1997 Restoration Workshop

JANUARY 23-25

ANCHORAGE, ALASKA

ABSTRACTS OF 1996 RESTORATION PROJECTS

EXXON VALDEZ OIL SPILL
TRUSTEE COUNCIL
645 G STREET, ANCHORAGE, AK. 99501
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AS OF 1/7/97

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Exxon Valdez Oil Spill Trustee Council

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January 7, 1997

Dear Workshop Participant:

These abstracts describe the results of most of the Research, Monitoring, and General Restoration projects carried out as part of the Fiscal Year 1996 Work Plan and are compiled here for the benefit and information of participants in the 1997 Restoration Workshop and the public. Any abstracts submitted after January 7 will be available at the workshop, which is scheduled for January 23 - 25, 1997.

These abstracts describe works in progress and their contents are the responsibilities of the authors. **The abstracts have not received scientific peer review and are not intended for citation in scientific publications.** If you have questions about a particular project, please contact that project's principal investigator or project leader.

Thank you.

Sincerely,

Molly McCammon

Molly McCammon
Executive Director

MM/ty

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[1]This is an FY 97 project.

[2]This was not a Trustee Council funded project, but the work was accomplished on a SEA cruise at the request of SEA and APEX investigators.

[3]This is an FY 97 component of the APEX project.

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Project Number and Title: 96001- Recovery of harbor seals from EVOS: Condition and health status.

Principal Investigators: Michael Castellini, Brian Fadely, Judith Castellini and Tania Zenteno-Savin. School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, Alaska 99775.

Abstract: Continuing analyses of blood chemistry, body morphology and other condition indices reveal distinct differences among seals within Prince William Sound (PWS), and between seals from the Sound and southeast Alaska or Kodiak Island regions. Within southwest PWS, adult female seals during 1993-96 exhibited increasing plasma glucose and cholesterol levels, decreasing blood urea nitrogen to creatinine ratios, elevated activities of alanine aminotransferase and aspartate aminotransferase, and increases in white blood cell and relative neutrophil counts. Adult male seals did not show these patterns, though body condition indices based on morphometrics, blubber depth or bioelectrical resistance were similar for both sexes between 1994-96. Many other blood parameters also exhibited regionally specific seasonal and interannual variability among the three Gulf of Alaska regions.

We also assessed blubber quality as a potential indicator of food limitation. Blubber quality was measured as energy density in samples provided by the Harbor Seal Tissue Biosampling Program. Across all samples, blubber energy density varied by 12%, but this variability was independent of changes in blubber depth or seal girth. These results suggest that changes in seal condition can not be adequately described using only changes in blubber mass or thickness. Female blubber energy density decreased seasonally from spring to winter months, presumably in association with reproductive requirements. Male blubber did not change in energy density seasonally, but decreased significantly with increasing body mass. Blubber sampled during spring 1996 from PWS and southeast Alaska indicated that female blubber was more energy dense than male blubber, and the blubber of PWS seals was about 2% more energy dense than blubber from southeast Alaska seals. Our results indicate that when other sources of variability are considered (such as age and sex of seal) we can observe clear seasonal and regional differences in many blood parameters and condition indices, both within PWS and between PWS and other Gulf of Alaska regions. These differences could arise either from food-related impacts or other sources.

Project Number and Title: EVOS Project 96007A- Archaeological Index Site Monitoring

Principal Investigators: Judith E. Bittner and Douglas R. Reger, Office of History and Archaeology, Department of Natural Resources, 3601 C St., Suite 1278, Anchorage, AK, 99503-5921 (Phone (907) 269-8725); Charles E. Diters, Alaska Regional Office, U.S. Fish and Wildlife Service, 1101 E. Tudor Rd., Anchorage, AK, 99503 (Phone (907)786-3635); Linda Finn Yarborough, Chugach National Forest, 3301 C St., Anchorage, AK, 99503-3998 (Phone (907) 271-2511).

Abstract: Index sites monitored during 1996 were located in Prince William Sound, on the lower Kenai Peninsula, and in the Kodiak Island area. Index sites are on public land and suffered damage primarily from vandalism. The sites are indicators of levels of vandalism which can be extended other sites as well.

The U.S. Forest Service visited two sites in the Prince William Sound spill area. SEW-077 was mapped and sediments collected to detect presence of petroleum hydrocarbons. An accurate map of intertidal artifact locations was tied to property lines for further monitoring. Analysis of the sediments is in process. SEW-469 was monitored for vandalism which occurred during cleanup. Continued disturbance at the site appears to be from land otter activity rather than human vandals.

Sites monitored in the Kenai Peninsula area were SEL-129, SEL-178, and SEL-025. The SEL-129 site was re-visited after a two year hiatus. Exposures of midden noted during the earlier visit have re-vegetated and show no evidence of recent disturbance. Recent foot traffic at SEL-178 has further injured the cultural remains there. The injuries were un-intentional but identify need for better training of agency restoration personnel to avoid such injury. The SEL-025 site has not been re-visited since 1991 and has suffered injury from recent human digging.

Sites in the Kodiak Island area continue to be injured from deliberate looter digging. The AFG-081 site was damaged during cleanup but was subsequently left un-disturbed. Severe vandal damage occurred during the summer of 1996. Recent injury continues to occur at AFG-046, and KOD-171. Natural erosion and vandalism both impact those sites. A visit to the AFG-097 recently documented several holes dug into the site by unauthorized individuals. This site is on property recently acquired by the Trustees from the Kodiak Borough. Prior year injury at the AFG-129 Site has re-vegetated and no new vandalism was noted during 1996.

Vandalism does continue in the Kodiak area where sites are eroding and thus very conspicuous. Sharing of monitor collected information with land manager field people will help track destruction and help eliminate injury.

Project Number and Title: 96007B - Restoration of Oil Spill Damaged Archaeological Sites

Principal Investigator: Linda Finn Yarborough, Chugach National Forest, 3301 C Street, Suite 300, Anchorage, Alaska 99503 (telephone: 907/271-2511)

Abstract: The purpose and objectives of this project are to apply restoration measures recommended by a multi-agency panel of experts in archaeology of the region for each of two oil spill-damaged archaeological sites on Eleanor and Knight Islands respectively. Injury consisted of oiling, and displacement and erosion of the archaeological resources as a result of foot traffic, high pressure water treatment during the cleanup response and unmonitored cleanup activities. Each site's condition was assessed and hydrocarbon samples were taken from their intertidal zones. Both sites were tested using standard archaeological methods, materials, and equipment to recover data. No revegetation work was done, as it was determined that the sites were revegetating well naturally. Data collection was oriented towards determining the nature of the sites, their age and the depth of cultural deposits. The data recovery requirements of the mitigation are considered to have been met, with the completion of the 1995 field season. Analysis results have been received from various labs, and the PI has been synthesizing those results in relation to the cultural and environmental data which was recovered. As indicated by radiocarbon dates, humans used the site at SEW-440 during the first half of the first millennium A.D., and in the middle of the second millennium A.D. The site at SEW-488 was occupied at least three times and possibly four. The first use of the site was for a short period during the early first millennium B.C., however during the late first millennium A.D. the site began to be used seasonally on a fairly continuous basis through the middle to late second millennium A.D. Evidence of a short early twentieth century A.D. use is indicated by historic artifacts above lapilli from the 1912 Novarupta or Katmai event. A radiocarbon date on charcoal from a possibly mixed stratigraphic situation may nevertheless represent an additional short early first millennium A.D. use of the site. The artifacts form both sites indicate that woodworking and fishing were important activities. Study of the faunal data indicates subsistence use of a variety of non-salmonid fish, migratory birds, and shellfish. The presence of artifacts made of non-local materials indicates the importance of long-distance travel or trade during the late prehistoric period. Tephras present in the sites appear to represent the Valdez ash, believed to have originated in the Wrangell Mountains and been deposited sometime between 1000 and 500 B.P. and the White River east lobe (1260 B.P.) or Rude River (1420±65 to 1265±30B.P.) ashes. An older ash recovered from a non-cultural test may represent the Bligh Island (<5230+60 B.P.) or Oshetna (5600-5200 B.P.) ashes. The sites were occupied during a time when the general geological trend was one of coastal subsidence, with occasional seismic uplift. Both sites appear logical trend was one of coastal subsidence, with occasional seismic uplift. Both sites appear likely to be eligible for the National Register of Historic Places. Restoration as measured by the mitigation specifications will be completed with the finalization of the project report.

Project Number and Title: 96012--Comprehensive Killer Whale Investigation in Prince William Sound, Alaska

Principal Investigators: Craig O. Matkin, North Gulf Oceanic Society, P.O. Box 15244, Homer, AK 99603 (907/235-6590) and Dr. David Sheel, Prince William Sound Science Center, P.O. Box 705, Cordova, AK 99574

Abstract: Goals of this project include: 1) determination of recovery status of the damaged killer whale population(s) that regularly use Prince William Sound, 2) examination of aspects of killer whale behavior and ecology particularly in regard the damaged harbor seal population, and 3) determination of the potential separation of killer whale populations.

Monitoring of killer whales (*Orcinus orca*), a species currently considered injured following the *Exxon Valdez* Oil Spill, continued on a reduced level in 1996. In 1996 AB pod was still traveling as two groups; one of those groups was again traveling with AJ pod. One mortality occured in the pod (AB4, an older male) and two females (AB25, AB26) produced calves (AB51, AB50, respectively). There were 23 whales in ABpod in 1996 compared to 36 prior to the oil spill; recovery of AB pod has not occurred. All other major resident pods have increased in number duing the same period. There were only 4 encounters with the AT1 trasnsient group and only six of the original 22 whales in that group were photographed. Ten of those whales have not been observed for 7 years are believed dead. This group is genetically distinct from the resident pods and from other transient groups sampled. Their long-term survival is in doubt.

Mitochondrial DNA analysis was used to clarify the degree of separation of proposed killer whale populations in Prince William Sound and to judge the separatenesss of these populations from others in the Eastern North Pacific. After intial use of an RFLP (restriction frament length polymorphism) approach, populations were separted using direct sequencing of the D-loop region of the mitochondrial genome. The sequences were found to vary at 10 of the 937 bases. A maximum likelihood algorithm was used to calculate an unrooted tree. This tree revealed 6 putative populations: Gulf of Alaska transients, AT1 (Prince Willliam Sound) transients, British Columbia transients, British Columbia northern residents and Prince William Sound residents, British Columia southern residents, and offshores. This is clear genetic evidence supporting stock separation of transient (marine mammal eating) and resident (fish eating) killer whales and establishes the uniqueness of the AT1 transient group.

Contaminant analysis of killer whale tissue taken by biopsy of the subdermal blubber layer, also supports the separateness of resident and transient killer whales and their dietary specialization. Concentrations of total selected cholorbiphenyl congeners (CB)s well as chlorinated pesticides (CP) averaged over 10 times greater in transients (avg 67,000 ppb CBs and 100,000 ppb CPs) than in residents (avg 6500 ppb CBs and 5100 ppb CPs). Concentrations of contaminants were found to vary depending on age, sex, and reproductive status of the animal. Contaminants appeared to be passed from mothers to offpring: first calves had very high contaminant levels compared to their mothers. Thus there is wide variation in contaminant loads among individuals.

Data entry into the GIS database was completed for all NGOS killer whale records from 1984 to 1996 (1508 boat-days, 663 encounters with whales). Search effort was greatest in Knight Island Passage, with lower effort throughout the Sound. Encounter rates with transients varied within Knight Island Passage, but were not significantly lower outside the area of greatest search effort. Transients used the southwest parts of the Sound for a total of 810 whale-days during a 118 day field season in 1990 (when the most sampling was done). We do not expect that transient use is lower during other seasons; and it is therefore appropriate to extrapolate transient killer whale use over the remainder of the Sound and across all seasons to arrive at the total use of the Sound by transient killer whales.

Project Number and Title: 96025-- Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators

Principle Investigators: Brenda Ballachey[1], James Bodkin[1], Terry Bowyer[2], Tom Dean[3], Larry Duffy[4], Dan Esler[1], Leslie Holland-Bartels (Chief Scientist)[1], Stephen Jewett[2], Lyman McDonald[5], David McGuire[8], Chuck O'Clair[6], Alan Rebar[7], Paul Snyder[7], Glenn VanBlaricom[9]

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Abstract: The nearshore ecosystem served as a repository for much of the oil spilled by the T/V *Exxon Valdez* (EVOS). Mortalities occurred across a suite of apex predators, as well as in benthic invertebrate and plant populations. The initial changes in composition and abundance of species which resulted from these acute mortalities and habitat disturbances likely continue to modify important structuring processes in the nearshore populations (i.e., competition, predation, and recruitment), thus constraining recovery. The Nearshore Vertebrate Predator Study (NVP) . focuses on the status of system recovery using a suite of injured apex predators as indicators of environmental stress--the invertebrate feeding sea otter *Enhydra lutris* and harlequin duck *Histrionicus histrionicus*, and fish feeding pigeon guillemot *Cepphus columa* and river otter *Lutra canadensis*. The project takes a multispecies, integrated approach to assess several potential mechanisms constraining recovery by asking "Are vertebrate populations recovering?" If so, "Are they recovering as quickly as possible given potential rates of population increase?" Population density and demographic factors are measured at both oiled (Naked and Knight Islands) and unoiled sites (Montague Island and Jack Pot Bay) to examine possible reasons for **lack** of recovery, and to assess **progress** toward recovery given demographic constraints. In conjunction with this "recovery monitoring" approach, we ask **" is it oil?"** or **"is it food?"** that is potentially limiting recovery through evaluation of health, biomarkers of oil exposure, and availability of prey for each of the study predators in our oiled and unoiled study areas.

With a successful pilot year in 1995, the full NVP design was implemented in 1996 for all four species with significant progress made toward assessing the core hypotheses. Below is a summary of what each species tells us to date about our hypotheses:

INVERTEBRATE FEEDERS--SEA OTTER: A synthesis of traditional ecological knowledge and EVOS NRDA and Restoration research indicated that seas otters had not completely recovered in some of the most heavily oiled areas of PWS by 1995. Preliminary results from 1996 NVP studies suggest that sea otter numbers are still below estimated pre-spill levels, but that continued exposure to residual oil may not be limiting recovery. Initial analyses of pelage swabs and P450 assays show little continued oil exposure and no differences between oiled and unoiled study areas. We also found that neither reproduction in otters nor blood chemistries differed between sites. Results of sea otter food habit studies indicate diets are similar between areas, although otters are retrieving more and larger prey in the oiled compared to unoiled area. We have also found that the ratio of available urchins, clams and mussels to the number of otters present is higher in the oiled area. Also, more large individuals of all three prey types are present at this site. In addition, various other nearshore species were examined as potential copredators that might confound our interpretation of "Is it food?" However, we found little evidence that invertebrates such as sea stars and various sea ducks and shore birds are important in this respect. Our preliminary findings lead us to speculate that sea otter numbers in the oiled study area remain below expected numbers, but may not be constrained by food availability. In fact, survey and capture efforts in 1996 identified a group of young male sea otters off eastern Knight Island, a social pattern seen elsewhere during early stages of population recovery.

HARLEQUIN DUCK: Molting and wintering ecology studies were initiated in fall 1995 in which more than 700 individuals were captured, allowing deployment of radio transmitters for survival studies, sampling of bioindicators for assessment of health and oil exposure, and evaluations of body composition variation. We conducted boat surveys during winter to determine the factors that affect densities and distribution of this species, including habitat, food abundance, and oiling history. Winter survival for adult females, the cohort that largely influences population dynamics, was 94% in the unoiled area, but 77% in the oiled area. From a demographic perspective, this difference would result in significant declines in harlequin ducks the western Sound in the absence of immigration. Bioindicator levels (blood chemistry, haptoglobin, and P450) were similar between oiled and unoiled sites for molting birds. Birds were collected on Kodiak Island in fall 1996 to derive a condition index that could be applied to the Sound and would allow us to assess body composition of captured birds at our study sites. Surveys of harlequin ducks have indicated that bird numbers are consistent among seasons and years with densities much lower on Knight Island (oiled: 1.5 birds/km shoreline) than Montague (unoiled: 9.6 birds/km). We are analyzing these data to determine if habitat differences may confound our assessment of oiling history. Preliminary conclusions for harlequin ducks are that differing demographics between areas may be limiting recovery, while oil exposure does not appear to be occurring during molt, and that the limiting effects of food are unknown.

FISH FEEDERS--RIVER OTTER: Previous research on river otters demonstrated that otters living in oiled areas had significantly lower body mass and elevated biomarkers in their blood (e.g. Haptoglobin (hp) and Interleukin-6 (il6)) than otters from unoiled areas. Likewise, otters from oiled areas had significantly higher levels of fecal porphyrins, ate less diverse diets, had larger home ranges, and selected habitats differently than otters from areas not receiving heavy oiling. In 1996, we noted significantly higher levels of P450 in otters on our oiled study site than on our unoiled site (Jackpot Bay), suggesting that otters were still being exposed to

hydrocarbons. Similarly, haptoglobins were significantly higher in the oiled site, suggesting health impacts to these otters. These two biomarkers (P450, hp) correctly classified 74% of 39 otters as to whether they were captured at oiled or unoiled sites. No differences occurred in the body mass of otters between areas, and the abandonment of latrines sites failed to provide a useful index to otter populations.

PIGEON GUILLEMOTS: Work on this aspect of the NVP study began June, 1996 in collaboration with the APEX Predator Experiment (APEX). As in the other elements of NVP, an array of health, demographic, and trophic measures were collected. Blood samples and growth information were collected from chicks at 20, 25, and 30 days of age to compare health between oiled and unoiled sites. Reproductive success of nests was also monitored. Adults, chicks, and eggs were swabbed to determine if any external exposure to oil was occurring. Finally, diet composition of chick meals and chick provisioning rates were assessed. Analyses of data with respect to the NVP hypotheses will begin this winter.

OVERVIEW: Our four species are providing valuable pieces to the puzzle of nearshore recovery status. By using an integrated approach, the NVP Project is beginning to develop insight into the complex issue of both the status of recovery and factors continuing to constrain this recovery that was difficult to obtain under the former single-species or single-objective approach. For example, based on the 1996 data, a different picture is evolving between sea otters and river otters. Sea otters seem more likely to be in early stages of recovery (as suggested by our food habits analysis and survey and capture data) with little evidence to suggest oil or food availability is constraining recovery. Obtaining estimates of river otters proved problematic in 1996 so we are uncertain of population status, however, we have evidence to suggest that river otters continue to be exposed to oil. Although both are mammals and inhabit the nearshore, these animals are ecologically quite different. For example, sea otters feed more in the subtidal zone, while river otters use intertidal areas extensively. Such ecological differences may begin to explain differences we see in our study results and provide future guidance in recovery efforts. We plan to verify our 1996 results in 1997 and continue to assess ecological factors that may explain these different pictures.

Project Number and Title: 96025- Avian Predation on Blue Mussels Component of NVP

Principal Investigator: Mary Anne Bishop, Copper River Delta Institute, US Forest Service, P.O. Box 1460 Cordova, AK 99574 (Phone: 907/424-7212) and Dept. Fisheries, Univ. Washington, P.O. Box 357980, Seattle, WA 98195

Abstract: The objective of this component was to determine if differences exist between oiled and unoiled areas with respect to the distribution, abundance and consumption patterns of avian blue mussel predators. Two sites in Prince William Sound were compared during spring (April-May) and summer (May-August): Montague Island (Graveyard Point to Mooselips Bay; unoiled area), and Knight Island (Bay of Isles and Herring Bay; oiled area). The most numerous mussel predators observed on both study areas during spring and summer nearshore boat surveys included: Barrow's goldeneye, harlequin duck, glaucous-winged gull, mew gull, black oystercatcher and surfbird. Based on bird days, where 1 bird=1 bird day, the most abundant species at both Montague and Knight Islands were migrant surfbirds in spring (Montague: 39,518 bird days; Knight: 4,614 bird days) and harlequin ducks in summer (Montague: 16,883 bird days; Knight: 3,917). Bird abundance varied by study area. Except for Barrow's goldeneye, Montague Island had 2.5-8x the number of birds per species in spring. A similar trend was observed in summer.

Two events impacted bird abundance during this study: distribution of spawn at Montague Island, and gull colony failure at Bay of Isles. Historically in spring, as many as 65,000 glaucous-winged gulls have been observed during one-day surveys of Pacific herring schools and herring spawn deposition. Spawn occurred in the NVP Montague Island study area 13 of the 15 years prior to this study. In 1996, however, no spawn occurred in the study area and we recorded <4,000 glaucous-winged gull bird days during the 34 day spring field season at Montague Island. At Bay of Isles, a gull colony estimated at 40 pairs has nested in the past. On 4 visits between 7-18 July 1996 we found no signs of nesting at the colony.

Using a bioenergetic model, we estimated mussel consumption for the 6 most numerous *Mussel* predators. Our model is based on field metabolic rates, energy content of blue mussel, assimilation efficiency of blue mussels, and an estimated proportion of daily energy acquired from blue mussels. Assuming that 100% of their diet is blue mussels, for spring, surfbirds and Barrow's goldeneyes were the top consumers (kg consumed) at Montague and Knight Island, respectively. For summer, mew gulls and glaucous-winged gulls were the top consumers at Montague and Knight Islands, respectively.

We conducted a pilot study on the feasibility of using exclosures to determine co-predator effects on mussel density. Cages were installed in a mussel bed in Orca Inlet in mid-March 1996 and removed in late September 1996. Preliminary results indicate that cages designed to exclude both birds and sea otters, but allow invertebrates showed a trend to exhibit more sedimentation. A size-frequency histogram of our field estimates of mussel size indicated a peak in mussel density at the 0-5mm and 16-20mm classes. We found significant differences in mussel densities between sampling period, block and cage size (large versus small), but not for treatments.

Project Number and Title: 96025 - Mussel Component: Mussel populations in relation to the recovery of nearshore vertebrate predators in areas oiled during the Exxon Valdez spill.

Principal Investigators: Charles E. O'Clair and Mandy Lindeberg National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, AK 99801 (Phone 907/789-6016)

Abstract: The purpose of this component was to determine the extent to which the abundance of mussels, *Mytilus trossulus,* as one component of the prey base of sea otters, *Enhydra lutris*, and sea ducks (principally harlequin ducks, *Histrionicus histrionicus*) limits the recovery of these vertebrate predators in areas oiled by the *Exxon Valdez* spill. Our objective in 1996 was to estimate mussel abundance and compare mussel size-frequency distributions in areas where sea otters and sea ducks were unaffected by the oil spill and in areas where these vertebrate predators were affected by the spill. Mussel populations were sampled using stratified, systematic/random methods at northwestern Montague Island and northern Knight Island in Prince William Sound, Alaska in May/June and July 1996. A total of 1,076, 500 cm2 quadrats were examined and mussels collected along 108, 200m-long shore segments within the two study areas. The shell length of a total of 55,380 mussels (≥ 5mm in shell length) were measured.

