Project ID 199702400, "Avian Predation on Juvenile Salmonids in the Lower Columbia River": Response to ISRP comments provided by the project sponsors (OSU/USGS/CRITFC/RTR).

Comment 1: "Although this proposal does not dwell on the court case, there was impetus from it toward the directions this proposal now takes for looking at other bird predators of salmonids (to put terns into better context) and other potential nesting sites for research and management attention (upriver and coastal). The budget expanded along with the court-mandated tasks, as described in Part 1. Why BPA should have to pay for these studies is unclear."

A recent (April 2, 2002) settlement agreement between the plaintiffs (National Audubon Society, Defenders of Wildlife, Seattle Audubon Society, and American Bird Conservancy) and defendants (U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service) requires that the defendants complete a long-term management plan and EIS. This management plan and EIS are restricted to Caspian terns nesting in the Columbia River estuary; it does not apply to either Caspian terns nesting outside the estuary or other bird predators of salmonids. Although data collected as part of our BPA funded work will most certainly be used in these court-mandated studies, lead responsibility and funding for the development of a Caspian tern management plan and EIS for the Columbia River estuary will not come from BPA or our research team.

Our studies of other piscivorous waterbirds (i.e., double-crested cormorants, white pelicans, various gull species) within the Columbia River basin are ongoing and are not related to the recent settlement agreement. The expansion of our proposed project budget for 2003 ($713,000) over the previous years budget ($663,000) is largely due to inflation and the implementation of new and expanded research tasks. New tasks include: (1) a pilot study of predation on juvenile salmonids in net pens (Task 1.4), (2) a radio-telemetry study of foraging behavior by Caspian terns nesting at the Crescent Island colony (Task 1.2), (3) investigations of avian predation at lower Columbia River dams (Task 3.3), and (4) use of genetic markers for species identification of salmonids consumed by birds (a new task not included in original proposal reviewed by the ISRP; see below).

Comment 2: "A key question however is the continued relevance and value of the program to the goals of saving salmon in the FCRPS. This five-year program is clearly in its mature if not senescent stages as far as benefits to the FCRPS system…..Research in the future should be more focused on experiments that would primarily assist salmonid recovery in the FCRPS…..This project would be more valuable to the FCRPS with more focus on the salmon aspect of the problem….Should we rethink the artificial production and release strategy rather than predator removal strategy? Other parts of the monitoring and research proposal tasks seem to be on details and data not directly useful or have large payoffs for the FCRPS management objectives."

As a result of relocating the Rice Island tern colony to East Sand Island, smolt consumption by terns nesting in the estuary was reduced by 4.4 (38%) and 5.9 (50%) million smolts in 2000 and 2001,

respectively, as compared to the 1999 consumption estimate (CBR 2002). Preliminary results in 2002 indicate that similar reductions in smolt consumption by terns were achieved, as compared to the 1999 estimate (CBR 2002). Caspian terns nesting on East Sand Island in 2001 still consumed an estimated 5.9 million smolts (CBR 2002), with some ESA-listed stocks still suffering significant losses to tern predation (Ryan et al. 2001a, Ryan et al. 2001b). To achieve further reductions in consumption of juvenile salmonids by Caspian terns in the estuary it will likely be necessary to relocate a portion of the East Sand Island colony to alternative sites outside the estuary. This approach has received the support in principle of regional fish and wildlife managers and the plaintiffs in the recent court case (see above). The research that we propose for 2003-2005 is designed to guide and monitor future management actions aimed at further reductions in smolt consumption by Caspian terns, as well as potential management of other piscivorous waterbirds (e.g., double-crested cormorants), as warranted.

The ISRP suggests that the proposed research, and perhaps the current tern management efforts, have matured to the point that they will have limited usefulness to the FCRPS system in the future. Although we agree with the ISRP that future research should place additional emphasis on the "salmon aspect of the problem"(see below), we disagree that the current proposal fails to provide prospects for significant additional benefits to salmon recovery in the FCRPS beyond those that have already been achieved. The perception of the ISRP is understandable given the effect of the previous court injunction has had on tern management in the estuary. The recent settlement agreement, however, has paved the way for the development of a long-term Caspian Tern Management Plan and further reductions in smolt consumption by terns in the Columbia River estuary[1]. This plan will likely include management initiatives aimed at (1) dispersing some of the terns nesting on East Sand Island to restored colony sites outside the estuary and (2) reducing the vulnerability of smolts to predation by terns and other avian predators by modifying fish management (e.g., changes in hatchery and/or transportation practices).

