The Northern Pikeminnow Management Program

An Independent Review of Program Justification, Performance, and Cost-Effectiveness

Prepared by: Dr. David G. Hankin
Professor of Fisheries
Humboldt State University
Arcata, CA 95521

Dr. Jack Richards
Assistant Professor of Economics
Portland State University
Portland, OR 97204

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PREFACE

The Northern Pikeminnow Management Program (NPMP), Project 90-07700, has been recommended to receive funding of $2.506 million in fiscal year (FY) 2000 funds, with the expectation that $800,000 would be available in carryover from FY 1999 funds bringing the project total to $3,306,000 in FY 2000. Given the large annual cost of this program and the need for long-term, continued funding to ensure Program effectiveness, Council staff recommended that future funding of the NPMP be dependent on an independent review of this project (Minutes of Meeting No. 270, 21-22 September 1999). The purpose of our report is to respond to this recommendation for preparation of an independent review.

Production of our review benefited from several meetings and discussions with Council staff (primarily Gustavo Bisbal, Sharon Ossmann, Terry Morlan), the NPMP Technical Administrator (Frank Young), and the BPA contracting officer for this project (John Skidmore). At these meetings, held at the NWPPC office in Portland, we were provided with relevant documentation of the NPMP (a collection of project proposals, reviews, annual reports, publications, etc. available from G. Bisbal, NWPPC), and we engaged in discussions of the direction that our review should take so as to be most useful for the Council. We also submitted a series of questions to NPMP management staff; the response to these questions has been included as Appendix 3 of this report. Additional important publications, unpublished information and assistance on several technical issues were received from David Ward of the Oregon Department of Fish and Wildlife (ODFW). Extensive updated program cost information was provided by Russell Porter, Pacific States Marine Fisheries Commission (PSMFC). We thank all of these named individuals for their assistance in preparation of our report, and we wish to give special thanks to David Ward and Terry Morlan for their extensive and much-appreciated assistance in development of biological and economic material, respectively.

Earlier draft versions of this report were distributed to all agencies participating in the NPMP. This final draft incorporates changes that we have made in response to comments or suggestions received from agency participants. As in the draft versions of this report, we first present a consideration of various biological issues raised by the NPMP, we follow with a consideration of economic issues, and we conclude with a concise listing of findings and recommendations with respect to both general areas.

Minor and/or perhaps major errors in presentation of NPMP organization, accomplishments or other matters no doubt remain in the final report. Any such inaccuracies that remain are unintentional and, we hope, unimportant when compared to our substantitive findings and recommendations. We have tried in our review to provide the Council with some ideas for constructive improvements in the NPMP, and we have tried to identify explicitly specific areas where we believe costs might be reduced without impairing overall Program effectiveness.

INTRODUCTION

The Northern Pikeminnow Management Program began on a test basis in 1990 and was in full operation beginning in 1991. The Program has three essential fishery components: (a) a "sport-reward" fishery in which participating public anglers are compensated for their catches of northern pikeminnow, (b) a "dam-angling" fishery for which agency personnel are hired to angle for northern pikeminnow directly from dams or in boats operated close to dams, and (c) "site-specific" gill-net fisheries that attempt to remove northern pikeminnow at locations where high levels of predation may occur (e.g., near hatchery release points or tributary mouths). The Pacific States Marine Fisheries Commission (PSMFC) and the Washington Department of Fish and Wildlife (WDFW) together have responsibility for administration and record-keeping for the sport-reward fishery, whereas the Columbia River Inter-Tribal Fish Commission (CRITFC) and four Indian tribes have responsibility for adminsitration of the dam-angling and site-specific fisheries. Oregon Department of Fish and Wildlife has responsibility for evaluation of program accomplishments in terms of impacts on (reductions in) juvenile salmonid predation by northern pikeminnow. The total annual budget for administration and funding of these fisheries and for evaluation of Program impacts has been approximately $3 million, making the NPMP the single most expensive project funded as part of Bonneville's annual research program (approximately $130 million total) to mitigate for the impacts of the Federal Columbia River Power System.

Beamesderfer et al. (1996) have estimated that approximately 16.4 million emigrating juvenile anadromous salmonids were consumed by northern pikeminnow annually in the Columbia and Snake rivers prior to the NPMP. Total systemwide impacts are not evenly distributed throughout the Columbia and Snake rivers, but are concentrated in the lower Columbia River below the Dalles Dam where approximately 13.0 million of the 16.4 million total salmonids are believed to have been consumed by northern pikemnnow (Beamesderfer et al. 1996, Table 1). When compared to the estimated 200 million juvenile anadromous salmonids produced in these combined river systems, the northern pikeminnow are thus believed to have consumed approximately 8 percent of all downstream migrants; about 6.5 percent of these downstream migrants are comsumed below The Dalles Dam. The NPMP has a systemwide scope, despite the clear concentration of impacts in the lower Columbia River, but Program activities do seem more concentrated in the lower Columbia River.

Although northern pikeminnow are a native species and have always preyed upon juvenile salmonids, development of the Columbia River hydropower system has likely increased the level of predation. Dams have slowed water velocity and decreased turbidity, effects which have increased exposure time of juvenile salmonids to predators and probably also increased predation success. Development of the hydropower system has also resulted in increased water temperatures, and therefore increased predator activity and consumption. Dams concentrate prey in forebay and tailrace areas, further increasing the likelihood of predation. Juvenile salmonids in dam tailraces are likely disoriented from passage through or around turbines, spillways, or bypass systems, increasing their vulnerability to predation.

In "natural" systems where northern pikeminnow or related pikeminnow species coexist with anadromous salmonids, Brown and Moyle (1981) found that predation by pikeminnow in streams was minimal except near dams and other structures, and Buchanan et al. (1981) found that predation on salmonids by northern pikeminnow was minimal in free-flowing reaches of the Willamette River. Beamesderfer and Rieman (1991) and Ward et al. (1995) confirmed that northern pikeminnow densities were highest near dams, and Vigg et al. (1991) and Ward et al. (1995) confirmed that consumption rates are also highest near dams. Together, these studies suggest that the predation impact of northern pikeminnow in the Columbia and Snake rivers today is likely much greater than what it may have been prior to construction of dams.

The concept of the NPMP can be directly traced to Rieman and Beamesderfer (1990) who found that relatively low annual exploitation rates (10-20 percent) applied to northern pikeminnow populations could, in principle, result in a reduction of approximately 50 percent in the total consumption of juvenile salmonids by northern pikeminnow. Northern pikeminnow apparently become a serious predator of juvenile salmonids only after they reach a size of approximately 250 mm fork length (FL) (approximately 279 mm total length); thereafter their importance (daily consumption of juvenile salmonids) as a predator increases with their increasing size. Because northern pikeminnow are relatively long-lived (specimens have been aged up to 16 years in the Columbia River) and their annual natural mortality rates are believed to be relatively low ($M = 0.13 - 0.44$)(see Rieman and Beamesderfer 1990, Parker et al. 1995), a relatively small increase in annual mortality rate can produce a substantial reduction in the number of larger, older northern pikeminnow. As these larger and older fish have greatest predation impact (i.e., consume the greatest numbers of juvenile salmonids), a substantial reduction in their numbers can in principle have an important impact on total population predatory impact even though the overall population size is not dramatically reduced.

Annual catches of northern pikeminnow in the sport-reward fishery averaged approximately 150,000 fish from 1991-1993, but declined to an average of approximately 114,000 from 1997-1999. Average catches in the combined dam-angling and site-specific tribal fisheries have declined from an average of about 29,000 fish from 1994-1996 to approximately 6,000 fish for the period 1997-1999. A substantial proportion of the decrease in numbers of fish caught is no doubt due to the effectiveness of the ongoing Program. In a setting like this, where a fishery is first imposed on a previously unexploited population of fish, catches would be expected to be greatest in the first few years of Program operation and to thereafter decline to lower but eventually stable levels. There are indications, however, that some of the declines in catches may reflect decreasing participation in the sport-reward fishery, and/or decreased effectiveness in the tribal fisheries.

Given the high annual cost of the NPMP and the need to fund this Program on a long-term continuing basis, assuming the Program is well-justified, it is worthwhile to reexamine the justification, performance and cost-effectiveness of this Program based on nine years of full Program implementation. Our review task was greatly simplified by our ability to access many papers that have been published in reputable fisheries journals (Transactions of the American Fisheries Society, North American Journal of Fisheries Management, Canadian Journal of Fisheries and Aquatic Sciences), authored primarily by ODFW fishery scientists who have been involved in the evaluation component of the NPMP. These fishery scientists are to be highly commended for the impressive number and quality of publications that have presented the theoretical justifications for the NPMP and have documented the apparent performance of this Program.

Our review consists of three main sections. In the first section (Biological Evaluation), we review the essential justification for and biological performance of the NPMP in view of data collected since 1991. In the second section (Economic Evaluation), we examine the cost-effectiveness of the NPMP according to a wide-ranging set of criteria. We conclude with a third section that presents our principal findings and recommendations concerning biological and economic issues. In summary, our findings and recommendaitons address the following:

BIOLOGICAL

1. **Age Validation**. We recommend a scale age validation study.
2. **Relative Consumption Rates**. Current models may overestimate the relative consumptions rates of large northern pikeminnow as compared to small northern pikeminnow, especially among females.
3. **Estimation of the Force of Natural Mortality, M.** Improved estimates of natural mortality are needed.
4. **Exploitation Rates.** It appears reasonable to assume that long-term annual exploitation rates will be no more than 12 percent.
5. **Abundance of northern pikeminnow.** We recommend a detailed independent review of the many issues that have been raised in calculation of systemwide abundance and impacts of northern pikeminnow.
6. **Exaggerated savings.** We calculate that true savings of salmonids would be closer to 2.5 to 5.2 million juveniles, given reductions in the force of northern pikeminnow predation corresponding to 25 percent and 50 percent, respectively.
7. **Minimum Size for Rewards.** We recommend that modest rewards be provided also for the capture and removal of smaller northern pikeminnow.
8. **Tribal Fisheries.** Tribal fisheries have had essentially negligible biological impacts with respect to achieving the long-term goal of exploitation rates on northern pikeminnow that exceed 10 percent.
9. **Biometrics Consultation.** We recommend a statistical consultation to assist in (a) finding improved methods for estimating natural mortality and exploitation rates, and (b) reviewing methods that have been used to estimate northern pikeminnow population abundance.

