change in rewards paid out to anglers participating in the sport-reward fishery. On July 10, 2001, mid-way through the season, rewards for northern pikeminnow ≥ 200 mm FL increased to $5, $6, and $8 per fish for the three tier levels in the program. In addition, rewards for tagged northern pikeminnow were raised substantially from $50 to $1,000 per fish. This increased both catch and effort to levels above what is normally seen during the later half of the season (L. Fox, WDFW, personal communication). This may have led to more tagged fish being recovered during the second half of the season than is usually the case. In 2000, about 30% of the year's tag recoveries occurred during the second half of the season. In 2001, this proportion increased to 50%. The greater proportion of tag recoveries in the later part of the season may help explain the higher exploitation rates.

Exploitation of all northern pikeminnow ≥ 200 mm by all fisheries combined increased from 2000 levels in the area below Bonneville Dam and in McNary Reservoir. On the other hand, exploitation rates dropped in Bonneville, The Dalles, and Lower Granite Reservoirs. For the first time since inception of the program, the exploitation rate in The Dalles Reservoir was 0.0%. In contrast, John Day reservoir has had an exploitation rate of 0.0% in five of the last eight years.

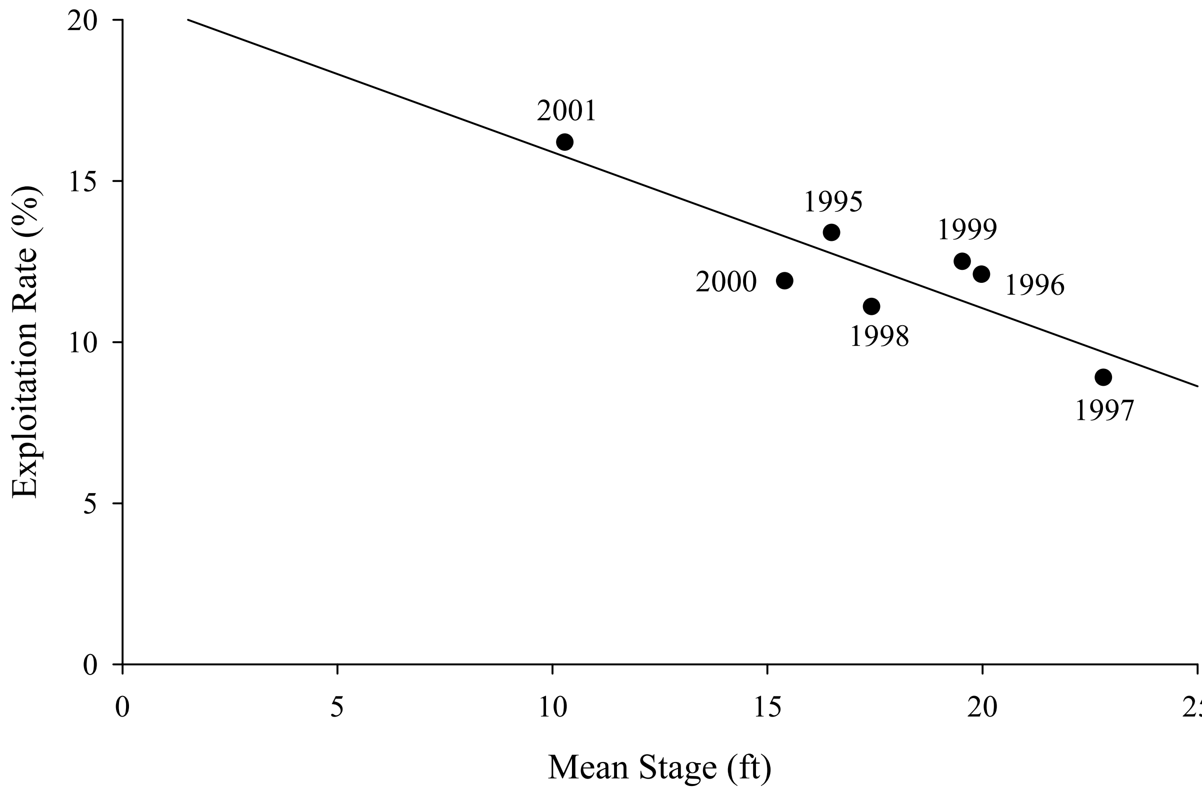

Figure 6. Relationship between sport-reward exploitation of northern pikeminnow greater than or equal to 250 mm FL and mean Columbia River stage (gauge height in feet below Bonneville Dam) during the sport-reward season (May-September) for the period 1995-2001.