Currently, Caspian terns nesting in the Columbia River estuary are the only pisicivorous waterbirds under active management to reduce losses of juvenile salmonids to bird predators. Caspian terns in the estuary are not the only fish-eating birds, however, that have an impact on survival of juvenile salmonids in the Columbia River basin. We anticipate that the next phase of management of avian predation in the region will involve other species, most likely double-crested cormorants nesting in the Columbia River estuary. Although young salmon are not as prevalent in the diet of double-crested cormorants as compared to the Caspian terns that formerly nested on Rice Island (Collis et al. 2002), cormorants nesting on East Sand Island consume about 4 – 6 million smolts annually, or roughly 4 – 6% of all young salmon that reached the estuary each year (D. E. Lyons, Oregon State University, unpublished data). Like terns, cormorants are using anthropogenic habitat for nesting in the Columbia River estuary (Collis et al. 2002) and their numbers are increasing (C. Anderson, Oregon State University, unpublished data). Cormorants use pile dikes throughout the estuary as perching and roosting sites while foraging on juvenile salmonids, especially near Rice Island (Collis et al. 2001b). Given the magnitude of smolt losses to cormorants in the estuary and the fact that cormorant predation is exacerbated by

[1] Despite the reduction in smolt consumption associated with relocation of the tern colony from Rice Island to East Sand Island, Caspian terns continue to consume about 6 million juvenile salmonids in the Columbia River estuary annually (CBR 2002). Based on smolt PIT tags recovered from the East Sand Island tern colony in 2000 and 2001 (Ryan et al. 2001a, Ryan et al. 2001b), some ESA-listed salmonid stocks from the Columbia River basin continue to suffer significant losses to tern predation.

anthropogenic perturbations to the Columbia River estuary, management of cormorant predation on juvenile salmonids may be warranted. As part of the research proposed for 2003-2005, we will work with regional fish and wildlife managers to test and implement management initiatives to reduce cormorant predation on juvenile salmonids from the Columbia River basin. These initiatives may include, but are not limited to, (1) testing social attraction techniques as a method to relocate nesting cormorants from East Sand Island to alternative nesting locations and (2) testing methods to protect smolts where they may be especially vulnerable to cormorant predation (e.g., near pile dikes).

We agree with the ISRP that the solution to the bird predation problem does not lie solely in management of the birds themselves. We must also look at differences in vulnerability to predation of various salmonid stocks and investigate the cause(s) for those differences. We have proposed numerous research tasks to address these questions. First, the research on smolt PIT tags recovered from piscivorous waterbird colonies that we have done previously (Collis et al. 2001a) and propose to do in the current study (Task 1.4[2]) will address the relative vulnerability of different groups of salmonids to predation. These results, coupled with information on fish origin, health, and passage history, will be used to help identify the potential causes for differences in vulnerability to avian predation, including testing predictions of the delayed mortality hypothesis. Second, we will assess the condition, contaminant burdens, and health status of salmonid smolts consumed by piscivorous waterbirds to compare with the condition of smolts caught in river. These analyses will enable us to test hypotheses regarding the compensatory/additive nature of avian predation. Third, we are proposing a new task (based on the ISRP's comments) to use genetic markers to identify the salmonid species and stocks, if feasible, present in stomach content samples from piscivorous waterbirds. Fourth, we will test the feasibility of experiments using juvenile salmonids in net pens anchored near Caspian tern colonies to test hypotheses regarding the cause of differences in vulnerability among salmonids (see Task 1.4). Further, net pens offer the potential for providing terns with an alternative food source, thereby reducing their reliance on in-river migrants. Finally, the proposed research addresses the growing concern surrounding avian predation at mainstem Columbia River dams (NMFS 2000). As part of this work, we will monitor the numbers of piscivorous waterbirds and their prey consumption rates at mainstem dams and evaluate how dam operations affect predation rates (Task 3.3). With this information, fisheries managers will be able to modify fish management practices to reduce the impacts of avian predation on the survival of juvenile salmonids from the Columbia River basin, as warranted.

