55-0165

February 20, 2004

FEB 2 3 2004

Bonneville Power Administration, Communications
DM-7 P.O. Box 14428
Portland, Oregon 97293-4428

Re: Summer Spill Analysis Comments

Please find the enclosed comments by the Oregon Department of Fish and Wildlife on the Federal Agencies' proposal and analyses to evaluate summer spill reductions and mitigation actions to offset impacts.

We appreciate the opportunity to provide these comments; if you have any questions please contact me at 503-657-2000 Ext 415, or raymond.r.boyce@state.or.us.

Sincerely,

[Signed copy to follow in mail]

Raymond R. Boyce
Fish Division

ODFW Comments on the Federal Agencies' Proposal and Analyses to Evaluate Summer Spill Reductions and Mitigation Actions to Offset Impacts

Submitted February 20, 2004

The Oregon Department of Fish and Wildlife (ODFW) submits the following comments on proposals and studies related to reduction in summer spill this year at mainstem Columbia and Snake River dams. We have divided our comments into three parts: 1) to provide an overall context for our comments on the Federal Agencies proposal, we first briefly review fish and wildlife recovery and mitigation needs as addressed in the Four State Governor's fish and wildlife strategy and the Northwest Power and Conservation Council's Fish and Wildlife Program; 2) we provide technical comments on analyses by the Federal Agencies on fishery impacts from summer spill reduction options; and 3) we provide technical comments on proposed measures to offset fishery impacts. ODFW at a later time will provide alternative mitigation measures for consideration by the region. We understand that additional background material will be provided by the Federal Agencies related to these proposals and may be providing follow-up comments on this additional material at a later time.

Executive Summary

Our overall assessment is that the analyses of biological impacts (SIMPAS modeling and methods to determine effects on juvenile and adult survival) are fundamentally flawed and available scientific data collected in the Columbia Basin do not support the Federal Agencies' findings. If the analyses had considered the effects of reduction of spill on delayed hydrosystem mortality, and had included a full range of uncertainty associated with key inputs to the model, impacts to adult fall chinook stocks in the basin including ESA listed Snake River fall chinook could be magnitude higher than predicted (2,000-19,000 adults for spill reduction options considered). The proposed mitigation actions (offsets) by the Federal Agencies fall far short what would be necessary to mitigate for reductions in spill because each of them would provide either marginal or uncertain benefits, and not accrue for many years in the future. None of the offsets would provide mitigation for specific life histories affected by spill reductions ("in place in kind" concept), one of the stated offset principles. As discussed, any potential offset needs to mitigate for fall chinook above and beyond mitigation currently being provided under the NOAA Fisheries Biological Opinion. Alternative offset options should be developed that focus on addressing passage impacts on a real time basis (such as improvements in flow or improvements in spill efficiency and survival) to provide certainty that stocks do not incur additional mortality during the Biological Opinion's 10-year evaluation period. The

5 and 8 year check-ins may indicate that the current mainstem measures including spill are not enough and additional measures are needed to avoid jeopardy of the listed stocks.

Federal Agencies Proposal to Evaluate Reduced Summer Spill

The Four Governor's June 2003 "proactive fish and wildlife recovery strategy" outlines an approach that avoids breaching of dams. A critical element of this strategy is full implementation of mainstem hydro measures of NOAA Fisheries' Biological Opinion of the Federal Columbia River Power System (Biological Opinion). Full implementation of hydro measures is critical during the 10-year evaluation period to determine if the Biological Opinion can meet survival and recovery standards, or whether alternative mitigation actions are required. A cornerstone of this recovery strategy is passing maximum number of juveniles over conventional or modified (i.e. Raised Spillway Weirs on the Snake River and other surface bypass technologies being tested in the basin) spillways that have consistently been shown to provide the highest survival of any passage route at Columbia River dams. Any reduction in spill, even as part of an "evaluation", is risky because this may cause additional mortality of stocks that cannot be addressed by offsite mitigation measures being implemented under the Biological Opinion. As discussed in Oregon's comments on the Biological Opinion (Oregon 2000), there is a high likelihood that the projected survival improvements in the Biological Opinion are underestimates of those necessary for survival and recovery of listed populations; spill reductions will only take us further from meeting these survival and recovery thresholds. Additionally, as discussed below, the weight of evidence indicates that the proposed mitigation measures will not offset survival impacts from the reduced spill options. The proposed offsets will provide only marginal benefits and will not accrue for many years (perhaps decades). These offsets also assume that the current measures being implemented under the Biological Opinion are adequate to avoid jeopardy and that there is no opportunity costs to fish survival of such tradeoffs. Whether this is true will not be known for several years after the 5 and 8 year check-ins; these evaluations may indicate that mainstem measures above and beyond current Biological Opinion actions may be necessary to avoid jeopardy.

The newly adopted Northwest Power and Conservation Council's Fish and Wildlife Program includes an evaluation of the biological effectiveness of summer spill and exploration of less costly alternatives that provide equal or greater survival benefits. Through the Council's amendment process we recommended comprehensive evaluations to determine the effects of various spill levels (including that currently being provided under the Biological Opinion) on smolt-to-adult returns (SARs) of key summer migrant populations. In the 2003 Mainstem Amendment to the Fish and Wildlife Program, the Council called *"for NOAA Fisheries, the federal operating agencies, and salmon* *managers to immediately implement tests to examine the benefits of the current summer spill program for outmigrating juvenile fall Chinook, and to determine whether the biological benefits can be achieved in a more effective and less costly manner.*" The Council is committed to "*work with the federal operating and fish and wildlife agencies, in consultation with the state fish and wildlife agencies and tribes and the Independent Scientific Advisory Board in a rigorous evaluation of the biological effectiveness and costs of spillway passage at each project and bring that information to bear in a systematic way in decisions when, and how much to spill*", and that it "*will conduct a public review process with the goal of providing recommendations to the federal agencies for the most biologically effective spill actions at the lowest cost possible.*" Efforts to reduce spill in 2004, without a regionally agreed upon evaluation plan in place, will place listed as well as important unlisted fish at risk without an opportunity to learn whether and how the action impacts survival and whether the proposed offsets will mitigate for these impacts. Also, the Federal Agencies' proposal to reduce spill without knowledge of the effects on the survival and recovery of listed and unlisted salmon, and without a public process, precludes effective regional debate on the decision. The federal government has not explained or justified in biological and/or economic terms, why it is necessary and appropriate to subject fish to an unknown, and potentially significant risk in 2004, or rush such an important decision without the public review process contemplated by the Council.