Among reservoirs/areas, McNary Reservoir had by far the highest exploitation rate for all size classes of northern pikeminnow. In addition to the increased catch and effort due to the new reward system, another factor that may have played a role is the possible shift in distribution of northern pikeminnow within the Hanford Reach (defined as the Columbia River from the confluence of the Yakima River to Priest Rapids Dam). Data from 2000 and 2001 indicate that a larger proportion of the tagged northern pikeminnow within the Hanford Reach were tagged in the upper half of the reach in 2001 compared to the previous year (Figure 7). This concentration of fish in the Priest Rapids tailrace may have been the result of very low river flow in 2001. Whether this apparent shift occurred due to feeding opportunities, spawning, or some other reason is unclear. In McNary Reservoir, 78% of the recaptured tagged fish were turned

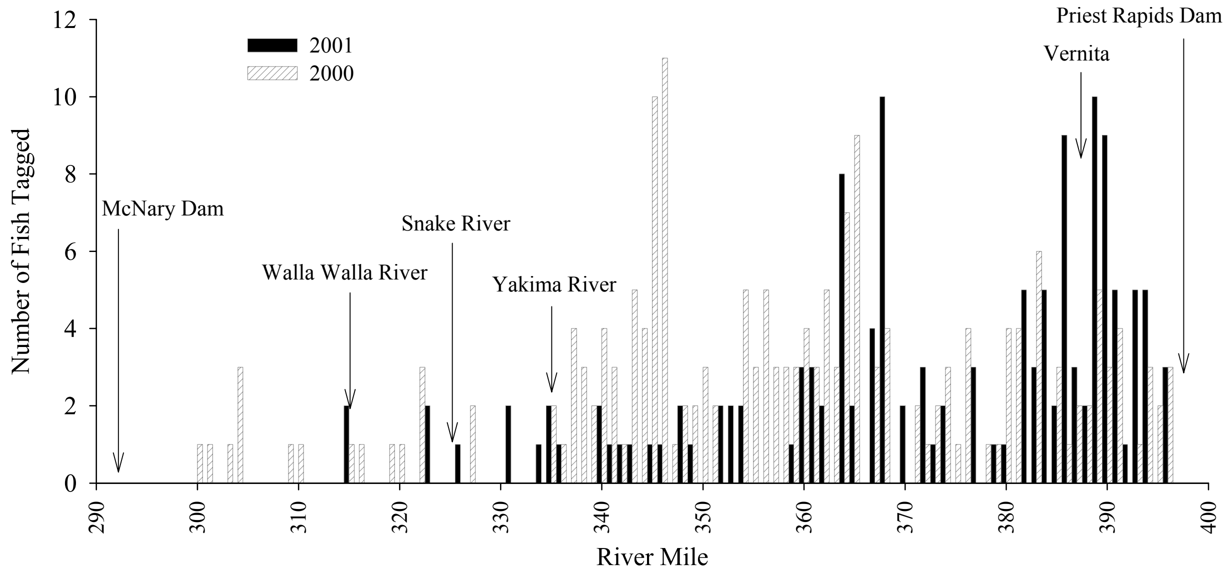

Figure 7. Distribution of northern pikeminnow tagged in 2000 and 2001 in the Columbia River in McNary Reservoir (including Hanford Reach).

in at the Vernita Bridge Rest Area check station within the tailrace area of Priest Rapids Dam, presumably indicating that those anglers had fished in the general vicinity of Vernita. Therefore, it is possible that anglers had exceptional success catching northern pikeminnow, including tagged fish, that had concentrated in this area.