In summary, while this research project has identified, helped implement, and monitored management actions that have reduced mortality of juvenile salmonids in the Columbia River estuary by about 6 million smolts annually, the project has the potential to reduce mortality by several million more smolts annually through bird management alone. By identifying factors that enhance vulnerability of smolts to avian predators, management of salmonids and the FCRPS may further reduce losses to avian predators.

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[2] This work was described in our 2003 proposal as follows: "Previous and on-going studies of smolt PIT tags recovered on Caspian tern colonies in the lower Columbia River indicate there is high variability among salmonid stocks in vulnerability to tern predation (Collis et al. 2001a). Further analysis of smolt PIT tags recovered from various Caspian tern colonies will be used to assess the relative vulnerability of various groups of salmonids to tern predation. Factors that will be examined for effects on vulnerability to tern predation include out-migration history (e.g., whether the smolt was transported and, if so, where it was picked up for transportation; at how many dams was the smolt detected in the juvenile bypass facility)…."

Comment 3: "Much of the future work however appears aimed more at preserving terns (see court comment above) than at preventing further degradation of salmonids due to predation…..Much of the proposed new tern research is aimed at assisting the growth, development and monitoring of new tern colonies elsewhere, which seems counterproductive to salmon recovery."

The atmosphere surrounding the management of birds for the sake of salmon is politically charged and highly contentious. Over the past several years lawsuits have been filed regarding the management of Caspian terns in the Columbia River estuary. On one side, "pro-fish" groups have argued in court that the federal management agencies are not moving fast enough or going far enough to manage avian predators on salmonids in the estuary. On the other side, "pro-bird" groups have argued that efforts to manage avian predators are moving too fast, and that more research is needed before we can proceed with full-scale management initiatives. In either case, basic research on the magnitude of avian predation on juvenile salmonids and the impacts of management on the long-term viability of bird populations is viewed as imperative in resolving differences among stakeholder groups as to the best solution to the problem.

As part of the 1994 Columbia Basin Fish and Wildlife Program (NPPC 1994), Bonneville Power Administration and other agencies have been charged with monitoring and assessing bird predation on juvenile salmonids in lower Columbia and Snake river reservoirs (5.7B.20) and in the Columbia River estuary (5.7B.21), and identifying non-lethal methods for control of piscivorous waterbird populations posing a problem to salmon survival (5.7B.22). Clearly, these directives sought a solution to the bird predation problem that avoided lethal take and minimized impacts to the bird populations themselves. This concern is shared by many regional fish and wildife management agencies and stakeholder groups, as evidenced by the principles and measures laid out in the recent settlement agreement (see above). Much of our recent research, including the research proposed in FY 2003, is focused on monitoring and evaluating the effects of management inititaives on both smolt consumption rates and the affected bird populations. This information is critical in evaluating the effectiveness of management, including its effect on the long-term viability of bird populations. We would disagree with the ISRP that the current proposal is "aimed more at preserving terns…..than at preventing further degradation of salmonids due to predation". Instead, the focus of the proposed work is to continue to collect the information needed to develop, evaluate, and improve predation management initiatives aimed at improving smolt survival, while at the same time minimizing the impacts to bird populations. Any new research with the goal of assisting the growth, development, and monitoring of new tern colonies elsewhere is designed to provide alternative nesting habitat for Caspian terns currently nesting on East Sand Island. By providing less tern habitat at the East Sand Island colony site, the size of the colony can be reduced thereby shifting at least part of the East Sand Island tern colony to other restored colony sites outside the estuary. This would clearly provide further reductions in tern predation on juvenile salmonids in the Columbia River estuary.

Comment 4: "Additionally, it is less clear how details about bioenergetics of tern diet, stable isotope ratios studies, fatty acid signatures, and contaminant levels may be valuable to reducing tern impact on salmon."