ECONOMIC

1. **Tribal Fisheries**. We recommend that serious efforts be made to reduce the costs of tribal fisheries.
2. **Management Inefficiency.** A reduction of the number of agencies involved in the Program should be considered in order to further reduce costs.
3. **Tiered-Reward System.** Additional research to study the most effective use of the tiered reward system should be supported.
4. **Program Promotion.** Explore the potential to have the current sport-reward schedule included with the fishing regulations published annually by the states.

We believe that implementation of our biological recommendations would improve the scientific basis for operation and continuation of the NPMP, and would also improve the biological performance of the Program. We believe that consideration and implementation of our economic recommendations would result in a more cost-effective Program that could achieve the objectives of the existing NPMP at a reduced long-term cost.

BIOLOGICAL EVALUATION (D.G. Hankin)

Although the essential conceptual basis of the NPMP - that a small amount of fishing may have a substantial effect on total predation impact by northern pikeminnow - has strong roots in basic fishery theory, assessment of the actual rather than theoretical performance of the NPMP depends sensitively on accurate knowledge of five key features of northern pikeminnow biology and of the fisheries that target them. These key features may be phrased as the following questions:

(1) What are the *growth rates* of male and female northern pikeminnows?
(2) What are the *age- and/or size- specific predation impacts* of northern pikeminnow?
(3) What are the *natural mortality rates* (M) of male and female northern pikeminnow?
(4) What are the *annual exploitation rates* that have been achieved in the NPMP?
(5) What is the *total population size* of northern pikeminnow in the Columbia and Snake rivers?

A final question is also of substantial importance for assessment of the actual impacts of the NPMP:

(6) What are the *total system losses* of emigrating anadromous salmonid juveniles ?

Below, we address each of these six key questions in turn, based on information presented in published papers, annual reports or relayed to us by NPMP personnel.

(1) What are the *growth rates* of male and female northern pikeminnows?

According to Beamesderfer et al. (1996), northern pikeminnow are long-lived, slow-growing predaceous minnows that reach a maximum size of approximately 600 mm and a maximum age of approximately 16 years in the Columbia River system. Growth rates of males and females are, however, quite different from one another and there appear to be modest within system differences in growth rates, presumably due to within system variations in water temperatures and/or prey base. David Ward, ODFW, provided us with parameter estimates of von Bertalanffy growth equations fit separately to male and female northern pikeminnow collected from several general locations in the Columbia and Snake rivers. For the “Below Bonneville” location, estimated ultimate lengths (Linf), growth rates (K) and “tzero” parameters were 588 and 416 mm, 0.135 and 0.223, and -0.126 and -0.342, respectively, for female and male northern pikeminnow. Based on these estimated parameter values, expected fork lengths of females and males at ages 1 through 16 would be:

Age	Fork length (mm)	
	Females	Males
1	82.9	107.6
2	146.7	169.2
3	202.4	218.6
4	251.1	258.0
5	293.7	289.6
6	330.8	314.8
7	363.3	335.1
8	391.7	351.3
9	416.5	364.2
10	438.1	374.6
11	457.1	382.8
12	473.6	389.5
13	488.1	394.8
14	500.7	399.0
15	511.7	402.4
16	521.3	405.1

Thus, although male and female northern pikeminnow are of similar size at ages 4 and 5 when they first begin feeding on juvenile salmonids, males grow more slowly than females after age 5 and never reach the large size of females. Differences in growth rates are large enough that it should be important to account for these differences in models of northern pikeminnow predation impact. The original Rieman and Beamesderfer (1990) modeling effort did not account for differential growth of northern pikeminnow by sex, and it is unclear just how such sex-specific growth differences have been incorporated in more recent modeling efforts.

The above estimates of von Bertalanffy equation parameters are estimated from measurements and ages based on reading scales of northern pikeminnow. Generally, scales tend to produce negatively biased estimates of age for the oldest fish in any population and it is preferable to use otoliths for aging of long-lived fish. According to D. Ward (personal communication, see also Parker et al. 1995), however, ODFW personnel have had no success aging northern pikeminnows from otoliths or other structures. Also, there appear to have been no attempts to “validate” (i.e., to verify the accuracy of) scale ages of northern pikeminnow (see Beamish and McFarlane 1983). We think that an age validation study should be carried out immediately and we suggest a possible strategy for this study in the Findings and Recommendations section.

(2) What are the *age- and/or size- specific predation impacts* of northern pikeminnow?

Friesen and Ward (1999, page 420) present three possible equations that span a broad range of possible relations between the “relative consumption rate” of juvenile salmonids and the fork lengths of northern pikeminnow. In each case, the intention of these equations is to produce a *relative* numerical value of predation impact (juvenile salmonid consumption) for a male or female northern pikeminnow of a given age and expected length. The original equation from Rieman and Beamesderfer's (1990) modeling effort (one of the three equations used) has relative consumption rate increasing according to the *6th power* of fork length. This equation may seriously exaggerate the relative consumption rates of larger fish as compared to smaller fish and the original data on which this curve was apparently based (Rieman and Beamesderfer 1990, their Figure 2; compare with Fig. 3 from Beamesderfer et al. 1996)) do not provide strong support for that equation among the largest fish.

Appendix 1 provides a summary of relative consumption rates at size and age that are produced by the three alternative equations provided in Friesen and Ward (1999). We believe that the second of these equations (relative consumption rate increases according to the cube of fork length) probably provides the most realistic representation of changes in juvenile salmonid consumption with northern pikeminnow size and age. For this model, an individual age 16 female northern pikeminnow would have a relative consumption rate of approximately 8.3 times consumption rate at age 4, and an individual age 16 male northern pikeminnow would have a relative consumption rate of approximately 3.8 times consumption rate at age 4. The difference is greater for females than for males because females grow to a much larger size than males.

We believe that the original Rieman and Beamesderfer (1990) contention that total northern pikeminnow predation impact could be reduced by 50 percent given annual exploitation rates of 10 - 20 percent was based on an unrealistic equation relating relative consumption rate to fish size and age. This equation probably overestimated the relative impact by larger northern pikeminnow as compared to smaller northern pikeminnow and thereby exaggerated the reduction in overall impact that might be achieved by a targeted fishery at low exploitation rates.

In various NPMP reports and/or publications, it has been concluded that removal of a larger and older northern pikeminnow has more impact (saves more juvenile salmonids) than does removal of a smaller and younger northern pikeminnow. This conclusion is then used, for example, to suggest that the "per fish" impacts of catching generally larger fish in the tribal fisheries exceed the "per fish" impacts in the sport-reward fisheries in which mean fish size is generally smaller. Although there is some logic to this conclusion (see below), we believe that it is incomplete and is also at odds with the fundamental conceptual basis for the Program.

The NPMP justifiably asserts that a small rate of removal for fish age 5 and older can produce a pronounced shift in the demographic structure of the northern pikeminnow population, thereby substantially reducing numbers of older and larger northern pikeminnow and the total number of juvenile salmonids consumed by the entire population. Viewed from this perspective, removal of only larger, "more important", northern pikeminnow, e.g. beginning at age 11, would have relatively small overall, long-term, demographic impact as compared to removal of northern pikeminnow beginning at, say, age 5. How then can it be concluded that the removal of a large, age 11, northern pikeminnow "saves more salmonids" than removal of a smaller, age 5 northern pikeminnow?

Appendix 2 (based on a similar table provided by D. Ward, ODFW) provides a quantitative illustration of the logic behind the conclusion that removal of a large northern pikeminnow might have more importance than removal of a small northern pikeminnow. The lower part of the table provides calculated values of the expected lifetime (relative) consumption of juvenile salmonids by a northern pikeminnow given that it has survived to age *i*. Thus, for example, the expected lifetime consumption given that a northern pikeminnow has survived until age 4 is 2.809. This value is relatively low because, at age 4, it is relatively improbable to survive to age 11, say, at which age the relative consumption of salmonids is high. Indeed, the maximum expected "conditional" lifetime relative consumption (5.674) is achieved for an age 11 northern pikeminnow. Because the *conditional* lifetime expected consumption from age 11 on (5.674) exceeds that from age 4 on (2.809), it has therefore been concluded that removal of an age 11 northern pikeminnow has greater impact (saves more juvenile salmonids) than removal of an age 4 northern pikeminnow.

Although we do not dispute the essentially validity of the calculations presented in Appendix 2, we believe that the above conclusion rests on "incomplete" logic: it fails to account for the fact that the northern pikeminnow captured at age 11 has had the opportunity to engage in predation for the previous 7 years. Thus, from Appendix 2B, given that a northern pikeminnow has survived to age 11, its expected (relative) consumption of juveniles salmonids from age 4 to 11 would have been 0.239 + 0.383 + 0.545 + 0.718 + … + 1.259 = 5.127. Thus, we argue that the "net" or *unconditional* lifetime savings from capture of a northern pikeminnow at age 11 (compared to age 4) is better represented by the value 5.674 (expected consumption from age 11 on) – 5.127 (predicted consumption from age 4 through age 10) = 0.547. Capture of northern pikeminnow at age 4 prevents survival to older ages and thus, from a demographic perspective, has greatest long-term impact. Capture of northern pikeminnow at age 11 certainly has a larger immediate impact due to the large size of the predator removed, but capture age is too late to have a substantial long-term impact on overall prey consumption by the total northern pikeminnow population.

(3) What are the *natural mortality rates* (M) of male and female northern pikeminnow?

Estimation of the "force of natural mortality" (Everhart and Youngs 1981) or, equivalently, the "instantaneous natural mortality rate" (Ricker 1975), M, is a difficult task in any fish population. In the original modeling effort of Rieman and Beamesderfer (1990), M=0.25 appears to have been used as a "best guess" of instantaneous natural mortality rate, but they allowed M to vary from 0.14 - 0.44. For M=0.25, the required annual exploitation rate to (eventually) reduce total predation to 50 percent of its unexploited value was 13 percent. At the upper range of M for their simulations, annual exploitation rate would need to be approximately 20 percent to achieve the same 50 percent reduction. Parker et al. (1995) attempted to estimate natural mortality rates from catch curves (see Ricker 1975), always a problematic technique, and produced poor estimates with large variation. Knutsen and Ward (1999, in press), again relying on catch curve analysis, presented estimates of the total force of mortality (Z= F+M, where F = instantaneous fishing mortality rate) for years in which the northern pikeminnow population had been subjected to exploitation as part of the NPMP. Although these estimated mortality rates generally exceeded those estimates for periods prior to exploitation, these estimates were again highly variable (see Table 2 of Knutsen and Ward, 1999).