<u>Analyses to Evaluate Summer Spill Reductions</u>

ODFW has earlier commented (ODFW 2001; Joint Technical Staff Memorandum 2001a, 2001b, 2001c) on the limitations of the use of SIMPAS modeling as a predictive tool to assess the effects of reduction in spill on juvenile survival and adult returns. Our overall assessment is that the SIMPAS modeling and methods to determine juvenile and adult impacts are fundamentally flawed and available scientific data collected in the Columbia Basin do not support the Federal Agencies' findings. Specifically:

1. The NOAA Fisheries in the Biological Opinion and the Council's Independent Scientific Advisory Board recognize the limitations in the use of SIMPAS modeling to assess effects on adult returns because the model uses parameters derived from project (route specific) and reach survival that cannot capture the effects of changes in spill and resultant effects on forebay and tailrace mortality. The Biological Opinion (Appendix D page D-9) specifically states that "The juvenile survival rates…are based on juvenile passage studies only and cannot be used to infer the likelihood of adult returns." Radio tag studies conducted in the past have shown extensive delay (up to one week and often upstream migrations) of Snake River subyearling fall chinook under no spill conditions. As discussed below (Offset Action 1), reductions

in spill could greatly increase predation rate by pikeminnow because spill serves to increase velocity in tailraces that disperses predators away from bypass outfalls and below turbines where smolts are most vulnerable to predation.

2. The point estimates of model parameters are inadequate to address the high degree of uncertainty and biases associated with model parameters so there is no way to assess biological risk and consequences of results. This problem is compounded by multiplying several model parameters to derive system smolt survival rates and adult return.
3. The model results do not simulate historic and current differences in stock performance in the Columbia Basin and has not been validated comparing to adult returns (ODFW 2001a). The biggest discrepancy is the adult returns predicted in the analysis for upper Columbia summer chinook; for example the predicted number of adult upper Columbia summer chinook under the Base Case (Biological Opinion spill during July and August) is 21,200 which is returns to the mouth of the Columbia that is order of magnitude less (22-26%) than observed recent escapements measured at Priest Rapids Dam (96,326 in 2002 and 83,004 in 2003) (ODFW and WDFW 2004).
4. The magnitude of impacts of spill reductions on the various summer migrant stocks is largely dependent on the proportion of juveniles that migrate during the proposed spill reductions in July and August. Although it was assumed that 90% of the Snake River wild fall chinook migrate in July and August, it was assumed that only 41-66% of upriver (Hanford and Yakima) and mid-Columbia (Deschutes, Klickitat, Umatilla, Little White Salmon) bright and upper Columbia summer chinook migrate in July and August. Review of historic migration timing (Joint Technical Staff Memorandum 2003) of these stocks indicates large variability in migration timing in the lower Columbia and in some years >90% of all stocks migrate by August 31. The assumption that had the largest effect on results was that it was assumed only 66% of Hanford wild and hatchery migrants (over 35 million juveniles or over 65% of the basins' total summer migrants) migrate in July and August that was derived by averaging migration timing of PIT tagged Hanford wild (85%) and subyearlings run-at-large (48%) at John Day. It is unclear why migration timing of Hanford Reach wild fish was averaged with subyearlings run-at-large at John Day since the later includes all summer migrant stocks above John Day Dam. If stock specific migration timing of Hanford wild fish (85%) was used in the analysis, reduction in spill in July and August would impact an additional 4.675 million juveniles from this stock alone.
5. The analysis did not address additional mortality to adults that would fallback through powerhouse routes including turbines under no spill conditions. Turbine mortality for adults is high (>50%) and any increase in adult fallback through turbines would further increase biological consequences to stocks.
6. The modeling analysis does not address delayed "extra" hydrosystem mortality of transported and inriver fish that has been demonstrated in spring and summer

chinook. The weight of evidence presented in Budy et al. (2002) and comments submitted by Oregon on the NOAA Fisheries Biological Opinion (Oregon 2000) indicates that the hydrosystem (causing increased stress to juveniles due to dam passage including multiple bypass passage) causes a delayed and indirect mortality in both transported and inriver fish that is not considered in the SIMPAS modeling analysis.

7. One of the biggest flaws was the analysis did not adequately evaluate the biological benefits of transportation vs inriver passage (with spill at collector projects) for Snake River fall chinook. The analysis assumed Biological Opinion transport operations where all fish collected are transported resulting in about 95% of Snake River fish being transported and only 5% left to migrate inriver. However, recent adult returns and studies strongly suggest that this transport policy maybe reducing survival of fish vs allowing fish to migrate inriver. Smolt-to-adult data of PIT tagged transported and inriver ("undetected") fall chinook returning to the Snake River reported by NOAA Fisheries (NOAA 2003) indicates that despite that 95% of fish are transported from the Snake River each year, fish that had migrated inriver constitute up to 36% of adult returns from PIT tagged fish. Transportation research data from McNary Dam (NOAA 2003) also indicates that transportation is providing at best equal (and perhaps less) survival benefits for Hanford Reach wild and hatchery subyearling migrants (principal stock transported at McNary Dam). Based on these data it is clear that the differential "D" mortality estimate for transported fish used in the analysis (.24) likely overestimates survival of transported fish from the Snake River. Because the analysis assumed that 95% of Snake River fall chinook is transported is why small impacts from spill reductions were shown. However, if the analysis had assumed that a higher proportion of fish migrated inriver (that survival data indicates may increase survival survival) and that inriver passage was enhanced (through higher spill including at collector projects), the value of spill to Snake River fall chinook would be demonstrated. Future analyses and studies should be directed at determining survival of transported vs inriver Snake River fall chinook not only maintaining Biological Opinion spill in the lower Columbia but also enhancing inriver passage conditions in the Snake River by spilling at collector projects and enhancing flows as discussed in the Biological Opinion's RPA Action 46.
8. The SIMPAS model itself predicts the ineffectiveness of transportation and the potential benefit of summer spill to Snake River fall chinook. An analysis done by Bouwes (2004) using SIMPAS (but using more a more realistic D mortality for mid and lower Columbia summer and fall chinook and more representative saltwater-Lower Granite SARs) indicates that ceasing transportation and providing a spring like summer spill at collector projects would increase fall chinook adult returns to the Snake River by over 3,000 or a six fold increase over the average for 1985-94. Although this finding using SIMPAS has the same limitations discussed above, it

does illustrate why BPA's analysis indicates there would be little impacts to Snake River stocks.

Mitigation Actions to Offset Spill Reductions

Below we provide comments on the 6 offset alternatives that are designed to mitigate for impacts from spill reductions. As discussed in the Offset Principles, we agree that: offsets should provide equal or greater survival as that provided by Biological Opinion spill; offsets should provide mitigation for the specific life histories affected by spill reductions ("in place in kind" concept); and importantly these offsets for fall chinook should mitigate for losses above and beyond mitigation currently being provided under the Biological Opinion. We conclude that the 6 proposed offsets will be largely inadequate to mitigate for reductions in spill because each of them would provide either marginal or uncertain benefits, and not accrue for many years in the future. Some also lack implementation (ex: NEPA for Tern Relocation) authority. As discussed, we will not know if these offsets are "above and beyond" that needed to avoid jeopardy of the listed stocks until the 10-year evaluation process is completed. In the future, ODFW along with other Salmon Managers will provide Federal Agencies alternative mitigation options for consideration. As discussed, in the Joint Agency comments, one of the most potentially viable alternatives that should be considered is a flow offset that would involve increasing summer flows high enough to provide survival benefits equivalent from reduced spill.