The four methodologies listed above all provide important information relevant to assessing the diets of avian predators and the magnitude of avian predation on juvenile salmonids. Bioenergetic models are a key technique used to accurately estimate the numbers of various species of juvenile salmonids consumed by Caspian terns (Roby et al, in review a) and other avian predators (D. E. Lyons, Oregon State University, unpublished data). Without information on the bioenergetics of piscivorous waterbird diets, these models can not yield reliable estimates of smolts consumed. Stable isotope ratios and fatty acid signatures are relatively new techniques for integrating diet composition over extended time periods. By using these two techniques in conjunction with standard stomach content analysis, it is potentially possible to gain more insight into the reliance of individual predators on juvenile salmonids as a food source over a period of weeks or months. Stable isotope ratios can reveal the trophic level at which a predator is feeding and the predator's reliance on marine or freshwater prey (Thompson and Furness 1995, Sydeman et al. 1997). Fatty acid signatures reveal the fatty acid composition of the prey (Racot et al. 1998, Surai et al. 2001), which is likely to be markedly different among hatchery-raised and wild salmonid stocks. Contaminants can also be used as dietary markers to help identify diet composition of predators (Stewart et al. 1997). By comparing contaminant burdens of avian predators that consume mostly salmonids versus those that consume few salmonids, and by comparing contaminants in avian predators that forage on salmonids in the estuary versus further up-river, it is possible to assess the extent and timing of contaminant exposure in out-migrating smolts.

We agree with the ISRP that future work on this project should focus not only on bird management but also on the "salmon aspect of the problem" (see above). In addition to the many fish-oriented tasks in our proposal (see above), we propose to divert some funding allocated to other research tasks (e.g., measuring contaminant burdens, stable isotope ratios, and fatty acid signatures) to the new task of identifying species and, when possible, stocks that are being consumed by piscivorous waterbirds using genetic markers. Currently, we have been identifying prey fish consumed by birds using morphological characteristics (i.e., visual identification of intact fish and diagostic bones). These methods limit our ability to identify specific salmonid species and stocks, information important in determining stock- and species-specific consumption rates and relative vulnerability. Analysis of PIT tags recovered from bird colonies provide a means to assess these questions; however, not all stocks are PIT tagged including virtually all the stocks originating from subbasins below Bonneville Dam, and the recovery of PIT tags from some bird colonies has been problematic (e.g., double-crested cormorants nesting among rocks on East Sand Island or in trees on Foundation Island). We will accomplish this new species/stock identification task within the budget originally proposed (no additional funding will be requested).

Comment 5: "Like northern pikeminnow management, it would be good to know about more direct consequences and cost:benefits of the program on adult return rates….Is there a correlation between the tern relocation effort and this year's return rate of steelhead?"

Correlating trends in adult returns and any particular management activity is problematic due to confounding factors such as other recovery activities or variable ocean conditions. In a manuscript

currently in review (Roby et al. in review a), we used a matrix population model framework developed by NMFS (Kareiva et al. 2000, McClure et al. 2000), to assess the potential improvement in the average annual population growth rate (λ) due to reductions in tern predation associated with the tern colony relocation. Assuming tern predation is neither entirely additive nor entirely compensatory but instead somewhere in between (we assumed 50% additive), and assuming the steelhead mortality rate due to tern predation declined 50% with tern colony relocation (consistent with diet composition changes [Roby et al. 2002] and preliminary bioenergetic calculations of number of steelhead consumed [www.columbiabirdresearch.org]), we estimated that λ likely increased 0.85% (0-1.7%) on average, for listed steelhead ESUs. This improvement in λ is less than what is estimated is needed to recover most listed Columbia River salmonid ESUs ($\Delta\lambda$ = 5-15%, NMFS 2000), and less than the hypothesized improvement for other potential recovery activities (e.g., hydropower operational changes: $\Delta\lambda$ = 3-15% [NMFS 2000], etc.), but perhaps more than some other documented improvements in juvenile survival (northern pikeminnow: $\Delta\lambda$ = 0.4 – 0.7% [Ward et al. 1995, Beamesderfer et al. 1996, Roby et al. in review a]). These kinds of analyses are ongoing (as part of our research program) and will be incorporated into future manuscripts submitted for publication in the peer-reviewed literature.