Mytilus density (shell length ≥ 5 mm) was greater on Knight Island (mean density, 1,403/m2) than on Montague Is. (mean density, 1,021/m2; $p < 0.05$). The length-frequency distribution of mussels was dominated by young-of-the-year mussels at both study areas but the abundance of this size class was greater at Knight Is. than at Montague Is.. The density of large mussels (shell length ≥ 40 mm, the size range preyed upon by sea otters) was low at both study areas, but tended to be greater on Knight Is. (mean density, 3/m2) than on Montague Is.(mean density, 2/m2; $p < 0.05$). Mussel habitat differed in several respects between study areas. The mussel zone was wider ($p < 0.001$) and the slope of the shore was shallower ($p < 0.001$) at Montague Is. than at Knight Is.. More of the shoreline within the study area was covered with mixed substrate (66%; sediment particle sizes from silt to cobble) at Montague Is., whereas more of the shoreline on Knight Is. was rocky (71.6%; boulders and bedrock).

These results indicate that mussel abundance is probably not limiting the recovery of sea otters and sea ducks at Knight Island where the populations of these vertebrate predators are considered to have been reduced by the *Exxon Valdez* oil spill.

Project Number and Title: 96031 - Development of a productivity index to monitor the reproductive success of murrelets in Prince William Sound. Close-out.

Principal Investigator: Katherine J. Kuletz, U.S. Fish and Wildlife Service, 1011 E. Tudor Rd, Anchorage, Alaska, 99503. Ph: (907)-786-3453. e-mail: kathy_kuletz@mail.fws.gov.

Abstract: Marbled murrelets (*Brachyramphus marmoratus*), one of the most abundant seabird species in the *Exxon Valdez* oil spill zone, were injured in the spill. Earlier restoration studies identified murrelet nesting habitat to guide habitat acquisitions. Although 22 nests were found during these earlier studies, there was no practical way to determine the reproductive success of murrelets. Therefore, we developed a marbled murrelet productivity index for southcentral Alaska that uses at-sea counts of hatching-year birds (HY = juveniles) and after-hatch-year birds (AHY = adults and non-breeders). Our objectives were to define abundance patterns between age classes, evaluate different types of indices, and describe marine habitats used by juveniles. This project was implemented in 1995 and close-out funds were allocated in 1996.

In Prince William Sound (PWS) we conducted pilot boat surveys at 2 sites in 1994 and complete boat surveys at 6 sites (45-60 km of shoreline each) in 1995, with 10-14 replicate surveys/site. At all sites, numbers of AHY birds peaked in late July and declined throughout August, whereas HY birds increased after 28 July. Because AHY birds were leaving study sites in August, the percentage of HY birds increased; however, patterns varied slightly among sites. Comparing HY densities between sites and years, rather than HY:AHY ratios, might avoid potential problems from different post-breeding dispersal patterns of adults. HY densities in July/August were highly correlated with June AHY densities. Thus, adults present in June may best represent the breeding population of an area, and these ratios may be more reliable than the concurrent July/August HY:AHY ratios typically used for such comparisons.

Juveniles preferred waters <200 m from shore, and rarely occurred along exposed coasts. However, there were no other significant habitat relationships that were not also associated with seasonal changes (ie., water temperature, salinity, turbidity). In July/August, HY birds ranged among sites from 2%-13% of total murrelets, and 'high' and 'low' productivity were found at both fjord and island sites.

The pilot surveys at two sites were compared to their 1995 surveys. In 1995, peak juvenile occurrence was 7-10 days earlier and juvenile density and HY:AHY ratios were significantly higher, whereas adult densities remained stable. These results agree with preliminary analyses of other EVOS studies on the timing of the spring plankton bloom and relative fish abundance between years. If timing and abundance of forage fish influenced murrelet reproductive success, similar correlations should be demonstrated in a long-term study.

The murrelet productivity study was not continued in 1996, but will resume as a project in cooperation with the APEX ecosystem study in 1997 and 1998. The APEX study will determine forage fish species abundance and distribution in PWS and Kachemak Bay. We will test the hypothesis that forage fish abundance limits murrelet productivity by comparing these two variables among years and among sites in PWS, and between the regions of PWS and Kachemak Bay. The two regions have different seabird communities and different relative abundances of forage fish. The local diets and breeding success of other seabirds studied by APEX will also be compared with results from the murrelet project.

Project Number and Title: 96038 - Restoration of Seabirds Following the *Exxon Valdez* Oil Spill

Principal Investigators: Kenneth I. Warheit, Pacific Seabird Group, P.O. Box 178, Tenino, WA 98589 (Tel: 360-902- 2595, email: warheit@u.washington.edu); Craig S. Harrison, Pacific Seabird Group, 4001 North 9th St., Arlington, VA 22203 (Tel: 202-778-2240, email: charrison@hunton.com). George J. Divoky, Institute of Arctic Biology, Univ. of Alaska, Fairbanks, AK 99775 (Tel. 206-365-6009, email, ftgjd@aurora.alaska.edu).

Abstract: Seabird restoration involves the identification and implementation of management techniques to assist in the recovery of seabird populations reduced by natural or anthropogenic effects. As a science seabird restoration is in its infancy but receiving increased attention due to the appearance of dedicated funding, typically from settlements from oil spills. In order to consider the restoration options for seabird species not recovering from the Exxon Valdez Oil Spill (EVOS) the Pacific Seabird Group held a Seabird Restoration Workshop in the fall of 1995, consisting of approximately 50 seabird biologists and managers from Great Britain, Belgium, France, New Zealand, Japan, Canada, and the United States. Although the workshop focused primarily on the four seabird species the EVOS Trustees listed as "not-recovering" in 1995 (Common Murre, Harlequin Duck, Marbled Murrelet, and Pigeon Guillemot), discussions were not limited to these species or the EVOS situation. Initial workshop discussions addressed seabird restoration from a general or generic (i.e., not oil-spill specific) perspective, and then applied the results to species and populations of concern to the EVOS Trustees.

The workshop produced a series of species-specific restoration techniques with supporting justification. First, we provided guidelines for identifying the seabird species or populations requiring restoration. We recommended criteria to be used to determine if the population effects resulting from a spill are a concern, and to establish a priority list for restoration activities. Second, we established specific operational goals for restoration activities, and evaluated these goals in terms of their assumptions, constraints, and our ability to measure progress through monitoring. Third, we described and discussed more than 20 different restoration techniques (including natural recovery) and outlined their assumptions and deficiencies. In addition, we discussed the importance (and assumptions and limitations) of modeling restoration activities. Forth, we outlined population-, community-, and ecosystem-level factors that may affect restoration of seabird populations, and emphasized that restoration efforts may be constrained by factors that are either uncontrolled by the restoration activities, or uncontrollable (e.g., global warming and its effect on fish distribution). Lastly, we made recommendations about general restoration issues, and about specific restoration techniques for particular species of seabirds.

We concluded that the most promising restoration techniques included: 1) managing human impacts (e.g., reducing fisheries bycatch of seabirds; reducing breeding habitat loss resulting from habitat destruction or colony disturbance; preventing introduction of predators), 2) habitat or nest-site creation or enhancement (e.g., habitat preserves; land purchases; improve quality of habitat), and 3) predator control at colonies were the most promising of restoration techniques. The innovative technique of enhancing seabird prey resources through alteration of fisheries management practices was deemed to have potential but its current application limited by

uncertainty of logistic feasibility of or the potential population- or community-level effects. We recommended that studies be conducted to address these areas of uncertainty. We also recommended that the EVOS Trustees examine the effects of gillnet bycatch, nearshore community structure, and predation on the recovery of Marbled Murrelets. Finally, among a series of general recommendations, we advocated that the EVOS Trustees enlarge the "spill-impact area" to reflect the migratory and dispersal behavior of seabirds. Populations breeding outside of the spill zone could have been injured by the spill. Additionally, enhancement of populations outside of the spill zone could increase the rate of recovery for injured populations.

Project Number and Title: 96043b - Monitoring of Cutthroat Trout and Dolly Varden Habitat Improvement Structures.

Principal Investigators : Dan Gillikin, Chugach NF., P.O. Box 129, Girdwood, AK. 99587, (Phone) 783-3242, (FAX) 783-2094

Abstract : This project provides for monitoring of habitat improvement structures and their effects on cutthroat trout and Dolly Varden populations. These structures were installed in 1995 under EVOS Restoration Project number 95043B. Cutthroat trout in PWS are at the northern extent of the species' North American range. Generally speaking, species inhabiting the extreme limits of their habitat exhibit higher sensitivities to environmental stresses than the same species well within the habitat limits. Interspecific competition with juvenile coho salmon is believed to limit cutthroat trout production in quality pool rearing habitat which is one of the key factors for cutthroat trout survival. Concerns have been raised that certain types of habitat enhancements may increase coho salmon populations, thereby increase competitive stress on cutthroat trout populations. This monitoring is seeking to address those questions, and concerns.

During the 1995 field season, USFS, Glacier Ranger District Fisheries crews installed a total of 63 habitat improvement structures at Otter Lake, Gunboat Lakes, Red Creek and Billy's Hole in Prince William Sound to improve cutthroat trout and Dolly Varden habitat. The distribution and abundance of cutthroat trout, Dolly Varden and coho salmon were monitored at these locations using standard mark recapture techniques to provide baseline information on the various systems prior to enhancement activities. The existing habitat at each project site was surveyed using a modified Hankin and Reeves methodology prior to and then again after structure installation to provide a basis of comparison. The completed stream surveys were also used to determine the proper sampling distribution to trap fish in a stratified random sampling design within the affected stream reaches. Trapping effort was conducted proportional to the availability of the three major habitat types found in each sampling area.

Sampling by Glacier Fisheries Crews in 1994, 1995 and again in 1996 suggested that cutthroat trout densities were greatest in habitat units with moderate gradient found in the upper reaches of the inlet streams at the project locations. This is consistent with studies that have shown that cutthroat trout juveniles are pushed to less desirable habitats by the more dominant coho salmon juveniles. Results from data collected in 1996 are not yet available. Due to the small populations of cutthroat trout in these systems and the resulting small sample size no conclusion can be drawn at this time regarding the effects of the enhancement work in 1995. Sampling has been proposed to continue through 1999 by which time enough information should be gathered to reach a reliable conclusion concerning this type of enhancement activity.

CHUGACH REGIONAL RESOURCES COMMISSION

Community Involvement Project - 96052

The Community Involvement Project was funded through the *Exxon Valdez* Oil Spill (EVOS) Trustee Council to facilitate the involvement of the members of the local communities who were impacted by the 1989 oil spill. This project has two components: Community Involvement and Traditional Ecological Knowledge (TEK). Activities under the Community Involvement portion of the project include the hiring of one Spill Area Wide Coordinator and nine Community Facilitators to facilitate communication between the EVOS Trustee Council, researchers working on oil spill restoration projects, and residents of communities impacted by the spill. Facilitators are also responsible for identifying oil spill related community issues, concerns, questions, and ideas for new projects, developing a resource list to include community members with available boats and other equipment as well as community members available to work; and coordination of community visits from researchers and Trustee Council representatives. The second component consists of efforts to integrate Traditional Ecological Knowledge into the EVOS restoration process by developing guidelines, protocols and procedures for the systematic collection and analysis of traditional ecological knowledge, in consultation with the oil spill impacted communities; developing a database for the management of TEK; and providing training and technical assistance to EVOS researchers on the interpretation and potential application of TEK to their restoration projects.

Martha Vlasoff was hired at the onset of the project as the Spill Area Wide Coordinator and tasked with working with seven communities and two regional organizations to get the Community Facilitators hired and with serving as the communications link between the Restoration Office and the communities affected by the oil spill. All Community Facilitators were hired within the first four months of the project through subcontracts between the village tribal governments and the Chugach Regional Resources Commission.

The Community Facilitators participated in the Restoration Workshop in January which was very timely as the main focus of the workshop was the value and use of indigenous science in the restoration process. The Spill Area Wide Coordinator also spent time providing technical assistance to the communities on proposal development for the FY97 Workplan.

A workshop was conducted with the communities to formulate protocols, procedures, and guidelines in regards to the use of TEK as it relates to the restoration process. The final draft was presented to the research scientists and principal investigators for their input and then distributed back to the communities for their adoption. Once finalized and approved by both the tribal governments and Trustee Council, this document will serve as a guide for all parties involved in dealing with the oil spill impacted communities and utilizing TEK in the restoration effort.

Respectfully submitted,

Patty Brown-Schwalenberg
Executive Director, CRRC

Project Number and Title: 96064 - Monitoring, Habitat Use and Trophic Interactions of Harbor Seals in Prince William Sound.

Principal Investigators: Kathryn J. Frost, Lloyd F. Lowry, and Sara J. Iverson. Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701 (KJF and LFL); Department of Biology, Dalhousie University, Halifax, Nova Scotia, B3H 4J1, Canada (SJI) (KJF phone 907-459-7214, e-mail "kfrost@fishgame.state.ak.us")

Abstract: Since 1984, harbor seals (*Phoca vitulina richardsi*) in Prince William Sound (PWS) have declined by 70% for unknown reasons. More than 300 harbor seals were estimated to have died because of the *Exxon Valdez* oil spill (EVOS), and since then seals have continued to decline at about 6% per year. The objectives of this study were to monitor the status of PWS harbor seals to determine whether the population has continued to decline, stabilized, or increased; to attach satellite tags to describe their movements, use of haulouts, and hauling and diving behavior; and to collect samples to study trophic interactions, genetic relationships, and health of harbor seals in PWS compared to other areas. Aerial surveys of 25 trend count sites during 1989-1996 showed a continuing decline in the number of seals during the molt. The 1996 counts of harbor seals in PWS were 31% lower than counts in 1989.

One hundred and forty-five seals have been captured, sampled, and tagged since 1993: 28 in 1993, 36 in 1994, 42 in 1995, and 39 in 1996. Fifty-two of these were instrumented with satellite-linked time-depth recorders (SLTDRs). Most seals equipped with SLTDRs remained within PWS near the locations where they were tagged. Several made feeding trips to the Gulf of Alaska, one as far as Yakutat and several to the Copper River Delta, but later returned to PWS. A few seals made regular trips between haulouts in southcentral PWS and glaciers in the north. For the first time in 1996, a small, 1/4-watt SLTDR became available and was attached to a pup to test the feasibility of future work on pups.

Forage fishes comprise an important part of the diet of harbor seals. In the mid-1970s, herring, pollock, cod, and eulachon were the most common prey of adults. Capelin and pollock were the main prey of pups and yearlings. It has been suggested that long-term changes in forage fish abundance have resulted in reduced availability of food to seals and thus may be causing or contributing to the decline. To evaluate this hypothesis, it is necessary to obtain recent data about the diet of seals in PWS.

In this study, we have developed a new method for determining harbor seal diets. This method uses fatty acid signatures in seal blubber in combination with classification and regression tree (CART) analysis. We took blubber biopsies from all seals caught in 1994-1996. In addition, subsistence hunters collected samples of blubber for us as part of the biosampling program. Samples of potential prey were provided by investigators studying forage fish in PWS. Fatty acid composition was determined for 104 seals and 388 individual prey were. Our results indicate that fatty acids in harbor seal blubber vary as a function of haulout site, suggesting that PWS harbor seals depend on a very localized prey base. Different species of prey differed notably in fatty acid composition, and prey species could be identified from signatures. Within species such as herring and pollock, the fatty acid composition varied directly as a function of body size, yet each could still be differentiated as a species. The results imply that size and age class of prey can be determined from fatty acid signatures.

The analysis of fatty acids in blubber samples and prey suggests that herring and large pollock dominate the diets of harbor seals from southcentral PWS, while small herring and sandlance predominate in northern PWS. The actual determination of seal diets from fatty acid signatures will require completion of an extensive prey library and development of a numerical matching approach. We conclude that this approach will likely result in an important contribution to understanding foraging ecology and marine food webs in PWS and elsewhere. In combination with data provided by other aspects of this study, it will provide information about the food dependencies of harbor seals in PWS and about changes in harbor seal diets over the last 20 years that may have led to the ongoing decline.

Project Number and Title: 95074. Health and reproductive implications of exposure of Pacific herring (*Clupea pallasi*) adults and eggs to weathered crude oil, and reproductive condition of herring stock in Prince William Sound six years after the *Exxon Valdez* oil spill.

Principal Investigators: Mark G. Carls*, Jo Ellen Hose, Scott W. Johnson, Gary D. Marty, Robert. E. Thomas, and Stanley D. Rice. *NOAA/NMFS, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801 (Phone 907 789-6019)

Abstract: Herring spawned in Prince William Sound (PWS) a few weeks after the *Exxon Valdez* oil spill (*EVOS*); all life stages were potentially exposed. In 1993 the herring population in PWS collapsed, leading to speculation that herring were reproductively impaired by oil. Poor recruitment of juvenile fish to the spawning population, and a high incidence of disease raised concern that the oil spill directly or indirectly caused these delayed problems. This study reports laboratory and field measurements designed to 1) examine immune function in adult herring as related to oil exposure, opportunistic disease, and mortality, 2) determine if genetic damage to early life stages of herring could be caused by exposure of pre-spawning adults and eggs to oil, and relate this damage to larval survival potential, and 3) determine the long-term implications of exposure of Pacific herring to *Exxon Valdez* oil in PWS. In the laboratory, the life stage exposed to oil was varied (adult and egg), but endpoint measurements (including analysis of chromosomal condition in actively dividing cells of larvae) remained the same. In the field survey, the current reproductive condition of females from four sites in PWS and from three control sites in Southeast Alaska were assessed by rearing their spawn and assessing larvae viability.

In laboratory tests, pre-spawn adult herring were negatively impacted by exposure to oil, principally by suppression of the immune system and increased expression of disease. Correlations were strong between oil exposure, induction of aryl hydrocarbon hydroxylase, suppression of leukocytes, increased prevalence of viral hemorrhagic septicemia virus, and mortality. However, exposure of pre-spawn adult herring caused negligible damage in progeny at high polynuclear aromatic hydrocarbon (PAH) concentrations (58 ppb). In contrast, exposure of eggs to comparably weathered oil during incubation caused significant morphological defects at PAH concentrations as low as 9 ppb. Effects of more weathered oil were significant at concentrations as low as 0.2 ppb, suggesting the toxicity of the more persistent, heavier and more substituted PAH was greater than that of lighter, less substituted PAH. Significant genetic damage (chromosomal aberration) was observed in larvae at 0.7 ppb in the more weathered oil, but several morphological responses were significant at lower concentrations. It is likely that most larvae with genetic defects would die due to concomitant morphological abnormalities, thus the likelihood that defective DNA would enter the gene pool appears low. The abnormal larvae observed in PWS in 1989 more likely resulted from direct exposure of eggs than from exposure of pre-spawn adults.

There was no evidence of reproductive impairment in PWS herring stock six years after the *EVOS*. Responses of all year-classes combined or restricted to the same year-class did not differ significantly between regions ($P > 0.50$); the best and worst responses generally occurred in Southeast Alaska. Within each site, response of the 1989 year-class (most likely impacted by the oil spill in PWS) generally did not differ significantly from any other year-class. Reproductive impairment is not a factor limiting further recovery.

Project Number and Title: 96076- Effects of Oiled Incubation Substrate on Straying and Survival of Wild Pink Salmon

Principle Investigator: A.C. Wertheimer. Co-investigators: S.D. Rice, J.F. Thedinga, R.A. Heintz, R.F. Bradshaw, J. Maselko and A.G. Celewycz. Auke Bay Fisheries Laboratory, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau, AK 99801. 907-789-6040 (Wertheimer)

This project examines the effects of oil exposure during embryonic development on the straying, survival to emergence, and gamete viability of pink salmon *Oncorhynchus gorbuscha*. The objectives of the straying component are to conduct a related series of controlled experiments on straying of pink salmon to determine the role of oil and other factors (stock, transplant, and tagging) on straying; and to use the results to interpret the high straying rates observed for wild populations of pink salmon in Prince William Sound (PWS) after the *Exxon Valdez* oil spill. The objectives for the survival and gamete viability components are to verify the trends observed in Project 191B, which indicated that these parameters are reduced by embryonic exposure.

The project is a multi-year program based at the National Marine Fisheries Service research facility at Little Port Walter (LPW) on Baranof Island in Southeast Alaska. This location was chosen to examine the response of pink salmon straying to oil exposure at a geographic locale remote from PWS, away from the confounding effect of prior oil exposure. The project was initiated in 1995 with the collection and spawning of pink salmon, and the placement of the fertilized eggs at LPW into incubators simulating oiled and non-oiled intertidal habitat which occurred in PWS after the oil spill. Treatment levels of oil were selected based on the results of Restoration Project 191B; relatively low dosages were used to ensure high survival to fry emergence. Small but significant reductions in survival of pink salmon embryos from fertilization to the eyed stage of development were detected at nominal dosages as low as 0.4 g oil per kg of gravel. There was no difference in survival between exposed and control embryos from the eyed-stage to emergence in the spring of 1996.

Following their emergence from the gravel, 459,000 pink salmon fry from wild and experimental treatment groups were marked with coded-wire tags or ventral fin-clips. These included 344,000 fry with coded-wire tags representing seven emigration time strata from the oil-exposed and control groups and the two wild streams; and 115,000 control fish with fin-clips to separate the effects of the coded-wire tag on survival and straying.

In fall 1996, 25 streams within 40 km of the natal streams were surveyed to estimate pink salmon escapements, examine carcass retention, and to determine which streams would be best for sampling. In 1997, returning adults will be examined for marks in natal streams, other streams within 40 km of the natal streams, and an adjacent fishery. Recoveries of tagged adults will determine if oil exposure increases straying and decreases survival to spawning. Escapement and sampling rates in natal and non-natal streams will be estimated so that actual straying rates within the sampling region can be estimated, and the effects of oil, stock, transplant, and tagging on straying rate can be evaluated. Adults from the oil-exposure experiments that return to the release site will be identified to treatment and then spawned. The fertilized eggs will be incubated in a clean environment to verify whether oil exposure decreases the gamete viability of the exposed fish.

Project Number and Title: 96086C (closeout) - Herring Bay Experimental and Monitoring Studies

Principal Investigators: Raymond Highsmith, Michael Stekoll, Peter van Tamelen,. Susan Saupe, Tama Rucker, Lawrence Deysher, Andy Hooten, Institute of Marine Science School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks, Fairbanks, Alaska 99775-1090 (Phone 907/474-7836)

Abstract: A comprehensive assessment of coastal habitat was initiated as Coastal Habitat Study No. 1 in 1989 following the *Exxon Valdez* oil spill disaster. In 1990, experimental studies began in Herring Bay, Knight Island, Prince William Sound, which were designed to compliment the overall monitoring program by experimentally assessing intertidal community dynamics and mechanisms of recovery. This experimental approach went beyond basic species inventories, allowing a more comprehensive assessment of the oil spill impacts on physical and biological interactions mediating community structure. The manipulative experiments were designed to evaluate the strength of important species interactions and the role of physical factors in community structure.

Intertidal studies established in 1990 in Herring Bay, Prince William Sound in response to the *T/V Exxon Valdez* oil spill continued through the 1995 field season. Data were compared for matched oiled and control sites. For the dominant intertidal alga, *Fucus gardneri*, densities were lower, the reproductive plants had fewer receptacles per plant, and egg settlement rates were lower on oiled sites, especially in the higher intertidal. *Fucus* canopy enhanced recruitment of germlings. *Fucus* germlings were negatively affected by herbivores and desiccation, and substrate affected long-term survival. Excluding plants which lost thallus material, plants grew faster at oiled sites. Experiments employing biodegradable erosion control fabric mats to act as a substrate for *Fucus* germlings showed dense populations of *Fucus* one year after deployment, but deterioration of the fabric occurred over winter in the second year. *Tectura persona* and *Littorina sitkana* continued to show reduced densities on oiled sites in 1995. Filamentous algal percent cover and mussel recruitment and growth were greater on oiled sites. These patterns appear to be related to the detection of greater water motion on oiled sites based on calcium sulphate cylinder dissolution rates.