Offset Action 1- Northern Pikeminnow Management Program Heavy-Up

The objective of this offset is to decrease predation on juvenile salmonids through increased harvest of northern pikeminnow. Northern pikeminnow are currently harvested by a sport-reward fishery as part of the Northern Pikeminnow Management Program (NPMP). It is proposed that the most logical and feasible approach to increase fishery performance would be to increase the reward structure, using a temporary increase implemented in 2001 as a model. Based on results from the 2001 "heavy-up", it is hypothesized that an increased catch of 20,000 to 40,000 fish can be reasonably expected in 2004. It is further hypothesized that such an increase in annual harvest would represent a 1 percent to 2 percent increase in exploitation rate, and would result in savings of 0.7 to 1.4 million juvenile salmonids across the projected lifespan of the northern pikeminnow caught. Savings in 2004 would be far fewer (number not specified, but analyses giving the lifespan total yield within-2004 estimates of about 100,000 to 200,000 juvenile salmonids saved.

Such analyses fail to consider (1) confounding factors affecting exploitation rates, (2) longer-term trends in seasonal exploitation rates, (3) variation inherent in all exploitation rate and predation estimates, (4) affects of a "heavy-up" on human behavior, and (5) direct effects of discontinuing spill on predation. We begin our comments with a brief refresher on the NPMP. We then address each of the five points in order.

Northern Pikeminnow Management Program Refresher

The goal of the NPMP is to reduce predation on juvenile salmonids through sustained harvest of northern pikeminnow. The NPMP is based primarily on four premises: (1) development of the Columbia River basin hydropower system has increased fish predation on out-migrating juvenile salmonids, (2) northern pikeminnow are responsible for the overwhelming majority of this predation, (3) population dynamics and behavior of northern pikeminnow facilitate relatively large reductions in predation from relatively low exploitation, and (4) compensation by surviving northern pikeminnow or other predators is unlikely. Support for these premises is based on 20 years of predation research in the Columbia River basin.

The primary control mechanism is the cumulative effect of exploitation, which systematically reduces the number of older piscivorous individuals through time. Northern pikeminnow are long-lived and slow-growing, and become increasingly piscivorous with age. Salmonids are generally an important diet component only for large, old individuals, and consumption rates of juvenile salmonids by northern pikeminnow increase as size increases. As would be expected with a previously unexploited population such as northern pikeminnow, the biggest relative benefits (in terms of population re-structuring) were realized in the first few years of the program. Sustained exploitation now serves mainly to maintain the new population structure; substantial increases in exploitation greater than 1-2 percent would be necessary to increase benefits by further restructuring the northern pikeminnow population.

Two questions commonly asked about the benefits of the NPMP are (1) do northern pikeminnow feed mostly on dead salmonids, thereby making actual benefits less than estimated, and (2) do remaining northern pikeminnow compensate for removals by increasing consumption, growth, fecundity, etc.? Estimates of predation losses are relatively unbiased by consumption of dead or injured juvenile salmonids (Beamesderfer et al. 1996). Petersen et al. (1994) marked and released live and dead salmonids into a tailrace in a 10% dead proportion (similar to turbine mortality) and found that 22% of the marked salmonids subsequently recovered from northern pikeminnow were dead before release. If dead fish constitute 22% of northern pikeminnow prey near dams, dam effects extend 10km upstream and downstream, and 69% of predation occurs in that zone (Petersen 1994), then 85% of the estimated predation would be on live fish (1-(0.69x0.22).

Rieman and Beamesderfer (1990) concluded that compensation by surviving northern pikeminnow was unlikely because (1) fecundity is much lower than fecundity of species considered resilient, (2) growth is slow and mortality low compared with other species, and (3) density-dependent growth was not obvious. Knutsen and Ward (1999) and Zimmerman et al. (2000) reported that northern pikeminnow compensation has not been observed to date.

Confounding Factors Affecting Exploitation

On first glance, harvest data from 2000-03 (the period in which the minimum size for reward fish has been approximately 200 mm fork length) appears to support the argument that the 2001 "heavy-up" increased catch and exploitation rate (Table 1).

Table 1. Catch and exploitation rate of northern pikeminnow in the sport-reward fishery, 2000-03. Minimum reward size was reduced from 250 to 200 mm fork length in 2000.

Year	Catch	Exploitation Rate (95% Confidence Intervals)
2000	189,054	10.9% (6.8% - 16.8%)
2001	240,894	15.5% (10.0% - 25.0%)
2002	200,445	10.6% (5.8% - 19.6%)
2003	195,974	10.5% (8.1% - 14.4%)

Catch and exploitation rate differ little among 2000, 2002, and 2003, but are notably less than exploitation in 2001, when rewards were significantly increased on July 10. However, relatively large confidence bounds preclude statistical differences among years. Exploitation rates for fish >250 mm fork length (minimum size until 2000) were 11.9%, 16.2%, 12.3%, and 13.0% for 2000 through 2003. Again, exploitation was highest in 2001, although the difference was not as great, and exploitation varied more among other years.

The increase in catch and exploitation in 2001 is at least partially explained by the environmental conditions that lead to the "heavy-up" (i.e., low river flow). Information collected since 1995 indicates that exploitation of northern pikeminnow (>250 mm) by the sport-reward fishery is highly correlated with river flow (mean gage height below Bonneville Dam) during the fishery (Figure 1). The analysis is limited to fish >250 mm to ensure consistency among years.

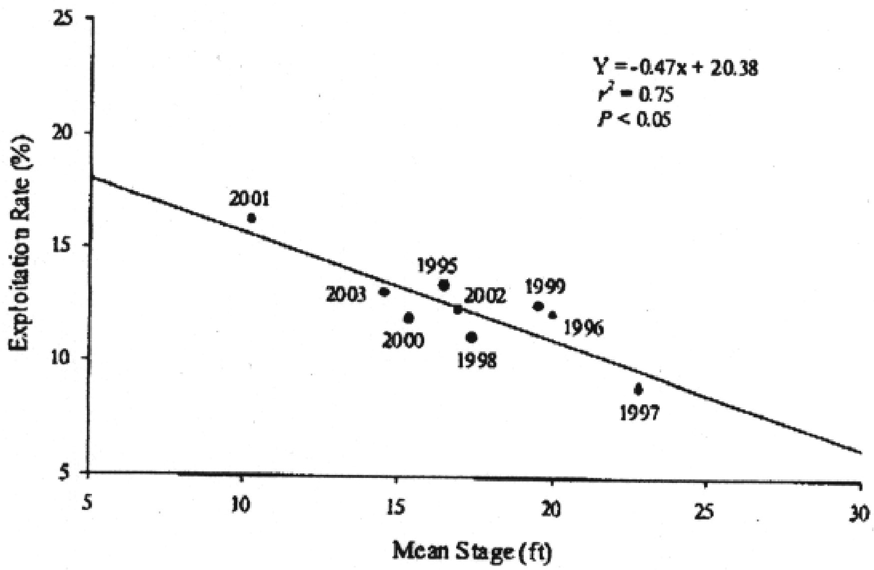

Figure 1. Relationship between sport-reward exploitation and mean gage height below Bonneville Dam during the fishery season, 1995-2003.