Comment 6: "Several important questions that seem relevant to the FCRPS are the relationship of predation loss to juveniles that (1) migrated in river or (2) were transported near the estuary in a barge. One important strategy that could reduce tern predation is the timing, location and release patterns of smolts from barges in the estuary. For example, if terns are daylight feeding birds, would release at night improve predator avoidance? Or, would release closer to the ocean reduce bird predation without other impacts to the SAR rate…..Some further management options and experiments that relate to how transported fish are released from barges (where, when, etc) may be useful to the FCRPS…..Could the recent upsurge in bird predators be a result of….barging and mass releases?….One program option would be to alter the project (and reduce funding) to refine how better to manage improvement of……transport and release programs as they relate to avian predation and other factors of smolt survival. "

At present, the relationships between losses to avian predators and migration history are unclear. We investigated the relative vulnerability of transported vs. in-river migrating steelhead and yearling chinook using PIT tags recovered from the Rice Island tern colony in 1997 and 1998 (Collis et al. 1999). In 1998, PIT-tagged yearling chinook smolts that were transported (barged or trucked around dams) were more vulnerable to tern predation compared to non-transported smolts. In contrast, PIT-tagged steelhead that were transported were less susceptible to predation by terns as compared to non-transported steelhead in 1998. In 1997, there was no difference in the prevalence of transported and non-transported chinook or steelhead smolts in the diet of terns nesting on Rice Island. Subsequent PIT tag analysis conducted by NMFS (Ryan et al. 2001), suggested that transported chinook salmon and steelhead were "generally less vulnerable" than their in-river migrating counterparts. These results suggest that predation risks associated migration history (i.e., transported versus non-transported) vary by species and migration year.

Studies have shown that there are species differences in the affects of transportation on smolt quality (Congleton et al. 2000) and that different condition factors (i.e., levels of disease, stress, and

smoltification) affect predator avoidance and survival of smolts (Mesa 1994, Handeland et al. 1996, Mesa et al. 1998, Schreck and Stahl 1999). Congleton et al. (2000) investigated stressors associated with transportation in yearling chinook and steelhead smolts. Stress levels in yearling chinook were positively correlated with steelhead loading density in the barge or truck, whereas stress levels in steelhead were not correlated with loading densities. Steelhead are generally larger and more aggressive than yearling chinook. Due to agonistic interactions that occur between the two species when transported together, steelhead may negatively affect both the stress levels and physical condition of chinook smolts. This is one possible explanation for the greater susceptibility of transported yearling chinook to tern predation in some years, as compared to non-transported chinook. Other potential explanations are that the incidence and intensity of disease in transported chinook smolts are greater than in their non-transported counterparts or transported juvenile salmonids are less smoltified and tend to reside longer in the estuary thereby increasing their exposure to predation.

Unlike yearling chinook, transportation does not appear to adversely affect the condition of steelhead smolts (Congleton et al. 2000) and, with regard to tern predation, may reduce vulnerability in some years. Following release, transported smolts tend to migrate down-river in tighter aggregations compared with run-of-the-river smolts (Ledgerwood et al. 1997), which may serve to swamp predators and increase survival compared to non-transported fish. Steelhead smolts, because they are larger and more fully-developed than yearling chinook, are also likely to move through the estuary more rapidly, regardless of whether they are transported.

Certainly, release timing and location are factors affecting the vulnerability of transported smolts to bird predation in the estuary. Nighttime releases of transported smolts in the estuary (or near ocean) would most likely reduce the vulnerability of transported smolts to bird predation, assuming the released fish do not remain in the estuary after release. This prediction is supported by the observed declines in avian predation associated with the nighttime release of juvenile salmonids from hatcheries and net pens in the Columbia River estuary (J. Hill, Clatsop County Economic Development Council, personal communication; B. Davies, Sea Resources, personal communication). We would welcome the opportunity to collaborate on a study aimed at testing the affects of different transportation release strategies on avian predation in the estuary, if warranted.

In 1998, the NMFS (POC: Brad Ryan) secured separate funding from the U.S. Army Corps of Engineers to recover PIT tags from bird colonies on the lower Columbia River. This research is ongoing and will likely continue to address questions of relative vulnerability of transported versus non-transported juvenile salmonids, among other research questions. We have recently approached NMFS about the possibility of collaborating on additional PIT tags studies and plan to work with NMFS and others to continue to address the research questions posed by the ISRP in the coming years.