Project Title: 96090, Recovery Monitoring and Restoration of Intertidal Oiled Mussel Beds in Prince William Sound Impacted by the *Exxon Valdez* Oil Spill.

Principal Investigators: Malin M. Babcock, NOAA/NMFS/Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626 and Gail V. Irvine, National Biological Service, Alaska Science Center 1011 East Tudor Rd., Anchorage, Alaska 99503. 907-789-9423 (Babcock)

Abstract: The persistence of *Exxon Valdez* crude oil underlying some dense mussel (*Mytilus trossulus*) beds began to cause concern in the spring of 1991. These beds were intentionally left untreated during cleanup activities, 1989-1991, because they provided physical stabilization in the intertidal area and the mussels were a food source for higher consumers. The beds did not appear to be recovering rapidly through natural processes and the continued presence of oil-contaminated mussels could be incorporated into the food chain and affect consumer species. The goals of this project in 1996 were to 1) complete hydrocarbon chemistry for samples taken in 1995, and 2) produce a final report covering all work under oiled mussels beds, 1992-1995.

In 1992 and 1993, we documented 31 mussel beds in Prince William Sound and two beds along the Kenai Peninsula with underlying sediment concentrations in excess of 10,000 µg/g total petroleum hydrocarbons (TPH). Mussels from these beds contained the highest petroleum hydrocarbons seen in PWS since 1990. In 1994, cooperatively with the Alaska Department of Environmental Conservation and residents from Chenega, Alaska, twelve mussel beds at five different locations were restored. Oiled sediment underlying the mussels was removed and replaced with uncontaminated sediment.

All chemical analyses were completed including sediment samples collected from the restored beds in May and June of 1996, at no cost to the project. The multi-agency, multi-year final report will be available for review soon.

Project Number and Title: (96101) Introduced predator removal from islands

Principal Investigators: G. Vernon Byrd, Edgar P. Bailey, and Steven Ebbert, Alaska Maritime National Wildlife Refuge, 2355 Kachemak Bay Drive, Suite 101, Homer, AK, 99603. (Phone 907/ 235-6546).

Abstract: In order to restore black oystercatchers (*Haematopus bachmani*) and pigeon guillemots (*Cepphus columba*), 2 species injured by the *T/V Exxon Valdez* oil spill, the introduced predator, arctic fox (*Alopex lagopus*), was removed from 2 islands in the Shumagin Island group near the western edge of the trajectory of the oil. In 1994, most of the foxes were removed from Simeonof Island (33 animals) and all foxes were eliminated from Chernabura Island (3 animals). The remaining 5 foxes were removed from Simeonof by July 1995. Surveys of oystercatchers and guillemots in 1994 and 1995 indicated that breeding populations at Simeonof and Chernabura were below levels that would be expected based on the amount of available breeding habitat.

Estimated densities of oystercatcher breeding pairs on fox-free islands in the Shumagins ranged from approximately 0.5 to 2.5 pairs km^{-1} of coastal breeding habitat. Although no oystercatchers were nesting on Simeonof in 1994 and no more than 1 pair was found on Chernabura, , we predict that following fox removal the islands will eventually have 21-88 and 16-65 nesting pairs, respectively, based on the amount of habitat available and the range of densities on nearby fox-free islands.

In contrast to oystercatchers, which are almost completely excluded from nesting on islands with foxes, pigeon guillemots are able to sustain reduced nesting populations because they nest in rock crevices, a proportion of which are inaccessible to foxes. In spite of this protection, foxes prey on guillemots. Fox-free islands near Simeonof and Chernabura had density indexes approximately 4-50 times higher than the islands with foxes. We predict Simeonof and Chernabura each eventually will have hundreds of nesting guillemots.

It is apparent that the presence of introduced foxes is detrimental to breeding populations of oystercatchers and guillemots on islands and was probably the cause of low breeding populations of these birds on Simeonof and Chernabura islands. This project was successful in removing all foxes from Simeonof and Chernabura islands in 1994 and 1995, and recovery of oystercatcher, guillemot, and other native bird populations to natural levels is now underway.

Project Number and Title: 96106 (closeout) - The Effects of the *Exxon Valdez* on Eelgrass Communities in Prince William Sound, Alaska, 1990-1995.

Principal Investigators: Stephen C. Jewett (Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks, Fairbanks, Alaska 99775-7220, Phone 907/474-7204) and Thomas A. Dean (Coastal Resources Associates, Inc, 1185 Park Center Drive, Suite A, Vista, California 92083).

Abstract: Injuries to the shallow subtidal eelgrass community were observed in the heavily oiled portions of Western Prince William Sound following the *Exxon Valdez* oil spill of March 1989. In 1990, average concentrations of polynuclear aromatic hydrocarbons (PAH) exceeded 4,900 ng g^{-1} in shallow subtidal sediments adjacent to heavily oiled shorelines. High PAH concentrations were associated with observed differences in communities at oiled *vs*. Unoiled sites. Several dominant taxa within the eelgrass community, including infaunal amphipods, infaunal bivalves, helmet crabs, and leather stars were less abundant at oiled sites in 1990. Other taxa, including several families of opportunistic or stress tolerant infaunal polychaetes and gastropods, epifaunal polychaetes and mussels, and small cod, were more abundant at oiled sites. By 1995, there was apparent recovery of most constituents of the community. PAH levels declined to less than 230 ng g^{-1}, and there were far fewer differences in the abundance of taxa between oiled and reference sites. However, not all taxa had recovered fully. There was still some evidence of slight hydrocarbon contamination at some sites, and three infaunal bivalves, two amphipods, a crab, and a sea star were still more abundant at reference sites than at oiled sites.

Project Number and Title: 97115 - Sound Waste Management Plan, Phase II

Principal Investigators: James Winchester, Prince William Sound Economic Development Corporation, PO Box 2353, Valdez, Alaska 99686

Abstract: The objective of the Sound Waste Management Plan (SWMP), Phase II is to reduce marine pollution in Prince William Sound by constructing Environmental Operations Stations (EVOS) in all five principle communities of Prince William Sound; Chenega Bay, Cordova, Tatitlek, Valdez and Whittier. The EVOS Stations will serve as centers for the recycling of waste oil and household hazardous waste. The SWMP II project is funded at $1,132,000 and will be completed in a planning phase and construction phase.

The Prince William Sound Economic Development Council and the Alaska Department of Environmental Conservation completed contractual negotiations on 12/16/96. Work on the planning portion of SWMP II began immediately. The first meeting of the SWMP advisory committee is tentatively scheduled for 1/28/96. The agenda includes a discussion of proposed floor plans, recycling equipment, construction sites, building costs, codes, relevant environmental permitting and the responsibilities of each community in maintenance and usage.

The action, or construction phase of SWMP II is scheduled to begin in June, 1997. Construction plans developed for each community through the committee process will be actualized. Contractors to supply waste handling equipment and to build recycling structures will be chosen through a standardized selection process developed for the project. Criteria for selection will include cost, familiarity with the work and familiarity with the community where the facility is being placed. All five EVOS stations will be completed by Fall, 1997.

Project Number and Title: 96127 - Tatitlek Coho Salmon Release

Principal Investigators: Gary Kompkoff, Tatitlek IRA Council, Box 171, Tatitlek, AK 99677 (Phone 907-325-2311); James Winchester, Prince William Sound Economic Development Council (PWSEDC), P.O. Box 2353, Valdez, Alaska 99686 (Phone 907-835-3775)

Abstract: The project was proposed by Tatitlek IRA Council and has been undertaken in cooperation with ADF&G, Prince William Sound Economic Development Council and the Valdez Fisheries Development Association. The objective of this project is to create a coho salmon return to Boulder Bay near the village of Tatitlek. Traditional subsistence resources available to residents of Tatitlek were severely disrupted by the oil spill and this project was initiated to provide coho salmon to fishermen near Tatitlek until other resources injured by the spill, such as harbor seals, could recover.

The coho salmon return was created through an annual release, beginning in 1990, of 20,000 coho smolts near the village. The smolts are produced at the Solomon Gulch Salmon Hatchery under an agreement between its operator, the Valdez Fisheries Development Corporation, and the Tatitlek IRA Council. The smolts are transported from the hatchery to Tatitlek by boat, placed in net pens for about two weeks and then released into the wild. Coho are currently returning to Tatitlek and are being utilized by the subsistence and sport fishermen.

Project Number and Title: 96131 - Chugach Native Region Clam Restoration

Principal Investigators: Jon Agosti, Qutekcak Shellfish Hatchery, Box 369, Seward, AK 99664, (907) 224-5181; Jeff Hetrick and David Daisy, Chugach Regional Resources Commission, 4201 Tudor Centre Drive, Suite 211, Anchorage, AK 99508, (907) 562-6647

Abstract: Clams were once a major subsistence resource in the Native communities of Nanwalek and Port Graham in lower Cook Inlet and Tatitlek in Prince William Sound. Local clam populations have been decreasing in recent years and their contribution to the subsistence harvest has been greatly reduced. There are probably several reasons for this including changes in currents and beach patterns, increasingly heavy sea otter predation and the *Exxon Valdez* oil spill. The oil spill impacted the wild clam populations and their importance as a subsistence food in two ways. First, some clam beds suffered from direct oiling. Second, even though many clams were not directly impacted by the oil, they have a tendency to accumulate, concentrate and store the toxic contaminants from non-lethal amounts of oil. This has badly eroded the confidence of the villagers in the healthfulness of the remaining wild clam populations as a subsistence food.

The project goal is to provide the project villages with safe, reliable, easily accessible sources of clams for subsistence use. Project objectives for 1996, the second year of the project, will be to continue to improve hatchery production techniques for littleneck clams (*Protothaca staminea*), initiate hatchery work with cockles (*Clinocardium nuttalli*), continue work with the nursery ponds near the hatchery and experiment with a tidally driven fluidized upwelling nursery system (FLUPSY), seed test plots on beaches near the project villages, test predator control coverings on razor clam beaches near Eyak, and conduct the initial beach surveys on beaches near the villages of Chenega Bay in Prince William Sound and Ouzinkie on Kodiak Island.

An experienced shellfish hatchery technician was hired to operate the shellfish hatchery in Seward with the goal of bringing the hatchery and adjacent nursery pond operations up to standard. In addition, the project is investigating the potential of remote tidally operated fluidized upwelling systems (tidal FLUPSY) for producing nursery stock. A prototype tidal FLUPSY is being tested this year at Tatitlek using 5 mm seed produced by the hatchery. Results to date have shown that significant seed growth is possible with the FLUPSY.

Very little work has been done in culturing cockles. Dr. Ken Brooks of Aquatic Environmental Sciences in Port Townsend, Washington has been contracted to develop procedures for spawning cockles for this project. His work so far has met with limited success.

Small test plots have been seeded in August on three different beach types near the project villages using hatchery produced seed. These test plots will be used to determine growth rates on each beach type as well as test predator control measures. Initial sampling indicates that growth rates are exceeding expectations on all beach types. Additional predator control tests are also being conducted on razor clams near Eyak (Cordova).

Baseline beach surveys were conducted near the villages of Chenega Bay and Ouzinkie. When growout techniques are developed, and seed stock becomes available, these village beaches can be treated with the appropriate enhancement procedures.

PROJECT NUMBER AND TITLE: 96139A1 - Salmon Instream Habitat and Stock Restoration - Little Waterfall Barrier Bypass Improvement.

PRINCIPAL INVESTIGATOR: Steven G. Honnold, Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, 211 Mission Road, Kodiak, Alaska, 99615 (907) 486-1873.

ABSTRACT: Restoration work began at Little Waterfall Creek in 1994 as result of surveys conducted on Kodiak Island to evaluate instream habitat and stock restoration techniques for wild salmon stocks. These surveys were intended to identify potential sites that could provide mitigation for instream habitat damage that resulted from the *Exxon Valdez oil spill*. Data from these surveys indicated that Little Waterfall Creek contained a significant amount of spawning habitat that was underutilized by pink and coho salmon due to an ineffective barrier bypass structure. Further surveys revealed that this barrier bypass structure was deficient due to steep gradients and excess water velocity.

The primary objective of this restoration project was to improve salmon passage through this bypass, thus, increasing escapement to underutilized spawning habitat upstream of the barrier. The priorities of the project were to renovate the bypass to reduce the gradients and to design resting pools to minimize water velocity. Pink and coho salmon production data were assessed in conjunction with the renovation work to determine pre-project status and for later comparison to post project data. Specifically, escapement, preemergent fry indices, and relative abundance of rearing juveniles (coho) upstream and downstream of the barrier were assessed.

The bypass renovation was completed in the fall of 1995, with gradients reduced from 27% to 17-20% and the addition of two resting pools and an entrance pool. The steeppass sections were staggered between pools to reduce the velocity of stream flows. In 1996, Little Waterfall Creek pink salmon escapment was poor (5,500); however, 44% of the escapement (2,400) passed through the improved bypass. By comparison, in 1995, only 22% of the pink salmon escapement was observed upstream of the bypass. The 1996 bypass use represented the highest proportion of escapement ever observed in upper reaches of the system. Coho escapement surveys in 1996 were hampered by high water conditions which prevented initial assessment of bypass use.

Project Number and Title: 97139-A2, Port Dick Creek Tributary Restoration Project.

Principal Investigators: Nick Dudiak (Principal investigator), Mark Dickson (project manager).
3298 Douglas Street, Homer, Alaska 99603. 907-235-8191

Abstract: Restoration surveys on the outer coast of the Kenai Peninsula resulted in the identification and feasibility analysis for the restoration of pink and chum salmon spawning habitat within a tributary system of Port Dick Creek. Port Dick Creek is located approximately 25 miles southeast of Homer on the Kenai Peninsula. The primary project goal involves the restoration of the native Port Dick Creek Pink Salmon, *Onchorynchus gorbusca* and Chum Salmon *Onchorynchus keta* stocks through in-stream habitat restoration in two intermitted spawning tributaries of Port Dick Creek.

Continuous water table fluctuation (depth) measurements were taken from driven standpipes and recorded onto battery operated data recorders during the winters' 1991-1995 and the data used to design the excavation and restoration of the two tributaries. Three pieces of heavy equipment were transported to the site via landing craft barge in June, 1996 and were used to excavate approximately 3,000 cubic yards of material from the two tributaries to establish a stable water source and create additional spawning habitat. In July and August, approximately 572 pink and 300 chum salmon invaded the tributaries and spawned, generating an additional projected adult contribution of over 11,600 adults beginning in 1998. Juvenile and adult Dolly Varden and juvenile coho salmon have also been observed utilizing the new habitat.

The restored tributaries were designed to withstand two extremes; very low and very high water discharge events. Post construction evaluation will determine the capability of the tributaries to withstand the two extremes through modeling and measuring sedimentation and critical water discharge. Additional post construction analysis will include physical parameter monitoring and measurements such as water temperature, water level, salinity and stream velocity as these parameters are well correlated in the literature with spawning success; egg fertilization and egg/fry survival. Actual egg/fry survival within the tributaries will be determined using fish traps and enumerating live salmon fry during the spring out-migration. These evaluation studies will be conducted annually to 2000 pending EVOS Trustee council project and budget approval.

Unusually low precipitation during the spawning run on the outer coast of the Kenai Peninsula resulted in low water levels and restricted spawning activity to approximately 75% of the recently restored tributaries. It is expected that with "normal" precipitation and water levels, 100% of the newly restored spawning habitat will be utilized in the future by spawning salmon.

Project Number and Title: 96139C1 - Montague Island Riparian Rehabilitation

Principal Investigator: David Schmid, USDA Forest Service, PO Box 280, Cordova, AK 99574 (907) 424-7661

Abstract: A number of watersheds on the west side of Montague Island were clearcut in the 1960's and 1970's without leaving buffer strips along the streams. In addition, large woody material was removed from the streams in the belief that salmonid migration and spawning area would be enhanced. As a result of these practices, the streams have suffered increased erosion, stream widening, loss of pools, erratic flows, and high bedload movement. Pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*) redds in downstream areas are subject to displacement and desiccation. Coho salmon (*Oncorhynchus kisutch*) and Dolly Varden char (*Salvelinus malma*) spawning and rearing areas are also adversely affected.

We have tried to restore these streams to a more natural condition by building instream structures with logs and boulders and by thinning the thick stands of Sitka spruce (*Picea sitchensis*) that have emerged in the riparian areas. The structures would take the place of the large woody material that was removed from the streams and would create pools, trap sediments, and reduce water velocities and erosion. Thinning the Sitka spruce stands would accelerate the growth of the remaining trees which will provide the source of large woody material for the streams in the future. Although this project does not directly address the effects of the *Exxon Valdez* oil spill, it was felt that the benefits to the wildstock salmonid species in these areas would help the overall restoration of these species in Prince William Sound.

In 1994, 32 structures were built, mostly in Hanning Creek and its tributaries. Although all of the structures survived bankfull flows during the first summer, 10 structures failed during high flows associated with the spring runoff. Four structures were rebuilt in 1996 using better anchoring techniques. The surviving structures have functioned as intended, creating pools, protecting banks, and providing fish habitat. During low flows, large numbers of juvenile Dolly Varden char have been observed in the pools created by the structures. Changes in channel geometry, substrate composition, and streamside vegetation will be assessed in 1997 to determine whether the structures have helped to reduce velocities, erosion, and bedload transport.

Crowded Sitka spruce stands were thinned along Hanning Creek, Quadra Creek, Swamp Creek, and an unnamed creek. Mainstem and whorl growth were measured in treated and untreated areas. In areas where only competing alder and willow were removed, the Sitka spruce showed significantly greater growth than untreated areas for only one year, after which, intraspecific competition reduced growth. In areas where alder and willow were removed and Sitka spruce were thinned, growth was significantly higher than untreated areas and areas where only alder and willow were removed. The final assessment will occur in 1997.

Project Number and Title: 96142—Status and Ecology of Kittlitz's Murrelet in Prince William Sound

Investigators: Robert H. Day (Principal) and Debora A. Flint, ABR, Inc., P.O. Box 80410, Fairbanks, AK 99708-0410 (Phone of RHD 907/455-6777; e-mail of RHD bday@abrinc.com)

Abstract: This project investigated aspects of the ecology of Kittlitz's murrelet (*Brachyramphus brevirostris*) in four glaciated fjords in northern Prince William Sound (PWS) during 3-week cruises in early (May-June) and late summer (July-August) 1996. The small size of its world population, its restricted distribution, and uncertainty over impacts to its PWS population from the *Exxon Valdez* oil spill result in conservation concerns. The objectives of this study were (1) to conduct population surveys in the four bays; (2) to estimate population sizes; (3) to determine distribution and habitat use; (4) to develop and measure indices of reproductive performance; and (5) to describe trophic levels and feeding ecology.

Kittlitz's murrelets were common on nearshore surveys, uncommon on offshore surveys, and very rare on pelagic surveys. In early summer, Kittlitz's murrelets were still arriving in Unakwik Inlet and College Fjord, whereas their numbers in Harriman Fjord and Blackstone Bay were stable. Numbers decreased rapidly in late summer as birds left; two of the bays had been abandoned by the time we began sampling. Populations in all bays were small and collectively totaled ~1,425 $\pm$ 1,700 (95% CI) birds. Habitat use was highly variable among bays and between cruises but generally was consistent between cruises within bays. At a gross scale, Kittlitz's murrelets used areas with more ice than was available to them overall; at a fine scale, however, they used open water that occurred within these zones of heavier ice. In early summer, Kittlitz's murrelets did not use waters of different sea-surface temperatures than was available to them, but they did in late summer as they moved into areas near glaciers and in cooler parts of bays.

The percentage of breeding-plumaged birds in early summer decreased through time. There was extreme variation in plumages suggesting that either (1) many of these birds were breeding in what was not a "normal" breeding plumage or (2) if such a plumage is required for breeding, many birds were not breeding. Ratios of juveniles:older birds indicated that reproductive output in all bays was extremely low or absent in 1996; birds also spent little time in two bays. We were unable to catch Kittlitz's murrelets with floating mist nets to examine trophics directly and to catch newly fledged juveniles to study their residence times. Many more Kittlitz's murrelets fed in nearshore areas than in offshore areas. There was no difference in feeding frequency between morning and afternoon and little relationship to tidal stage. Feeding frequency was high when tidal currents were weak and/or moderate, low when currents were strong, and high in glacial affected habitats. The few birds seen feeding ate fishes, probably sandlance, Pacific herring, and/or capelin, and primarily from 0- or 1-year age classes.

These results suggest that Kittlitz's murrelets in these bays had fairly small population sizes and low reproductive output in 1996. There is a possibility of a population decline since the early 1970s, although the baseline is of questionable validity. A widespread lack of reproduction in this species has been recorded previously; consistently low reproductive performance would result in population declines and their inability to increase.

Project Number and Title: 96144 - Common Murre Population Monitoring.

Principal Investigators: David G. Roseneau, Arthur B. Kettle, and G. Vernon Byrd, U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, 2355 Kachemak Bay Dr. (Suite 101), Homer, Alaska 99603-8021 (Telephone 907/235-6546).

Background: The Barren Islands in the northwestern Gulf of Alaska supported one of the largest breeding concentrations of common murres *(Uria aalge)* in the path of the *Exxon Valdez* oil spill. When winds and currents swept oil through the region during April and early May 1989, many murres were killed: they comprised 74% of 30,000 bird carcasses recovered by 1 August. Based on this information and a computer modeling study, estimates of total bird mortality suggested that 74,000-315,000 murres died after contacting floating oil. Because murre mortality was high, the U.S. Fish and Wildlife Service (FWS) conducted *Exxon Valdez* Oil Spill Trustee Council-sponsored common murre damage assessment and restoration studies at the Barren Islands during 1989-1991 and 1992, respectively. These studies collected data on numbers of birds attending the colonies. During 1990-1992, Exxon-sponsored studies also provided information on Barren Islands murre numbers. In 1993-1994, we counted murres at the Barren Islands East Amatuli Island - Light Rock and Nord Island - Northwest Islet colonies during Trustee Council-sponsored restoration monitoring Projects 93049 and 94039. Although complete censuses were not obtained in 1995, we counted murres on three sets of East Amatuli Island - Light Rock monitoring plots during APEX Project 95163J. In 1996, after common murre population monitoring Project 96144 was approved, we returned to the islands and censused birds at both breeding colonies.