The 100% exploitation rate on northern pikeminnow 200-249 mm in McNary Reservoir was an artifact of small sample size and coincidence. Appendix Table A-8 shows that during Sampling Week 20 only one tagged northern pikeminnow in this size class was at large; however, it just happened to get caught that same week. This resulted in a weekly exploitation rate of 100%. Since total exploitation for the season is a sum of weekly exploitation rates, the final exploitation on these fish in McNary Reservoir was also 100%. Although we try to minimize the amount of overlap between the tagging and sport-reward seasons, some overlap is unavoidable due to budgetary and sampling constraints. If the 200-249 mm tagged fish had not been recaptured until after all tagging in McNary Reservoir had been completed, the exploitation rate would have been 20%--probably a more realistic estimate. In the future, we will continue to try and reduce overlap between the tagging and sport-reward seasons and seek to complete tagging in a given reservoir within one week whenever possible.

As in 2000, system-wide exploitation of northern pikeminnow 200-249 mm was lower than that for fish ≥ 250 mm. The exploitation rate on the smaller fish will probably always be relatively low; however, harvest of these fish will prevent them from reaching the size of maximum predation on juvenile salmonids.

The dam angling and site-specific gillnet fisheries accounted for only 1.1% and 0.2%, respectively, of the total northern pikeminnow harvest and did not recapture any tagged fish, resulting in exploitation rates of 0.0% in 2001. However, these fisheries do harvest concentrations of northern pikeminnow in areas that sport-reward anglers cannot access (e.g. boat-restricted zones near dams) or are unwilling to target (Beamesderfer and Rieman 1991; Poe et al. 1991; Collis et al. 1995). Therefore, there may be some value in continuing them, particularly the dam angling fishery which appears to catch more northern pikeminnow with very little incidental catch.

Incidental catch rates for the management fisheries have been very stable over the past several years. This year's rates were very close to the average incidental catch rates for the 5-year period 1996-2000 of 30% in the sport-reward fishery, 5% in the dam angling fishery and 57.3% in the site-specific gillnet fishery. Incidental catch rates have consistently been highest for the gillnet fishery and lowest for the dam angling fishery. In 2001, there was a three-fold increase in the catch rate of salmonids compared to the 5-year average of 0.3%. This is probably due to both increased effort by sport-reward anglers and the record numbers of spring chinook and summer steelhead that returned to the Columbia River in 2001. Nevertheless, for the second consecutive year, the dam angling fishery did not catch any salmonids.

Potential predation has slightly decreased in the past two years. This reverses a modest increasing trend from 1997 to 1999 (Figure 2). However, it appears that most of the reduction in predation has been realized in the first seven years of the NPMP. If exploitation rates remain similar to mean 1995-2001 levels, further reductions in potential predation are likely to be minimal. Even if exploitation continues near the record-high level observed in 2001, potential predation probably will not decline significantly. Therefore, maintaining potential predation near the current level of 76% may be a more realistic goal for the future rather than trying to gain additional large reductions in predation.

In accordance with recommendations made in the audit of the NPMP (Hankin and Richards 2000), we are currently working on an updated predation model. We plan to use this new model once our aging and tag loss assessments are completed.

Although no tag loss fish were reported captured by any of the management fisheries in 2001, a within-year tag loss rate of 0.0% seems unlikely. In 2000, tag loss for spaghetti tags was estimated to be 2.6%, with the potential of being as high as 6.6% (Takata and Ward 2001). Due to the larger than usual catches of northern pikeminnow in this year's sport-reward fishery, some fish may not have been examined for fin marks and tag loss scars. This may especially be the case for fish turned in at the end of the sampling day (L. Fox, WDFW, personal communication). Therefore, we will conduct the tag loss study again in 2002.