Although variation should be considered when using this information to make specific recommendations, it is apparent that differences in flow alone, and not increases in rewards, could account for exploitation in 2001 being approximately 3% higher than exploitation in 2000, 2002, and 2003 (observed differences in point estimates ranged from 3.2% to 4.3%). Exploitation rate in 2001 was slightly higher than would be predicted from the relationship (Figure 1); however, this is also true for 1995, 1996, and 1999.

As explained previously, the most important factor in changing the size and age structure of the northern pikeminnow population is exploitation rate, not total catch. Catch may be affected by variations in northern pikeminnow year-class strengths, but exploitation rate estimates are not. Catch totals also include northern pikeminnow caught illegally (e.g., out of the project area), but exploitation estimates do not. We have found that catch is not a reliable predictor of exploitation rate (Figure 2; $P > 0.05$).

Long-Term Trends in Seasonal Exploitation Rates and Catch

Benefits of the 2001 "heavy-up" are attributed to increased catch and exploitation rate after July 10, when rewards were increased. An examination of exploitation rates before and after July 10 for all years since 1995 does not support this argument. Although we found no apparent relationship between exploitation rates before and after July 10 (Figure 3; $P > 0.05$), exploitation after July 10 was always less than that before July 10, and the seasonal change in 2001 was similar to that in many other years. Exploitation after July 10 in 2001 appears much greater than would be expected based on 1998-2000 and 2002 data; however, the pattern of exploitation in 2001 is similar to that observed from 1995-97 and in 2003. Differences in flow among years with seasonal similarities in exploitation patterns (Figures 1 and 3) further exemplify the difficulty in attributing changes in exploitation to a particular cause.

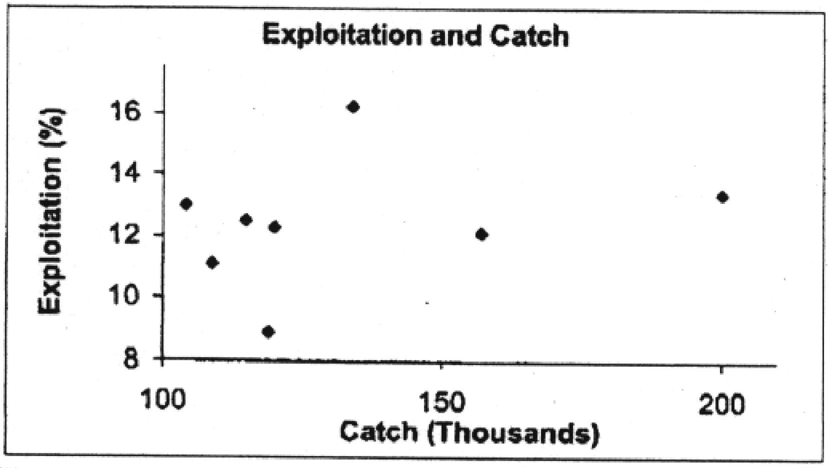

Figure 2. Relationship between catch of northern pikeminnow (>250 mm) and exploitation rate, 1995-2003.

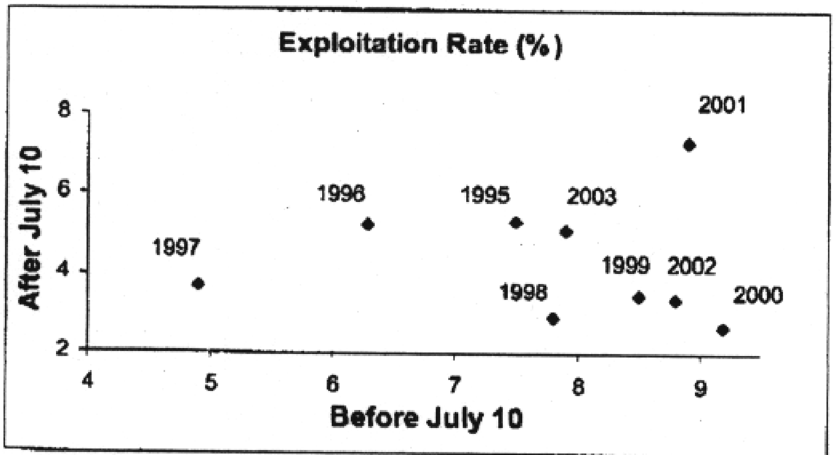

Figure 3. Relationship between exploitation rate on northern pikeminnow before and after July 10, 1995-2003. Although not included here, confidence limits around each point are relatively wide, and similar in proportion to those in Table 1.

We also found no significant relationship between catch of northern pikeminnow before and after July 10 (Figure 4; P > 0.05). Examination of the information indicates that the seasonal change in 2001 was similar to that in most other years. The relationship between catch before and after July 10 in 2001 was similar to that from all years except 1995 and 1997.

Variation in Exploitation Rate and Predation Estimates

An objective of the "heavy-up" is to increase exploitation rate on northern pikeminnow by 1 to 2 percent. Confidence limits around estimates of exploitation are much wider than this (Table 1), making it unlikely that such an increase can be detected with any confidence. Confidence limits for all years overlap, even when the point estimate for a year such as 2001 is compared to years of consistent exploitation such as 2000, 2002, and 2003.

The goal of the NPMP is to change the size (age) structure of the northern pikeminnow population to reduce the number of large, piscivorous individuals, and thereby decrease predation on juvenile salmonids. Evidence indicates that the size structure has been altered somewhat (Figure 5). Although reduced in number, large piscivourous northern pikeminnow are still present, indicating that substantial increases in exploitation may result in some further decreases in predation.

An increase of 1-2 percent is not substantial enough to realize any detectible reductions in predation. Results from a model developed by Friesen and Ward (1999) indicate that long-term (15 year duration) exploitation rates of 12%, with lower and upper bounds of 8% and 16% (observed bounds are actually greater than these) result in estimates of predation ranging from 60% to 87% of predation prior to implementation of the NPMP. Increasing exploitation to 13%, with corresponding bounds (8.7% to 17.3%) results in predation estimates of 58% to 86% of prior levels. Differences between the two estimates are indistinguishable.

Affects of a "Heavy-up" on Human Behavior

As mentioned previously, catch totals include northern pikeminnow caught illegally. As rewards increase, the incentive to harvest fish outside the project area and turn them in for rewards increases. The 2001 reward increase led to a large increase in angler fraud (Eric Winther, Washington Department of Fish and Wildlife, personal communication). Such fraud makes it difficult to assess the actual affect of increased rewards on the northern pikeminnow population within the project area.