Abstract: The Project 96144 objective was the same as previous restoration study objectives—to monitor the recovery of common murres at the Barren Islands nesting colonies. The Barren Islands are located at about 58° 55' N, 152° 10' W, between the Kodiak archipelago and the Kenai Peninsula. Study sites consisted of East Amatuli and Nord islands and two nearby islets, East Amatuli Light Rock (Light Rock) and Northwest Islet. These four areas, comprising the East Amatuli Island - Light Rock and Nord Island - Northwest Islet colonies, currently contain all of the breeding murres in the Barren Islands group. Methods used to make population counts and analyze data were the same as those used during our 1993-1994 restoration studies. We censused East Amatuli Island - Light Rock and Nord Island - Northwest Islet completely to obtain whole-colony estimates and total numbers of birds on major subdivisions of the colonies (e.g., East Amatuli Island, Light Rock). We also counted sets of plots (multicount plots) at both colonies at least five times for statistical analyses of among-year differences and trends in population size. Plots were counted from small boats by two observers using binoculars during the times of day (1100-2000 hrs) and season (peak of laying to first sea-going of chicks) when attendance was most stable. Plot boundaries were located using photographs in Alaska Maritime NWR files, and most plots were counted by 10's. Using plots as sample units, we statistically compared our results with data from previous FWS and Exxon postspill studies using Kendall's Tau (t) rank correlation tests and linear regression models to check for trends, and one-way analysis of variance (ANOVA), Tukey HSD multiple pairwise comparison, and two-tailed *t*-tests to check for differences among years at the 0.1 significance level. Although positive increases were detected in the 1989-1994 and 1990-1994 counts on two small sets of East Amatuli Island - Light Rock plots, no evidence of trends was found on these plots over the 1993-1996 interval. Also, no trends were apparent on the larger sections of the East Amatuli Island - Light Rock colony, nor at Nord Island - Northwest Islet over the 7-year postspill period. In summary, our results indicated that changes have occurred on some plots; however, no strong evidence of an overall increase in murre populations was found at the colonies over the postspill interval. The Barren Islands murre colonies will be censused again in 1997 (EVOS Project 97144). These counts may begin to detect increases in population numbers, because 3-year-old and 4-year-old birds from the high productivity 1993-1994 nesting seasons should begin returning to the nesting cliffs before the counts are made in mid-July - mid-August.

Project Number and Title: 96145 Cutthroat Trout and Dolly Varden in Prince William Sound, Alaska: The Relation Among and Within Populations of Anadromous and Resident Forms

Principal Investigators: Gordon H. Reeves and Kitty E. Griswold, USDA Forest Service, PNW Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331 (GHR 541-750-7314); Kenneth P. Currens, Northwest Indian Fisheries Commission, 6730 Martin Way E., Olympia, WA 98516-5540

Abstract: Dolly Varden (*Salvelinus malma*) and coastal cutthroat trout (*Oncorhynchus clarki clarki*) are important fish resources in Prince William Sound and are listed as injured resources whose recovery is unknown. Restoration efforts have taken the form of instream habitat modifications. The usefulness of this approach in the longterm is unknown so a strategy based on the ecological and genetic relations of these fish is needed. We are attempting to determine the relation between resident and anadromous forms of these fish within the same watershed and between watersheds across Prince William Sound. We are using meristic, life-history, and genetic features of each group to develop a longterm, comprehensive, and ecologically sound restoration strategy for these fish.

In the summer of FY96, we collected cutthroat trout at 11 sites and Dolly Varden at 12 sites in July and September at different locations around Prince William Sound. Fish were captured by hook and line, baited traps, and electrofishing. Sample sizes averaged 20 for cutthroat trout and 40 for Dolly Varden. A second year of field sampling is planned to repeat sampling from 1996 sites as well as include additional sites in areas not sampled this year. We are exploring a combination of techniques to determine the genetic structure among populations. We are using allozymes, mitochondrial DNA (RFLP), and nuclear DNA (microsatellites) techniques. To date, we have completed preliminary allozymes analysis on cutthroat trout. Resulting groupings do not follow geographic patterns. Mitochondrial results have not shown any differences among sites. We have not completed the microsatellite portion of the study at this time. Neither have we started the genetic analysis of Dolly Varden. Meristic and life-history determinations have began but complete data are not available at this time..

Project Number and Title: EVOS Project 96149- Archaeological Site Stewardship

Principal Investigators: Douglas R. Reger, Office of History and Archaeology, Department of Natural Resources, 3601 C St., Suite 1278, Anchorage, AK, 99503-5921 (Phone (907) 269-8725); Debra G. Corbett, U.S. Fish and Wildlife Service, 1011 E. Tudor Rd., Anchorage, AK, 99503 (Phone (907) 786-3399).

Abstract: An important key to saving Alaska's cultural heritage sites from continuing loss is promotion of local stewardship of historic and prehistoric sites. The idea of site stewardship is to get local people to take an interest in sites and the information they contain and to convince people to report site destruction or damage to sites. During 1996, stewards monitored archaeological sites for vandalism and other injuries in the Kenai Peninsula, Kodiak Island, and Chignik areas.

Stewards received instruction in recording information from damaged sites through site visits and on-site training. Disposable cameras, notebooks, and basic information about the sites and area archaeology were provided to stewards in the process. Level and breadth of training varied according to the recordation needs of sites and the prior archaeological experience and ability of the individual stewards. Physical site visits were attempted at each site monitored by the steward and trainer.

Kachemak Bay area steward training and coordination were conducted by a two person area coordination team. In addition to the area coordinators, three site stewards were active and eight sites were visited. Four of the sites were initially identified for attention with the additional four sites visited because they are close to the targeted locations. Vandalism injury was documented at three sites and erosional damage documented at all sites.

Kenai Peninsula site stewards were active along the Kenai River and at one site along the Kasilof River. A total of six site stewards received training to monitor five sites. A local coordinator monitors steward activities. A site stewardship program by the U.S. Fish and Wildlife Service in cooperation with the Kenaitze Tribe and CIRI is also developing in conjunction with the EVOS funded stewardship program. Injury to sites on the Kenai Peninsula derives primarily from fishing activities but also includes vandalism.

Kodiak Island site stewards are local guides or commercial fishermen monitoring sites near their guiding and fishing locations. The training of stewards in the Kodiak area is still developing. Seven individuals have volunteered to monitor sites. Approximately eight sites have been identified for monitoring injuries from vandalism and erosion.

At least six people have shown interest in being site stewards in the Chignik area. Training of people has proceeded slowly. Injured sites are mostly on private corporate land and extensive coordination requires considerable time to develop.

Experience over the past season has reinforced the impression that stewardship programs must be highly adaptable to local conditions. A tightly structured program will not succeed. Strong local support is required for the program to continue to exist.

Project Number and Title: 96159 - Marine Boat Survey - MARINE BIRD ABUNDANCE IN PRINCE WILLIAM SOUND, ALASKA: TRENDS FOLLOWING THE *T/V EXXON VALDEZ* OIL SPILL FROM 1989-96.

Principal Investigators: *Beverly A. Agler,** and *Steven J. Kendall,* U. S. Fish and Wildlife Service, Anchorage, Alaska 99503. (Phone 907/786-3681)

Abstract: After the *T/V Exxon Valdez* oil spill, natural resource damage assessment studies found that several marine bird species were injured by the spill. The main objectives of the present study were to monitor recovery of injured species and to determine whether additional species were showing an oil spill effect. To do this, we conducted small boat surveys of Prince William Sound during March of 1990, 1991, 1993, 1994, and 1996 and during July of 1989, 1990, 1991, 1993, and 1996. We then estimated populations of marine birds and mammals in the oiled and unoiled zones. To determine what species, if any, have recovered we compared the population trends between the two zones.

During March, cormorants, scaup, and Steller's sea lions showed significant differences in trends between oiled and unoiled zones, with cormorants and sea lions showing an oil spill effect. During July, scoters, black-legged kittiwakes, gulls, Kittlitz's murrelets, horned puffins, and all puffins also showed significant differences in trends between oiled and unoiled zones. Black-legged kittiwakes, gulls and scoters are showing an oil spill effect. Within the entirety of Prince William Sound, bald eagles, black-legged kittiwakes, and cormorants showed significant increasing trends during March, and bald eagles and northwestern crows were found to be increasing during July. No populations were found to be declining significantly Sound-wide.

Of the species with significant differences in trends between the oiled and unoiled zone, only cormorants and Kittlitz's murrelets were listed as injured species. Cormorants are showing a continued oil spill effect, but Kittlitz's murrelets are showing possible recovery. Although these data indicate that some species are exhibiting recovery, most are not. Thus, recovery of many marine bird species from a large perturbation, such as the *T/V Exxon Valdez* oil spill, is slow or not statistically detectable with data from only 5 surveys.

Project Number and Title: 97161 - Differentiation and Interchange of Harlequin Duck Populations Within the North Pacific

Principal Investigators: Buddy Goatcher, Katmai National Park and Preserve, Coastal Unit Office, 202 Center Avenue, #201, Kodiak, Alaska 99615-6312, (907) 486-6730

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Abstract: We are using genetic analyses and color-banding programs to assess the degree of population differentiation and movements among geographically separate groups of harlequin ducks (*Histrionicus histrionicus)*. The primary area of study encompasses *Exxon Valdez* oil spill impacted areas of the northeast coast of the Alaska Peninsula (Katmai National Park) and Kodiak Island Archipelago (Kodiak National Wildlife Refuge) along the Shelikof Straits and Prince William Sound. Other investigators in the North Pacific region contributed additional samples for molecular genetics evaluation.

Harlequin ducks were captured in molting drives, genetic samples were collected, and leg-bands were applied with site specific colors and individual alpha-numeric codes before release on *Exxon Valdez* Oil Spill affected shorelines of Katmai (N=39), Kodiak (N=313) and Prince William Sound. A more practical live-trap design that should increase capture efficiencies was developed and constructed in 1996 and will be field tested in 1997. Resightings of colored bands from 14 flying birds were obtained in the Kodiak study area during 15-21 November. Other Prince William Sound studies have accumulated over 400 coded bandings and over 700 banded ducks to date.

We are using both nuclear bi-parentally inherited markers (microsatellites) and maternally inherited mitochondrial DNA (mtDNA) for genetic analyses. To date, 209 individuals from 6 regions [Katmai (N=35), Kodiak (N=21), Prince William Sound (N=74 from 4 locations), British Columbia (N=21), Aleutian Islands (N=23), and Washington state (N=35), have been assayed at one microsatellite locus. Preliminary results suggest that population allele frequency does not vary significantly among populations across the North Pacific. In an effort to obtain additional loci, cloning efforts are underway to develop additional polymorphic loci. We feel the microsatellite analysis will prove far superior to multilocus minisatellite (DNA fingerprinting) analysis for the purposes of this study.

If population interchange is limited among regions, recovery of populations injured by the oil spill can occur only through the recruitment of young into the population. However, if movements exist among areas, as evidenced by genetic mixing or direct band returns from this study, recovery can be enhanced by immigration from non-injured populations. We will continue to address these issues with genetic analyses and recoveries of banded individuals.

Project Number and Title: 96162(II) -- Investigations of Disease Factors Affecting Declines of Pacific Herring Populations in Prince William Sound

Principal Investigators: Richard M. Kocan, Box 355100, University of Washington, Seattle, WA 98195 (telephone 206/685-2984); James Winton, NW Biological Science Center, U.S. Geological Survey, Seattle, WA 98115; Gary D. Marty, Univ.of California, Davis, CA 95616; and Theodore Meyers, Alaska Department of Fish and Game, Juneau, AK 99802

Following the 1993-1994 Pacific herring (Clupea pallasi) population crash in Prince William Sound, free-ranging herring began showing signs of external hemorrhagic lesions, and viral hemorrhagic septicemia virus (VHSV) was isolated for the first time from herring. The fungal pathogen Ichthyophonus hoferi was also reached ezizootic proportions in 1994. Although both organisms are known to be pathogenic for various fish species, neither organism was previously known to cause disease in Pacific herring. This project was designed to determine whether either or both of these organisms is pathogenic for herring.

Controlled studies have shown that the North American strain of VHSV causes clinical disease and mortality that approaches 100% in juvenile Pacific herring. Specific-pathogen-free (SPF) herring were reared in the laboratory from eggs in filtered, UV-sterilized, natural seawater then challenged at 5, 9, 13 and 18 months of age by waterborne exposure to varying levels of VHSV. Mortality began 5 days post-exposure and peaked at approximately 1 week in fish exposed to > 1,000 virus particles (PFU/ml). Fish exposed to < 500 PFU of VHSV began dying 7 days post-exposure with peak mortality occurring on days 10-11. No mortality or lesions were observed in control fish or in surviving groups of SPF herring exposed to the lowest levels of VHSV, and no virus could be isolated from their tissues. Little or no increase in resistance was observed with increasing age. External signs of disease were usually limited to 1-2 mm hemorrhagic areas on the lower jaw, isthmus and around the eye, even though extensisve epidermal necrosis was observed histologically. Histopathologic examination of tissues from moribund fish sampled at 2-8 days post-exposure revealed necrosis (cell death) in liver, kidney, spleen, blood-forming tissues and skin. Virus titers were first detected in tissues of experimentally infected SPF herring 48 hours post-exposure and peaked at day 6-8 post-exposure at >10 million PFU/gm. Fish began shedding new virus at 48 hours post-exposure with water titers reaching almost 1,000 PFU/ml at 4-5 days post-exposure, just prior to peak mortality. When the water flow was turned off for 3 hours, titers in the water rose to 4,000 PFU/mL and the amount of virus shed by each infected fish (3 million PFU/hr) appeared sufficient to initiate an epizootic in the wild. These data suggest that VHSV could be a significant limiting factor among populations of Pacific herring in nature.

Controlled field studies on VHS in herring held in net pens have been carried out in PWS and Puget Sound. Except under unusual circumstances VHSV has not be routinely isolated from free-ranging herring. When these same herring are placed into net pens, either in the pound fishery or as bait fish, 15-20% begin shedding significant amounts of virus into the water within 48 hours of capture and virus can be detected in their tissues at levels in excess on 1 million PFU/gr. When fish are held in the laboratory and sampled at regular levels they show a peak in virus prevalence and shedding between 2-7 days post-capture, but then become free of detectable

virus by 30 days post-capture. When the surviving fish are challenged with 10 times the known minimum lethal dose of VHSV they are solidly immune and show no signs of disease. All age classes of herring (0-year through spawners) have shown the same pattern of disease progression and virus expression when held in captivity, although 0-year fish suffer the highest level (> 50%) of mortality.

Controlled studies with Ichthyophonus have demonstrated that it is also a pathogen of Pacific herring, causing up to 100% mortality in experimentally infected fish. Sculpins fed infected herring tissue became infected and died within 30 days of exposure, indicating that a carnivore may play a role in the life cycle of this pathogen. The route of infection for herring however, is still unknown but believed to involve an infected invertebrate food item such as a copepod. Studies on field detection and evaluation of pathogenesis are planned for 1997.

Project Number and Title: 96162IIIa - Investigations of Disease Factors Affecting Declines of Pacific Herring Populations in Prince William Sound: Part III: Laboratory Studies on Herring Fitness.

Principle Investigator: Christopher J. Kennedy, Department of Biological Sciences, Simon Fraser University, Burnaby, BC, Canada, V5A 1S6 (Phone 604/291-5640)

Abstract: It has been suggested that exposure of Pacific herring, *Clupea harengus pallasi*, to environmental stressors such as oil pollution and pathogens may be responsible for population declines in Prince William Sound. If these hypotheses hold true, it is unclear if fish that survive exposures to one or more of these stressors are 'healthy' or are surviving at a reduced fitness level. The ability of fish to maintain position, escape predators and catch food all require swimming capability which may be altered by exposure to such environmental stressors. Therefore, the objective of this study was to determine the effects of oil exposure on the swimming performance of juvenile herring.

Juvenile herring were acutely exposed to varying doses of the water-soluble fraction (WSF) of North Slope crude oil for either 24 or 96 hours. Upon completion of an exposure period, fish were examined for 1) acute mortality, 2) alterations in 'stress' biochemistry, 3) swimming performance and 4) their recovery from exercise. Exposure to WSF for 24 and 96 hours resulted in significantly higher mortalities than in control fish. Percent mortalities at 24 h were 2%, 2%, 7% and 13% in control, low, medium and high WSF concentrations. At 96 hours, percent mortalities were 2%, 5%, 12% and 15%, respectively.

Biochemical parameters which have been shown to be good indicators of 'stress' in fish including plasma cortisol, glucose and lactate, and hematocrit were measured at 0, 2,4,8,24 and 96 hours of exposure to WSF. Significant increases in plasma cortisol, lactate, glucose and hematocrit were seen in fish exposed to WSF, however, levels appeared to be returning to control values by 96 hours. These data indicate that WSF induces a classic 'stress response' in herring to which they compensate for by 4 days of exposure. Swimming performance, as measured by the critical swimming speed (Ucrit-a measure of the maximum prolonged swimming speed), was affected by exposure to WSF. Fish exposed to medium and high concentrations of WSF, had reductions in Ucrit of 6% and 22% , respectively following a 96 h exposure to WSF. No effect on swimming could be determined after a 24 h exposure to WSF.

The recovery of fish following exercise is key in terms of delayed mortality and refractory period before exercise can occur again. Herring which had been dosed with varying concentrations of WSF for 96 hours were exercised in the form of burst swimming and sampled before exercise, and at 0, 0.5, 1, 2, 4, 8, and 12 hours following exercise. Higher mortalities occurred in exercised fish following an exposure to both medium and high WSF concentrations. Exposure of herring to the two highest concentrations of WSF resulted in delayed recovery in the following parameters: hematocrit, plasma lactate, and plasma [Na+], [K+] and [Cl-].

The results of this study indicate that the WSF fraction of crude oil is acutely toxic to juvenile herring and induces a classic 'stress response'. As well, WSF exposure affects both the swimming performance of herring and their ability to recover following burst swimming. These results indicate that exposure to oil can have sublethal effects on herring fitness with ecological significance.

Project Number and Title: 96162(IIIb) - Investigations of Disease Factors Affecting Declines of Pacific Herring Populations in Prince William Sound. Part III: Alterations in the immunocompetence of juvenile Pacific herring exposed to the oil-water dispersion fraction of crude oil.

Principal Investigators: Susan M. Sanders, A.P. Farrell, and C.J. Kennedy, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., V5A 1S6

Abstract: Exposure of Pacific herring to oil-water dispersion (OWD), of crude oil has the potential to be immunosuppressive. If this is true, alterations in the immune function, following exposure as juveniles, may have contributed to the observed increases in disease prevalence in the spawning biomass of Pacific herring in Prince William Sound (PWS), Alaska since 1994. In particular, viral hemorrhagic septicemia virus and *Ichthyophonus hoferi*, a fungal pathogen, have been recorded. If an increase in susceptibility to these pathogens, and other relevant organisms, can be demonstrated, a link between crude oil exposure, disease incidence and declining populations may be established.

Two experiments consisting of a) exposure of juvenile herring (1 - 5 g) to the OWD of crude oil for 22 days and b) oil exposure plus a disease resistance challenge with *Vibrio anguillarum* were performed at the Bamfield Marine Station, B.C. Herring were exposed to the OWD fraction of crude oil (North Slope, Alaska) of varying doses; low, medium and high in duplicate (chemical analysis in progress). Following oil exposure, herring (n=10) from each oil exposed tank and 2 control tanks were sampled. The measures of general immune function evaluated were the hematocrit, leucocrit and white blood cell (WBC) differential counts. The leucocrit value was elevated in the medium group (2.24%) relative to controls (1.68%). No other significant differences were evident between groups for leucocrit or hematocrit values. Nonspecific macrophage activity was examined by evaluating the ability of head kidney (HK) macrophages to phagocytose formalin-killed *V. anguillarum*. The phagocytic index of HK macrophages was reduced in oil-challenged fish compared to controls demonstrating a reduction in macrophage function. In the second experiment the remaining oil-dosed fish and controls, were bath-challenged with *V. anguillarum*. Mortalities were greater in the low dose oil-exposed fish (91%) relative to *Vibrio* only exposure (74%). Plasma antibody titres to *V. anguillarum* were evaluated, at 6 weeks post-infection. Results demonstrate a four times greater mean titre in herring not exposed to oil (1:19193) compared to the mean titre of all oil-dosed fish (1:4726) although no oil dose-dependent differences in titre were detected. Hematocrit values were reduced in all Vibrio-dosed fish; oil (14.7%; 13.0%; 10.7%) and non-oil exposed groups, (14.9%), while the leucocrit values were significantly greater in all three oil exposed groups (2.3%; 3.8%; 0.5%) compared to the non-oil exposed group (0.19%).

These results suggest that juvenile herring exposed to the OWD fraction of crude oil may have altered immunocompetence based upon several immunological measurements. In addition, the presence of lower antibody titres to *Vibrio anguillarum* in oil-challenged fish reflects a degree of immunosuppression. These results may, in part, illuminate the relationship between oil exposure, disease and population declines.

ABSTRACT

Project 95163 A - Biomass and Distribution of Forage Species in Prince William Sound

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This component of the APEX project has the objective of estimating the species composition, biomass and distribution of forage species utilized by avian predators in Prince William Sound. The abundance and distribution of forage fishes was estimated in three areas (north, central, south) that encompass foraging sites for seabird colonies injured by EVOS. Sampling was conducted during July 1996 with downlooking and sidelooking hydroacoustic equipment. As in 1995, a series of offshore transects were surveyed; in addition, the 1996 survey added an extensive series of nearshore transects. The offshore and nearshore surveys were conducted independently and concurrently. A beach seine survey was also conducted in conjunction with the nearshore acoustic survey. The species composition of offshore forage fish aggregations was assessed by midwater trawl, whereas nearshore fish were identified by purse seine and video observations. Offshore, relatively few forage fish aggregations were encountered, and were mainly walleye pollock older than 1 year. This was a major change from 1995, when young-of-the-year pollock were found in large aggregations over deep water in the central part of the Sound. In the nearshore survey forage fish abundance varied among the three areas, and within each area there were locations where forage species were concentrated. In all areas forage fishes were found in relatively small but dense schools. The central study area had the highest abundance of nearshore forage fishes that were concentrated near the Bay of Isles and Cabin Bay and comprised of herring and some sandlance . The north area had notable concentrations of forage fishes in Port Gravina, where herring, sandlance and walleye pollock were present. The south area had relatively few schools of forage species - mainly herring in Dangerous Passage and Prince of Wales Passage. In 1996 we did not observe the large aggregations of capelin that in 1995 occurred at Port Gravina, Naked Island and Montague Island. Herring were by far the most prevalent forage species in nearshore waters throughout the three study areas, they were mainly juvenile young-of-the-year or one-year olds.

Project Number and Title: 96163B - APEX Project Component B - Seabird/forage fish interactions.

Principal Investigators: William D. Ostrand, U.S. Fish and Wildlife Service, 1011 E. Tudor Rd. Anchorage, Alaska 99503 (Phone 907/786-3849)

Abstract: This component of APEX has 2 objectives: 1) To determine whether forage fish school characteristics and/or interactions among seabirds limit food availability and 2) determine whether seabird foraging group size and species composition correlate with prey patch size. Working with the Forage Fish Assessment component (97163A) we collected hydroacoustic and bird-observation data simultaneously along transects in three areas of Prince William Sound (PWS). We also examined mixed species flocks of foraging birds located off transects and collected separate behavioral data on birds and hydroacoustic data on the associated fish. We derived depth, area, density, total depth of water, distance to shore, and distance to the nearest seabird colony for each sampled forage-fish school. Subsequently we determined which schools were associated with Tufted Puffins or Brachyramphus murrelets (Marbled and Kittlitz's Murrelets). We determined the probability of the association of fish schools with puffins and murrelets. We compared characteristics of fish schools associated with mixed species foraging flocks to fish schools sampled on the transect survey and examined the relationship between flock size and characteristics of the associated fish schools.

Our analysis indicated that Tufted Puffins foraged on fish schools that were closest to their colony. Brachyramphus murrelets selected larger, denser fish schools in shallower water when compared to sampled fish schools. The mean number of Brachyramphus murrelets and Tufted Puffins associated with a forage-fish school was 1.7 ± 1.1 (SD) and 1.2 ± 0.7, respectively. Forage-fish schools associated with mixed species foraging flocks were closer to shore and in shallower water than fish schools sampled on the transect survey. Foraging flocks size increased with increasing fish school size, decreasing depth to school, and decreasing density.