We found that both absolute agreement and agreement within ± one year between readers for ages assigned to scales were lower in 2001 than in 2000. This could be due to a variety of reasons, from differing experience levels of readers to changes in the quality of prepared samples. However, it may also be a reflection of the inherent difficulty in aging northern pikeminnow scales. This may be especially true for older fish where later annuli are very difficult to identify.

Absolute agreement and agreement within ± one year for ages assigned to opercles was even lower than it was for scales. Opercles have many opaque lines that may or may not be true annuli. This could easily lead to different counts between readers. Overall, there appeared to be no clear trend in discrepancies between the readers; that is, one reader did not consistently age higher than the other reader for all groups of samples.

Both complete agreement and agreement within ± one year were higher for scales from northern pikeminnow tagged in 2001 and recaptured the same year compared to scales from fish tagged in 2000 and recaptured in 2001. It is possible that the relatively small sample size for the later set of scales (Figure 4) may have contributed to these differences. Interestingly, complete agreement and agreement within ± one year for the scales from fish tagged in 2001 and recaptured that year were similar to results for scales taken from northern pikeminnow tagged in 2000 and recaptured in 2000 (Takata and Ward 2001), even though the readers themselves were different.

Final ages assigned to opercles were frequently different than final ages assigned to scales from the same fish. In general, opercle ages tended to be older than scale ages. This is similar to the findings of Campbell and Babaluk (1979) who aged scales and opercles from walleye, and aging by the Washington Department of Fish and Wildlife of northern pikeminnow from the Columbia River (J. Sneva, WDFW, personal communication). Both of these studies concluded that ages derived from opercula may be more accurate than those from scales, particularly for older fish. If scales do underestimate the ages of northern pikeminnow, we may be overestimating natural mortality rates which can affect our assessment of population structure and predation. Although opercles may provide more accurate ages than scales, our findings indicate that between-reader variability appears to be higher for opercles (see above). We will continue to evaluate the potential of using opercula to age northern pikeminnow.

ACKNOWLEDGMENTS

We are grateful to Chris Burnside, Tanna Clark, Greg Jackel, Cordell Manz, Matt Powell, George Reed, and Josh Tompkins who worked long hours in the field to collect the data in this report. In addition, a special thanks to Chris Burnside, Tanna Clark, and Josh Tompkins for their excellent work on data entry and scale preparation. We would also like to thank Bonnie Cunningham for her assistance with preparing samples and aging northern pikeminnow scales and opercula.

This research was funded by the Bonneville Power Administration, John Skidmore, Project Manager (Contract DE-B1719-94BI24514). John North of the Oregon Department of Fish and Wildlife and Russell Porter of the Pacific States Marine Fisheries Commission administered the contract and/or critically reviewed the manuscript.

We thank Lyle Fox and his staff (Washington Department of Fish and Wildlife) and George Lee and his staff (Yakama Nation) for their cooperation and help with project coordination. We would also like to thank John Sneva of the Washington Department of Fish and Wildlife for his technical advice on the preparation and reading of northern pikeminnow opercula. In addition, the U.S. Army Corps of Engineers staff was very cooperative regarding entry into project boat-restricted zones. In particular, we appreciate the assistance of Brad Eby, Jennifer Sturgill, and Miro Zyndol. Finally, our thanks to Suzanne Miller of the U.S. Geological Service for providing Columbia River hydrologic data.

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APPENDIX A

Exploitation of Northern Pikeminnow, 1996-2001

Appendix Table A-1. Exploitation rates (%) of northern pikeminnow ≥ 250 mm fork length (FL) for all fisheries combined, 1996-2001.