It would be accurate to conclude that the force of natural mortality has not yet been reliably estimated for northern pikeminnow in the Columbia River system. Further, it is reasonable to suppose that natural mortality rates for the generally smaller males may be greater than for females. The long-term impact of the NPMP depends senstitively on the force of natural mortality (and on whether or not mortality rates are equal for both sexes). Nevertheless, based on the maximum observed age of female northern pikeminnow prior to fishery exploitation, we believe that it is reasonable to suppose that M for females probably lies somewhere between 0.18 and 0.28. As the brief table below indicates, for M < 0.15, the probability that an individual northern pikeminnow would survive from birth to age 16 would exceed 10 percent, arguing that age 16 and older fish might be encountered with reasonable frequency if M were that small. For M exceeding 0.32, the probability of surviving from birth to age 16 would be less than 0.6 percent, suggesting that it would be rare indeed to encounter an age 16 fish among sample collections.

M	P(survive from birth to age 16)
0.12	0.147
0.15	0.091
0.18	0.056
0.24	0.021
0.28	0.011
0.32	0.006
0.36	0.003

Although we guess that the force of natural mortality probably ranges from about 0.18 to 0.28, and a best guess may be approximately 0.24 (see Reiman and Beamesderfer 1990), we believe that the current poor understanding of natural mortality rates of northern pikeminnow is an important biological weakness of the existing Program. We believe that this weakness is unacceptable given the long-term funding commitment that may be required if the Program is continued indefinitely. The catch curve analysis approaches that have been chiefly used to estimate natural mortality rates cannot be expected to produce reliable or accurate estimates of natural (M) or total mortality (Z) rates. Instead, we recommend that the NPMP investigate the potential for implementation of a multi-year tag-recovery program and use of models presented in

Brownie et al. (1985). The potential use of such statistical models would require that NPMP biologists explore the performance (tag loss and angler recognition) of alternative reward tags. Although the existing application of spaghetti tags is no doubt effective for ensuring angler recognition of tags, it appears to have unacceptably high tag loss after fish have been more than one year at large (D. Ward, ODFW, personal communication).

(4) What are the *annual exploitation rates* that have been achieved in the NPMP?

NPMP biologists have used recoveries of special $50 reward-tagged northern pikeminnow to estimate exploitation rates achieved in the sport-reward, dam-angling, and site-specific fisheries. Based on these kinds of recovery data, NPMP biologists have estimated that systemwide exploitation rates (from all fisheries combined) have ranged from about 8 percent to 15.5 percent from 1991 through 1998 and have averaged approximately 11.7 percent. Thus, existing estimates of exploitation rates argue that it has been feasible to achieve, on average, the minimum target of a 10 percent annual exploitation rate, but it has not been possible to achieve the more ambitious mean levels of 15 percent or 20 percent. From 1997 through 1999, these exploitation rates have been achieved through average annual sport-reward catches of approximately 114,000 fish as compared to average annual catches in the combined dam-angling and site-specific fisheries of approximately 6,000 fish. Thus, the sport-reward fishery has accounted for about 95 percent of total NPMP catches over the past three years.

Although this approach to estimation of exploitation rates seems generally appropriate, we do have concerns regarding specific aspects of the approaches that have been taken. Our primary concerns are the following: (a) the total numbers of fish that have been marked and recovered are relatively small, especially on an area-specific basis. For example, in 1998 only 242 fish were tagged and 20 recovered in Bonneville reservoir; only 61 were tagged and eight recovered in The Dalles reservoir; (b) fish are tagged and released prior to and during the fishing season, thus requiring that estimates of exploitation rate are made via a summation method (see Leader et al., draft 1999 evaluation report), thus greatly complicating variance estimation; (c) current methods invoke assumptions that may not be valid, namely that (c1) all captured tagged fish are returned and reported, and that (c2) no tagged fish die naturally over the course of the tag recovery experiments, typically a period of 20-25 weeks (5-6 months) of sport fishing; (d) some anglers that are not participating in the NPMP return tags and kill fish. It is unclear how best to deal with this fact as unknown numbers of such fish may be unreported; (e) estimates of exploitation rates are adjusted upward assuming a tag loss of 4 percent.

Taken together, the above complications argue that existing estimates of exploitation rates may be relatively inaccurate. However, we suspect that existing estimates of exploitation rates are also probably negatively biased because some of the assumptions are probably not met (e.g., it seems likely that not all tags are returned and that some or many tagged fish die naturally). Generally, we feel that existing estimates do support a contention that annual exploitation rates have averaged approximately 12 percent from 1991-1998, but we recommend that statistical methods used to estimate exploitation rates and natural mortality rates both receive a more detailed review from a biometrician with special expertise in application of mark-recapture methods.

(5) What is the *total population size* and *total impact* of northern pikeminnow in the Columbia and Snake rivers?

Knowledge of the approximate total abundance of northern pikeminnow prior to implementation of the NPMP is of central importance for calculation of the total impact (total number of juvenile salmonids consumed) of northern pikeminnow predation. Beamesderfer et al. (1996, pages 2900-2902) present a concise but detailed summary of methods that have been used to estimate total northern pikeminnow abundance and impact in the Columbia and Snake rivers. Numerous complex analysis issues are raised in Beamesderfer's (1996) summary, but time limitations in our review effort prevented us from engaging in a critical assessment of these methods. We believe, however, that it would be worthwhile to solicit an in depth independent review of methods that have been used to estimate total abundance and total impact.

The NPMP does not purport to directly estimate the number of juvenile salmonids that are saved via exploitation of northern pikeminnow populations. Instead, NPMP staff have used an indirect modeling approach to calculate hypothetical reduction given those life history and fishery parameters that have been the subject of our own review. If annual recruitment of northern pikeminnow is assumed constant and unaffected by exploitation, we note that this kind of *indirect assessment* of the reduction in northern pikeminnow predation due to NPMP fisheries does not require knowledge of true total northern pikeminnow abundance. That is, given a specified force of natural mortality, lengths at age, size-specific consumption rates, and exploitation rates, it is possible to calculate the expected *percentage* or *relative* reduction in total northern pikeminnow impacts. It is also possible to make such calculations given conjectured stock-recruitment relations that account for possible changes in recruitment of young northern pikeminnow due to reductions in adult stock (Rieman and Beamesderfer 1990).

(6) What are the *total system losses* of emigrating anadromous salmonid juveniles ?

Although we are in general agreement with NPMP arguments that indirect modeling methods represent the only practical way to attempt calculation of probable reduction in northern pikeminnow consumption of juvenile salmonids, we believe that the NPMP has exaggerated the savings that might result due to such reduction. The NPMP currently argues that, if pre-1990 northern pikeminnow consumption of juvenile salmonids were 16.4 million fish, then a 50 percent reduction in the hypothetical consumption by northern pikeminnow would save 8.2 million fish. We disagree with that conclusion.

Chiang (1968) presents a general *competing-risks-of-death* framework that allows calculation of probable savings of juvenile salmonids due to reduction of northern pikeminnow predation. The standard fisheries mortality model (Ricker 1975) is a simple competing-risks-of-death model in which there are only two causes of death: (all) natural causes and fishing. Associated with each of these two causes of death are *forces of mortality*, typically labelled as M and F in fisheries. The behavior of this simple fisheries mortality model is well known. As fishing (F) increases in intensity, a greater proportion of the population dies due to fishing and, at the same time, a smaller fraction of the population dies from natural causes. Thus, if a large and intense fishery were severely reduced in magnitude, the proportion of fish dying from fishing would be reduced, but the proportion of fish dying from natural causes would increase due to reduction of fishing. The same logic may be applied to reduction of northern pikeminnow predation.

Theoretical, indirect modeling methods allow one to calculate not the numbers of salmonids saved but the *reduction in the theoretical force of mortality associated with northern pikeminnow predation*. The actual savings of juvenile salmonids depends not only on the reduction in the force of northern pikeminnow predation but also on the intensity of all other forces of mortality. In the Columbia and Snake rivers, it is currently estimated that 200 million emigrating smolts are produced. Of these, it has been estimated that approximately 16 million had been comsumed by northern pikeminnow prior to implementation of the NPMP. For the sake of argument, assume that total system losses of downstream migrants in 1998 were 111 - 119 million juvenile salmonids, including approximately 7.5 - 15.2 million losses due to Caspian tern predation. Thus, in the absence of the NPMP, northern pikeminnow predation would have accounted for approximately 16.3/(111-119) = 13.7-14.7 percent of total systemwide losses.

Given the above values, the competing-risks-of-death model allows one to calculate the expected total systemwide losses of juvenile salmonids due to all causes of death if the force of northern pikeminnow predation, FP, were reduced by a specified amount. True savings can be calculated as the difference between total losses prior to reduction of northern pikeminnow predation and total losses after NPMP-induced reductions. The following table presents calculated savings of downstream migrants that might result from specified percent reductions in the force of northern pikeminnow predation, FP. These calculations assume a total smolt production of 200 million fish, total system losses of 115 million, and that losses due to northern pikeminnow were 16 million before the northern pikeminnow population was exploited.

Percent Reduction in FP	Total Losses from all causes	Savings (in numbers of smolts) due to Reduction in FP
0	115.0 million	0.0 million
10	114.0 million	1.0 million
20	113.0 million	2.0 million
30	111.9 million	3.1 million
40	110.9 million	4.1 million
50	109.8 million	5.2 million

Thus, if fisheries resulted in reduction of the total force of northern pikeminnow predation to approximately 50 percent of its original value, approximately 5 million smolts might be saved annually, substantially less than 50 percent of the original 16 million fish (= 8 million fish) that are estimated to have been consumed annually by northern pikeminnow. There are many other causes of death that are competing to kill juvenile salmonids.

In defense of the NPMP, however, we feel obligated to point out that we suspect that few if any other projects designed to save juvenile salmonids have accounted for other causes of death in the Columbia and Snake river system. Thus, the NPMP is probably no more or less guilty of false savings than any other Program activities designed to increase survival or reduce mortality.

ECONOMIC EVALUATION (J. Richards)

Overview of Economic Issues

The economic section of this report will compare the effects of the Northern Pikeminnow Management Program (NPMP) with its associated costs, within the limitations of available data. Most past Program evaluation has focused on biological issues, and many formal publications have resulted from this analysis. Economic information, by contrast, has received little attention. Nonetheless, Program managers have made important attempts to evaluate Program goals and accomplishments and instigated a number of adjustments to make the Program more cost-effective. This section will summarize the gains in Program efficiency compared to changes in Program costs from past management actions and suggest areas where the Program can be made more cost-effective and efficient. The appropriate unit to measure Program effectiveness is discussed first. This is followed by a summary of recent trends in the overall Program and a comparison of the benefits and costs of each Program component. Future changes that should be considered are then summarized.