Our results suggest that Tufted Puffins and Brachyramphus murrelets used different foraging strategies to find different types of forage-fish schools. Also, both groups forage extensively as individuals or in small groups and infrequently participate in foraging flocks. These findings suggest that within PWS, individual seabirds have sufficient knowledge of available forage to select prey patches in specific types of areas with specific physical characteristics. We believe our findings on the foraging efficiencies and strategies were due to local oceanographic features that concentrated or otherwise made prey more predictably available to the seabirds of PWS. Our findings also indicate that Tufted Puffins, a species that was not injured by the Exxon Valdez oil spill, are not limited by the characteristics of fish schools. Brachyramphus murrelets, which were injured by the spill, prefer to forage in shallow water habitats and were less frequently associated with forage fish located in deep water. Therefore, if food is limiting the recovery of murrelets, it may be the result of a lack of fish schools that meet their selection criteria, rather than a lack of total forage biomass. Analysis on foraging flocks indicates there is a correlation between flock size and prey patch size. However, our data does not yet allow us to determine whether the relationship between mixed species foraging flocks and forage-fish is the result of birds selecting schools of particular characteristics or the modification of schools by foraging predators.

Project Number and Title: 96163C - Diet overlap, prey selection and potential food competition among forage fish species.

Principal Investigators: Molly V. Sturdevant. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, AK 99801 (907-789-6041)

Abstract: The diets of forage fish collected principally by trawl were examined with the goal of assessing potential competition for food between species and age-classes. Fish diets were compared to available zooplankton prey as sampled with 243μ mesh nets towed vertically from the depth fish were caught. This study is a component of the Alaska Predator Ecosystem Study (APEX), designed to examine trophic interactions of seabirds injured by the *Exxon Valdez* Oil Spill and their forage species in three regions of Prince William Sound (southwest, central and northeast). Results from earlier, preliminary diet studies were updated from analysis of additional stomach and plankton samples collected in 1995. Collections from 1996 have not been examined.

Forage fish diet composition was described from samples collected in summer, 1995 (n = 370) and fall, 1994 and 1995 (n = 270). Collections were primarily comprised of multiple age-classes (as suggested by mean preserved fork lengths (FL)) of herring and pollock, with smaller samples of capelin, eulachon, osmerid larvae, juvenile pink salmon, tomcod and sandlance. Diet composition was described as percent biomass, percent numbers and percent frequency of occurrence of pooled prey categories. Diet overlap was assessed using Percent Similarity Index (PSI) calculated from biomass of prey taxa. Prey selection from available zooplankton assemblages was described using the Rank Preference Index (RPI). Shifts in prey utilization and diet overlap between forage species collected from mono-specific versus multi-species schools were then used to suggest potential food competition.

Most dietary biomass was contributed by few prey categories and both spatial and temporal differences were observed between species and age-classes. In summer, small calanoid copepods comprised up to 70% of prey biomass in young-of-the-year (YOY) species and smaller percentages in older species. Large calanoids were prominent in diets of both older herring and older pollock. Hyperiid amphipods were also common prey in summer, but regional and species differences were observed in the utilization of teleosts, barnacle larvae, euphausiids and chaetognaths as prey. Euphausiids were more commonly consumed in the fall than in summer. Unlike other species, most capelin and eulachon stomachs were empty.

Diet overlap was greatest among co-occurring YOY forage species (up to 60% PSI), and was common for pairs involving herring in both spring and fall. Diet overlap was lowest for species combinations involving older pollock in summer. These results suggest that, although the prey resources responsible for the considerable dietary overlap observed change seasonally, competition for food could occur between several species and age classes of forage fish throughout the summer and fall.

Project Number and Tile: 96163E - APEX Project Component E - Reproduction and foraging of Black-legged Kittiwakes.

Principal Investigators: David Irons and Robert Suryan, U.S. Fish and Wildlife Service, 1011 E. Tudor Rd., Anchorage, Alaska 99503 (phone 907/786-3376)

Abstract: The distribution of Black-legged Kittiwakes (*Rissa tridactyla*) nesting in Prince William Sound (PWS) has changed dramatically since the early 1970s. Certain colonies have greatly increased while other sites have been abandoned. Sixty-three percent of the population now nests in the northern half of PWS in contrast to 30% in 1972. Population analyses of these colonies indicate that between 1984 and 1996 five northern colonies (n = 9) were reproductive sources (adult mortality ≤ productivity) while all southern colonies (n = 18) were reproductive sinks (adult mortality > productivity). We hypothesize that potential changes in oceanography and forage fish composition and abundance in the Gulf of Alaska (GOA) has limited the productivity of kittiwakes in southern PWS (where foraging areas are most influenced by the Alaska Coastal Current). In contrast, production of forage fishes within PWS (herring and sand lance) has maintained productivity of kittiwakes in portions of PWS. This evidence, in conjunction with the fact that productivity of kittiwakes between 1985 and 1989 in PWS (0.31 fledglings/nest) was considerably greater than the GOA mean (0.19 fledglings/nest), indicates that portions of PWS may be somewhat buffered from changes in the GOA.

As part of the APEX project we are conducting detailed studies of three kittiwake colonies located in northwestern (Shoup Bay), central (Eleanor Island), and southwestern (North Icy Bay) PWS. Based on the above hypothesis, we would expect the Shoup Bay colony to have the greatest success followed by Eleanor Island and Icy Bay. Preliminary results of data collected in 1996 only partially support this theory. Productivity was greatest at Shoup Bay (0.73) followed by Eleanor Island (0.53) and Icy Bay (0.28). Chick growth rates were also greatest at Shoup Bay and least at Icy Bay, although these differences were smaller than anticipated (< 0.6 g/day). On average, adult kittiwakes at Icy Bay were slightly lighter (1.5 - 4%) than adults at Eleanor Island and Shoup Bay. These differences also were not as great as expected. Results indicated that food was not dramatically limiting those chicks at Icy Bay that survived to fledging age. However, a larger percentage of southern colonies (83%, including Icy Bay) were reproductive sinks compared to northern colonies (56%).

Data from this and other studies in 1996 indicate potentially increasing abundance of forage fishes and, in turn, greater seabird productivity in PWS and the GOA. If we are experiencing a regime shift from conditions present during the past two decades, continued study of focus colonies and broad scale monitoring will allow documentation of relationships between oceanographic processes and seabird productivity. If this potential regime shift occurs, we would expect all reproductive parameters at Icy Bay to increase to levels similar to those at Shoup Bay. However, even though productivity may increase throughout PWS, results of a population projection model indicate the nesting population of kittiwakes in PWS should decrease by approximately 12% by 1999 (assuming no immigration). This projected decline is due to unfavorable conditions in PWS between 1990 and 1995 in which kittiwake reproduction did not compensate for adult mortality.

Project Number and Title: 96163F - APEX Project Component F - Breeding and feeding ecology of pigeon guillemots on Naked Island, Prince William Sound, Alaska.

Principal Investigator: D. Lindsey Hayes, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503 (Phone 907 786-3694)

Abstract: The objective of this component was to evaluate the breeding and feeding ecology of pigeon guillemots (*Cepphus columba*) with respect to the abundance and availability of forage fish in the nearshore environment. We monitored the reproductive success of 50 guillemot nests at Naked Island, Prince William Sound (PWS). Using binoculars and spotting-scopes, we determined the diet of guillemot chicks by identifying fish carried to the nests by adult birds.

The population of pigeon guillemots in PWS decreased from about 15,000 in the early 1970s to less than 5,000 in the 1990s. Study colonies at Naked Is. and four neighboring islands in PWS have shown a similar trend since the late 1970s. During this same period, the diet of pigeon guillemot chicks on Naked Is. also changed. In the late 1970s Pacific sand lance (*Ammodytes hexapterus*), a schooling forage fish, dominated the chick diet. In the 1990s chick diet has been dominated by fish that live on or near the bottom, such as gunnels, pricklebacks, sculpins, and cod-like fish. The correlation between percent sand lance in the chick diet and the total guillemot population is strong, and we suggest that there is a link between the change in diet and the population decline.

The productivity of guillemots at Naked Is. was lower, but not significantly so, in the 1990s than it was in the late 1970s. After 1989, predation was more prevalent at our study colonies than it was previously, and was the cause of numerous failed nesting attempts. Guillemots at Naked Is., however, are doing better than guillemots in other regions where populations may also be declining. The weighted average productivity of guillemots on Naked Is. (0.81 fledgling/nest) is higher than the combined weighted average, from numerous studies, of guillemots in British Columbia, Washington, and Oregon (0.65 fledgling/nest). Thus low productivity, at least for birds attempting to nest, is not an obvious factor in the population decline in PWS.

Data from numerous sources indicate that there has been a change in the Gulf of Alaska marine ecosystem that began around the late 1970s, which in turn has probably affected marine bird populations. The populations of many species of piscivorous marine birds and mammals have declined in PWS since the early 1970s. This ecosystem shift and the accompanying changes in the food web may account for many of the observed population declines. Besides the 1989 oil spill, other possible contributing factors are winter mortality of adults and juveniles, and low proportions of birds attempting to breed. However, these factors are also likely food-related and thus linked to changes in the ecosystem.

In 1996, we observed more schools of sand lance and more seabird foraging flocks around Naked Is. than in either of the two previous years. This may indicate a strong year class for sand lance and possibly future increases in their abundance. The percent of sand lance in the chick diet was 17% in 1996 compared to 10% for each of two previous years. This component of the APEX study will further investigate the link between the diet, population and productivity of guillemots and the abundance and distribution of forage fish in PWS.

Project Title and Number: 96163G - APEX Project Component G - Diet Composition, Reproductive Energetics, and Productivity of Seabirds Damaged by the *Exxon Valdez* Oil Spill

Principal Investigators: Daniel D. Roby and Jill A. Anthony, Oregon Cooperative Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331, robyd@ccmail.orst.edu, (541) 737-1955.

Abstract: The basic premise of this component of the APEX Project is that a shift in the marine trophic structure of the Exxon Valdez oil spill area has prevented recovery of injured seabird resources. Specifically, the research addresses whether shifts in diet quality may have constrained reproduction in Pigeon Guillemots (*Cepphus columba*), Common Murres (*Uria aalge*), and Marbled Murrelets (*Brachyramphus marmoratus*), all resources injured by the spill. The major hypothesis tested is that differences in the nutritional quality of forage fishes are a primary determinant of energy provisioning rates to seabird nestlings, which influences growth and survival of young. During the 1996 breeding season, we collected samples of nestling meals and measured nestling growth rates, provisioning rates, and nesting success in relation to diet for Black-legged Kittiwakes (*Rissa tridactyla*) nesting at Eleanor Island (oiled site), and Shoup Bay and Icy Bay (nonoiled sites) in Prince William Sound, and Kachemak Bay and the Barren Islands (reference sites) in Lower Cook Inlet. We also collected data on Pigeon Guillemots nesting at Naked Island (oiled site) and Kachemak Bay (reference site).

Lipid content of seabird forage fish varied from a low of 3% dry mass in juvenile walleye pollock (*Theragra chalcogramma*), to intermediate values of 22% in sand lance (*Ammodytes hexapterus*) and 37% in capelin (Mallotus villosus), to highs of 48% in juvenile herring (*Clupea harengus*) and 52% in eulachon (*Thaleichthys pacificus*). Intraspecific variation in lipid content of forage fish was related to age, sex, location, and reproductive status. Energy densities of forage fishes ranged from 2.8 kJ/g wet mass in pollock, to 6.37 kJ/g in sand lance, to 7.35 kJ/g in capelin, and finally to 10.0 kJ/g in eulachon and some herring. Consequently, piscivorous seabirds can experience nearly a four-fold difference in energy intake rates based solely on the quality of forage fish consumed. Kittiwake diets were dominated by high-energy forage fishes (herring, capelin, sand lance) at all study sites in 1996. Kittiwakes fed their young primarily on herring in Prince William Sound and capelin in Lower Cook Inlet, both fishes that were in decline but are now rebounding. At Shoup Bay, kittiwake nestlings were fed mostly large herring and had higher growth rates and lower incidence of brood reduction than those at Eleanor Island and Icy Bay, where juvenile sand lance was a higher proportion of the diet. The incidence of pollock in kittiwake diets was lower than in 1995, reflecting lower availability in the Sound. For guillemots, availability of sand lance apparently plays an important roll in growth performance and productivity: guillemots with a higher proportion of sand lance in the diet grew at significantly higher rates compared with those consuming mostly nearshore demersal fishes or gadids. Our results support the hypothesis that productivity of kittiwakes and guillemots in the oil spill area is determined in part by the nutritional quality of forage fishes available to nesting adults. The incipient recovery of herring and sand lance stocks in Prince William Sound and of capelin stocks in Lower Cook Inlet has potentially set the stage for recovery of seabird resources injured by the spill.

Project Number and Title: 96163I - APEX Planning and Project Leader

Project Leader: David Cameron Duffy, Alaska Natural Heritage Program and Department of Biology, University of Alaska Anchorage, 707 A Street, Anchorage AK 99501 USA (telephone 907-257-2784) (Email: afdcd1@uaa.alaska.edu).

Abstract: This project was created to provide scientific oversight and coordination among the subprojects of the Alaska Predator Ecosystem Experiment or APEX Project. The past year was spent working with the P.I.'s to undertake our first full season of field work, primarily by shifting effort to the nearshore for sampling and fine-tuning projects' goals in response to our initial year of work. We also brought in two new projects, 96163 H and 96136 Q, to undertake analysis of fish samples and to provide initial modelling of the relation between forage fish and seabird reproduction, and we greatly increased support to 96163 M in Cook Inlet.

Within the project, we supported a graduate student to work with K. Frost of ADF&G and with APEX PI's, to examine the relation between harbor seal diving and fish distribution. To date most of effort has been expended on preparing the data for ArcView and INFOCAD.

In addition, we have undertaken a project with USFWS's seabird atlas to examine whether the distribution of seabird colonies in Prince William Sound may be determined by food, with the predictions that bigger colonies should be farther apart and that colonies with less demand for food within their exclusive foraging zones should do better than colonies with overlap. Data layers have been acquired and brought into ARCINFO. Analysis is underway.

Some time has also been devoted to planning for a symposium on change in Pacific seabirds to be held in 1998. This will allow for the first time a comparison of events in the Sound with those of the rest of the Pacific.

Finally, much of the project is involved in the generation of reports, coordinating research efforts and methods, and in discussions of future needs that appear as the APEX project matures.

The results of the APEX research are discussed in the abstracts for projects 96163 A, B, C, E, F, G, J, K, L, M, N, O, and P.

Project Number and Title: 96163J - APEX Project Component J - Barren Islands Seabird Studies

Principal Investigators: David G. Roseneau and Arthur B. Kettle, Alaska Maritime National Wildlife Refuge, 2355 Kachemak Bay Drive (Suite 101), Homer, Alaska 99603-8021 (Phone 907/235-6546)

Abstract: The objective of this APEX component was to monitor the breeding and foraging parameters of common murres (*Uria aalge*), black-legged kittiwakes (*Rissa tridactyla*), and tufted puffins (*Fratercula cirrata*) at the Barren Islands, Alaska. By comparing information from these species with results from other years, we are investigating responses of seabirds to changes in food availability and quality. The three study species were chosen because of their different foraging behaviors. Both murres and puffins dive to capture prey, but puffins usually feed closer to their breeding colonies and to shore, and closer to the surface than do murres. Kittiwakes are surface feeders. Because the foraging strategies of these species differ, their responses to changes in forage fish availability may also differ, giving us the opportunity to learn how changes in the prey base affect seabird reproductive success.

This project began in 1995; data from other studies in past years are also available from this location for comparison. Associated project components include similar seabird studies at other locations in Cook Inlet and in Prince William Sound, forage fish surveys, and studies of forage fish energy content and nutrient values.

As in 1995, we monitored egg-laying and chick-fledging success, breeding chronology, foraging trip length and nest attendance by adults, and the diet, feeding frequency, and growth rate of chicks. Most data were collected by regularly observing nest sites in study plots; we visited nests to measure chicks and collect food samples.

Data are still being analyzed. However, productivity (the number of chicks fledged per nest) of murres and kittiwakes was relatively high and normal, respectively, at East Amatuli Island in 1996; these results were similar to those of the previous two years. Growth rates of kittiwake chicks were normal and similar to those of 1995. The composition of murre and puffin chick diets was also similar to that of 1995: murre chicks were fed about 90% capelin (*Mallotus villosus*), and puffin chicks received mainly capelin, walleye pollock (*Theragra chalcogramma*), and Pacific sand lance (*Ammodytes hexapterus*). However, puffins fledged fewer chicks than in 1995, and the growth rate of chicks was low. Less food may have been fed to puffins than in 1995. Further analysis of these data may indicate whether this food shortage was season-long or occurred during only part of the nesting season, and why it affected the reproductive success of only puffins and not that of murres and kittiwakes.

Reproductive success has been low in some years in some seabird populations in the Gulf of Alaska, Cook Inlet, and Prince William Sound during the 1990's. There is evidence that the composition of the prey base changed between the 1970's and the 1990's. Additional work in 1997 (Project 97163J) may help identify the ecological processes that may affect seabird breeding and foraging behavior, and assess the ability of seabird populations to recover from the *Exxon Valdez* oil spill.

Project Number and Title: 96163L - APEX Project Component L - Synthesis and Analysis of Gulf of Alaska Small-Mesh Trawl Data 1953 to 1995.

Principle Investigators: Paul J. Anderson, National Marine Fisheries Service, Alaska Fisheries Science Center, P.O. Box 1638, Kodiak, Alaska 99615 (907-487-5961); James E. Blackburn, Alaska Department of Fish and Game, 211 Mission Road, Kodiak, Alaska 99615; William R. Bechtol, Alaska Department of Fish and Game, 3298 Douglas Street, Homer, Alaska 99603

Abstract: Large declines of apex predator populations (murres, kittiwakes, harbor seals, and Steller sea lion) have occurred in the Gulf of Alaska since the 1970s. Changes in the composition and abundance of forage species may be responsible for the decline of these predator populations. In an effort to delineate changes in the trophic regime and forage species, if any, over the last several decades, we have gathered together scientific survey data covering a long time span and large area. The study area includes the continental shelf (0 - 200 m.) and upper slope (201 - 400 m.) from 144° W. longitude (in the vicinity of Kayak Island) westward to 168° W. longitude (vicinity of Unalaska Island, eastern Aleutians). Most of the data was collected in trawlable locations associated with the numerous gullys and bays in this area. Project objectives are to review and analyze data from small-meshed trawl studies conducted in the Gulf of Alaska by the Alaska Department of Fish and Game and the National Marine Fisheries Service and its predecessor agencies from 1953 through 1995. Over 10,000 individual sampling tows are in the current project database. Objectives are to quantify the spatial and temporal changes in forage species abundance and distribution that have taken place in the Gulf of Alaska. An ultimate goal is to test hypothesis of the mechanisms that cause these shifts in forage species abundance.

A crustacean/forage fish epibenthic community changed to the current regime dominated by fishes during a brief time period between 1978 and 1981 in the central and western Gulf of Alaska. The two main forage species groups, shrimp and osmerids, declined from relatively high levels of abundance in 1970-84 to uniformly low abundance during 1985-95. Capelin maximum mean catch for late summer and fall surveys was in 1972 at 23.7 kg/km; other peaks in abundance occurred in 1976 at 21.2 kg/km and again in 1980 at 15.9 kg/km. Abundance has remained at less than 0.1 kg/km since 1987 and shows no sign of recovery. In contrast, gadids (mostly pollock and cod) and several species of flatfishes have increased since about 1980. The shift from the crustacean/forage fish regime to the current epibenthic community now dominated by cod, pollock, and pleuronectid flatfishes is well correlated with relatively warm near-shore seawater temperatures during winters of 1977-88.

Project Number and Title: 96163M - Lower Cook Inlet component of the APEX Project

Principal Investigators: John F. Piatt, Alaska Science Center, Biological Research Division, USGS, 1011 E. Tudor Rd., Anchorage AK 99503 (907/786-3549) and David G. Roseneau, Alaska Maritime Natl. Wildlife Refuge, USFWS, 2355 Kachemak Bay Dr., Homer AK 99603.

Abstract: It is difficult to assess recovery of seabirds from the *Exxon Valdez* oil spill (EVOS) because long-term changes in the marine environment were apparently also affecting seabirds at the time of the spill, and during subsequent years. Since the late 1970's, seabirds in the Gulf of Alaska have shown signs of food stress: population declines, decreased productivity, changes in diet, and large-scale die-offs. Coincidentally, a shift in forage fish community composition occurred in the late 1970's: some species (e.g., capelin, shrimp) virtually disappeared, while predatory fish (e.g., gadids, flatfish) populations increased markedly. These changes correlate with long-term cycles in seawater temperature. The Cook Inlet Seabird and Forage Fish Studies (CISeaFFS) was initiated in 1995 as a long-term research project to characterize relationships between seabird population dynamics (numerical response), foraging behavior (functional response), and forage fish densities in lower Cook Inlet--the area in which most seabirds were killed by the EVOS. CISeaFFS is a collaborative project of the Alaska Science Center and the Alaska Maritime National Wildlife Refuge (AMNWR), with major funding and logistic support from the EVOS Trustees under the APEX Project (Apex Predator Ecosystem Experiment), the Minerals Management Service, the Biological Resources Division of the U.S. Geological Survey, the U.S. Fish and Wildlife Service, and the Alaska Department of Fish and Game.

In 1995 and 1996, populations, productivity, diets and foraging behavior of 6 seabird species (murre, kittiwake, guillemot, puffin, cormorant, gull) were studied at three seabird colonies in lower Cook Inlet (Chisik, Gull and Barren islands). Oceanographic measurements, seabird and hydroacoustic surveys, trawls, and beach seines were conducted in waters around (<40 km) each colony. Offshore and southern waters of Cook Inlet were dominated by juvenile walleye pollock and capelin, important prey for murres and puffins. Nearshore waters of Cook Inlet were dominated by sandlance, which were consumed by many seabirds (e.g., kittiwakes, guillemots, murres). Forage fish densities ranged from 10's fish/cubic m (pollock) to 100's and 1000's of fish/cubic m (sandlance). Acoustically-measured forage fish biomass was lowest around Chisik Island, moderate in Kachemak Bay, and highest around the Barren Islands. Correspondingly, breeding success in some seabirds ranged from low in the Chisik Island area to high in the Barren Islands area. Populations of seabirds at Chisik Island continued a long-term decline, whereas populations at Gull and Barren islands are stable or increasing. Behavioral studies revealed that some seabirds worked harder (longer foraging trips, less "free" time) at colonies where nearby fish densities were lower, and thereby maintained high levels of breeding success. Further research will aid in our understanding of how different seabirds respond to changes in forage fish abundance and distribution, and help to determine whether seabird populations can recover from effects of the *Exxon Valdez* oil spill.

Project Number and Title: 96163N - APEX Project Component N - "Effects of Diet Quality on Post-Natal Growth of Seabirds: Captive Feeding Trials."

Principal Investigators: Marc D. Romano and Daniel D. Roby, Oregon Cooperative Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331; John F. Piatt, Alaska Science Center, USGS/BRD, Anchorage, AK 99503.