Area or Reservoir	1996	1997	1998	1999	2000[a]	2001[a]
Downstream of Bonneville Dam	12.7	8.0	8.4	9.6	10.0 (9.7)[a1] (9.9)[a2]	16.2 (11.4)[a1] (15.9)[a2]
Bonneville	9.1	9.7	9.2	14.5	16.3 (5.2)[a1] (12.7)[a2]	8.5 (8.6)[a1] (8.6)[a2]
The Dalles	15.5	5.8	12.8	16.1	6.1 (0.0[c])[a1] (4.5)[a2]	0.0[c] (0.0[c])[a1] (0.0[c])[a2]
John Day	7.0	0.0[c]	0.0[c]	3.7	0.0[c] (0.0[c])[a1] (0.0[c])[a2]	0.0[c] (0.0[c])[a1] (0.0[c])[a2]
McNary	18.2	16.5	13.6	15.9	9.7 (33.3)[a1] (10.2)[a2]	26.0 (100.0)[a1] (26.0)[a2]
Ice Harbor	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]
Lower Monumental	0.0[c]	0.0[c]	0.0[c]	0.0[c]	16.7 (0.0[c])[a1] (6.7)[a2]	--[b]
Little Goose	8.9	0.0[c]	0.0[c]	0.0[c]	16.7 (0.0[c])[a1] (11.8)[a2]	--[b]
Lower Granite	11.7	15.5	12.1	6.1	8.7 (18.2)[a1] (10.5)[a2]	9.4 (9.1)[a1] (9.4)[a2]
System-wide	12.9	9.6	11.5	12.7	11.9 (7.1)[a1] (11.0)[a2]	16.2 (10.6)[a1] (15.5)[a2]

[a] Rewards were paid for northern pikeminnow ≥ 200 mm FL. Figures in parentheses indicate the exploitation rate for northern pikeminnow 200-249 mm FL ( )[a1] and the total exploitation rate for northern pikeminnow ≥ 200 mm FL ( )[a2].
[b] No northern pikeminnow tagged.
[c] Northern pikeminnow harvested, but no tags recovered.

Appendix Table A-2. Exploitation rates (%) of northern pikeminnow ≥ 250 mm fork length (FL) for the sport-reward fishery, 1996-2001.

Area or Reservoir	1996	1997	1998	1999	2000[a]	2001[a]
Downstream of Bonneville Dam	12.7	7.8	8.2	9.6	10.0 (9.7)[a1] (9.9)[a2]	16.2 (11.4)[a1] (15.9)[a2]
Bonneville	6.1	8.0	7.8	13.9	16.3 (4.1)[a1] (12.4)[a2]	8.5 (8.6)[a1] (8.6)[a2]
The Dalles	15.5	5.8	12.8	16.1	6.1 (0.0[c])[a1] (4.5)[a2]	0.0[c] (0.0[c])[a1] (0.0[c])[a2]
John Day	0.0[c]	0.0[c]	0.0[c]	3.7	0.0[c] (0.0[c])[a1] (0.0[c])[a2]	0.0[c] (0.0[c])[a1] (0.0[c])[a2]
McNary	18.2	16.5	13.6	15.9	9.7 (33.3)[a1] (10.2)[a2]	26.0 (100.0)[a1] (26.0)[a2]
Ice Harbor	--[b]	--[b]	--[b]	--[b]	--[b] --[b] --[b]	--[b]
Lower Monumental	0.0[c]	0.0[c]	0.0[c]	0.0[c]	16.7 (0.0[c])[a1] (6.7)[a2]	--[b]
Little Goose	8.9	0.0[c]	0.0[c]	0.0[c]	16.7 (0.0[c])[a1] (11.8)[a2]	--[b]
Lower Granite	11.7	15.5	12.1	6.1	8.7 (18.2)[a1] (10.5)[a2]	9.4 (9.1)[a1] (9.4)[a2]
System-wide	12.1	8.9	11.1	12.5	11.9 (6.6)[a1] (10.9)[a2]	16.2 (10.6)[a1] (15.5)[a2]

[a] Rewards were paid for northern pikeminnow ≥ 200 mm FL. Figures in parentheses indicate the exploitation rate for northern pikeminnow 200-249 mm FL ( )[a1] and the total exploitation rate for northern pikeminnow ≥ 200 mm FL ( )[a2].
[b] No northern pikeminnow tagged.
[c] Northern pikeminnow harvested, but no tags recovered.