NPMP Benefits

The direct benefit of the NPMP is the increased survival of juvenile salmon and, hopefully, a corresponding increase in the sustainability of adult salmon populations. Adult fish have direct economic value as harvested fish and other important ecological, cultural and social values. The actual activities under the NPMP go beyond the direct harvesting of northern pikeminnow. Four categories of activity may be identified:

1. Predator removal including all costs that are essential to this effort. This would include primarily costs related to payments to anglers, management, record keeping, and fish handling costs.

2. Program elements intended to improve information that can make the Program more effective over time. This includes information regarding the predator, the predator/smolt relationship, and related information.

3. Program evaluation to measure progress and Program effectiveness.

4. Management and administration of the Program and the associated costs.

The metric for most of our economic evaluation relates to the direct purpose of the Program, the removal of predators. However, the other categories of activity contribute a large share of the NPMP costs and are therefore considered to the extent possible in our review. The direct products of these other categories are not well defined or identified in the NPMP, and it is therefore difficult to be precise about their roles in the Program and their contributions to Program costs. The benefits of these other categories should be directly related to the cost-effective[1] removal of predators and the assurance that the removal of predators is contributing significantly to the increased survival of salmon smolts.

Measuring the Benefits

Ideally, benefits from the NPMP would be measured by the value of adult salmon and steelhead that are either harvested or return as spawners to provide for future production. However, due to concerns about the accuracy of the estimated number of smolts saved by the Program and the many other causes of mortality, benefits have not been quantified using monetary values of adult salmon and steelhead. Without a measure of monetary benefits, other measures of Program effectiveness must be used. Other possible measures of effectiveness would be the number of smolts saved by the removal of predators or just the number of predators removed. Due to data limitations, the more direct measure of effectiveness, numbers of predators removed, is used.

The use of adult predators removed is appropriate to measure the internal cost-effectiveness of the NPMP, but it provides no information to compare the NPMP with other programs that are aimed at improving smolt survival. For example, flow augmentation, smolt transportation, spill, fish-friendly turbine designs, and bypass systems all share the goal of improved smolt survival. Although the cost-per-smolt-saved may be less for the NPMP than for some of these other Columbia River programs that are intended to reduce losses of smolts during their downstream migration, comparing the cost-effectiveness of the NPMP to other projects was beyond the scope of our review. Therefore, we remind readers that the analysis provided below is intended *only* to indicate internal cost-effectiveness of NPMP and its components. Even the least cost-effective components of the NPMP may have favorable cost-efficiency when compared to other Columbia basin projects, but this analysis cannot confirm or deny this.

Using adult predators removed as a measure of effectiveness needs to take into account important trends that can affect Program costs. Since this Program has operated for almost a decade, cost per adult predator removed would be expected to increase due to reducing the predator biomass. That is, since over 10 percent of the larger predators are removed annually, fish available for catch have been reduced substantially. The Program does not aim at eliminating the northern pikeminnow population, but at altering its size and age composition through removal of the largest fish, which tend to eat juvenile salmon. Since the NPMP's inception in 1990, the number of larger predators removed annually would be expected to decline as would the catch per unit of effort. These effects would be expected to increase the cost per adult predator caught. Two other factors

[1] The term "cost-effective" is not generally used in a technical sense in this review. Economists have a technical meaning for the term that relates costs to some fixed goal, such as meeting jeopardy standards, for example. In this review, cost-effectiveness mostly refers to the relationship between program effects and costs. In most cases, program effects are measured as numbers of predators caught as opposed to a fixed standard or goal. Economists would consider this a form of cost/benefit analysis.

might somewhat counteract this cost increase, however. First, in some fisheries there is an important “learning effect” that may result in increased fishing efficiency and reduced cost per fish harvested. Probably far more important for the NPMP, however, has been improved efficiency resulting from management actions. While important areas for further improvement of efficiency may remain (several are discussed below), many efficiencies have been implemented by Program managers to reduce costs.

The number of predators removed in any particular year will vary depending on the impact of declining fish availability due to prior year harvests, fishing conditions such as high or low water years, Program structure, the payment levels in the sport-reward fishery or other promotional activities, and similar variables. The effects of all of these variables are present in the data analyzed below and make it difficult to interpret the underlying trends in northern pikeminnow removal.

NPMP Costs

Program Administration and Structure

This section follows the cost organization used by Pacific States Marine Fisheries Commission (PSMFC), which allocates costs by agencies involved to each Program component. The NPMP is managed and implemented by six different agencies and four Indian tribes. The distribution among participating agencies is presented in Table 1 for 1998 and 1999. Table 1 also indicates the role of each agency in the overall Program.[2] The sport-reward fishery includes expenditures for Washington Department of Fish and Wildlife (WDFW) for running registration and creel check stations, Columbia Basin Fish and Wildlife Authority (CBFWA) for technical oversight and PSMFC for contractual oversight, reward fund, subcontracting, fiscal and reward payments, and for IRS 1099 forms for anglers. The Columbia River Inter-Tribal Fish Commission (CRITFC), the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, Yakama Indian Nation and the Warm Springs Tribe[3] share the budget for the dam-angling and site-specific components. The Oregon Department of Fish and Wildlife (ODFW) handles Program evaluation including northern pikeminnow population studies, the tagging program to determine exploitation rates, and evaluation of any possible population response and change in salmonid predation by walleye and smallmouth bass due to less competition as a result of northern pikeminnow removals.

Evaluation has been an important component of the NPMP. ODFW performs the evaluation function. Reflecting the maturity of this Program, starting in 1996, evaluation is scaled back in two out of three years. 1999 was a full evaluation year and about $450,000 was budgeted to accomplish this. This is about 14 percent of the total NPMP

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[2] The numbers in Table 1 may not be directly comparable to those in other tables in this section. In some cases budgetary data are used and in others actual program expenditures are used. All data for 1999 are based on budget requests, since actual expenditures are not yet available for the 1999 program year, which ended in March 2000.

[3] The Confederated Tribes of the Warm Springs Reservation withdrew from the program for FY 2000. Letter from Patty O’Toole to Russell Porter (PSMFC) and Frank Young (CBFWA) dated March 24, 2000.

budget. By contrast, in 1998, evaluation activities were largely limited to estimating exploitation rates, and evaluation was only about 8 percent of the NPMP budget.

Table 1. Costs by Agency for the Northern Pikeminnow Management Program, 1998 and 1999.

Agency	1998 Expense ($)	% of Total	1999/1 Budget ($)	% of Total
CBFWA (Technical Coordination)	$105,941	3.3	$63,589	1.9
PSMFC (Program Administration)	$59,376	1.8	$61,733	1.9
WDFW (Sport-Reward Implementation)	$1,129,963	34.7	$1,019,932	30.9
PSMFC				
Sport-Reward Money	$1,000,000	30.7	$1,000,000	30.3
Sport-Reward Administration	$145,608	4.5	$164,501	5.0
CRITFC + TRIBES				
Dam-angling	$210,055	6.4	$193,074	5.8
Site-Specific	$278,539	8.5	$264,714	8.0
ODF&W (Program Evaluation)	$249,748	7.7	$448,090	13.6
BPA (Sport-Reward Promotion)	$80,000	2.5	$85,000	2.6
Total	$3,259,230		$3,300,633	

/1 Budget data are taken from the Northern Pikeminnow Management Program 1999 project proposal.

The actual payments to fishers in the sport-reward component of the NPMP are included in the PSMFC budget. The PSMFC handles all aspects of the voucher system used to reward sport anglers. Budgeted at $1 million in 1998 and 1999, the actual amount expended for fisher rewards varies depending on Program participation and angling success. Due to uncertainty regarding the size of the sport-reward catch, extra budget is requested to cover all potential costs. The unused funds, which can be in the range of $500,000 to $800,000 annually, are then subtracted from the total request for funds during the following year. In 1998, for example, actual rewards paid were $471,950 [Northern Pikeminnow Management Program, Annual Report, 1998]. The rest of the sport-reward program budget is used for program implementation and management, which is the primary function of WDFW. In 1998, this amounted to $1,355,571 ($1,129,963 for WDFW and $145,608 for PSFMC). The unused portion of the sport-reward budget was about 16 percent of the NPMP budget in 1998, and the actual amount spent on the sport-reward component, including implementation and management, was about 55 percent.

In 1998, dam-angling accounted for 6.4 percent of the NPMP budget and site-specific angling for 8.5 percent. Each of the participating tribes manages its own portion of these fisheries, with CRITFC providing coordination and reporting functions.

General administrative and technical coordination functions are performed by both CBFWA and PSMFC. Combined, in 1998, these two functions accounted for 5.1 percent of the NPMP budget. In 1999, the CBFWA and PSMFC administrative costs fell to 3.8 percent of the budget, largely due to a significant cut in the CBFWA budget. In addition to these explicit administrative and technical costs, the other individual components of cost include varying amounts of indirect and administrative costs. These vary for different tribes and agencies from roughly 20 to 40 percent of the direct Program costs.

We think that there are currently too many agencies involved in the NPMP to keep administrative costs at a minimum. Since this Program has been in existence for a decade, it may be possible to reduce the number of agencies involved and thereby achieve significant administrative efficiencies. An effort should be made to combine Program goals under the control of the minimum possible number of agencies. Alternatively, it may be more efficient to administer the Program through competitive bids from private sector consultants or organizations.

Unfortunately, cost information is not available by Program objective, and it is therefore difficult to identify specific efficiencies that might be achieved. Important project objectives are shared among agencies. Without cost information by objective, it is not possible to gain a clear understanding of the cost-effectiveness of Program elements because benefits cannot be directly related to expenditures. Currently, for example, several agencies carry out research, reporting, and evaluation objectives, and we could not get a clear picture of how these may or may not overlap. We recognize that some objectives of the NPMP may not relate directly to reducing predation and that, therefore, cost-effectiveness may not be the only relevant measure of Program success. An example of such an objective that may be served by the NPMP is involvement of the tribes in the management and implementation of fish and wildlife programs. Meeting this objective may be desirable even though it results in reduced administrative efficiency in the NPMP because of duplication of management structures and expenses for each of the participating tribes.