Abstract: Declines in availability of certain schooling forage fishes (capelin, sandlance, herring) have potentially contributed to the lack of recovery of some fish-eating seabirds (Pigeon Guillemots, Common Murres, Marbled Murrelets) that were injured by the *Exxon Valdez* oil spill. These forage fishes tend to have high lipid content and, consequently, are assumed to have high nutritional value as food for nesting seabirds. This study tests the hypothesis that composition of the diet is one factor constraining the growth and development of fish-eating seabirds. We raised seabird nestlings (Black-legged Kittiwakes, *Rissa tridactyla* and Tufted Puffins, *Fratercula cirrhata*) in captivity on rations of either capelin (*Mallotus villosus*) or Pacific sandlance (*Ammodytes hexapterus*), as representative of high-quality forage fish, or walleye pollock (*Theragra chalcogramma*), as representative of low-quality forage fish. Lipid content of capelin diets (31% dry mass) and sandlance diets (22% dry mass) were considerably higher than that of pollock diets (9% dry mass).

Seabird nestlings fed rations of either capelin or sandlance had much higher growth rates of body mass and somewhat higher growth rates of wing length than nestlings fed the same ration (weight) of pollock. Puffin chicks fed equivalent caloric diets of pollock and capelin showed little difference in rates of mass or wing growth. In this iso-caloric (ca. 330 kJ/d) comparison, birds had to be fed 80 g of pollock to get the same calories as 45 g of capelin. Differences in body mass gain between nestlings fed capelin/sandlance vs. pollock were more pronounced than differences in wing growth, suggesting that nestlings raised on low-quality forage fish may go to sea with inadequate energy reserves. Puffin nestlings converted food biomass to body mass more efficiently than kittiwake nestlings, suggesting that under conditions of low food quality or availability, puffins will fare better than kittiwakes. We conclude that when provisioning rates of seabirds to their young are constrained, the lipid content and nutritional quality of forage fish fed to nestlings has a marked effect on growth rates and, potentially, on reproductive success. One consequence of subsisting on pollock instead of lipid-rich forage species is that predators must expend more energy and catch more prey to meet the energy requirements of their offspring. This conclusion provides more support for the hypothesis that recovery of certain seabird resources that were injured by the *Exxon Valdez* oil spill is dependent on recovery of key forage fish stocks, especially capelin, sandlance, and herring.

Project Number and Title: 96163O - APEX Statistical Review of Study Design and Analysis

Principal Investigator: Dr. Lyman L. McDonald, WEST, Inc., 2003 Central Avenue, Cheyenne, Wyoming 82001 (Phone 307/634-1756)

Abstract: Review of study plans and advice on statistical analyses of data were provided for field work in the Alaska Predator Ecosystem Experiment (APEX) Project. In particular, this work included: (1) interaction with Principal Investigators Lew Halderson, Tom Shirley, and Ken Coyle for design and analysis of data from hydro acoustic sampling of forage fish and (2) interaction with Principal Investigators David Irons, Lindsey Hayes, William Ostrand, and John Piatt for study of sea birds and foraging behavior. Since the 1996 field season, we have provided advice concerning analysis of 1995 and 1996 data as requested. In particular, computer programs have been written and provided to Ken Coyle in anticipation of analysis of the unique sampling plan used to collect 1996 hydro acoustic data on abundance and distribution of forage fish. These data were collected on sets of strip transects resulting in data which are dense along transects and sparse between transects. This spatial pattern in the sampling design induces spatial auto-correlation in the measurements which can be used for constructing maps of biomass density and which may affect standard statistical procedures for estimating standard errors of means and totals. We showed that local, computationally feasible Kriging equations can be solved repeatedly and combined using a weighted solution of the global Kriging equations. This result was applied to develop approximate variance formulas for mean biomass which account for the effect of spatial auto-correlations. In some cases, standard errors which incorporate auto-correlations are two times greater than those obtained through the assumption that data are independently distributed. In addition, draft reports on seabird/forage fish interactions have been reviewed and advice has been given on further statistical analysis of data on food selection by sea birds. This project plays an unique role in the APEX project in that all interactions are on projects directed by other Principal Investigators. Results of these interactions will be included in reports released from the other APEX projects.

Project Number and Title: 96163P - Assessment of the PAH contamination of the Forage Fish, Ammodytes sp., Inhabiting Clean and Oil Impacted Sediments

Principal Investigator: Jack W. Anderson and Jennifer M. Jones, Columbia Analytical Services, 6060 Corte del Cedro, Carlsbad, California (619/930-0417).

Abstract: APEX investigators collected samples of sand lance from East and West Block Island, McPherson Bay, McPherson Narrows, Cabin Bay, and East Bob Day Bay. Sediments were collected from Eleanor Island, Block Island, Mac Bay, and Fuel Cache Bay, McPherson Narrows, and East Bob Day Bay. All samples were extracted by EPA methods (3540, 3550) to produce dichloromethane (DCM) extracts, and small aliquots of these were applied to human liver cancer cells (101L), which produce a luminescent enzyme (luciferase) if dioxins, furans, coplanar PCBs and polycyclic aromatic hydrocarbons (PAHs) are present. The amount of luciferase produced (light) is measured with a luminometer, and the intensity is a function of the concentrations and potency of the planar organic compounds present in the extract.

This test simulates the response of mammals and fish which may ingest contaminated Ammodytes. Tissue extracts were from composites of several whole fish, with the combined dry weight per sample of between 0.5 and 2.9 grams. Previous investigations with fish tissue collected in Southern California have detected levels of PAHs of from 0.3 to 4.0 ug of Benzo(a)pyrene Equivalents per g (ppm) in muscle, liver and ovary tissues.

In this study, sediments were found to contain between 0.2 and 3.5 ug B(a)PEq/g. Levels of approximately 3 ug B(a)PEq/g were found in sediments collected at Eleanor Island SE and Block Island NW. Many of the sand lance samples did not show any significant contamination, but other samples ranged from 2 to 16 ug B(a)PEq/g. A few samples of fish from Block Island E contained 5.5 to 16.2 ug B(a)PEq/g, and one sample from Bob Day Bay contained 3.3 ug B(a)PEq/g. There appears to be significant contamination in some of the fish and sediment samples, which is likely from high molecular weight PAHs. These data will need to be discussed with the investigators who collected the samples and others with knowledge of the levels of oiling at these sites during the spill. Extracts can be sent to an analytical laboratory for confirmation.

Project Number and Title: 97163Q - FACTORS THAT LIMIT SEABIRD RECOVERY IN THE EVOS STUDY AREA: A MODELING APPROACH

Principal Investigators: DAVID G. AINLEY, H.T. Harvey & Associates, P.O. Box 1180, Alviso CA 95002 (Ph 408-263-1814); R. GLEN FORD, Ecological Consulting, Inc., 2735 N.E. Wielder St., Portland OR 97232; and DAVID C. SCHNEIDER, Ocean Sciences Centre, 4 Clark Place, Memorial University, St. John's, Newfoudland, Canada A1B 3X7.

Abstract: The APEX Project underway in Prince William Sound is based on the assumption that reduced food supply during the chick provisioning period of seabird reproduction is slowing the recovery of seabird populations from mortality incurred during the *Exxon Valdez* oil spill (EVOS). This assumption has precedent, in that it was argued to be the case for similar species at the same latitude nesting around the British Isles. However, the assumption has not been tested among the Prince William Sound colonies and the few pertinent studies available indicate that geographic scale figures importantly in the way that the effect could come about.

We will be developing and using models to assess the ways in which food supply could be affecting recovery. For seabirds nesting in the EVOS study area, we will develop models of foraging effort and success as it relates to breeding productivity. Results not only will test the degree to which the assumption of food limitation is valid, but will indicate the scale at which researchers should be assessing interactions between food availability and the colonies being studied. Moreover, results also should provide ways to "aim" the APEX research effort so that sufficient data are collected to provide input into the overriding APEX objective: to understand the ways in which food supply is limiting recovery of seabirds in the EVOS study area. Our work will be based on existing data (e.g. colony size, demography) and certain results of ongoing APEX studies (e.g. foraging range of affected species in the region).

At present, our effort is in the data gathering phase. We will be working closely with all APEX PIs, soliciting their input in all phases of our effort.

Project Number and Title: 96165 - Genetic discrimination of Prince William Sound herring populations.

Principal Investigators: **James E. Seeb**, **Lisa W. Seeb**, and **Susan E. Merkouris**, Alaska Department of Fish and Game, Genetics Laboratory, 333 Raspberry Road, Anchorage, Alaska, 99518. (Phone 907/267-2385). **Jonathan Wright**, Marine Gene Probe Laboratory, Department of Biology, Life Sciences Center, room 6080, Dalhousie University, Halifax, Nova Scotia, Canada, B 3H 4H1. **Paul Bentzen**, Marine Molecular Biotechnology Laboratory, University of Washington, School of Fisheries, HF-10, 3707 Brooklyn Ave. NE, Seattle, Washington, 98195.

Abstract: The Prince William Sound herring fishery was curtailed in 1993 and remained closed through the spring of 1996. The Alaska Department of Fish and Game recovery effort includes incorporating a knowledge of genetically-derived population structure into harvest management. In this continuing project we are delineating the structure of Prince William Sound population(s) and related North Pacific populations using both nuclear and mitochondrial DNA analyses. Tests for temporal and spatial diversity within years and temporal stability across years will be conducted.

Preliminary results of year-one nuclear DNA (microsatellite) sample analyses by Dalhousie University indicate very high levels of genetic diversity. The divergence estimates suggest very limited exchange between the Bering Sea/Kodiak Island populations and the PWS populations, and there is evidence of significant levels of genetic divergence within PWS. Repeat sampling is required to determine if the observed pattern of differentiation is consistent over time.

Project Number and Title: 96166 - Herring spawn deposition and reproductive impairment.

Principal Investigators: Mark Willette, John Wilcock, and Greg Carpenter. Alaska Department of Fish and Game, Box 669 Cordova, AK 99574 (907-424-3214).

Abstract: Underwater dive surveys of deposited eggs and acoustic techniques were used to estimate the 1996 adult spawning population of Pacific herring *Clupea pallasi* in Prince William Sound (PWS). A stratified random sampling design was employed to estimate the number of herring eggs deposited. Divers estimated the number of eggs within a systematically placed 0.1^2 m quadrat along transects randomly selected from all areas of spawn identified during aerial surveys. Diver estimates of egg numbers were corrected for systematic bias using an inverse prediction procedure that compared diver egg counts and gravimetrically determined laboratory egg counts for the same quadrats. The spawn deposition estimate of the spawning biomass of herring was 27,669 tons with a 95% confidence interval ranging from 14,373 tons to 40,965 tons. This project is also evaluating the feasibility of using acoustic echointegration techniques to estimate herring biomass immediately prior to spawning. Net sampling was conducted to estimate species, size and age composition of the insonified fish. The spring 1996 acoustic biomass estimate was only 5,011 tons. However, all herring known to be in the area were not included in the survey because the fish moved into shallow water and began to spawn while the survey was being conducted. In the future, acoustic surveys will be conducted earlier in the season to avoid this problem. Acoustic biomass estimates are being compared with spawn deposition biomass estimates to evaluate the cost effectiveness and accuracy of each method. At present, the spawn deposition estimates are used in conjunction with aerial observations of spawn distribution and basic biological information (age composition, sex ratios, average size and fecundity) to forecast spawning returns the following year using an age structured assessment (ASA) population model. The second component of this project relates to the factors affecting egg loss of PWS herring. Egg loss was studied during spawn deposition surveys in 1990, 1991, 1994, and 1995. The proportion of eggs lost through physical removal and mortality was investigated to improve diver survey biomass estimates and our understanding of the mechanisms controlling early life history survival. Prior to 1994, a 10% egg loss was assumed for surveys conducted 5-6 days after spawning based on literature values. Results indicate that egg loss rates are highly variable, site specific and are generally higher than previously estimated. Depth of spawn deposition and wave exposure accounted for much of the variation in instantaneous egg loss rates in the Montague Island area.

Project Number and Title: 96170 - Isotope Ratio Studies of Marine Mammals in Prince William Sound

Principal Investigator: Donald M. Schell, Inst. of Marine Science /Water and Environmental Research Center, Univ. of Alaska Fairbanks, Fairbanks AK 99775

ABSTRACT: This study consists of two major tasks -- (I) provision of analytical support in the form of stable isotope ratio analysis for EVOS investigators and (II) investigation of reasons for the major declines of harbor seal populations in the western Gulf of Alaska including Prince William Sound.

I. The analytical work has continued with a growing number of samples from investigators employing isotope ratio techniques to investigate both trophic transfers and transport of offshore production into the Prince William Sound area. At this date, several thousands of isotope ratio samples from marine mammals, sea and river otters, potential prey species and zooplankton have been analyzed or are in the process of being analyzed. A proposal to the National Science Foundation for instrument funding was approved and the capability of the laboratory will be expanded in 1997 increasing throughput of samples and expanding the elements analyzed to include sulfur.

IIa. Validation studies on captive harbor seals and sea lions are currently being conducted at the Mystic Marinelife Aquarium on two harbor seals and two adult female sea lions. The animals have been infused at several month intervals with C-13 and N-15 labeled glycine which is then incorporated into the whiskers as a marker. After a year of growth a whisker is clipped and run for isotope ratios to obtain absolute growth rates of the vibrissae over the period between infusions. Blood samples were also taken before and after infusion and at subsequent handling opportunities. The data to date reveal rapid turnover of the amino acid carbon but significant retention of the amino nitrogen through transamination. After two months, approximately 50 percent of the N-15 was still in the sea lion.

IIb. A retrospective study of carbon and nitrogen isotope ratios in archived marine mammal tissues was conducted as a means of assessing changes in the carrying capacity of the marine ecosystem and as a means of identifying any potential changes in trophic structure and food webs of the region. Isotope ratios of carbon and nitrogen offer an alternate means of assessing relative rates of primary productivity since they are determined primarily by the growth rates of the algal cells. In high latitude ecosystems algal growth rates determine the seasonal production and total energy supply to the system. We have found that the average carbon isotope ratios in marine mammals from the Bering Sea and Gulf of Alaska have declined 3.8 parts per thousand over the past few decades implying a significant decrease in the productivity of the ecosystem. Zooplankton biomass estimates by Japanese investigators correlate well with the isotopically indicated changes in primary production supporting the inferences derived from the isotope ratios. By using baleen plates from 22 bowhead whales archived at the Los Angeles County Museum and recently taken by native hunters, we have assembled a year by year record of average carbon and nitrogen isotope ratios back to 1947. From this record we infer that primary productivity in the Bering Sea (and presumably the Gulf of Alaska) was at a higher rate over the period 1947 - 1965 and has then declined until 1995, the last sampling date. The carbon isotope ratios for 1994 and 1995 are the lowest observed since 1947. Nitrogen isotope ratios also declined for over thirty years and show oscillations on a two - four year periodicity that may be in response to changes in trophic structure in the zooplankton community. The indicated decline in productivity in the North Pacific and Bering Sea may be a contributive factor to the observed declines in the populations of some marine mammals and sea birds in the region.

Project Number and Title: 96180 - Kenai River Habitat Restoration and Recreation Enhancement.

Principal Investigators: Art Weiner, Alaska Dept. Natural Resources, 3601 C St. Anchorage, AK 99503 (Phone 907/269-8424); and Mark Kuwada, Alaska Dept. Fish and Game, 333 Raspberry Rd. Anchorage, AK 99518-1599 (Phone 907/267-2277).

Abstract: This project focuses on restoring and protecting fish habitat on public lands along the Kenai River mainstem; improving recreational access to the Kenai River in a manner that restores and protects fish and wildlife habitat; and providing educational information to the public on the river's ecology and proper use of its resources. In 1996, the first year of the project, principal investigators put together an Interdisciplinary Team (IDT) of biologists and Kenai River resource managers to develop a process for identifying, evaluating and ranking restoration project sites on the river. The process identified 16 sites on public lands that could potentially benefit from restoration efforts. The agencies responsible for managing the lands were asked to prepare individual project proposals. Two sites were withdrawn when the managing agencies requested more time to prepare restoration options; one proposal was eventually funded from another source. The thirteen remaining proposals were then subjected to a set of threshold and evaluation criteria to determine their potential restoration benefit and relative ranking.

Threshold criteria determine whether a proposal will initially qualify for evaluation. The IDT assessed whether each proposal: 1) would protect, restore or enhance the historic functional attributes of a site and the surrounding area; 2) was located on public land; 3) was endorsed by the managing agency; 4) would be supported by the managing agency in terms of future maintanence and management for its intended restoration purpose; 5) was permittable; and 6) was not a mitigation requirement from some other project. In some cases, design refinements were needed to ensure that all threshold criteria were met, particularly for project permitting.

The thirteen proposals were then ranked on the basis of evaluation criteria that assessed: 1) habitat value; 2) recreation value; 3) existing site disturbance; 4) potential rate of recovery; 5) potential impact on the surrounding environment; 6) a proposal's design effectiveness; and 7) a site's vulnerability to post-restoration impacts. Again, several proposals were modified on the basis of feedback from the IDT during this process.

Finally, each proposal was evaluated for cost-effectiveness to maximize the amount of restoration work that could be accomplished given limited funds.

Once the evaluation process was complete, a National Environmental Policy Act (NEPA) Environmental Assessment document was prepared to address program implementation over a three-year period. This included an option to do restoration work on parcels of land that were acquired in the EVOS Small Parcel Habitat Protection Process. It also included an option to restore damages along a public access easement that the U.S. Fish and Wildlife Service currently manages on private lands near the City of Soldotna (an issue that was being addressed concurrently in a separate NEPA document prepared by the USFWS). The Kenai River Habitat Restoration and Recreation Enhancement Project NEPA compliance process was completed and approved in late - May 1996.

To date, one restoration project has been initiated, the Kenai Beach Dunes project at the mouth of the Kenai River. At least six additional projects are scheduled for completion in the spring and early summer of 1997. Approved restoration techniques include streambank bioengineering, installation of elevated light-penetrating walkways, floating docks, access stairways, trail improvements and barriers.

Project Number and Title: 96186 - Coded wire tag recoveries from pink salmon (*Oncorhynchus gorbuscha*) in Price William Sound

Principal Investigators: Timothy L. Joyce, Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, P.O.Box 669, Cordova, AK 99574 (telephone: 907-424-3212)

Abstract: The *Exxon Valdez* oil spill required a means of separating and protecting the damaged wild pink salmon stocks from large hatchery stocks in the southwestern portions of Prince William Sound. Coded wire tags were applied to a small percentage of emergent fry at the four hatcheries producing pink salmon. The tags applied in the spring of 1995 were recovered in the returning adults in the summer of 1996. The information retrieved from the returning fish allowed managers to make informed decisions on fishing time and area where mixed stocks occurred. Wild stock escapement goals were not met in the western portion of Prince William Sound, but were achieved and exceeded in the eastern portion. Preliminary return numbers based on coded wire tags indicate that 83% of the commercial common property catch was produced by hatchery released pink salmon. Cannery Creek had an ocean survival rate of 5.3% while Solomon Gulch and W.H. Noerenberg hatcheries had ocean survival rates of 3.5% and 3.1% respectively. A.F. Koernig hatchery again had the lowest survival rate at 1.6%. An exceptionally high tag loss rate occurred again in the Cannery Creek returning adult fish averaging 58%. Fish that were released from A.F.Koernig and W.H.Noerenberg hatcheries in mid June of 1995 at approximately 1.3 and 1.0 gram respectively had survivals over two times greater that other release groups.

Project Number and Title: 96188 - Otolith mass marking of hatchery pink salmon *Oncorhynchus gorbuscha* in Prince William Sound

Principal Investigators: Timothy L. Joyce, Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, P.O.Box 669, Cordova, AK 99574 (telephone: 907-424-3212)

Abstract: Otolith mass marking of hatchery pink salmon was introduced as a replacement for coded wire tagging in an effort to provide more precise information to fishery managers in mixed stock fisheries in Prince William Sound. It is believed that with better information, management of the resource will be improved, and thus so will the restoration effort. In 1995, all pink salmon hatcheries in Prince William Sound installed water heating devices to allow rapid and sustainable temperature changes to the incubation water. Thermal marks were applied on the otoliths of all hatchery pink salmon in Prince William Sound in the fall of 1995 and 1996. Each hatchery was assigned a unique thermal banding pattern which allows estimation of contributions from different hatchery stocks as well as the more general distinction between hatchery and wild stocks. Voucher samples taken in the spring of 1996 from swim-up fry at each hatchery indicated that the marks applied were highly visible on the otolith from all lots of pink salmon. Mixtures of hatchery fry and wild fry were sent to the statewide otolith laboratory in Juneau in a double blind test to determine the rate at which the laboratory could successfully decode the marks laid down in the fall of 1995. The origin of the otolith was identified correctly about 98% of the time. Very little between or within-reader variability was found in the success rate of otolith identification.

The first adult pink salmon returns carrying an otolith mark are expected in 1997. Of critical importance to the success of the proposed estimation techniques will be the ability of technicians to take representative samples from the tenders. In preparation for the return in 1997, the proposed method of tender-sampling was tested during the cost-recovery harvest at the Solomon Gulch facility in 1996. Known numbers of externally-marked fish were added to the holds of tenders while they serviced local seiners. Tenders containing marked fish were then sampled at the dock with the proposed sampling method to determine whether representative samples could be taken using the proposed technique. Analysis of the coverage properties of calculated confidence intervals failed to detect any evidence that the sampling methodology was biased ($p=0.81$). Simulations are ongoing to determine the most efficient sampling rates.

Project Number and Title: 96190 - Construction of a linkage map for the pink salmon genome.

Principal Investigator: Fred W. Allendorf, Division of Biological Sciences, University of Montana, Missoula, MT 59812 (Phone 406/243-5503)

Abstract: The objective of this project is to construct a detailed genetic linkage map for pink salmon by analyzing the genetic transmission of several hundred DNA polymorphisms. The ability to genetically map the location of oil induced lesions will allow the thorough identification, description, and understanding of oil induced genetic damage. This research will also aid other recovery efforts with pink salmon, including estimating straying rates, describing stock structure, and testing if marine survival has a genetic basis.

We have begun constructing the linkage map using haploid gynogenetic progeny from a single female (F103) returning to Armin F. Koenig (AFK) hatchery in August 1995. Several different types of polymerase chain reaction (PCR) based molecular markers are being used: random amplified polymorphic DNA's (RAPDs), simple sequence repeat microsatellites (SSRs), amplified fragment length polymorphisms (AFLPs), and interspersed repetitive element (SINE/transposons) mediated PCR. To date, we have examined the joint segregation of 43 polymorphic loci from female F103. We have identified 5 linkage groups.

We have developed a PCR-based system to identify a Y-linked marker (GH-2p) that is only present in male pink salmon. We are using this marker to confirm that our putative haploid progeny do not contain any chromosomes from the males used to activate the eggs. In addition, we will use this marker to test for sex-linked markers that are on the Y-chromosome.

We have also used haploid gynogenetic progeny to test for the Mendelian inheritance of 7 different SSR markers in families from 7 females. All results are compatible with expected Mendelian ratios. One of the markers (FGT1-1,2) is a duplicated isolocus.