Appendix Table A-3. Exploitation rates (%) of northern pikeminnow ≥ 250 mm fork length (FL) for the dam-angling fishery, 1996-2001.

Area or Reservoir	1996	1997	1998	1999	2000[a]	2001[a]
Downstream of Bonneville Dam	0.0[c]	0.2	0.0[c]	0.0[c]	0.0[c] (0.0[c])[a1](0.0[c])[a2]	0.0[c] (0.0[c])[a1](0.0[c])[a2]
Bonneville	0.0[c]	0.0[c]	0.5	0.0[c]	0.0[c] (1.0)[a1](0.3)[a2]	0.0[c] (0.0[c])[a1](0.0[c])[a2]
The Dalles	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c] (0.0[c])[a1](0.0[c])[a2]	0.0[c] (0.0[c])[a1](0.0[c])[a2]
John Day	7.0	0.0[c]	0.0[c]	0.0[c]	0.0[c] (0.0[c])[a1](0.0[c])[a2]	--[d]
McNary	0.0[c]	0.0[c]	0.0[c]	--[d]	--[d]	--[d]
Ice Harbor	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]
Lower Monumental	0.0[c]	--[d]	--[d]	--[d]	--[d]	--[b]
Little Goose	0.0[c]	--[d]	--[d]	--[d]	--[d]	--[b]
Lower Granite	0.0[c]	--[d]	--[d]	--[d]	--[d]	--[d]
System-wide	0.3	0.1	0.1	0.0[c]	0.0[c] (0.4)[a1](0.1)[a2]	0.0[c] (0.0[c])[a1](0.0[c])[a2]

[a] Rewards were paid for northern pikeminnow ≥ 200 mm FL. Figures in parentheses indicate the exploitation rate for northern pikeminnow 200-249 mm FL ( )[a1] and the total exploitation rate for northern pikeminnow ≥ 200 mm FL ( )[a2].
[b] No northern pikeminnow tagged.
[c] Northern pikeminnow harvested, but no tags recovered.
[d] No fishing effort.

Appendix Table A-4. Exploitation rates (%) of northern pikeminnow ≥ 250 mm fork length (FL) for the site-specific gillnet fishery, 1996-2001.

Area or Reservoir	1996	1997	1998	1999	2000[a]	2001[a]
Downstream of Bonneville Dam	0.0[c]	0.0[c]	0.3	0.0[c]	--[d]	--[d]
Bonneville	3.0	1.7	0.9	0.6	0.0[c] (0.0[c])[a1](0.0[c])[a2]	0.0[c] (0.0[c])[a1](0.0[c])[a2]
The Dalles	0.0[c]	0.0[c]	0.0[c]	0.0[c]	--[d]	--[d]
John Day	0.0[c]	0.0[c]	0.0[c]	--[d]	--[d]	--[d]
McNary	0.0[c]	--[d]	--[d]	--[d]	0.0[c] (0.0[c])[a1](0.0[c])[a2]	--[d]
Ice Harbor	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]
Lower Monumental	--[d]	0.0[c]	--[d]	--[d]	--[d]	--[b]
Little Goose	--[d]	--[d]	--[d]	--[d]	--[d]	--[b]
Lower Granite	--[d]	--[d]	--[d]	--[d]	0.0[c] (0.0[c])[a1](0.0[c])[a2]	--[d]
System-wide	0.5	0.6	0.3	0.2	0.0[c] (0.0[c])[a1](0.0[c])[a2]	0.0[c] (0.0[c])[a1](0.0[c])[a2]

[a] Rewards were paid for northern pikeminnow ≥ 200 mm FL. Figures in parentheses indicate the exploitation rate for northern pikeminnow 200-249 mm FL ( )[a1] and the total exploitation rate for northern pikeminnow ≥ 200 mm FL ( )[a2].
[b] No northern pikeminnow tagged.
[c] Northern pikeminnow harvested, but no tags recovered.
[d] No fishing effort.