To the extent that administrative, research and evaluation objectives can be achieved more efficiently, additional money could be applied directly to the primary objective of reducing Northern Pikeminnow predation on salmon smolts. Currently, about a quarter of the total NPMP budget pays for directly compensating sport-reward and tribal fishers. The use of the other 75 percent needs to be more carefully documented and allocated to specific objectives in order to facilitate economic assessment of the Program.

Cost-Effectiveness of Overall Program

As noted above, the cost per predator removed reflects northern pikeminnow abundance, angler learning, management adaptations to reduce costs, and annual fishing conditions such as water flows. Program managers have experimented with changes in gear, reductions in the number of reporting stations in the sport-reward component, implementation of a tiered reward system (beginning in 1995) to retain the most productive anglers and increase angler participation, and numerous procedures to expand angler interest, including contests or other incentives. Within the elements under their control, the Program managers have made substantial use of the limited information available to them and have initiated important cost-reducing programs. This may be the most important element influencing the cost per predator removed over the decade that this Program has been in existence. However, we caution again that comparisons over time should include measurement of change in fish availability and the certain decline in large predators resulting from removal of an important fraction of these fish each year.

Based on the information available, the overall cost per predator removed does not appear to have increased significantly. This is demonstrated in Table 2. It appears that angler learning and management adaptation have probably neutralized the decline in predator availability. Without an adequate measure of the rate of decline in fish abundance, the gains by management efforts to reduce costs are obscured. However, the comparison among Program components in the following section is not affected by these factors since comparisons are made on an annual basis where all components face similar conditions with regard to predator availability.

Table 2. Total Expenditures and Catch, Cost Per Predator Removed and the Estimated Exploitation Rate for the Northern Pikeminnow Management Program, 1990 to 1999.

Year	Expenditure /1	Total Catch /1	$ Cost/Fish	Exploitation Rate (%) /2
1990	$1,421,813	17,106		
1991	$5,259,629	193,862	$27.13	10.7
1992	$6,846,410	215,498	$31.77	12.0
1993	$4,253,600	123,518	$34.44	8.1
1994	$3,670,707	154,555	$23.75	13.2
1995	$4,311,186	214,382	$20.11	15.5
1996	$3,846,248	168,158	$22.87	12.9
1997	$3,730,347	125,370	$29.75	9.6
1998	$3,259,230	114,887	$28.37	11.5
1999 /3	$3,306,000	119,870		

/1 Expenditures and catch are taken from the Northern Pikeminnow Management Program 1999 project proposal. Because all expenditures cannot be known in advance, especially level of participation in the sport-reward component, approximately $500,000 to $800,000 are unused each year and deducted from the following year budget.
/2 Exploitation rates are from Leader et al. (1999), Appendix 1.
/3 Budget request only for 1999. Because the planning year for this program runs through March of the following year, actual expenditures for 1999 are not available.

Cost of Program Components

This section looks at the costs and northern pikeminnow catches in the three separate fishery components of the NPMP. There are significant differences between the components both in terms of Northern pikeminnow harvested and in costs per harvested fish. Total numbers of northern pikeminnow captured in tribal site-specific gill-netting fisheries plus dam-angling fisheries during 1997 through 1999 have averaged approximately 6,000 fish per year as compared to an average of approximately 114,000 fish per year captured in the sport-reward fishery (Table 3). The rate of decline in numbers of fish caught annually in the tribal fisheries has been much greater than the more modest declines in annual catches that have taken place in the sport-reward fishery.

We do not believe that declines in tribal catches can be explained in terms of reducing the size of populations due to previously successful angling. We believe that decreased success in tribal dam fisheries may have resulted from changes in dam operations resulting in higher levels of spill. Since 1995, spills at dams have generally been at higher levels and of longer duration than during previous years, in part a reflection of normal or high water years (as compared to low water years) and in part a reflection of changing spill policies. Based on earlier studies of northern pikeminnow response to increased spills at dams (Faler et al. 1988), we believe that northern pikeminnow probably shift their physical distribution below areas of intense turbulence during high levels of spill, thus making them less available immediately below dams.

As total catches in the tribal site-specific and dam-angling fisheries have been declining, the cost per predator removed has been increasing. As shown in Table 3, the cost per predator caught is substantially higher in the dam-angling and site-specific fisheries than in the sport-reward fishery. Between 1994 and 1998, the cost per predator caught in tribal fisheries averaged nearly five times the comparable cost for the sport-reward part of the Program.

Table 3 does not show information before 1994 due to substantial changes in Program structure in 1994. Since 1994, the cost per predator caught has been fairly stable in the sport-reward fishery. The site-specific and dam-angling costs per fish increased dramatically between 1994 and 1995. Since 1995, the site-specific fishery cost per predator caught has continued to increase, while the dam-angling cost per predator caught has shown some decrease. In both cases, the actual costs have declined along with the declining catch. However, both of these components of the NPMP have very high costs relative to their contribution to the Program objectives. The decreased productivity of the tribal components of the Program was reflected in the decision by the Confederated Tribes of the Warm Springs Reservation, footnoted above, not to participate in the NPMP for Program year 2000.

Table 3. Cost (dollars) Per Predator Removed by Program Fishery.

Year	Sport-Reward			Site-specific			Dam-angling		
	Cost	Catch	Cost/Fish	Cost	Catch	Cost/Fish	Cost	Catch	Cost/Fish
1994	$1,716,618	129,434	$13.26	$291,342	10,392	$28.04	$440,621	16,097	$27.37
1995	$2,396,703	199,600	$12.01	$427,741	9,634	$44.40	$495,295	5,488	$90.25
1996	$2,046,640	156,538	$13.07	$335,622	6,165	$54.44	$372,534	5,455	$68.29
1997	$1,997,036	119,047	$16.78	$341,820	2,806	$121.82	$299,954	3,517	$85.29
1998	$1,658,919	108,372	$15.31	$263,217	3,035	$86.73	$186,491	3,480	$53.59
1999 /1	$2,018,753	114,687		$270,008	1,604		$196,935	3,599	
Average 1994-98	$1,963,183	142,598	$14.09	$331,948	6,406	$67.08	$358,979	6,807	$64.96

Source: Based on personal communication from Russel Porter at PSMFC.
/1 Based on budget request only for 1999, actual expenditures not available.

The relatively high cost per predator removed in site-specific and dam-angling fisheries as compared to the sport-reward fishery may not be an adequate basis to judge the overall value of these tribal fisheries, however. For example, there are important employment and cultural benefits to tribal anglers that may help reduce widespread poverty among these families which are not being counted in Program benefits. In addition, reduced predation losses of threatened and endangered species have not been measured, and the predator removal program in the Snake River, although its cost-effectiveness is low, may contribute to the preservation of ESA-listed stocks. This Program may also help to mitigate losses related to dam construction. Research to improve information relating to salmon migration and predator/smolt relationships may also contribute to other programs. None of these is currently being evaluated as a Program benefit.

Since 1994, the sport-reward fishery has shown only modest declines in catch, and cost per fish caught has remained fairly stable. Declining catch, as discussed above, is expected in a new fishery. As noted earlier, we think that Program changes and efficiencies have kept the cost per fish caught relatively stable. The most significant innovation in the sport-reward fishery was probably the tiered rate for the rewards. The tiered reward was implemented beginning with the 1995 season and provides increased rewards for fishers that achieve higher levels of catch. The first 100 fish caught by an angler fall into the first tier. The second tier level (101-400 fish) was set to be low enough to be reachable by many anglers, while tier three (>400 fish) was set to encourage a small number of very successful anglers to fish longer into the season and fish longer each day. Since 1995, approximately 91 percent of the anglers have been at tier one, 6 percent at tier two and 3 percent at tier three. Managers believe that the tiered reward is the most cost-effective promotional activity that has been implemented in this fishery.

However, managers state that promoting angler participation and retention in the sport- reward fishery is a serious problem and the reason for the promotional activity included in the Program. During 1999, the top 40 anglers caught 49,217 fish (42.9 percent of the total). The top 25 anglers caught almost 33 percent of the total. The top 40 anglers' earnings averaged $7,000 each during 1999, and the highest paid individual received $16,314. [Based on personal communication from John Skidmore of Bonneville Power Administration on Nov. 24, 1999.]

The reward rate structure creates the incentives for an effective and efficient Program and merits the serious attention it has been given in the past. It likely holds the key for the effectiveness and efficiency of the sport-reward program and may hold promise for further gains in the future.

Comparison of Program Effectiveness by Geographic Areas and Seasons

The northern pikeminnow consumes migrating smolts from the mouth of the Columbia River to Rocky Reach Dam and from the mouth of the Snake River to Hells Canyon Dam. However, the largest concentrations of this predator and the largest amount of smolt losses to predation occur downstream from Bonneville Dam (Beamesderfer et al. 1996). In order of decreasing smolt predation, the area below Bonneville Dam is followed by the The Dalles, the John Day and the Bonneville reservoirs, with smaller, but substantial, losses in the McNary and Rock Island reservoirs. The location of fishing effort and catch of northern pikeminnow in the 1998 sport-reward fishery is shown in Table 4. Location 1 is the farthest down river location, and locations then proceed upriver sequentially with 1 through 9 below McNary Dam. Locations 10 and 11 are in the upper Columbia below Priest Rapids Dam, and location 12 is in the upper Snake River. Area twelve may have special significance due to efforts to restore threatened and endangered species in that area.

Table 4. Location/Name, Catch, and Effort in the Sport- Reward Fishery During 1998.

Location/Name	Catch	Percent of Total	Level of Effort /1	CPUE
1 Cathlamet	2,893	2.52	1107	2.61
2 Rainier/Weyerhauser	8,356	7.29	2443	3.42
3 Gleason	12,250	10.68	2448	5.00
4 Washougal	5,122	4.47	2579	1.99
5 The Fishery	11,638	10.15	2500	4.66
6 Bonneville Trailhead	6,657	5.80	2076	3.21
7 Maryhill/Bingen	8,001	6.98	1560	5.13
8 The Dalles	12,775	11.14	2733	4.67
9 Giles Point	14,151	12.34	1863	7.60
10 Columbia Point	6,753	5.89	1659	4.07
11 Vernita	14,917	13.01	1514	9.85
12 Greenbelt	11,174	9.74	3423	3.26
Total Catch/Mean CPUE	114,687			4.43

Source: Based on personal communication from John Skidmore of the Bonneville Power Administration on Nov. 24, 1999.

/1 Level of effort is measured as number of registered anglers.