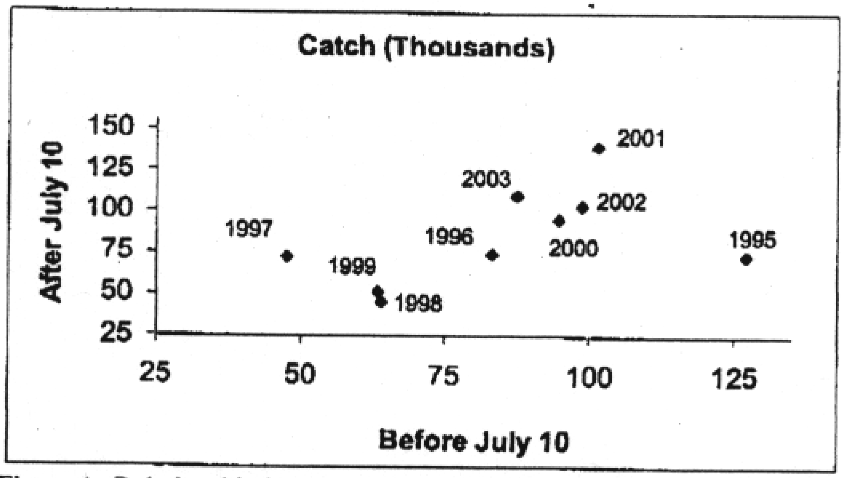

Figure 4. Relationship between catch of northern pikeminnow before and after July 10, 1995-2003.

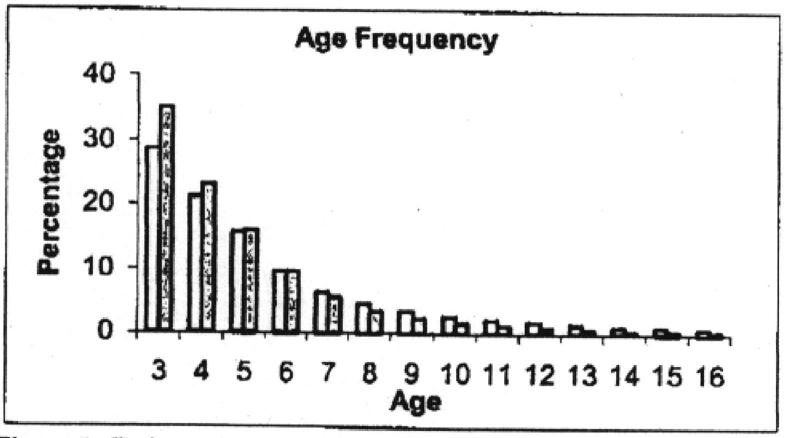

Figure 5. Estimated age structure of northern pikeminnow in the Columbia River before implementation of the NPMP (white bars) and

after sustained implementation (gray bars).

Direct Effects of Discontinuing Spill on Predation

Predation on juvenile salmonids by northern pikeminnow will likely increase in the absence of spill, adding to the number of salmonids required to be saved by any "offset" measure. Faler et al. (1988) found that northern pikeminnow in the tailrace below McNary Dam remained in protected shoreline areas when discharge rates were high (e.g., during spill), but moved close to the dam and the juvenile bypass outflow area when discharge rates were low. Trends in movement of northern pikeminnow were similar between short-term (short closures of the spillway) and long-term (spring flows vs. summer flows) changes in water velocity. Faler et al. (1988) noted that predation by northern pikeminnow at fish passage facilities may be reduced by providing high water velocity. Reducing predation in these near-dam areas is critical, because Ward et al. (1995) estimated that 33% of all predation by northern pikeminnow occurred in tailrace boat-restricted zones.

Laboratory findings (Mesa and Olson 1993) support the hypothesis that discharge and water velocity will affect predation by northern pikeminnow. Based on northern pikeminnow swimming performance, Mesa and Olson (1993) found that water velocities >100 cm/s may exclude or reduce predation by northern pikeminnow near Columbia River dams. High velocities also increase migration rates of juvenile salmonids near dams (Berggren and Filardo 1993), which may reduce encounter times between predators and prey.

Zimmerman and Ward (1999) discussed observed effects of spill on predation. They compared predation on juvenile salmonids by northern pikeminnow between pre-NPMP years (1990-92) and years after implementation of the NPMP (1994-96). Zimmerman and Ward (1999) speculated that large reductions in observed predation (44-91%) relative to reductions predicted by a model (14-38%; Friesen and Ward 1999) may be at least partly attributable to spill levels at dams. Total discharge and volume of water spilled averaged higher from 1994-96 than during 1990-92.

Any estimate of the actual number of juvenile salmonids lost that can be attributed to discontinuing summer spill is fraught with uncertainty. The following premises however, are based on peer-reviewed findings:

- The un-exploited northern pikeminnow population may have consumed approximately 16 million juvenile salmonids per year (Beamesderfer et al. 1996)
- The NPMP has resulted in an approximate 25% reduction in predation (Friesen and Ward 1999; 4 million smolts saved annually),
- Approximately 33% of predation occurs in near-dam tailrace areas (boat restricted

zones) during low-spill years (Ward et al. 1995)

- Information from Zimmerman and Ward (1999) indicates that spill may reduce this predation by at least 50%
- Predation is greater in the summer than spring (Ward et al. 1995; Zimmerman and Ward 1999)

Therefore, estimates of the number of salmonids that would be additionally consumed if summer spill was reduced could easily reach 1 million, and would likely not be offset by the relatively small increase in exploitation rate assumed in the offset proposal.

Offset Action 2- Smallmouth Bass Control

The objective of this offset is to decrease predation on juvenile salmonids through removal of smallmouth bass. It is hypothesized that large smallmouth bass (> 200 mm) may consume one juvenile salmon per day in some seasons and areas, and that control by removal is very feasible with sanction by fishery managers. Proposed methods for removal include agency electrofishing, a bass derby in Lower Granite Reservoir, and manipulation (short-term drawdown) of Lower Granite Reservoir. Success of these methods are potentially limited by (1) the biological benefits of removals (likelihood of decreasing predation), (2) feasibility of implementing active removals of a popular gamefish, and (3) logistics of manipulating a reservoir to control smallmouth bass. We limit our comments here to the biological benefits of removing smallmouth bass.

Background

Smallmouth bass are found throughout the lower Columbia and Snake rivers; however, smallmouth bass density is generally lowest below Bonneville Dam, intermediate in Columbia River reservoirs, and highest in Snake River reservoirs (Zimmerman and Parker 1995). Abundance in Columbia River reservoirs and below Bonneville Dam is far lower than abundance of northern pikeminnow (Beamesderfer and Rieman 1991; ODFW, unpublished data). Because of differences in abundance and consumption rates, predation on juvenile salmonids by smallmouth bass is minimal compared to predation by northern pikeminnow (Rieman et al. 1991; Vigg et al. 1991; Ward and Zimmerman 1999; Zimmerman 1999).

Abundance and Density

Beamesderfer and Rieman (1991) found that on average, abundance of smallmouth bass (>200 mm) was less than 40% that of northern pikeminnow (>250 mm) in John Day reservoir. Only in reservoirs of the Snake River, particularly Lower Granite and Little

Goose reservoirs, does abundance of smallmouth bass approach or exceed that of northern pikeminnow (Curet 1993; Zimmerman and Parker 1995; ODFW, unpublished data).