Appendix Table A-5. Weekly exploitation of northern pikeminnow ≥ 200 mm fork length system-wide in 2001.

Sampling Week	Tagged	Recaptures			At Large	Exploitation (%)		
		Sport	Dam	Net		Sport	Dam	Net
14	22	--	--	--	--	--	--	--
15	129	--	--	--	22	--	--	--
16	124	--	--	--	151	--	--	--
17	106	--	--	--	275	--	--	--
18	190	2	--	--	381	0.5	--	--
19	120	2	--	--	569	0.4	--	--
20	44	3	--	--	687	0.4	--	--
21	20	6	--	--	728	0.8	--	--
22	18	7	--	--	742	0.9	--	--
23	5	7	--	--	753	0.9	--	--
24	8	5	--	--	751	0.7	--	--
25	--	10	--	--	754	1.3	--	--
26	--	5	--	--	744	0.7	--	--
27	--	8	--	--	739	1.1	--	--
28	--	7	--	--	731	1.0	--	--
29	--	3	--	--	724	0.4	--	--
30	--	6	--	--	721	0.8	--	--
31	--	--	--	--	715	--	--	--
32	--	2	--	--	715	0.3	--	--
33	--	5	--	--	713	0.7	--	--
34	--	1	--	--	708	0.1	--	--
35	--	3	--	--	707	0.4	--	--
36	--	8	--	--	704	1.1	--	--
37	--	3	--	--	696	0.4	--	--
38	--	8	--	--	693	1.2	--	--
39	--	5	--	--	685	0.7	--	--
40	--	3	--	--	680	0.4	--	--
41	--	1	--	--	677	0.1	--	--
Total	786	110	0	0	--	15.5	0.0	0.0

Appendix Table A-6. Weekly exploitation of northern pikeminnow 200-249 mm fork length system-wide in 2001.

		Recaptures				Exploitation (%)		

Sampling Week	Tagged	Sport	Dam	Net	At Large	Sport	Dam	Net
14	1	--	--	--	--	--	--	--
15	3	--	--	--	1	--	--	--
16	14	--	--	--	4	--	--	--
17	36	--	--	--	18	--	--	--
18	9	--	--	--	54	--	--	--
19	1	--	--	--	63	--	--	--
20	11	1	--	--	64	1.6	--	--
21	2	2	--	--	74	2.7	--	--
22	3	1	--	--	74	1.4	--	--
23	2	--	--	--	76	--	--	--
24	3	--	--	--	78	--	--	--
25	--	--	--	--	81	--	--	--
26	--	1	--	--	81	1.2	--	--
27	--	--	--	--	80	--	--	--
28	--	--	--	--	80	--	--	--
29	--	--	--	--	80	--	--	--
30	--	2	--	--	80	2.5	--	--
31	--	--	--	--	78	--	--	--
32	--	--	--	--	78	--	--	--
33	--	--	--	--	78	--	--	--
34	--	--	--	--	78	--	--	--
35	--	--	--	--	78	--	--	--
36	--	--	--	--	78	--	--	--
37	--	--	--	--	78	--	--	--
38	--	1	--	--	78	1.3	--	--
39	--	--	--	--	77	--	--	--
40	--	--	--	--	77	--	--	--
41	--	--	--	--	77	--	--	--
Total	85	8	0	0	--	10.6	0.0	0.0

Appendix Table A-7. Weekly exploitation of northern pikeminnow ≥ 250 mm fork length system-wide in 2001.