Table 4 only reflects one particular year and is provided for illustrative purposes. The numbers and locations of reporting stations have changed over time as Program managers adjusted to data such as illustrated in Table 4. As discussed elsewhere in this report, it is not clear what attracts anglers to a particular area since little study has been done on the characteristics of the participating anglers. More study is needed to determine the characteristics that may be important in promoting greater participation in the sport-reward fishery.

Table 5 shows how catch in the sport-reward fishery was allocated among the months of Program operation during 1998. Sixty-five percent of the northern pikeminnow catch occurs in June and July. The catch is substantial in all the other months except for the component during October, which only accounted for 1.8 percent of the catch. October does not appear to contribute substantially to the Program benefits and may represent an opportunity for saving costs.

Table 5. Catch of northern pikeminnow during 1998 by month.

Month	**Catch**	**Percent of Catch**
May	15,017	13.23
June	27,054	28.83
July	41,247	36.34
August	11,519	14.65
September	11,519	10.15
October	2,047	1.80
Total	113,514	

Source: Based on personal communication from John Skidmore at the Bonneville Power Administration on Nov. 24, 1999.

Opportunities for improving cost-effectiveness

There are generally two ways in which the cost-effectiveness of the NPMP could potentially be increased: (1) through changes in the catch of northern pikeminnow, or (2) through changes to the costs of the Program.

It is important to recognize that a very attractive characteristic of the sport-reward fishery is that it has built-in incentives for efficiency. Anglers will tend to automatically adjust effort to areas where they expect fishing success, earnings, or fishing conditions to be the most rewarding. Anglers are likely to consider many variables with offsetting impacts. For example, more anglers are likely to be available near major population centers, fishing may be more pleasant in more isolated areas, past experience may be more effective in increasing catch under some water conditions, boats and available equipment may be more adaptable to certain areas, and similar factors. Market pricing, or in this case the sport-reward, will automatically adjust effort to the conditions such as geographic area, season or other factors within the regulatory constraints set by the predator removal program. More cost-effective results are likely by maintaining these adjustments and possibly adding gear type as well.

Because the sport-reward payments drive Program participation and motivate automatic adjustments that tend to increase the cost-effectiveness of the progran, changes in the reward structure may be useful to further improve cost-effectiveness. As changing effort and success are observed during Program evaluation, adjustments can be made to the administrative components of the Program. The potential gain from adjusting fishing areas and seasons would be reductions in administrative costs of collecting fish and associated research efforts. There could be some gain in cost-effectiveness, for example, by ending the fishing season at the end of September. Program implementation costs per fish caught must be very high during October since few fish are caught.

Another approach to decreasing costs on a per-fish-caught basis would be to find ways of increasing Program participaton and catch. In so doing, administrative cost would be spread over a larger catch, which increases the cost-effectiveness of the Program. One suggestion is to implement surveys to discover what motivates participation in the Program and use the results to adjust the design of the Program to encourage greater participation.

Other opportunites for improved Program cost-effectiveness may be available by directly addressing the management and administrative costs of the Program. We think there may be potential savings by avoiding potential duplication of effort or other inefficiencies that may exist between the management entities (six agencies and four Tribes). Our ability to assess this issue is hampered by the lack of documentation on how agency monies are spent and on the specific contributions made by each agency to the Program objectives. However, we suspect that substantial administrative efficiences might be identified through a careful review of the management structure of the NPMP.

In particular, there are currently too many full time positions being funded for WDFW, and the total cost of the support requested by WDFW seems excessive when compared to budget requests by other agencies. If the WDFW budget cannot be reduced adequately, the use of a private contractor should be considered to provide this support.

As can be seen in Table 3, the cost per fish landed in the tribal fisheries is much higher than the cost in the sport-reward fishery. This problem needs to be addressed. It may be possible to include the tribal fisheries into the sport-reward fishery and utilize the mechanism for this payment system and its fish disposal system. All costs of the sport-reward component (i.e. costs necessary for the removal of predators) should be included along with a potential change in the magnitude of this reward for all components. While some administrative or related costs may remain for the tribal anglers, this would also be true for the sport-reward fishery as well. Whether this structure is used or not, some form of market allocation needs to be considered to improve the cost-effectiveness of the dam-angling and site-specific fisheries.

FINDINGS AND RECOMMENDATIONS

BIOLOGICAL

1. **Age Validation**. NPMP biologists have not attempted validation of northern pikeminnow age assignments that have been based on reading of scales. Because methods used to model the effects of fishing on northern pikeminnow populations depend sensitively on expected size at age, it is important that age assignments be validated. We recommend adoption of a scale age validation study, and we suggest that scale age validation could be accomplished via collection of scales and aging of reward-tagged fish at the time of original collection and at their recovery for fish at large for more than one full year prior to recovery.

2. **Relative Consumption Rates**. There is substantial uncertainty in the relative consumption rate, or predation impact, of male and female northern pikeminnow of different sizes and ages. NPMP biologists have wisely attempted to address this uncertainty by incorporating three alternative equations for relative consumption rates in their modeling. We believe, however that the original equation presented in Rieman and Beamesderfer (1990) probably exaggerates the relative consumptions rates of large northern pikeminnow as compared to small northern pikeminnow, especially among females. We do not believe that this equation should be used in future modeling.

3. **Estimation of the Force of Natural Mortality, M.** The force of natural mortality for northern pikeminnow in the Columbia and Snake rivers remains poorly estimated despite nine years of NPMP data collection. Because the actual value of natural mortality is of critical importance for projection of the probable reduction of northern pikeminnow impact via the NPMP, we believe that NPMP staff should consider implementation of a multi-year tag-recovery program designed to estimate annual survival rates. Successful development of such a multi-year tag-recovery program would require use of an alternative tagging method that would have reduced tag loss as compared to the spaghetti tags that have thus far been used for reward-tagging. Also, we are concerned that natural mortality rates of males may be greater than those of females (we recognize that it may be difficult to obtain separate estimates by sex because northern pikeminnow sex is generally unknown at time of tagging.). Based on existing knowledge of northern pikeminnow age, we believe that it is reasonable to suppose that the true force of natural mortality falls somewhere between 0.18 and 0.28. We believe $M = 0.24$ is a reasonable value to use until improved estimates are available.

4. **Exploitation Rates.** Although we have some concerns regarding methods that have been used to estimate annual exploitation rates of northern pikeminnow under the NPMP, we believe that one can with reasonable assurance conclude that annual exploitation rates have averaged at least 12 percent since the full implementation of the NPMP beginning in 1991. For purposes of long-term projection of NPMP reductions of total northern pikeminnow predatory impacts on juvenile salmonids, it appears reasonable to assume that long-term annual exploitation rates will be no more than 12 percent.

5. **Abundance of northern pikeminnow.** Knowledge of the approximate total abundance of northern pikeminnow prior to implementation of the NPMP is of central importance for calculation of the total impact (total number of juvenile salmonids consumed) of northern pikeminnow predation. Time limitations prevented us from engaging in a critical review of this complex subject. Due to the importance of this subject, however, we recommend a detailed independent review of the many issues that have been raised in calculation of systemwide abundance and impacts.

6. **Exaggerated savings.** The NPMP has exaggerated the probable savings of juveniles salmonids that will result from reduction of northern pikeminnow predation. Current savings are calculated as the product of the estimated numbers of juvenile salmonids consumed by northern pikeminnow prior to implementation of the NPMP and model-based calculations of the expected reduction in the total number of juvenile salmonids that would be consumed by a hypothetical northern pikeminnow population of reduced abundance and decreased average age and size. This kind of calculation effectively ignores all other possible causes of death to emigrating salmonids in the Columbia and Snake rivers. Using a competing-risks-of-death model (assuming that northern pikeminnow originally accounted for losses of 16 million juvenile salmonids out of a total of 115 million losses, and that systemwide smolt production is 200 million), we calculate that true savings of salmonids would be closer to 2.5 million and 5.2 million fish given reductions in the force of northern pikeminnow predation corresponding to 25 percent and 50 percent, respectively, as compared to claimed savings of 4.0 million and 8.0 million fish, respectively, suggested in various NPMP documents and publications.

7. **Minimum Size for Rewards.** The current sport-reward fishery provides cash incentives only for fish in excess of 279 mm total length. As noted in the 1998 annual report of the sport-reward fishery, anglers caught nearly 27,000 northern pikeminnow less than 279 mm total length during 1998. Of these, approximately 17,000 were returned alive. We recommend that modest ($2.50/fish) rewards be provided also for these smaller fish so as to encourage their capture and removal from the northern pikeminnow population.

8. Tribal Fisheries. From 1997 through 1999, total catches of northern pikeminnow in the combined tribal fisheries averaged about 6,000 fish annually as compared to average annual sport-reward catches of about 114,000 fish. Thus, tribal fisheries accounted for only 5 percent of total NPMP catches of northern pikeminnow. With respect to achieving the long-term goal of exploitation rates on northern pikeminnow that exceed 10 percent, tribal fisheries have had essentially negligible biological impacts over the past several years.

Although the average size of northern pikeminnow captured in the tribal fisheries is greater than that of fish caught in the sport-reward fisheries, we are unpersuaded that tribal catches should be weighted more heavily than sport catches as a result. Indeed, there is more logic to a reverse argument: the long-term reduction in lifetime salmonid predation achieved by removal of an individual northern pikeminnow is greater when a fish is captured at small size and young age, prior to having engaged in substantial salmonid predation, than when a fish is captured as a larger adult fish that has already devoted several years to salmonid predation.

9. **Biometrics Consultation.** We recommend that the NPMP consider awarding a modest ($20,000 - $60,000) contract for statistical consultation so as to assist the Program in (a) finding improved methods for estimating natural mortality and exploitation rates, and (b) reviewing methods that have been used to estimate northern pikeminnow population abundance.

ECONOMIC

1. Tribal Fisheries. We find that the relative cost-effectiveness of tribal fisheries, as compared to the sport-reward fishery, is poor. We therefore recommend that serious efforts be made to reduce the costs of tribal fisheries. Cost-effectiveness may be improved through reductions in administrative costs or better targeting of and timing of fishing. For example, dam-angling fisheries might be suspended during projected high flow years. At the same time, we recognize that there may be compelling justifications for continuation of these fisheries if they currently provide a major source of funding for overall tribal fisheries programs. The social and cultural benefits of funding these tribal fisheries and of fostering co-management of Columbia River fishery resources may compensate for the relatively poor cost-effectiveness of these fisheries. Also, the cost-effectiveness of tribal fisheries may compare favorably to other programs designed to reduce losses of juvenile salmonids, although we have not examined this question in our review.