Comment 7: "Could one response to supplementation in the basin and outright hatchery releases be the creation of behaviors conducive to being eaten by birds, even after the long in-river journey?…..How much of the predation problem is a function of a fish hatchery system that artificially concentrates tens of thousands of smolts in the river?…Experiments that test predator avoidance fitness values in different types of new NATURES program fish may also be worthwhile endeavors for future research of both the artificial hatchery improvement

program and avian predator program….Could the use of terns in hatcheries make hatchery fish more fit as far as predator avoidance is a learned response?….One program option would be to alter the project (and reduce funding) to refine how better to manage improvement of smolt production.."

Differences among juvenile salmonids in their vulnerability to avian predation may be attributable to differences in fish origin, behavior, physiology, condition, or size (Campbell 1979, Matkowski 1989, Mesa et al. 1994, Collis et al. 2001a). Juvenile salmonids from the Columbia River basin differ in their (1) origin (hatchery versus wild), (2) migration history (transported versus non-transported and, for in-river migrants, the number of dams passed), (3) timing of migration through the estuary (Dawley et al. 1986, Martinson et al. 1999), (4) horizontal and vertical distribution in the river (Mains and Smith 1964, Smith 1974, Dawley et al. 1986, Dauble et al. 1989, Ledgerwood et al. 1991, Beeman et al. 2000), (5) degree of smoltification (physiological readiness to enter saltwater; Zaugg et al. 1985, Congleton et al. 2000), (6) stress levels (Congleton et al. 2000), (7) incidence of disease and trauma (Maule et al. 1997, Martinson et al. 1999), and (8) size (Martinson et al. 1999). All these factors may affect the relative vulnerability to avian predation of different groups of salmonids migrating through the Columbia River estuary.

A large body of evidence suggests that hatchery-raised juvenile salmonids suffer greater mortality in the wild than do naturally produced smolts (Miller 1954, Wales 1954, Vincent 1960, Reisenbichler and McIntyre 1977, Raymond 1988, Collis et al. 2001a, Ryan et al. 2001). Lower survivorship of hatchery smolts can be attributed in part to behavioral and physical traits that render them more vulnerable to predation (Dickson and MacCrimmon 1982, Olla et al. 1990, Johnsson and Abrahams 1991, Berejikian 1995). Hatchery-raised juvenile salmonids, as compared to wild fish, have elevated stress levels associated with handling (Schreck 1981, Olla and Davis 1989), lack both innate and learned predator avoidance behaviors (Olla and Davis 1989, Suboski and Templeton 1989, Berejikian 1995), and are more surface-oriented (Vincent 1960, Mason et al. 1967, Moyle 1969, Sosiak et al. 1979). All of these traits could contribute to the higher susceptibility of hatchery-raised juvenile salmonids to avian predation.

If we are successful in attracting free-ranging Caspian terns to feed on fish within a net pen[3] (Task 1.4), we will use this technique to conduct field experiments on the causes for differences in vulnerability to tern predation. For example, we can test the relative vulnerability of (1) surface fed versus sub-surface fed hatchery fish, (2) hatchery fish with predator training versus those without predator experience, (3) juvenile salmonids subjected to different levels of handling and stress, (4) juvenile salmonids of different size, (5) smolts with different migration histories, or (6) PIT-tagged or radio-tagged smolts versus untagged smolts. These experiments should provide greater insight into the causes for differences in predation vulnerability, information important in fish management decisions aimed at reducing the impacts of avian predators on the survival of juvenile salmonids.

[3] This approach seems feasible, as terns have been previously trained to forage on an artificial food supply at a local site as part of experiments to investigate food preferences (Shealer 1998).

Comment 8: "Is there something we're doing to enhance fish passage at dams that is making fish less fit farther downstream (delayed mortality)? Does less predation by northern pikeminnow because of the pikeminnow control program just mean more weak fish left for birds?"