		Recaptures				Exploitation (%)		

Sampling Week	Tagged	Sport	Dam	Net	At Large	Sport	Dam	Net
14	21	--	--	--	--	--	--	--
15	126	--	--	--	21	--	--	--
16	110	--	--	--	147	--	--	--
17	70	--	--	--	257	--	--	--
18	181	2	--	--	327	0.6	--	--
19	119	2	--	--	506	0.4	--	--
20	33	2	--	--	623	0.3	--	--
21	18	4	--	--	654	0.6	--	--
22	15	6	--	--	668	0.9	--	--
23	3	7	--	--	677	1.0	--	--
24	5	5	--	--	673	0.7	--	--
25	--	10	--	--	673	1.5	--	--
26	--	4	--	--	663	0.6	--	--
27	--	8	--	--	659	1.2	--	--
28	--	7	--	--	651	1.1	--	--
29	--	3	--	--	644	0.5	--	--
30	--	4	--	--	641	0.6	--	--
31	--	--	--	--	637	--	--	--
32	--	2	--	--	637	0.3	--	--
33	--	5	--	--	635	0.8	--	--
34	--	1	--	--	630	0.2	--	--
35	--	3	--	--	629	0.5	--	--
36	--	8	--	--	626	1.3	--	--
37	--	3	--	--	618	0.5	--	--
38	--	7	--	--	615	1.1	--	--
39	--	5	--	--	608	0.8	--	--
40	--	3	--	--	603	0.5	--	--
41	--	1	--	--	600	0.2	--	--
Total	701	102	0	0	--	16.2	0.0	0.0

Appendix Table A-8. Weekly exploitation of northern pikeminnow 200-249 mm fork length in McNary Reservoir in 2001.

		Recaptures				Exploitation (%)		
Sampling								

Week	Tagged	Sport	Dam	Net	At Large	Sport	Dam	Net
14	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--
19	1	--	--	--	--	--	--	--
20	--	1	--	--	1	100.0	--	--
21	--	--	--	--	0	--	--	--
22	3	--	--	--	0	--	--	--
23	1	--	--	--	3	--	--	--
24	--	--	--	--	4	--	--	--
25	--	--	--	--	4	--	--	--
26	--	--	--	--	4	--	--	--
27	--	--	--	--	4	--	--	--
28	--	--	--	--	4	--	--	--
29	--	--	--	--	4	--	--	--
30	--	--	--	--	4	--	--	--
31	--	--	--	--	4	--	--	--
32	--	--	--	--	4	--	--	--
33	--	--	--	--	4	--	--	--
34	--	--	--	--	4	--	--	--
35	--	--	--	--	4	--	--	--
36	--	--	--	--	4	--	--	--
37	--	--	--	--	4	--	--	--
38	--	--	--	--	4	--	--	--
39	--	--	--	--	4	--	--	--
40	--	--	--	--	4	--	--	--
41	--	--	--	--	4	--	--	--
Total	5	1	--	--	--	100.0	--	--

APPENDIX B

Dates of Sampling in 2001

Appendix Table B-1. Dates of each sampling week in 2001.

Sampling Week	Dates	Sampling Week	Dates
13	March 26 – April 1		
14	April 2 - April 8	28	July 9 - July 15
15	April 9 - April 15	29	July 16 - July 22
16	April 16 - April 22	30	July 23 - July 29
17	April 23 - April 29	31	July 30 - August 5
18	April 30 - May 6	32	August 6 - August 12
19	May 7 - May 13	33	August 13 - August 19
20	May 14 - May 20	34	August 20 - August 26
21	May 21 - May 27	35	August 27 - September 2
22	May 28 – June 3	36	September 3 - September 9
23	June 4 - June 10	37	September 10 - September 16
24	June 11 - June 17	38	September 17 - September 23
25	June 18 - June 24	39	September 24 - September 30
26	June 25 - July 1	40	October 1 - October 7
27	July 2 - July 8	41	October 8 - October 14