2. Management Inefficiency. A reduction of the number of agencies involved in the Program should be considered in order to further reduce costs. Since this Program has been in place for the past decade, some of the tasks that make up this Program should be considered for reduction or elimination. The oversight role of CBFWA and the advertising and promotion role of BPA, for example, perhaps should be considered for elimination or consolidation (merger) with other agency roles. Similarly, the support role of WDFW and the harvest role of the Tribes should be considered for consolidation and substantial reduction. The number of WDFW full time positions funded through the NPMP should be reduced, or cost of those positions should be shared by WDFW.

3. Tiered-Reward System. The ISRP in its memo to the Council of June 15, 1999, recognized the need for further study of the current reward system. This review agrees with that conclusion, but additional information, available only through questionnaires sent to current and past participants, is needed. Much of the emphasis probably should be given to anglers who no longer participate or who participate sporadically, to determine what motivates them to decide to fish for these predators or quit fishing. While participation would be expected to decline with a strong economy and improved job opportunities, it may be possible to promote both participation and retention of anglers by changing the reward system. Additional research to study the most effective use of the tiered reward system should be supported. This should include the potential to use this reward system for tribal fisheries as well.

It may also be possible to increase the catch by increasing the reward or to reduce Program costs per fish caught by simply catching more fish. As pointed out in recommendation 4 below, reduction of promotional expenditures could be redirected to an increased sport-reward payment. Similary, savings through improved Program administrative efficiency may provide funds that could be redirected to making the sport-reward incentives more effective. Further study is needed to determine what specific changes should be considered for the sport-reward program. This should be given high priority.

Finally, the biological findings of this review support extending the reward system to smaller-size fish (See Biological Recommendation 7). Currently many undersized fish are returned to the water. For a small cost, these fish might be retained and not allowed to develop to larger size. For example, $2.50 per fish might be offered for northern pikeminnow between 8" and 11" total length.

4. Program Promotion. BPA had a program promotion budget of $80,000 for 1998 and $85,000 for 1999 (see Table 1). According to work statements and budget documents in the 2000 NPMP proposal, the PSMFC and WDFW also apparently share in promotion responsibilities (e.g., sport shows, clinics, etc.). The combined costs of these activities would be adequate to fund nearly an additional $1 per fish added to angler rewards. WDFW indicated that anglers were surveyed in 1994 and 1995 to determine where they learned of the sport-reward fishery. Word of mouth was the overwhelming response, followed by newspaper advertising. The Program suffers from a very large turnover even among the core group of highly successful fishers. After a decade of Program existence, more anglers might be attracted to participate by higher rewards than from continued Program promotion. Program managers should explore the potential to have the current sport-reward schedule included with the fishing regulations published annually by the states if they have not already done so.

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Appendix 1. Expected mean length at age [$l_f(t)$ or $l_m(t)$ at annulus, in mm] and relative consumption rates [RC()] for male (M) and female (F) northern pikeminnow based on data for fish found below Bonneville Dam. Relative consumption rates are calculated for each of three alternative hypotheses relating consumption rate to fish length, based on values provided by David Ward, ODFW (personal communication with D. Hankin, 12 January 2000). Calculated values of RC for fish aged 3 or younger were converted to 0.00 based on apparent failure of such young pikeminnow to consume juvenile salmonids as prey. Maximum observed age has been reported at approximately 16 years. Parameter values generating data below are the following:

Von Bertalannfy growth equation for females: $l_f(t) = 588(1 - e^{-0.135(t+0.126)})$

Von Bertalannfy growth equation for males: $l_m(t) = 416(1 - e^{-0.223(t+0.342)})$

Equations relating relative consumption rates to fish length are from Friesen and Ward (1999, page 420):
$RC1 = -0.858 + 0.003703 l(t)$; $RC2 = 1.631 \times 10^{-8} l(t)^{2.986}$; $RC3 = 1.58 \times 10^{-15} l(t)^{6.02}$

Age	$l_f(t)$	RC1(F)	RC2(F)	RC3(F)	$l_m(t)$	RC1(M)	RC2(M)	RC3(M)
1	82.92	0.00	0.00	0.00	107.59	0.00	0.00	0.00
2	146.70	0.00	0.00	0.00	169.24	0.00	0.00	0.00
3	202.43	0.00	0.00	0.00	218.56	0.00	0.00	0.00
4	251.12	0.07	0.24	0.44	258.03	0.10	0.26	0.52
5	293.67	0.23	0.38	1.14	289.60	0.21	0.37	1.04
6	330.84	0.37	0.54	2.33	314.87	0.31	0.47	1.73
7	363.31	0.49	0.72	4.09	335.08	0.38	0.57	2.51
8	391.69	0.59	0.90	6.43	351.26	0.44	0.65	3.34
9	416.48	0.68	1.08	9.30	364.20	0.49	0.73	4.15
10	438.14	0.76	1.26	12.62	374.55	0.53	0.79	4.91
11	457.06	0.83	1.43	16.28	382.84	0.56	0.84	5.60
12	473.60	0.90	1.59	20.17	389.47	0.58	0.89	6.21
13	488.05	0.95	1.74	24.17	394.77	0.60	0.92	6.74
14	500.67	1.00	1.88	28.18	399.01	0.62	0.95	7.19
15	511.70	1.04	2.00	32.13	402.41	0.63	0.98	7.56
16	521.33	1.07	2.12	35.95	405.13	0.64	1.00	7.88

Appendix 2.

Part A. Age-Specific fork length, relative prey consumption, and survival probabilities from age 4 to age 4+i for female northern pikeminnow, i = 1, 2, 3, ,,,,, , 12. Assumes annual mortality rate of 0.24. Relative consumption (RC) vs. length (FL) is assumed to be RC = 1.631e-8(FL^2.986)

Age	4	5	6	7	8	9	10	11	12	13	14	15	16
Length	251	294	331	363	392	416	438	457	474	488	501	512	521
Consumption*	0.239	0.383	0.545	0.718	0.904	1.079	1.259	1.429	1.593	1.738	1.880	2.006	2.113
Survival**	1.000	0.760	0.578	0.439	0.334	0.254	0.193	0.146	0.111	0.085	0.064	0.049	0.037

Part B. Expected conditional age-specific relative prey consumption at ages i through 16 given that a fish is known to have survived to age i. Thus, e.g., the entry at age 6 for the Age 4 row equals the probability of surviving from age 4 to age 6 (.76^2) times relative prey consumption at age 6 (.545).

	4	5	6	7	8	9	10	11	12	13	14	15	16	Expected Lifetime Consumption from Age i through 16
Age 4	0.239	0.291	0.315	0.315	0.301	0.274	0.243	0.209	0.177	0.147	0.121	0.098	0.078	**2.809**
Age 5		0.383	0.414	0.415	0.397	0.360	0.319	0.275	0.233	0.193	0.159	0.129	0.103	**3.381**
Age 6			0.545	0.546	0.522	0.474	0.420	0.362	0.307	0.255	0.209	0.170	0.136	**3.946**
Age 7				0.718	0.687	0.623	0.553	0.477	0.404	0.335	0.275	0.223	0.179	**4.474**
Age 8					0.904	0.820	0.727	0.627	0.532	0.441	0.362	0.294	0.235	**4.942**
Age 9						1.079	0.957	0.825	0.699	0.580	0.477	0.387	0.309	**5.313**
Age 10							1.259	1.086	0.920	0.763	0.627	0.509	0.407	**5.571**
Age 11								1.429	1.211	1.004	0.825	0.669	0.536	**5.674**
Age 12									1.593	1.321	1.086	0.881	0.705	**5.586**
Age 13										1.738	1.429	1.159	0.928	**5.253**
Age 14											1.880	1.525	1.221	**4.625**
Age 15												2.006	1.606	**3.612**
Age 16													2.113	**2.113**

Appendix 3. Response from F. Young and J. Skidmore regarding economic issues of concern to the review team.

January 20, 2000

To: Terry H. Morlan

From: Frank Young and John Skidmore

Subject: Response to Questions on Northern Pikeminnow Management Program

Responses to questions in your January 5, 2000 memo follow:

Sport Reward Structure: *How was the current tiered structure of the sports reward amount arrived at? Do you have a significant level of confidence that this structure is appropriate and effective for encouraging program participation?*

Response: (WDFW) The tiered reward was implemented for 1995 season. The tiered reward system was intended to encourage experienced, productive anglers to spend more and longer angler days harvesting northern. pikeminnow and to recruit new anglers to the sport-reward fishery. Anglers were surveyed in 1995 to determine which promotional activities would be most likely to increase their participation in the sport-reward fishery (77 percent of successful anglers indicated tiered reward). During 1995 we saw the second highest level of effort and an increase in the number of individual participants. The second tier level (101-400 fish) was set to be low enough to be reachable by a majority of the anglers, while tier three (>400 fish) was set to encourage the small number of most skilled anglers to fish longer into the season and fish longer each day. Since 1995 approximately 91 percent of the anglers have been at tier one, 6 percent at tier two, and 3 percent at tier three. We believe that the tiered reward is the most cost-effective promotional activity we have implemented.

Sport-reward Budget: *It is necessary to budget enough sport reward funds to cover potentially high levels of success, but in most years the actual amount awarded is below the budgeted amount. How are the unexpended funds that exist in most years treated? Shouldn't the actual funding requirements over time average significantly less than the total amounts budgeted? How do these savings show up in the program, since the reward budgets remain essentially the same high level year after year?*

Response: Even though $1,000,000 is budgeted annually, only a portion of this is spent depending on the annual catch of northern pikeminnow. The remaining amount, along with the unspent amounts in the various subcontracts (which has been significant), is carried over to displace current funds in the next year's contract. The amount in the reward fund provides a buffer in the event of an increase in fishery effort and/or effectiveness in response to promotional incentives, environmental conditions resulting in an increase in catch, understanding the significant uncertainty in predicting the behavior of the fishing public or the environment and the significant risk if the program ran out of money to pay anglers. The budget tables in the November 12, 1999 Background Document show only the amount requested - not the amount actually spent - and can be off by $500,000 to $800,000.