The question of whether avian predation in the Columbia River estuary is additive or compensatory is important. We intend to address this question in the proposed research in several ways (Task 1.4). First, by comparing the condition (e.g., contaminant burdens, incidence of BKD) of smolts falling prey to avian predators versus smolts caught in-river, we can test hypotheses concerning the compensatory/additive nature of avian predation. If avian predation is compensatory, we might expect smolts falling prey to avian predators to be in poorer condition as compared to the smolts sampled in-river, whereas we might expect no difference in smolt condition between the two groups if predation were additive.

We also plan to use the PIT tag data to test predictions of the delayed mortality hypothesis by relating migration history (e.g., number of dams passed by in-river migrating fish) with the rate at which these fish are preyed upon. If dam passage has an effect on a smolt's ability to survive further downriver, we might expect a positive correlation between the number of dams passed by a migrating smolt and its probability of falling prey to avian predators. As mentioned above, we hope to work cooperatively with NMFS to address these questions in the future.

Comment 9: "Why are tern populations expanding inland?….Could the recent upsurge in bird predators be a result of the overwhelming preponderance of hatchery-raised smolts (which seem to be more susceptible)? ……Is new habitat being created?"

The number of Caspian terns nesting on East Sand Island in the Columbia River estuary is expanding, but inland colonies are either declining or stable. While the settlement agreement mandated creation of more tern nesting habitat on East Sand Island in 2002, nesting habitat at inland sites and along the Washington coast continued to decline. As a consequence, nesting terns are becoming increasingly more concentrated at a single site in the Columbia River estuary.

A breeding colony of Caspian terns first formed on Rice Island in 1986 (G. Dorsey, U.S. Army Corps of Engineers, personal communication) and quickly grew to 8,000 pairs by the late 1990's (Roby et al. 2002). The Rice Island colony was relocated to East Sand Island by 2001 and grew to nearly 10,000 breeding pairs by 2002. This one colony now represents about 70% of the Pacific Coast population of Caspian terns, 25% of North American numbers for this species, and ca. 10% of worldwide numbers (Cuthbert and Wires 1999, Wires and Cuthbert 2000). The double-crested cormorant colony on East Sand Island first formed in the late 1980's (R. Lowe, U.S. Fish and Wildlife Service, personal communication) and subsequently increased to around 7,000 pairs by the turn of the century (Collis et al. 2002), the largest colony on the Pacific coast of North America. It is evident that the rate of increase of these colonies could not have occurred without substantial immigration from other sites. Four factors seem to have played a role in attracting Caspian terns and double-crested cormorants to nest in the Columbia River estuary:

1. Declining forage fish resources along the coast due to poor ocean conditions associated with weak coastal up-welling during the positive Pacific Decadal Oscillation in the 1980's and 1990's (Emmett and Brodeur 2000).
2. A reliable food supply in the Columbia River estuary during the early part of the breeding season due to the production and release of 150-200 million juvenile salmonids annually from hatcheries throughout the Columbia River basin (Collis et al. 2001a).
3. Anthropogenic alterations to the estuary that provided suitable nesting habitat on islands (deposition of sandy dredge spoil for terns, construction of rock jetties for cormorants; USACE 2001).
4. Loss of nesting habitat at previous colony sites, especially for terns along the coast of Washington, but also for both species at interior sites due to drought and increased nest predation (there were fewer terns nesting at colonies on Columbia River above Bonneville Dam in 2002 as compared to 1996-2001; Collis et al. 1999, Collis et al. 2002, CBR 2002).

As part of our ongoing research (Task 1.3), we are developing a demographics model for Caspian terns, which we hope to use to assess factors that may have contributed to the past population growth and also to predict future population trends. Understanding current population trends is critical to assessing management impacts on bird populations, which is important for successful implementation (see above). In addition, demographic trends may also predict if current gains in estuary smolt survival due to tern colony relocation will persist. If the East Sand Island tern population continues to increase, management benefits for salmonids accrued to date may be reduced.

Comment 10: "Will moving terns to new locations create a burden for other forage species?"