Consumption

A few studies have found smallmouth bass to be major predators of juvenile salmonids in the Columbia and Snake Rivers (Curet 1993; Tabor et al. 1993), but these are generally limited to localized areas. Comprehensive studies in the Columbia River basin indicate that smallmouth bass eat few juvenile salmonids relative to northern pikeminnow (Rieman et al. 1991; Ward and Zimmerman 1999; Zimmerman 1999). Results from Tabor et al. (1993) were limited to a small area of the Hanford Reach, and Curet (1993) studied predation in Lower Granite and Little Goose reservoirs, where smallmouth bass are very abundant. Ward and Zimmerman (1999) and Zimmerman (1999) collected data from numerous sites throughout the Columbia and Snake rivers, and Rieman et al. (1991) published information from an extensive multi-year study of John Day Reservoir. Consumption rates approaching or exceeding one juvenile salmonid per day were limited to times of peak migration in very few areas (Zimmerman 1999). Ward and Zimmerman (1999) found consumption of juvenile salmonids by smallmouth bass to be zero in 74 of 104 estimates. Consistent evidence of predation on juvenile salmonids was found only in the upper reach of Lower Granite Reservoir in spring, and in the forebay of John Day Reservoir in summer.

Smallmouth Bass Population Dynamics and Behavior

Unlike northern pikeminnow, smallmouth bass possess a number of characteristics that may further limit the benefits of a removal program. Smallmouth bass grow relatively quickly, are not especially long-lived, and become piscivorous at a young age (Ward and Zimmerman 1999). Salmonids are generally not the most important diet component for any size or age group of smallmouth bass (Zimmerman 1999). Smallmouth bass vulnerability to most fishing gears decreases with size (Beamesderfer and Rieman 1988), instead of increasing with size like northern pikeminnow.

Potential Benefits of Removing Smallmouth Bass

Removing smallmouth bass is not an efficient way to increase survival of juvenile salmonids. Relatively low abundance will make removals of large numbers difficult. Relatively low consumption rates result in the benefit per fish removed being minimal. Population dynamics and behavior of smallmouth bass further decrease the likelihood of removals resulting in increased survival of juvenile salmonids.

Offset Action 3- Commercial Harvest Reduction

The current harvest of summer-migrating stocks is about 70 percent of the level prior to ESA listing. As the State of Alaska notes in its recent letter to NOAA Fisheries, the impacts on fish passage and survival caused by spill reductions are directly contrary to the 1999 Pacific Salmon Treaty Habitat and Restoration Agreement. This agreement was designed to ensure "safe passage" for Columbia River salmon and obligates the U.S. and Canada "to use their best efforts to maintain and, as needed, improve safe passage of salmon to and from their natal streams." Efforts to reduce harvest further to make up for reductions in spill may be inconsistent with the agreement of the U.S. and Canada and compromise treaty-trust responsibilities of the federal government with Columbia River tribes.

The overall proposal is so vague that it is difficult to provide any sound technical analysis. The statement is made that "Determining the appropriate location to focus depends upon a number of policy, market, and technical considerations" but there is no is no discussion of these issues.

The proposal does not reflect any recognition of ongoing harvest management negotiation/litigation processes, specifically, the Pacific Salmon Treaty, *U.S. v. Oregon*, and *U.S v. Washington*.

The introduction states that the document includes a description of potential alternatives as well as estimates of survival or productivity benefits, costs and implementation requirements but none of these are discussed in the "reduce fishing" alternative.

It is stated that "if modifications to fisheries are designed to limit the impact to no more than 5% of the total catch then the benefit to Columbia River fall chinook escapement may range between 1,000 and 6,000 adults at an estimated value of $125,000-275,000." If they are stating that a 5% reduction in ocean catch will get between 1,000 and 6,000 adults to the Columbia at a cost of 125-275K then they are grossly under estimating the size and value of ocean fisheries. For instance, in 2003 SE Alaska troll accounted for 331,000 chinook. A 5% reduction would equate to 16,600 chinook, with an average weight of 18lbs, price of $1.75 (estimate), and the 2x multiplier, the value of the SE Alaska Troll fishery chinook catch would be $1,045,800. There would also be reduced landings of coho, pink, and chum salmon which in 2003 accounted for 1.2 million, 200,000, and 200,000 respectively. The main point is that the estimated catch reduction and value used in the calculation greatly underestimates the cost of commercial harvest reduction.

Offset Action 4- Avian Predation Research

This offset proposes to reduce caspian tern populations in the estuary from 8-9,000 to 2,500-4,500 pairs that is estimated to reduce predation of subyearling fall chinook by 350,000-500,000. It is premature to predict that the selected alternative from the draft EIS will entail reducing the tern colony to the objective of about 3,500 pairs. The draft EIS hasn't been released for public comment yet and won't be until this July. Even if the preferred alternative identified by the responsible agency (USFWS) were this management action, alternative management actions may end up being selected in the Final EIS and ROD that will not be finalized until February 2005.

Assuming that the ca. 3,500-pair target for the tern colony is adopted for 2005, it will likely take several more years for the colony size to be reduced that much. This is because the plaintiffs to the suit will almost certainly insist that alternative colony sites outside the Columbia River estuary be developed and occupied by terns before any reduction in tern nesting habitat on East Sand Island occurs. Sites where thousands of pairs of terns can be relocated have yet to be identified, and all options being discussed are beyond the Columbia River estuary. Relocating a large proportion of the East Sand Island tern colony to San Francisco Bay (one of the prime alternative areas for tern colonies) would be challenging and would likely take several years.

The current EIS only addresses predation by terns, and does not address predation by other bird predators (ex: gulls, pelicans, and cormorants); predation by these other species can be significant, for example there are an estimated 10,000 brown pelicans on East Sand Island alone. Predation by these species may exceed that estimated for terns and we have no real basis for assuming that reducing the tern population will provide any net benefit to outmigrating smolts overall due to likely compensation by other predators.

The $300k mentioned in the planning document is the amount that BPA has allocated for avian predation RM&E in 2004. This is 55% down from BPA's allocation of $663k for avian predation RM&E in each of 2003 and 2002, but better than the $0k that the NWPCC recommended for avian predation support from BPA in 2004. The $300k is not to cover costs of any management action to reduce tern consumption of smolts in the estuary, because the Final EIS and ROD are required before any management action is allowable. The Corps has been asked to make up the difference in BPA's support for the avian predation project in 2004, and we recently learned that the Corps is likely to comply.

Offset Action 5- Pile Dike Removal

Very little is known about the effects of potential pile dike removal between RM 52 and RM 136 on cormorant predation of juvenile fall chinook. This stretch of the river (from about the mouth of the Clatskanie River up to Multnomah Falls) has no known significant breeding colonies of piscivorous waterbirds, so current research does not monitor foraging behavior of cormorants in this reach. Anecdotal observations along this stretch indicate that double-crested cormorants do use this stretch for foraging, do use pile dikes as perches between foraging bouts, and likely catch and consume some juvenile fall chinook smolts along this stretch of the Columbia River. But whether the removal of pile dikes will cause any measurable reduction in smolt consumption along this stretch is highly uncertain; pile dike removal as a management action has been question even near the large breeding colonies such as on East Sand Island at RM 5. At RM 52 - 136, where no known cormorant colonies exist, it seems unlikely that pile dike removal would provide appreciable mitigation for reduction in summer spill; however there are no data to document cormorant use of pile dikes on this stretch of the river during the fall chinook outmigration, or any other time of year.