We created families for further analysis from pink salmon returning to the Solomon Gulch Hatchery in August 1996. This will allow us to compare linkage relationships in odd- and even-year pink salmon. A bacterial infection in the incubation facilities of ADFG in Anchorage forced us to collect our samples at an earlier stage of development than we intended. However, preliminary DNA extractions from the 1996 egg samples show that they are at a point in their development when they will provide enough DNA for the even-year analysis of linkage.

Project Number and Title: 96191A(1)--Injury to Salmon Embryos and Preemergent Fry in Prince William Sound

Principal Investigators: T. Mark Willette[1], Andrew K. Craig[1], and Brian G. Bue[2],
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Abstract: This study was designed to monitor the recovery of pink salmon *Oncorhynchus gorbuscha* populations in Prince William Sound that were impacted by the *Exxon Valez* oil spill. Embryo mortality was examined in intertidal and upstream areas of both oil-contaminated and unaffected streams in Prince William Sound. Embryo mortality was elevated in oil-affected streams during the fall of 1989, 1990, 1991, 1992 and 1993. However; no statistical difference was observed in the fall of 1994 and 1995. We also tested the hypothesis that the differences in embryo mortality observed in the field were due to naturally occurring environmental variables that differed systematically between the oil-contaminated and reference streams. Gametes were collected from adults in spawning condition from eight oil-contaminated and eight reference streams, and matings were conducted at a hatchery. The resulting embryos were incubated in controlled environmental conditions. Embryos originating from oil-contaminated streams showed elevated mortalities when compared to those from reference streams in 1993, but not in 1994. Results from the controlled incubation study support the results in the field study.

These data indicate that the elevated mortalities observed in 1989 and 1990 were likely due to direct exposure to oil. Elevated mortalities observed in 1991, 1992 and 1993 may have been due to genetic damage sustained in the parental lines during embryonic development in 1989 and 1990 that was inherited in subsequent generations. Lack of a significant difference in 1994 and 1995 between oiled and reference streams demonstrates a possible recovery of the populations that have been monitored since 1989.

These data do not prove that the observed differences were caused by oil contamination. Some have suggested that the streams which were oiled also historically had lower embryo survival. We believe this to be unlikely because mortality between oil-contaminated and reference streams was not significantly different in 1994 and 1995. The controlled oiling experiment conducted by the National Marine Fisheries Service (\191B) will provide laboratory evidence to further clarify interpretation of these field data.

Project Number and Title: 96191A(2) - Laboratory Examination of Oil-Related Embryo Mortalities that Persist in Pink Salmon Populations in Prince William Sound

Principal Investigators: James E. Seeb, Christopher Habicht, Ben A. Greene, Eric J. Kretschmer, Jeffrey B. Olsen, David Evans. Genetics Program, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518. (JES telephone: 907-267-2385).

Abstract: Elevated mortality of pink salmon embryos in the streams within Prince William Sound (PWS) oiled as a result of the *Exxon Valdez* oil spill (EVOS) were documented in 1989 and continued through 1993, three generations after the oiling. Two hypotheses were suggested to explain these results: (1) the difference in embryo mortality was due to naturally occurring environmental factors that differed uniformly between oiled and non-oiled streams, or (2) oil-induced damage to the 1989 brood was transmitted multi-generationally within the oiled populations (either through germline genetic-damage or through physiological damage to adults expressed in their progeny). To test the first hypothesis, controlled incubation experiments were conducted in which gametes from fish returning to oiled streams and gametes from fish returning to unoiled streams were incubated under identical conditions. These experiments showed the same trend documented in the field: embryos from fish with oiled ancestry (at this point two to three generations removed from the oil exposure) had higher mortality rates than those without oiled ancestry, indicating that environmental factors alone could not explain mortality differences. These experiments, however, did not resolve if the mortality observed was due to physiological damage or genetic damage. Therefore the objective of this project was to determine if crude oil caused genetic damage in pink salmon. We used flow cytometry and haploid androgenesis to test the hypothesis that incubation of pink salmon embryos in an oiled substrate induces genetic damage. Further, we developed new and adapted existing methods to test for microlesions in a mitochondrial locus (cytochrome *b*) and a nuclear DNA tumor suppressor gene *(p53)*, of pink salmon. We also tested for amplification and expression in pink salmon at 35 microsatellite loci. Mortality and abnormality rates were higher for embryos in oiled incubators than for those in unoiled incubators. Despite high statistical power, we found no relationship between exposure to oil and incidence of genetic damage detectable by flow cytometry. Androgens produced from males incubated in oil as embryos demonstrated no elevated mortality; however, this experiment lacked statistical power due to unanticipated male-to-male variability. We found unexpectedly little polymorphism overall in either cytochrome *b* or the region of *p53* reported to be hypervariable in other species. A pilot study of four microsatellite loci showed no change of allelic expression among tissues between oiled and non-oiled treatments. Finally, we report development of a multi-locus DNA fingerprinting assay using *Tc1* and *Sma1* primers generated from other species that should prove useful for detecting small deletions or insertions in pink salmon DNA.

Project Number and Title: 97194 - Pink salmon spawning habitat recovery.

Principal Investigators: Michael L. Murphy and Stanley D. Rice, NOAA NMFS, Auke Bay Laboratory, 11305 Glacier Hwy, Juneau, AK 99801 (Phone 907/789-6036).

Abstract: The objective of this study, which began in Fiscal Year 1997, is to examine the level of oil contamination in pink salmon streams in Prince William Sound to document initial levels of oil exposure and subsequent habitat recovery after the *Exxon Valdez* oil spill. Results of this study are meant to complement and help interpret other Trustee studies of oil-related embryo mortality in pink salmon.

To document initial exposure levels, this study is analyzing approximately 400 sediment samples from nearly 200 pink salmon streams that were sampled by ADFG in 1989-90 but not analyzed. An additional 97 samples were collected in 1995 from 12 of ADFG's sites (11 oiled, 1 non-oiled) and are being analyzed to determine habitat recovery. Most samples were taken from stream banks immediately adjacent to pink salmon spawning areas. Samples are being fast-screened by ultraviolet fluorescence to measure total concentration of petroleum hydrocarbons, and representative samples are analyzed by gas chromatography/mass spectroscopy to determine concentrations of individual polynuclear aromatic hydrocarbon (PAH) analytes.

In the 1989 samples, initial results from 11 streams indicated that oil contamination varied widely by stream, with mean oil concentration ranging from 1 ῆg/g to over 45,000 ῆg/g. In the 1995 samples, petroleum hydrocarbons were still detected in sediments. At the 11 oiled sites sampled in 1995, mean oil concentration ranged from 1 ῆg/g to 240 ῆg/g, and individual sediment samples ranged up to 1,628 ῆg/g. Oil concentration was significantly higher than the control at seven of the 11 oiled sites. Analysis of PAHs confirmed that the source of petroleum hydrocarbons was *Exxon Valdez* oil. An exponential decay model interpolating between mean oil concentration in 1989 and 1995 indicated that oil levels probably still exceeded 1,000 ῆg/g at many oiled sites until 1993. Further analysis of the remaining samples should help to refine this relationship.

These results indicate that initial levels of oil contamination at streams in Prince William Sound were sufficient to cause elevated mortality of pink salmon eggs and embryos incubating in stream gravel. Although many streams had apparently recovered by 1995, some still had significant levels of oil that could cause impaired growth and reproduction of pink salmon.

Project Number and Title: 96195 Pristane Monitoring in Mussels and Predators of Juvenile Pink Salmon & Herring

Principal Investigator: Jeffrey W. Short, National Marine Fisheries Service, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626

Abstract: Pristane is an alkane hydrocarbon produced by *Neocalanus* copepods, which are the only natural source of pristane in Prince William Sound (PWS). Ecologically, these copepods are an important link from phytoplankton to production of higher-order consumers such as juvenile herring and pink salmon in PWS during Spring. Lipophilic pristane acts as a natural tracer molecule for lipid produced by these copepods. When consumers ingest these copepods, most of the lipid (& pristane) is absorbed across the intestine, but some is excreted as feces. These pristane-labeled feces may disperse in the water column and then be accumulated by suspension-feeders such as mussels. Thus, monitoring pristane concentrations in mussels in PWS may provide a semi-quantitative indication of juvenile fish production in the sound during Spring.

We established 30 monitoring stations in PWS in 1994 where we collected repeated samples of intertidal mussels during Spring. We sampled many of these stations monthly in 1994 beginning the end of April thru the end of July, and we sampled most stations biweekly in 1995 and 1996 beginning late-March thru the end of July. Additional sites were monitored daily near the Prince William Sound Aquaculture Corporation hatchery on Esther Island during a two week interval that bracketed the date of the mass-release of more than 120 million salmon fry. Also during this period, fecal material produced by *Neocalanus* copepods was collected to determine the contribution from this source.

Pristane concentrations in fecal material produced by *Neocalanus* copepods were less than 0.2 mg/g (dry weight basis), compared with concentrations of about 10 mg/g in fecal material produced by juvenile pink salmon when preying on *Neocalanus* copepods. Pristane concentrations in mussels during the period of the hatchery release increased 3-5 fold within 2 to 6 days of the release. The released pink salmon juveniles were observed preying heavily on *Neocalanus* copepods during this period, and defecating directly on the monitored mussel beds. The maximum pristane concentration of mussels observed during this period was about 25,000 ng/g, comparable with the highest concentrations observed in mussels elsewhere in PWS in this and in other years. These results suggest that juvenile salmon may be the dominant vector of pristane transmission into mussels during late April through May when pristane concentrations are highest in mussels.

Interannual comparison of pristane concentrations in mussels tends to confirm patterns observed in 1995: an initial increase at most northwest-sound stations by the end of March, with another increase in most stations of the sound between mid-April to mid-May. The 1996 "pristane-production index", an integrated measure of pristane in mussels at all stations over the year, was about 2/3 the 1995 value, suggesting less production of juvenile salmon in 1996 for the sound.

Project Number and Title: 96196 - Genetic structure of Prince William Sound pink salmon *(Oncorhynchus gorbuscha)*

Principal Investigators: James E. Seeb, Lisa W. Seeb, Christopher Habicht. Genetics Program, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518. (JES telephone: 907-267-2385).

Abstract: Embryos and alevins of wild-stock pink salmon in Prince William Sound (PWS) suffered increased mortality, diminished growth, and a high incidence of somatic cellular abnormalities as a result of spawning ground and rearing site contamination from the *Exxon Valdez* oil spill (EVOS). Elevated mortality of embryos in the oiled streams continued through 1993, three generations after the oiling. Understanding genetic structure of these damaged wild stocks is critical to their management and conservation. For example, managing on too fine a scale may adversely affect the fishing industry and waste management resources, while managing on too large a scale may result in loss of genetic adaptations and diversity. Knowledge gained through this project will be used to interpret and apply the findings obtained from the Sound Ecosystem Assessment analyses on a population basis, more properly define the population-level nature of the damage documented in previous study of EVOS damaged pink salmon, and otherwise guide the decision-making process in the management-oriented restoration of the EVOS-damaged pink salmon populations. Our objective is to define the genetic structure of pink salmon stocks in the EVOS-affected area of Prince William Sound. We are testing for both temporal and geographical structuring among even and odd year races by examining genetic differences between early and late season spawners, upstream and intertidal spawners, and stream of spawning. Thus far, genetic data were collected from 70 allozyme loci from 100 fish from 34 even-year and 16 odd-year collections. Haplotype data were collected from the NADH subunits 5 and 6 from 40 fish from each of 28 even-year and 16 odd-year collections. Finally, microsatellite data from an array of odd-year populations were collected to determine the utility of this method to describe population structure. Statistical analysis of the allozyme data from samples from the 1994 and a few 1992 brood years indicated that most variation occurred within populations (99.34%), however, significant heterogeneity was found among the ADFG management regions (0.09%), between upstream and tidal collections within one of the five tested, and between 1992 and 1994 collections at one stream. The mtDNA analysis also showed regional heterogeneity but showed no differences between upstream and tidal collections within the two streams tested and showed inter-annual stability within sites tested. Microsatellite data showed good concordance between geographic separation and genetic separation suggesting promise for assessment of population structure of pink salmon. This snap shot of population structure will be expanded to include two complete sets of observations for both the even-year and odd-year populations. Collections to investigate temporal genetic differences within stream of sampling were made in 1995 and 1996 collections and statistical analyses are underway for the 1995 collections. Finally, we are analyzing progeny from single-pair-matings to test for mendelian inheritance of both allozyme and microsatellite alleles that have not been previously tested. Through these matings we have verified inheritance for six allozyme loci and five microsatellite loci and have identified at least one allozyme locus (GDA) whose phenotype is environmentally affected and one microsatellite locus (Ssa 197) that appears to have a null allele.

Project Number and Title: 96210 - Prince William Sound Youth Area Watch

Principal Investigators: Roger Sampson and Mel Henning, Chugach School District, 165 E. 56th Ave., Suite D, Anchorage, AK 99518 (Phone: 907-561-3666)

Abstract: The project involves students from the Chugach School District in current research projects in Prince William Sound funded by the Trustee Council. Four research projects were identified in which the participating students were involved. Some of the students participated in all of the projects, whereas a few participated in only one. The research projects included the following: blue mussel collection / Pristane hydrocarbon analysis, harbor seal biosampling, juvenile herring AWL, meteorological data recording, and oceanographic water testing. This was a pilot project designated for the Chugach School District, and is designed to expand into a second and third year. Student involvement was from Tatitlek, Chenega, Whittier, and Hinchinbrook Island.

A project coordinator, with a degree in Fish and Wildlife Biology and an Alaska administrative and teaching certificate, was employed by the Chugach School District to supervise the students and coordinate the activities between the scientists and the students to bridge the gap between hard scientific research and meaningful application of project activities.

These projects increased the awareness of youth regarding the effects of the Oil Spill and encourages their involvement in subsistence, research and restoration. The youth in the communities became involved in the first steps of restoration processes and increased their understanding of what had occurred in the waters and on the shores of Prince William Sound. The success of long-term effective restoration is dependent on youth involvement, and therefore, having the support of our students within the Prince William Sound, the future responsibility of adequate subsistence and restoration can be carried on under their ownership.

Project Number and Title: 97214 - Documentary on Subsistence harbor Seal Hunting.

Principal Investigators: Gary Kompkoff, Tatitlek Village Council, Tatitlek, Alaska
William E. Simeone, Alaska Department of Fish and Game
333 Raspberry Road, Anchorage, Alaska (907) 277-1525

Abstract: The film will document all facets of harbor seal hunting, including the ecological and biological knowledge hunters use to hunt seals. In FY 96, through a competitive process, Taylor productions of Anchorage, Alaska, was awarded the contract to produce the documentary. In March of 1996 the Taylor Productions film crew accompanied Tatitlek seal hunters on a ten day hunt in Prince William Sound. In April the production crew, along with ADF&G staff members, spent a week in Tatitlek conducting and filming interviews with village elders and hunters about the importance of seal hunting for the community. Currently Taylor productions is editing the footage shot in March and April. A version of the film will be previewed in Tatitlek sometime in February and second preview will be held in Anchorage toward the end of February or early March. ADF&G will distribute the final version of the film beginning in March of 1997.

Project Number and Title: 96220 - Eastern Prince William Sound Wildstock Salmon Habitat Restoration

Principal Investigator: David Schmid, USDA Forest Service, PO Box 280 Cordova, AK 99574 (907) 424-7661

Abstract: Subsistence use of marine resources by residents of Prince William Sound was considerably reduced following the *Exxon Valdez* oil spill. Although harvest levels have increased, the harvest in some areas remains below pre-spill levels. The Village of Eyak, working with the US Forest Service, proposed a salmon habitat restoration or enhancement project for Eastern Prince William Sound. If salmon habitat and populations could be improved, there would be increased subsistence opportunities and cultural benefits. The project could also provide the opportunity for local youths to learn habitat enhancement techniques and use their knowledge of the streams and fish for the management of their lands.

Ten streams and their tributaries were selected in the Port Gravina, Sheep Bay, and Cordova areas in eastern Prince William Sound. Most of the streams support good runs of pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*) in the intertidal areas, but limited numbers of coho salmon (*Oncorhynchus kisutch*) in the upstream sections. Since coho salmon are preferred over the other species for subsistence use and could benefit more from habitat enhancement, the project focused on coho salmon habitat.

Habitat surveys were conducted on each of the streams to determine the amount of each habitat type (riffles, glides, various kinds of pools etc.), spawning area, winter rearing area, and large woody material. These data were then used in a coho salmon production model to determine whether the population is limited by some habitat feature, such as the lack of winter rearing area. In most of the streams, unalterable physical features, such as stream gradient or flows preclude any enhancement work. There are a few streams, however, where production appears to be limited by the amount of winter rearing habitat. Creation of deeper pools, protected backwaters, and additional cover could increase production. However, substantial amounts of winter habitat would need to be created to significantly increase the number of returning adults in these streams.

Project Number and Title: 96225 - Port Graham Pink Salmon Subsistence

Principal Investigators: Ephim Anahonak, Port Graham Salmon Hatchery, Box 5543, Port Graham, AK 99603, (907) 284-2233; Paul McCollum and David Daisy, Chugach Regional Resources Commission, 4201 Tudor Centre Drive, Suite 300, Anchorage, AK 99508, (907) 562-6647

Abstract: The goal of this project is to increase subsistence gathering opportunities for the Port Graham and Nanwalek villages by increasing the fry to adult survival of Port Graham hatchery pink salmon during the hatchery's broodstock development phase. Local runs of coho and sockeye salmon, the more traditional subsistence salmon species, are at low levels. This is putting more subsistence pressure on pink salmon at a time when the hatchery is building broodstock and needs to utilize as many of the returning adults as possible for hatchery spawning. A way to help mitigate this problem is to apply strategies that will increase marine survival, i.e., the number of hatchery released fry that return as adults.

The principal strategy being applied to increase marine survival is to increase the size of the fry prior to release into the wild. Pink salmon fry emerge from the incubators weighing 2.4 grams on average. Experiments on pink salmon fry around the state have shown that marine survival can be significantly enhanced by rearing the fry to at least double their emergent weight before releasing them. In 1996, the first year of the project, the project objective was to release three separate lots of pink salmon fry, each with a different average weight.

The first lot had an average weight of 0.5 grams and was released into a major zooplankton bloom on May 23, 1996. The second lot achieved an average weight of 1 gram and was released on June 10. The third lot was intended to be reared until it achieved an average weight eight grams which was estimated to be sometime in late August. The eight gram average weight was chosen because that is the size that juvenile pinks are believed to leave the near shore area, where predation is high, for the high seas where predation is somewhat less. Unfortunately in mid June this lot contracted a bacterial disease called warm water vibriosis. The ADF&G Fish Pathology Section recommended that these fish be released immediately. Consequently this lot was released on June 20, 1996 with an average weight of 1.2 grams.

Because of the disease problem future attempts to produce eight gram pink salmon smolt will be abandoned. Other methods are being investigated. One idea being considered is to use heated water to cause a batch of pink fry to emerge about 2 weeks earlier than normal. These fry would then be placed on 5° C seawater until the ambient seawater temperature reaches 5° C at which time they would be transferred to saltwater rearing pens and held until they reach a 1 gram average weight. It is estimated that by causing the fish to emerge earlier and rearing them on heated saltwater they would reach the 1 gram size by the end of May which is when the peak of the zooplankton bloom occurs. Releasing 1 gram fry into the peak of the zooplankton bloom should greatly enhance their marine survival rate. The hatchery already has on hand the heating and heat transfer equipment that could provide a limited amount of heated seawater. It may be possible to produce a small batch of fry for release this spring (1997).

Project Number and Title:
96244: Community-based Harbor Seal Management and Biological Sampling

Project Leaders:
Monica Riedel, Alaska Native Harbor Seal Commission, Box 2229, Cordova, AK 99574
(907)424-5882
James Fall, ADFG Subsistence Division, 333 Raspberry Rd., Anchorage, AK

Purpose and Objectives:

Harbor seals (*Phoca vitulina*) are among the injured biological resources of Prince William Sound that have not recovered following the *Exxon Valdez* Oil Spill. The continued decline in seal numbers throughout Alaska is of particular concern to Alaskan Natives for whom seals are of traditional, subsistence, and cultural importance. The premise of this project is that restoration of harbor seal populations will be facilitated by involving subsistence users in research and management activities and through facilitating the involvement of traditional knowledge in scientific studies. Objectives are to:

Train local technicians and hunters in biological sample collection procedures
Maximize sampling efficiency and coordination with other harbor seal projects
Evaluate the program's effectiveness and develop a long-term funding plan
Collect life history and harvest information about the harbor seals harvested in each village

In FY96, two workshops were convened to improve communication among the state's seal hunters/users and with agencies involved in seal research and management. A significant long-term outcome of the these meetings was the formation of the Alaska Native Harbor Seal Commission whose mission is to promote conservation and sustainability of harbor seals for the cultural well-being of Alaska Natives. In addition to expressing their concern for the sustained health of the seal population, workshop participants voiced their desire to be active participants in harbor seal research projects. As a result, a harbor seal biological sampling program was initiated in Prince William Sound and Kenai Peninsula villages in 1996 to combine the skills and interest of seal hunters with scientific expertise of harbor seal researchers.

The sampling needs and protocols of a variety of researchers from the Alaska Dept of Fish and Game, University of Alaska, and National Marine Fisheries Service were compiled into a user-friendly sampling manual, dataforms, and training program. In November and December 1996, two demonstration sessions were held in which hunters from six oil-impacted villages were given the background, training, and supplies necessary to collect tissue samples from harvested seals. At the Cordova training session, a dozen Youth Area Watch (Project # 96210) students also participated and were encouraged to assist biosamplers from their villages in the future.

Project technicians collected samples from 33 harbor seals harvested in Prince William Sound and Cook Inlet in 1996. Samples collected in this program have been archived at the University of Alaska Museum or dispersed to a variety of researchers for current or future analysis of the diet, genetics, reproductive status, health, and contaminant loads of the state and region's harbor seals (including Restoration Projects #96001,96064).

This program continues to support and promote communication and cooperation among those concerned for the health and sustainability of Alaska's harbor seal population. Workshops have brought together concerned users, managers, and researchers to discuss issues and share information on an ongoing basis. Biological sampling of harvested seals has provided researchers with tissue samples they need to study and better understand the seals' continued decline in the oil-impacted region. It has also provided a means by which to involve concerned hunters and youth in the statewide, on-going research of a vital subsistence resource.

Project Number and Title:
96255 - Kenai River sockeye salmon restoration.

Principle Investigators:
Lisa W. Seeb[1], Kenneth E. Tarbox[2], and James E. Seeb[1]

[1] Alaska Department of Fish and Game - Commercial Fisheries Management and Development Division, 333 Raspberry Rd., Anchorage, Alaska 99518 (Phone 907/267-2249)

[2] Alaska Department of Fish and Game - Commercial Fisheries Management and Development Division, 34828 Kalifornsky Beach Rd., Soldotna, Alaska 99669

Abstract:
Genetic data from sockeye salmon (*Oncorhynchus nerka*) were collected from the Kenai River, a major salmon-producing system affected by the *Exxon Valdez* Oil Spill, as well as all other significant spawning populations contributing to mixed stock harvests in Cook Inlet, Alaska. These data consist of a total of 67 protein-coding loci which were resolved from samples taken from 37 populations using starch gel electrophoresis.