Advertising and Promotion: *Why does a program that has been in existence for 10 years still need an advertising and promotion budget of $80,000? Have other alternative means of program recruitment been considered and tested?*

Response: The Program suffers from a very large turn-over in participants, even among the core group of highly successful fishers. The reasons for this are many. 1) Some people participate once, are disappointed with the results, and do not return. 2) In recent years (beginning in 1996) flows and ESA mandated spills are much greater than in the recent past and fishing conditions are much more difficult (especially for bank anglers and tribal dam anglers). 3) As the Northwest economy has improved more people are employed and unavailable to participate in the Program. 4) Northern pikeminnow may be getting more difficult to catch because those fish that are the most vulnerable to angling gear may have already been caught. These suggestions are based on our best judgement since no objective evaluations of participation have been done.

The cost is also high because advertising rates in high circulation mass media (The Oregonian) which reach large numbers of people in the principle target area (lower Columbia) are very expensive. Other means, such as radio, brochures, flyers at sporting goods stores, coupons for free reward with a fish, fishing clinics, tournaments, operating promotional booth at regional sportsman's shows and presentations to sportsman's groups are also being used.

(WDFW) Anglers were surveyed in 1994 and 1995 (Appendix D and C respectively) to determine where they learned of the Sport-Reward Fishery. "Word of mouth" was the overwhelming choice, followed by newspaper advertising.

Question on Personnel and Overhead: *It appears that a relatively small share of the total budget goes to the actual catching of predators. Management and overhead expenses seem to be duplicated across various program elements and tribal components. There are several full time positions supported as by of this part-year program. How did these multiple layers of management evolve, and what effects has this development had on the program budgets? How can $184,000 for full time staff be justified for WDFW management of a summer-time program? Have alternative management approaches been investigated? For example, would private sector management be less expensive? What were the key concerns that are reflected in the current method of reward processing? Have other methods of processing vouchers been tried or evaluated?*

General Response: The fishery agencies have held this program to standards of management and evaluation that are extraordinary because it was designed to test an extraordinary hypothesis. That hypothesis is that predator control can have long-term benefits at reasonable costs with minimal impacts to the predator population. Because of these requirements the Program has relatively high management and evaluation costs. Efforts to minimize these costs, however, have been a continuing activity within the Program.

Response by subcontract:

1. Sport-reward Subcontract: In earlier years there was a separate fish-handling subcontract with Oregon State University. This function has recently been incorporated under the sport-reward subcontract with WDFW at a substantial savings. Several registration stations have been closed or moved over the years in response to changes in fishing success and Program participation. In addition, part-time satellite stations have been established and hours of operation have been changed to facilitate participation at minimum cost. Seasonal personnel have been kept to the minimum necessary to carry out a well managed program while providing a reasonable opportunity for participation by fishers. Five positions (including one clerical) are funded year-round with Program funds even though the work is seasonal in nature.

When questioned about the need to have these positions funded full time with Program funds, WDFW has responded that they believe that it would be disruptive to lay off and rehire each year for these positions and that they lack the ability to fund these positions part time, from other funding sources, to maintain them as permanent employees if full time Program funds are not available. They also point out that there is a considerable amount of preparation and logistical work needed to keep the program running smoothly. Data must be analyzed, reports written, sports shows participated in for Program promotion, planning for next year, personnel recruitment (40 seasonal positions to fill), and various other tasks necessary to manage this very large program.

2. Tribal Subcontracts: The tribes originally operated under a single contract with their coordinating body, the Columbia River Inter-tribal Fish Commission (CRITFC) with a relatively low level of administration. Subsequently, there have been individual subcontracts to each of the four participating tribes, in addition to the original CRITFC subcontract, each with separate administrative activities, which have increased administration costs. As catches have declined in recent years, significant reductions have been made in tribal budgets, culminating in the decision by the Umatilla Tribes, for FY 2000, to forego further participation in the dam-angling fishery until prospects for success are improved. We believe that this decline in success of the dam-angling fishery since 1995 is associated primarily with increased flows and the associated forced spill at the dams which has resulted in the redistribution of northern pikeminnow from being concentrated in the tailrace area to being scattered below the spillway. We believe this shift in distribution of predators has occurred because most of their prey that formerly passed through the turbines are now passing via spill.

3. CBFWA Subcontract: These two positions are responsible for the technical administration of the Program and were originally funded as full time positions (total of 2 FTE). These positions are responsible for 1) guiding development of work statements and budgets, biological assessments and reports; 2) report editing; 3) coordinating program implementation; 4) track compliance with the "take" allowance under ESA Biological Opinion for the Northern Pikeminnow Management Program through provision of weekly field activity reports to NMFS;

5) review of program elements for cost-effectiveness and 6) guiding development of promotional activities designed to increase participation in the sport-reward fishery.

These positions have been incrementally reduced over the past few years down to one-quarter time (total of 0.5 FTE) to improve Program cost-effectiveness.

4. PSMFC Contract: (Russell Porter) PSMFC is the primary contractor with BPA. They provide contractual, fiscal and technical oversight for all components of the program; subcontract to the various agencies for their program tasks; coordinate promotion activities with BPA and program member agencies; issue reward payments, drawing and tournament prizes and provide associated accounting [including issuance of IRS Form 1099's to anglers at the end of the year], reporting and problem resolution for the program.

PSMFC completes all voucher entry, check generation, reporting and mailing services in their data entry section. This section is supported by other projects in addition to the NPMP. This allows for cost efficiencies. An average of 15,000 vouchers are processed each season. Data entry services begin in April with archiving last year's data and clearing all angler files and adjusting payment fields for the current year's program. Voucher processing begins in May and runs through November at the cut off date. Additional services for late vouchers continue into late December. IRS forms are generated and mailed to anglers in January. Additional functions include garnishments of reward payments by the IRS, state Child Support Enforcement agencies and others. This requires accounting and at times legal determinations as to the legality of the claim against the reward monies of the angler. PSMFC's data entry section is supported by additional coast-wide field programs requiring data entry. This allows for manpower and cost efficiencies in a section that is always busy and available for any task associated with the NPMP 12 months a year, but requiring only 6 months of funding. The reward payment process has been streamlined into a highly efficient computerized system. In most cases, checks are generated and mailed the day the vouchers are received from the anglers. In the beginning of the program under the state of Oregon, checks were taking weeks to be generated resulting in numerous complaints from anglers. The current fast turn around time is extremely popular with anglers and assists in angler participation in the program.

PSMFC's accounting section generates the subcontracts for all the participating agencies, processes and pays all monthly bills to the agencies and provides accounting and reporting to BPA in regards to all aspects of the NPMP program. PSMFC's overhead costs for all aspects of the program combined are slightly less than 2 percent of the program costs. No private sector management could run the program at this rate.

PSMFC is very strong in its belief that fishery management agencies that have the regulatory authority over fisheries are the best choice to run programs which not only must adhere to these regulations, but are intertwined with them. PSMFC's experience with NMFS in projects with private sector contractors have shown that there primarily is only a goal of getting numbers or performing basic contract tasks. When these are intertwined with fishery management issues it does not seem to work. There is no incentive or ownership for them to meticulously record fishery data such as that established by the NMFS Biological Opinion for listed species under the

ESA. Fishery management issues or conflicts would not be a high priority in most cases, nor are they normally capable of recognizing them as such when they do occur

Question on Declining Catch*: The total catch for 1998 was the lowest since the first year of the program. Does this reflect reduced program participation or the effect of the program in reducing northern pikeminnow abundance? Does the reduced catch imply that the target exploitation rate could be lowered significantly and still achieve targeted predation reductions?*

Response: The change in catch among years is primarily a function of river flows and Program participation. River flows effect both the distribution of northern pikeminnow and the availability of good fishing locations since most bank fishing locations, especially below Bonneville, are eliminated at higher river levels. River flow also effects water turbidity and temperature which effects fishing success. Program participation is effected by the amount of the reward, weather conditions, flow (fishing conditions), success (catch per unit of effort), availability of alternative employment and promotional activities (information). Another factor in the decline may be that there are fewer northern pikeminnow in the target size range after ten years of exploitation and that the most catchable fish have been removed from the population.

(Dave Ward) Catch in 1998 was low, but the overall exploitation rate of 11.5 percent was similar to the 1993-98 average of 11.6 percent. Catch in 1999 was similar to that in 1998, yet exploitation increased to about 12.5 percent. This reflects a general trend of decreasing abundance of northern pikeminnow, so that a given exploitation rate is achieved through a lower catch than previously required. This information indicates the program is working as expected.

There is absolutely no indication that target exploitation rates could be lowered and still achieve targeted reductions in predation. Reaching or maintaining targeted predation reductions relies on maintaining exploitation within the 10-20 percent range, regardless of the catch required to reach that exploitation level.

Question on Geographic Scope: *Predation by northern pikeminnow seem to be concentrated in the lower river. Is the current effort that the program applies in the upper river areas justified? Have the relative predation levels been reflected in the program design and evolution?*

Response: The Program has always attempted to focus northern pikeminnow removal activities in the lower river where the benefits are obviously greatest since saved smolts are more likely to survive to return as adult fish and the predator density is highest. However, we believe that there are benefits associated with removing northern pikeminnow throughout the Basin and that those benefits are substantially more cost-effective than other comparable ongoing mitigation measures such as spill, flow augmentation, transportation or debt service on by-pass systems where costs per smolt saved are much greater.

(Dave Ward) From 1990-93, we estimated about 97 percent of predation to occur in the Columbia River. Estimates were about 91 percent from 1994-96, and about 96 percent in 1999. Although estimates in the Snake River were low, the original predation indexing study design did not include the Snake River between Lower Granite Reservoir and Hells Canyon Dam. It seems likely that some predation occurs in this area, which usually accounts for 6-10 percent of the sport-reward catch. It certainly makes little sense to concentrate any effort in the Snake River below Lower Granite Dam. It may or may not be justified to allocate effort in the Snake River upstream from Lower Granite Dam to maintain 6-10 percent of the overall catch.

Within the Columbia River, most predation is concentrated downstream from John Day Dam. Similar to the Snake River, however, predation indexing did not include the Hanford Reach between McNary and Priest Rapids dams. Catch in this reach usually accounts for about 15-20 percent of the sport-reward total, indicating that the program should continue to allocate effort throughout the Columbia River downstream from Priest Rapids Dam.

Program design has been adjusted each year to reflect predation levels, assuming that predation levels are reflected by northern pikeminnow catch. In 1992, the sport-reward fishery included 20 check stations, of which 5 were in the Snake River. In 1999, only 12 check stations were operated full time, of which only one was in the Snake River. Only two stations were operated in the Columbia River, upstream from John Day Dam.