Offset Action 6- Anti-Stranding Flow Fluctuation Limits in the Hanford Reach

If adopted, the proposed Hanford Reach Fall Chinook Protection Program will lead to an increase in the survival of juvenile fall chinook in the Hanford Reach and a corresponding increase in adult returns; especially when compared to pre-protection plan years of 1998 and earlier. However, the estimated benefits from the program (10,972,192 smolts and 56,428 adults) are grossly overestimated.

It is not reasonable to use 1998 as the "baseline" to determine potential benefits for the program; the 20.23% mortality used for 1998 lacks validity since the estimate is based on very limited sampling unlike estimates beginning in 1999 that are based on standardized sampling protocols by the Washington Department of Fish and Wildlife in the 15.7 km index reach (reach wide estimates will become available beginning 2003). Additionally, 1998 is not representative of future operations without fluctuation limits because flows during fry emergence (April-May) in 1998 were historically low due to emergency drumgate (spillway) repairs at Grand Coulee Dam that made fry extremely vulnerable to flow fluctuations (fry entrapment at a given flow fluctuation is inversely related to flow with higher entrapment at lower flows). As discussed (and corroborated by estimates by WDFW), fry mortality has been very low (.37-.77% average 1999-2003 dependent on conversion assumptions, Tables 2 and 3) since 1998 and there is no expectation that this level of protection will not be provided in the future.

Aside from what is assumed as potential benefit of the program in terms of reduced fry mortality, the conversion factors used in the analysis (primarily egg-fry survival) would greatly overestimate effects to smolt production and subsequent adult returns of fall chinook to the Hanford Reach. WDFW (Table 1) showed that based on actual adult escapement data for 1998-2003, and using the 63.2% egg-fry and 75% fry-smolt survival estimates used in the analysis, that the estimated number of Hanford reach wild smolt estimates for these years (26 to 52 million) would exceed the McNary Passage Index (8-11 million) by nearly 500% not considering the 12 million hatchery fish released from Prosser, Priest, and Ringold hatcheries that are part of the McNary index. A 30% egg-fry survival rate used by WDFW may provide more reasonable estimates, but even that appears to overestimate actual smolts indexed at McNary Dam. WDFW further showed that the estimated adult returns (Tables 4 and 5) derived from survival rates used in the analysis would predict an adult return of 147,194 in 2003 or >150% actual escapements observed for 2003 (89,312).

Table 1. Potential fall Chinook egg, fry, and smolt production in the Hanford Reach, subyearling hatchery releases, and McNary subyearling passage indices, 1998 – 2004.

Emergence Year	2004	2003	2002	2001	2000	1999	1998
Adult Fall Chinook Escapement	89.312	69.117	44,140	36,027	27,012	29,410	34.007
Female (%)	50.9%	40.4%	36.5%	54%	46%	50%	50%
Fecundity	4,422	4.003	4.418	4.794	4,371	4.200	4,420
# of spawning females	45,460	27,923	16,111	19,455	12,426	14,705	17,004
Potential eggs	201.023.271	111,776,842	71.178,840	93.265,257	54,311.948	61,761.000	75,155,470
Egg Retention	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
Total eggs deposited	200,018,155	111.217,958	70,822.946	92,798.930	54,040.388	61.452,195	74,779.693
Egg to fry survival @ 30%	60,005.446	33,365,387	21,246,884	27,839,679	16,212,116	18,435,659	22,433,908
Egg to Fry survival @ 63.2%	126,011,437	70,067,313	44,618,456	58,463,326	34,045,445	38.714,883	47,111.206
Fry to Smolt survival @ 75%	45,004.085	25,024,040	15,935.163	20,879,759	12.159,087	13,826,744	16,825.431
Fry to Smolt survival @ 75%	94,508.578	52,550,485	33,463.842	43,847,495	25,534.083	29,036,162	35,333,405
Passage Index at McNary		10,561,371*	8,372,688	10.782,663	10,667,690	7,643,679	11,428.630
Hatchery Releases	12,150.000	12,255,089	10,913.482	11,976.344	12,293.934	11,870.800	11,924.206

Table 2. Mean river flows and loss estimates of juvenile fall chinook salmon to stranding and entrapment for a 15.7 km (584.5-600.2 Rkm) section of the Hanford Reach of the Columbia River from 1999 to 2002.

Year	Mean Flows (kcfs) March 1 to June 30 (Range)	Mean Chinook Mortalities (±1.96 S.E.)	Mean Revised Chinook Mortalities[1] (±1.96 S.E.)	Mean Chinook at Risk (±1.96 S.E.)
2003	124.7	154.853	154,853	164,643
	(39.9 to 260.9)	(83,903 to 225,802)	(83,903 to 225,802)	(91,093 to 238,192)
2002	145.0	67.409	70,903	144.249
	(50.8 to 304.4)	(28,623 to 106,195)	(31,517 to 110.288)	(28,813 to 259,685)
2001	77.5	2,013,638	2,013,638	2,013,638
	(37.5 to 206.4)	(-746,334 to 4,773,611)	(-746,334 to 4,773,611)	(-746,334 to 4,773,611)
2000	142.6	45,487	192,824	199,534
	(62.1 to 293.2)	(12,866 to 78,108)	(-70,865 to 456,514)	(-64,234 to 463,302)
1999	160.5	93.943	NA[2]	320.650
	(61.9 to 261.3)	(21,393 to 166.493)		(-54.006 to 695.307)

[1] Entrapments were revisited the next day to determine if fish would have died from drainage of entrapments or lethal temperatures (>24oC).
[2] Entrapments were not revisited in 1999.

Table 3. Hanford Reach fall Chinook fry production and mortality estimate (study area only) based on egg to fry survival rates of 30% and 60%, 1999-2003.

	2003	2002	2001	2000	1999	
Fry Production						
Egg to fry survival @ 30%	33,365,387	21,246,884	27,839,679	16,212,116	18,435,659	
Egg to Fry survival @ 63.2%	70,067,313	44,618,456	58,463,326	34,045,445	38,714,883	
Mortality Estimate	154,853	70,903	2,013,638	192,824	199,534	
Minimum Mortality in Study Area (%)						Mean[1]
Egg to fry survival @ 30%	0.46%	0.33%	7.23%	1.19%	1.08%	0.77%
Egg to Fry survival @ 63.2%	0.22%	0.16%	3.44%	0.57%	0.52%	0.37%

[1] Mean does not include 2002 mortality

Table 4. Expected adult returns to the Hanford Reach based on Offset 6 Rates for smolt survival and a smolt to adult return rate of 0.005.

	Age 2	Age 3	Age 4	Age 5	Age 6	Total
Natural Return						
1999	**4,770**					4,770
2000	3,920	**23,143**				27,063
2001	3,447	19,019	**85,507**			107,973
2002	5,919	16,725	70,268	**62,187**		155,099
2003	4,518	28,720	61,792	51,104	**1,060**	147,194
2004	7,094	21,919	106,111	44,940	871	180,935
Hatchery Returns						
1999	**1,610**					1,610
2000	1,603	**7,810**				9,413
2001	1,660	7,775	**28,857**			38,292
2002	1,617	8,053	28,727	**20,987**		59,383
2003	1,473	7,845	29,751	20,893	**358**	60,319
2004	1,654	7,148	28,983	21,637	356	59,779

Bold indicates 1997 Brood year, 1998 outmigration

Table 5. Age composition of Hanford natural spawning population, 1997-2002.