One approach toward further reducing losses of ESA-listed juvenile salmonids to Caspian terns is to relocate a portion of the terns currently nesting on East Sand Island to new and restored colony locations outside the Columbia River basin where alternative prey are available and impacts to ESA-listed stocks might be reduced (USACE 2001). This approach could also provide benefits to Caspian terns by redistributing nesting activities over a broader geographic area and a larger number of sites, thereby decreasing the risks to this tern population from local catastrophes. Restoration of alternative colony sites along the coast of the Pacific Northwest has not been initiated, however, due in large part to concerns for (1) salmonid stocks near potential sites for restored or new tern colonies, and (2) the welfare of the terns themselves. Many bays and estuaries along the coast of the Pacific Northwest are habitat for ESA-listed or declining runs of salmonids (NMFS 2002). Also, low food availability or locally abundant nest predators may render some former or prospective tern colony sites as population sinks (Penland 1982). Gaining information on the potential impacts to both local fisheries and the Caspian tern population of establishing new tern colonies outside the Columbia River estuary is critical for deciding whether to restore colonies along the coast of the Pacific Northwest and, if so, where these colonies should be located.

Other studies have shown that the diet composition of Caspian terns is not a simple function of local availability of forage fishes (Collis et al. 2001a). Caspian terns can commute considerable distances from their nesting colonies to foraging areas (Soikkeli 1973, 70 km; K. Collis, Real Time Research, unpublished data, 50 km), suggesting that impacts of tern predation on local fish stocks of special concern can not be predicted *a priori* by sampling fish in the vicinity of a proposed colony restoration

site. As a method to assess diet composition and productivity of terns at a potential colony restoration site, we tested the feasibility of attracting Caspian terns to nest on a barge that served as a temporary colony site in 2001. The main objectives of this study were to determine (1) if terns would readily use a barge as a nesting site, and (2) if tern diet composition and productivity data could be collected at the barge.

Results from this study[4] demonstrated that Caspian terns lacking alternative nesting sites can be attracted to nest on a sand-covered barge using social attractants in the first season of deployment. Also, we were successful in collecting data on tern diet composition and productivity at the barge tern colony. Food habits studies of terns using barges are especially crucial because these data could be used in models to estimate consumption, information needed to assess the potential impacts of a larger, permanent tern colony on the survival of local forage fish species of special concern, especially juvenile salmonids. The use of barges as temporary colony sites can be part of a comprehensive effort to evaluate the suitability of alternative sites for restoration of tern colonies along the coast of the Pacific Northwest and elsewhere.

Grays Harbor, Willapa Bay, Possession Sound, and Padilla Bay are all former Caspian tern colony sites along the coast of Washington (Collis et al. 1999), and are potential sites for deployment of tern barges. Little or no data are available on diet composition of Caspian terns at these former colonies, so temporary colonies on barges would help fill in these information gaps. We intend to work with regional fish and wildlife managers to pursue additional opportunities to use tern barges as a way to evaluate the suitability of various locales for tern colony restoration, as needed.

Comment 11: "As elaborated in a previous ISRP Review two years ago in 2000, we agree with the previous review that: " ...an in-depth independent peer-review be conducted to evaluate the results and conclusions generated from this project before proceeding with what would be potentially a very costly expansion of this work."

The results and conclusions from this study have been under intense scrutiny for the past five years. Researchers, regional resource managers, and policy makers on both sides of the bird predation issue have been presented with project results in numerous reports, publications, web pages, court depositions, public testimonies, posters, and presented/invited papers at professional society meetings. Since the ISRP last reviewed our research program (2000), we have had 3 manuscripts published in the peer-reviewed literature (Collis et al. 2001a, Collis et al. 2002, Roby et al. 2002), 2 manuscripts are in press (Collis et al. 2003, Roby et al. 2003), 2 manuscripts are in review (Roby et al. in review a, Roby et al. in review b), and many more manuscripts are in preparation. As scientists, we understand and appreciate the importance of the peer-review process. Over the years we have used peer review comments to improve our research program in many ways. Although we welcome additional peer review of our research program, we do not think that peer review of our research has been lacking. It is important to keep in mind that as a result of management based on this research program, smolt morality due to avian predation has been reduced by millions in each of the last three years, without

[4] This study was conducted with funding from USACE, USFWS, and NMFS. Any future barge studies will likely involve similar cost sharing.

harming managed bird populations, at least in the short term (CBR 2002). The recent settlement agreement has removed what has been a major impediment towards further reductions in smolt losses to birds, and it is for these reasons that we believe this project should not be delayed pending further peer-review.

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