Year	Age 2	Age 3	Age 4	Age 5	Age 6
2002	1.2	16.2	60.5	22.1	0.1
2001	5.8	21	50.9	21	1.3
2000	3.2	7.4	36.1	53.3	0
1999	3.2	12.3	65.8	17.5	1.3
1998	1.8	18.6	13.1	65.6	1
1997	1.1	2.9	64	31.8	0.2
Mean	2.7	13.1	48.4	35.2	0.6

References

Beamesderfer, R. C., and B. E. Rieman. 1988. Size selectivity and bias in estimates of population statistics of smallmouth bass, walleye, and northern squawfish in a Columbia River reservoir. North American Journal of Fisheries Management 8:505-510.

Beamesderfer, R. C., and B. E. Rieman. 1991. Abundance and distribution of northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:439-447.

Beamesderfer, R. C. P., D. L. Ward, and A. A. Nigro. 1996. Evaluation of the biological basis for a predator control program on northern squawfish (*Ptychocheilus oregonensis*) in the Columbia and Snake rivers. Canadian Journal of Fisheries and Aquatic Sciences 53:2898-2908.

Berggren, T. J., and M. J. Filardo. 1993. An analysis of variables influencing the migration of juvenile salmonids in the Columbia River basin. North American Journal of Fisheries Management 13:48-63.

Bouwes, N. 2004. Review of the Bonneville Power Adminstration's analysis of the biological impacts of alternative summer spill operations. Submitted to the Columbia Basin Fish and Wildlife Authority, January 29, 2004.

Curet, T. S. 1993. Habitat use, food habits, and the influence of predation on subyearling Chinook salmon in Lower Granite and Little Goose reservoirs, Washington. Master's Thesis. University of Idaho, Moscow.

Faler, M. P., L. M. Miller, and K. I. Welke. 1988. Effects of variation in flow on distributions of northern squawfish in the Columbia River below McNary Dam. North American Journal of Fisheries Management 8:30-35.

Friesen, T. A., and D. L. Ward. 1999. Management of northern pikeminnow and implications for juvenile salmonid survival in the lower Columbia and Snake rivers. North American Journal of Fisheries Management 19:406-420.

Joint Technical Staff Memorandum 2001a. Comments of the Columbia River Inter-tribal Fish Commission, U.S. Fish and Wildlife Service, Washington Department of Fish and Wildlife, Idaho Department of Fish and Wildlife, and Nez Perce Tribe on the Northwest Power Planning Council's "Recommendations on 2001 Federal Columbia River Power System Operations and Fish Survival", dated April 5, 2001. Submitted April 20, 2001.

Joint Technical Staff Memorandum. 2001b. Comments of the U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Columbia River Inter-tribal Fish Commission, and Idaho Department of Fish and Game on the Northwest Power Planning Council's "Effects of 2001 Mid-Columbia Hydropower Operations on Fish: Addendum to the Federal Columbia River Power System Issue Paper Council Document 2001-9, dated April 30, 2001. Submitted May 7, 2001.

Joint Technical Staff Memorandum 2001c. Comments of the Columbia River Inter-tribal Fish Commission, Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife on the Northwest Power Planning Council's Issue Paper "Analysis of Federal Columbia River Power System Operations on Fish Survival during Summer 2001" dated June 13, 2001. Submitted June 21, 2001.

Joint Technical Staff Memorandum 2003. Comments of the U.S. Fish and Wildlife Service, Columbia River Inter-tribal Fish Commission, Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, National Marine Fisheries Service, and Washington Department of Fish and Wildlife on the Northwest Power Planning Council's staff analysis on Hydrosystem Cost vs Benefit of Spill analysis. Submitted June 13, 2003.

Knutsen, C. J., and D. L. Ward. 1999. Biological characteristics of northern pikeminnow in the lower Columbia and Snake rivers before and after sustained exploitation. Transactions of the American Fisheries Society 128:1008-1019.

Mesa, M. G., and T. M. Olson. 1993. Prolonged swimming performance of northern squawfish. Transactions of the American Fisheries Society 122:1104-1110.

NOAA. 2003. Technical Memorandum "Effects of the Federal Columbia River Power System on Salmon Populations" by Williams et. al. Preliminary draft dated December 21. 2003. NOAA Fisheries, Seattle, WA.

ODFW. 2001. Comments of the Oregon Department of Fish and Wildlife on the Northwest Power Planning Council's "Recommendations on 2001 Federal Columbia River Power System Operations and Fish Survival". Submitted April

20, 2001. Salem, OR.

ODFW and WDFW. 2004. Joint Staff Report Concerning Commercial Seasons for Spring Chinook, Steelhead, Sturgeon, Shad, Smelt, and Other Species and Miscellaneous Regulations for 2004. Joint Columbia River Management Staff.

Petersen, J. H. 1994. Importance of spatial pattern in estimating predation on juvenile salmonids in the Columbia River. Transactions of the American Fisheries Society 123:924-930.

Petersen, J. H., D. M. Gadomski, and T. P. Poe. 1994. Differential predation by northern squawfish (*Ptychocheilus oregonensis*) on live and dead juvenile salmonids in the Bonneville Dam tailrace (Columbia River). Canadian Journal of Fisheries and Aquatic Sciences 51:1197-1204.

Rieman, B. E., R. C. Beamesderfer, S. Vigg, and T. P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:448-458.

Tabor, R. A., R. S. Shively, and T. P. Poe. 1993. Predation on juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. North American Journal of Fisheries Management 13:831-838.

Vigg, S., T. P. Poe, L. A. Prendergast, and H. C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

Ward, D. L., J. H. Petersen, and J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River, and in the Lower Snake River. Transactions of the American Fisheries Society 124:321-334.

Ward, D. L., and M. P. Zimmerman. 1999. Response of smallmouth bass to sustained removals of northern pikeminnow in the lower Columbia and Snake rivers. Transactions of the American Fisheries Society 128:1020-1035.

Zimmerman, M. P., and R. M. Parker. 1995. Relative density and distribution of smallmouth bass, channel catfish, and walleye in the lower Columbia and Snake rivers. Northwest Science 69:19-28.

Zimmerman, M. P., and D. L. Ward. 1999. Index of predation on juvenile salmonids by northern pikeminnow in the lower Columbia River basin from 1994-96. Transactions of the American Fisheries Society 128:995-1007.

Zimmerman, M. P. 1999. Food habits of smallmouth bass, walleyes, and northern pikeminnow in the lower Columbia River Basin during outmigration of juvenile anadromous salmonids. Transactions of the American Fisheries Society 128:1036-1054.

Zimmerman, M. P., T. A. Friesen, D. L. Ward, and H. K. Takata. 2000. Development of a systemwide predator control program: indexing and fisheries evaluation. Oregon Department of Fish and Wildlife. 1999 Annual Report to Bonneville Power Administration, Portland, Oregon.