The allozyme data reveal a substantial amount of genetic diversity among these populations. Within the Kenai River and Kasilof River, populations sharing a common nursery lake tend to be genetically similar, while populations from drainages without common nursery lakes tend to be much more dissimilar. Within the Kenai River, populations from the Russian River above the falls were found to be the most divergent group in Upper Cook Inlet.

Mixed stock analyses using maximum likelihood methods with the subset of 27 informative loci were evaluated to estimate the proportion of Kenai River populations in Cook Inlet fisheries. Simulations indicate that Kenai River populations can be identified in mixtures at a level of precision and accuracy useful for fishery restoration and management. Samples from fisheries were analyzed both inseason (within 48 hours of the fishery) and postseason. In 1996, the contribution of Kenai River populations to the Cook Inlet fisheries varied from 28.2% to 62.9% showing an increasing presence in the fishery over the five periods sampled. A similar trend was seen in the 1995 analysis. A sample from the Kenai River fish wheel was also analyzed to provide information on the presence of Russian River sockeye salmon in the lower Kenai River. Results from this study are currently being used in the management and restoration of Kenai River sockeye salmon populations affected by the 1989 *Exxon Valdez* oil spill.

Project Number and Title: 96256b - Sockeye Salmon Stocking at Solf Lake.

Principal Investigators : Dan Gillikin, Chugach NF., P.O. Box 129, Girdwood, AK. 99587, (Phone) 783-3242, (FAX) 783-2094 and Patrick Shields, Limnology Laboratory (ADF&G), 3428 Kalifornsky Beach Rd. #8 Soldotna, AK 99669, (Phone) 262-9368, (Fax) 262-4709

Abstract : This project is designed to benefit subsistence users of Prince William Sound, specifically the residents of Chenega Bay. Solf Lake in Herring Bay on Night Island has been recognized for many years as an opportunity to establish a self-sustaining sockeye salmon run. Habitat improvements to the lakes outlets were made in 1978, 1980 and 1981 to provide access to the lake for anadromous fish. The lake was never stocked, investigations during the 1996 field season suggest that it is currently only utilized by resident Dolly Varden but has adequate zooplankton biomass to support a sockeye salmon population. There are two phases to this project: the feasibility phase (FY96) has verified the ability of Solf Lake to support a population of sockeye salmon. Phase 2 would be to stock the lake with sockeye salmon and ensure adequate anadromous access to the lake. Stocking is planned to begin in 1998.

Sampling for the years 1982-1984, 1986, and 1996 found the total macrozooplankton biomass averaged 500 mg m^2. Assuming this amount of forage is available each year to sockeye fry, the stocking level for the first three years in Solf Lake should be 400,000 fry. Monitoring of the zooplankton once per month during June-October would be necessary. After three years of stocking at this level, if the zooplankton community did not show a significant impact, the level could be increased to perhaps 500,000 fry. This level of stocking should be done for another three years with continued evaluation of the zooplankton community. The instability of the macrozooplankton community in barren lakes when faced with predation necessitates stocking programs based on a conservative and gradual approach with close evaluation.

Based on the available spawning area it is estimated that Solf Lake could sustain a run of approximately 10,000 sockeye without supplementation. An escapement of approximately 4,500 fish would be required to fully seed the system and not deplete the zooplankton populations, leaving 5,500 harvestable sockeye.

Stream survey results of the 2 outlets indicate that while smolt passage is possible, upstream migration by adults is questionable. It has been determine that the old structure which dams the impassable outlet requires extensive reconstruction to provide adequate flow for fish passage at the lakes new outlet. Additionally, the outlet that would provide fish access to the lake requires reconstruction of a irrigation type control dam and stream channel modifications.

Project Number and Title: 96258 Sockeye Salmon Overescapement Investigations

Principle Investigators: Dana C. Schmidt, Ken Tarbox, and Charles Swanton. Alaska Department of Fish and Game, 34828 K Beach Road, Soldotna, Alaska 99669, Phone (907) 260-2909

Abstract: The objective of this study was to evaluate the effects of large escapements of sockeye salmon (*Oncorhynchus nerka*), following the EXXON Valdez oil spill (EVOS), on the subsequent productivity of major sockeye salmon systems in the spill area. In Kenai and Skilak Lakes, these investigations have identified a zooplankton based production model that explains the in-lake recruitment of smolt. In Red and Akalura Lakes on Kodiak Island, efforts have been focused on analysis of the dynamic changes in the zooplankton community coupled with long term evaluation of escapement trends through sediment core analysis of marine nitrogen isotope concentrations.

The 1995 Kenai/Skilak Lake production model that predicted fall sockeye salmon abundance from the variables of mainstem spawners, spring Cyclops biomass, and summer Cyclops biomass, continues to describe most of the recruitment variation with the addition of the 1996 data. However, the 1996 fall sockeye salmon fry abundance in Skilak and Kenai Lakes was the lowest in the 11 y record. We speculate that an effect on emergent fry production followed the large 1995 fall flood (>1/100 y). Summer *Cyclops* biomass during the summer of 1996 was also the lowest in the 11y record.

The 1997 Kenai River sockeye salmon run forecast would be expected to be quite high if the dominant parent year fall fry, spring fry, and smolt relative abundance correctly predict adult returns. This year also aligns with the dominant cycle year observed in 1982, 1987, and 1992. However, the sibling component present in the 1996 Kenai run (age 4) was weak, suggesting either poor marine survival or a marine age shift strongly favoring 5 year old fish. The 1997 adult return will resolve this point.

Because of the high predictability of the seasonal zooplankton model on Skilak/Kenai Lakes in determining fall fry recruitment, similar approaches are being applied to other glacial lakes.

The studies on Kodiak Island concluded in 1996 for both Red and Aklaura lakes. It is apparent that Red Lake is responding favorably both in terms of smolt and adult production. This system is now considered to be at or close to pre-spill adult sockeye salmon production levels. Conversely, Akalura Lake is still manifesting signs of depressed production of smolts with extant adult escapements far below pre levels. A preliminary rearing fry/presmolt predation hypothesis has been formulated but remains untested. Plans have been developed for an additional year of study for this system.

Project Number and Title: 97259 - Restoration of Coghill Lake sockeye salmon.

Principal Investigator: Gary Kyle and Dana Schmidt, Alaska Department of Fish and Game, Limnology Unit, 34828 Kalifornsky Beach Road, Suite B, Soldotna, Alaska 99669 (telephone: 907-260-2908, fax: 907-262-7646, E-mail: GaryK@fishgame.state.ak.us).

Abstract: Following the 1989 *Exxon Valdez* oil spill in Prince William Sound (PWS), Coghill Lake was selected as a system for sockeye salmon restoration to replace fishery stocks damaged by the oil spill. Prior to the recent decline in return per spawner values below the replacement level necessary to sustain a fish stock, Coghill Lake was the major producer of sockeye salmon in western PWS. Although limnological and juvenile fish data are not available before the decline, consecutive years of extremely high escapements in the 1980s may have adversely impacted the forage base (zooplankton) and reduced the lake's rearing efficiency. Other causes such as climatic effects on freshwater and marine survival, as well as changes in lake turbidity may also have contributed to the decline. However, the status of the zooplankton community was reminiscent of intense predation by sockeye salmon fry that has been observed in other lakes in which too many rearing fry relative to the rearing capacity were present from large escapements.

In 1993, a 5-year plan to treat Coghill Lake with nutrient additions was implemented to increase lake productivity and assist with restoring this stock. During the first three years of treatment (1996 data are currently being analyzed), the seasonal mean phosphorus concentration increased 20%, seasonal mean algal biomass (chlorophyll *a*) increased 3-fold, and a greater biomass of cladocera (*Bosmina*) zooplankters were present (and utilized by rearing fry) in the fall. Increases in primary and secondary production apparently benefited rearing sockeye juveniles as exemplified by the relatively greater number of smolts produced during 1994-1996 (average of 1.3 million) compared to before nutrient treatment (average of 275,000). While productivity has increased during nutrient treatment, restoring the run is contingent upon obtaining adequate fry recruitment. The escapement goal of 25,000 has been met four times since 1989. Recently, management strategies have focused on reducing the interception of Coghill Lake sockeye salmon in the commercial fishery to achieve the escapement goal. The intent of this project is to increase lake productivity relative to restoring (and sustaining) the sockeye salmon run. The key components of this project are to first restore the rearing environment and then balance the number of fry produced from the appropriate escapement with the existing zooplankton forage base in order to sustain the rearing capacity for succeeding fry.

This project (after four years of lake fertilization) has been terminated, and a final report will be completed for review in April of 1997.

Project Number and Title: 96272 Chenega Chinook Release Program

Principal Investigator: Jeff Milton, PWSAC, PO Box 1110, Cordova AK 99574
phone (907-424-7511 ext.111)

Abstract: The key objective of this project is to provide a return of adult chinook salmon to subsistence users in and around Crab Bay. During the spring of 1996 PWSAC continued the release of ~50,000 chinook salmon smolt in Crab Bay near the Native Village of Chenega. This four year project will be complete with the final release of smolt in the spring of 1997, fish should be returning into the year 2000. No fish were reported as having returned during the spring of 1996. (There is currently no monitoring program in place to accurately enumerate the return.)

Project Number and Title: 96290 - Hydrocarbon data analysis, interpretation, and database maintenance for restoration and NRDA environmental samples associated with the *Exxon Valdez* oil spill.

Principal Investigators: Jeffrey W. Short and Bonita D. Nelson, National Marine Fisheries Service, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626

Abstract: This project is a continuation of the NRDA and Restoration database management, hydrocarbon interpretation and sample storage service. Subsistence, Response and Restoration data are incorporated into the Trustee hydrocarbon database as these data are produced. In 1996, hydrocarbon results from 563 additional samples were incorporated into the archival database. Also completed in 1996 was the "*Exxon Valdez* Oil Spill of 1989: State/Federal Trustee Council Hydrocarbon Database 1989-1995" (EVTHD). This software product contains complete hydrocarbon results for environmental samples collected for the oil spill on behalf of the Trustees during the period 1989 through 1995, subject to consistent data quality criteria. The software consists primarily of an interface that permits ready selection of user-defined data subsets, so that results for particular hydrocarbons suites may be retrieved for any combination of geographic locations and collection times. The software interface also permits iterative examination of selected data subsets prior to export into a spreadsheet for more detailed analysis.

Included in the EVTHD are hydrocarbon results for 238 water samples, 3,433 sediment samples, 2,150 mussel samples, and 2,184 samples of other biological matrixes. Hydrocarbon results for each sample are derived from gas chromatography/flame ionization detection of 28 alkane hydrocarbons, and from gas chromatography/mass spectrometry detection of 43 polynuclear aromatic hydrocarbons. These results may be retrieved from the EVTHD on either a wet or dry weight basis, and may optionally be censored based on analyte- and laboratory- specific method detection limits.

Other unique features of the EVTHD are the identification of replicated samples, and an assessment of hydrocarbon contributions to samples from the oil spill and from natural sources. Replicate samples may be readily associated to facilitate variability estimates for hydrocarbon measures, such as standard deviations. The EVTHD also contains a probability estimate that the major hydrocarbon source is (a) oil spilled from the *Exxon Valdez*, and (b) hydrocarbons from natural geologic sources.

The EVTHD is available on four diskettes that install under windows 3.1 or windows 95. Documentation includes detailed installation instructions, a user manual, and appendixes that give full descriptions for all the location, species, and other abbreviations and acronyms used, and that also describe the basis for the source identification procedures used. The EVTHD is currently available from the principal investigators listed above.

Project Number and Title: 96320E SEA project component - Juvenile Salmon & Herring Predation.

Principal Investigators: Mark Willette and Mark Clapsadl, Alaska Department of Fish and Game, P.O. Box 669, Cordova, Alaska. 99574 (Phone 907/424-3214).

Abstract: This project is a component of the Sound Ecosystem Assessment (SEA) program. SEA is a multi-disciplinary effort designed to acquire an ecosystem-level understanding of the marine and freshwater processes that interact to constrain levels of pink salmon and herring production in Prince William Sound (PWS). This project collected data needed to test several hypotheses related to predator-prey interactions affecting the mortality of pink salmon (*Oncorhynchus gorbuscha*) in PWS. These hypotheses include the following: (1) predation on juvenile salmon and other age-0 fish is inversely related to the abundance of large calanoid copepods, (2) predation risk is related to the daily foraging times of juvenile salmon, and (3) predation on wild salmon fry is greater when wild fry are mixed with larger hatchery-reared fish. This project was designed to achieve the following objectives: (1) estimate the juvenile salmon consumption rate of fish predators in western PWS, (2) estimate the species/size composition of fish predators, and (3) conduct preliminary tests of predator/prey hypotheses. This project also provided logistical support (personnel and equipment) to the SEA herring program.

Our efforts in 1996 focused on estimation of predator abundance, as well as predator behavior and feeding rates in nearshore habitats. Results from the first two years of research suggest that predation in nearshore areas may have been underestimated. Studies were conducted at six nearshore sites during each of three time periods in northwest PWS during May and June. Each nearshore study site consisted of an approximately 3000 m long segment of shoreline. Fish sampling was generally conducted at two stations every 3 hours throughout a 12-hour period spanning the night. Otolith marked juvenile salmon were recovered at each site to estimate stock composition and test for differences in size and growth of wild and hatchery salmon fry. Age 1-2 Pacific cod, tomcod and walleye pollock appeared to be the most important fish predators on juvneile salmon in nearshore habitats in 1996. However, abundances of age 3+ pollock in the upper 50 m of the water column were much lower than in previous years. Pacific herring appeared to switch to feeding on juvenile salmon after the decline of the zooplankton bloom. This behavior had not been observed in previous years. We also examined the feasibility of using fixed uplooking video cameras to study salmon fry and fish predator behavior and estimate fish abundances in nearshore habitats not easily surveyed using acoustic methods. Two cameras were operated at three sites during May and June. Results indicated a strong inshore movement of salmon fry at night. Overall, this technique provided useful information at a relatively low cost. We also examined the feasibility of sonic tagging age 3+ walleye pollock to study diel feeding behavior. One fish was successfully tagged and tracked for two days. It exhibited a diel vertical migration, apparently moving inshore to feed at night and returning to the bottom during the day. A second fish was tracked for one day at which time it either regurgitated the tag or died. Net pen studies will be conducted to examine the mortality of fish tagged by various methods. Results from field studies conducted since 1994 will be used to construct the SEA pink salmon recruitment model and conduct tests of the SEA predator/prey hypotheses.

Project Number and Title: 96320G SEA - Phytoplankton and Nutrients

Principal Investigator: C. Peter McRoy, Institute of Marine Science, University of Alaska Fairbanks, Fairbanks AK 99775 (907-474-7783)

Abstract: This component of SEA is designed to collect data on the concentrations of the primary inorganic nutrients (nitrate, ammonia, phosphate and silicate), and on the quantity, nature and distribution of the phytoplankton community. The objectives are to provide field data to verify the SEA restoration models and to evaluate the hypothesis that restoration processes are bottom-up driven, i.e. the spatial and temporal variability in the primary level of the food web is translated through the ecosystem to the target species (in this case, pink salmon and herring) of upper trophic levels. Some of the questions examined by this component are: Is there a lake, a river, both or neither? Is there bottom-up control of ecosystem production? Does nutrient limitation translate to fish production?

We approach this problem by using two types of platforms. First, we use the AFK hatchery as a base laboratory to collect a time series of the required data during the spring months (April, May and June). This insures that we quantitatively and qualitatively describe the annual cycle of increase and decline in the phytoplankton community. The other base is the vessels that are used by other components of SEA, in particular the oceanography cruises. A comparable data set collected in March, April, May and June, provides a spatial scale to the description of the phytoplankton. At this writing not all 1996 samples have been analyzed so the results are necessarily incomplete.

The waters of Prince William Sound contain a well-defined spring bloom of phytoplankton that varies between years in magnitude and timing depending on light and mixing. In 1996, the bloom began in early April and terminated, probably by nutrient exhaustion, by the first of May, a phenology not unlike that 1995. In previous years we observed a shift between nitrogen and silica as the control of phytoplankton growth. Such a shift between major nutrients reflects significant changes in the ecosystem. The phytoplankton community consists of at least 50% diatoms in the size range of 20 to 100μm, indicating a direct herbivore link to the food web. The overall biomass in 1996 was lower than that in 1995.

Spatially, neither nutrients nor phytoplankton are uniformly distributed. The pattern 1995 was 'lake' conditions in the northern sound and a 'river' of Gulf of Alaska water in the southern sound. The high biomass of phytoplankton and zooplankton occurred only in 'lake' waters. No such striking stratification to the sound occurred in 1996. The spatial data set is being used to verify the results of the SEA ocean model.

Project Number and Title: 96320-H Sound Ecosystem Assessment (SEA): The role of large zooplankton in Prince William Sound.

Principal Investigator: R. Ted Cooney, Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, Alaska 99775-1080 (Phone 907-474-7407).

Abstract: The multi-disciplinary SEA study is describing ecological processes that constrain the production of pink salmon and herring in Prince William Sound, Alaska. Emphasis is being placed on the juveniles of these two species, the life stage when most of the mortality occurs. The survival of both species during early marine residence is hypothesized to be related to juvenile size and condition, numbers of predators, and the kinds and amounts of alternative prey for consumers that can also eat juvenile pink salmon and herring.

Previous studies (EVOS-sponsored and other) demonstrate a strong reliance by juvenile stages of both species on zooplankton as a principal food source. Some of these studies also demonstrate that the major fish and bird predators on small pink salmon and herring can also be planktivores, particularly during periods when zoo and ichthyoplankton stocks reach seasonal peaks.

The purpose of my component of the SEA program is to provide information to all investigators about time/space abundances and seasonal changes in the composition of zooplankton populations serving as energy for juvenile pink salmon and herring, and for consumers that also prey on juvenile pink salmon and herring. The work focuses on defining successional patterns in zooplankton population structure, on interannual differences in abundance, and on behaviors that lead to patchiness like layering and swarming. This information is being used to relate these dynamic features to phytoplankton fields lower in the food web, and to events that define critical periods in the survival histories of juvenile pink salmon and herring each year.

Field work in FY96 pursued collections from established oceanographic stations in the region, evaluated zooplankton samples from the hatchery regional plankton watch, and described the vertical distributions of large calanoid copepods and other macrozooplankters during early May, typically the time of the macrozooplankton bloom in the region. The R/V *Alpha Helix* was used to deploy continuous underway sampling equipment including the SEA aquashuttle (optical plankton counting, temperature, conductivity and phytoplankton florescence) and a towed, near-surface multi-frequency acoustic array. At selected stations, a MOCNESS sampling system was deployed to obtain discrete-depth collections of zooplankton in the upper 50 m.

Preliminary results of this survey, which sampled from the shelf break south of Hinchinbrook Entrance into and through Prince William Sound, demonstrate dense near-surface layers of large calanoids at most, but not all locations. When present, the biomass of this layer was composed primarily of stage 4 and 5 *Neocalanus plumchrus* and *N. flemingeri.* Generally, the layer occurred in the upper 50 m of the water column and occasionally intercepted the surface. Continuous underway acoustic measurements suggested the feature is affected by internal waves possibly generated by tidal currents. These observations confirm our suspicions that large calanoids can occur seasonally in sufficient densities and biomass to serve as food for filter-feeding adult pollock and other near-surface fishes during late April, May and early June.

Project Number and Title: 96320I - Sound Ecosystem Assessment (SEA): Confirming food webs of fishes using natural stable isotope tracers.

Principal Investigator: Thomas C. Kline, Jr., Ph.D., Prince William Sound Science Center, P.O. Box 705, Cordova AK 99574. 907-424-5800.

Abstract: The advective regime [transport by movements of water including currents, upwelling and downwelling] connecting the northern Gulf of Alaska (GOA) with Prince William Sound (PWS) may affect recruitment and nutritional processes in fishes that were either directly impacted by EVOS or are eaten by other organisms that were affected by EVOS. The transfer of carbon from the GOA to PWS being demonstrated by using natural stable isotope tracers in project 320I is providing direct evidence of these links in the PWS study area. These natural tracers involve differing ratios of the two types of carbon [C] and two types of nitrogen [N] that are distinguished by their number of neutrons and known as stable isotopes.

The large herbivorous [eat primarily single-celled plants] copepods [a common and important type of crustacean in the aquatic economy] of the genus *Neocalanus*, being used as a carbon [nutritional] source proxy, have distinctive 13C/12C "signatures" when sampled in the northern GOA compared to those from PWS. These signatures enable us to identify the origins of carbon in different fishes [since "you are what you eat"]. Analyses of 15N/14N and C/N of fishes were used to remove effects of fat content and food chain length on their 13C/12C signature, making it possible to determine the affinity of PWS fishes with GOA or PWS carbon. Our data suggest that these affinities range from total dependency on PWS carbon to significant input of carbon from the GOA and that these affinities vary with the fishes' life history stages. Fishes with high GOA affinity included the forage fishes capelin, salmon fry, and juvenile herring. Fishes with high affinity for PWS carbon included adult pollock, an important predator in PWS and juvenile gadids and sandlance, important forage fishes. Pacific herring ranged between GOA and PWS carbon affinity.

Fishes dependent on GOA carbon are subject to changes in carbon flow that result from physical oceanographic processes [e.g., currents and temperature and salinity gradients] that connect GOA with PWS. Fishes wholly dependent on PWS are more likely to be directly affected by internal PWS processes. Increased competition for PWS carbon by all species, however, may occur if GOA carbon is less available to those that normally use it. Shifting to increased dependency on PWS carbon by species with normal affinity for GOA carbon during years of poor GOA carbon availability would provide evidence of competition for a limited carbon supply by the increasing overlap in their 13C/12C signature. Increased competition for PWS carbon by all species, however, may occur if GOA carbon is less available to those that normally use it. Time-series measurements of natural stable isotopes in fishes combined with data on fish populations and cogent oceanographic measurements will enable a new understanding of how basic environmental processes affect fish recruitment and interaction.

Project Number and Title: 96320K Experimental Fry Release

Principal Investigator: Jeff Milton, PWSAC, PO Box 1110, Cordova AK 99574
phone (907-424-7511 ext.111)

Abstract: The objective of this project is to determine if size and timing of pink salmon fry releases has a predictable impact on marine survival. During the spring of 1996 PWSAC continued the release of large (~1.5gram) late (~June 10th) pink salmon at AFK and WNH with more than 11 million pink salmon fry. Due to warmer than average water temperatures and disease concerns all fry were released by the 5th of June. All hatchery produced pink fry were marked with both CWT and otolith banding.

A preliminary review of the 1996 adult pink salmon return continues to support the notion that release of larger fry late in the season has a positive impact on marine survival.

Project Number and Title: 95320-M - Sound Ecosystem Assessment (SEA) Component M - Upper Layer Variability of the Water Mass Properties of Prince William Sound.

Principal Investigator: Shari L. Vaughan, Prince William Sound Science Center, P. O. Box 705, Cordova, Alaska 99574 (907-424-5800)

Abstract: The main objective of the observational oceanographic part of the SEA program is to identify the dominant physical processes that influence pink salmon and Pacific herring production in Prince William Sound (PWS). A specific goal is to document the seasonal and interannual changes in the large scale water mass properties (temperature, salinity, and density), which can then be correlated with changes in plankton and nekton distributions in the Sound. Four oceanographic cruises were conducted in April, June, September, and December, 1996. Stations were occupied throughout PWS, and just outside the Sound in the Gulf of Alaska. Temperature and salinity were measured as functions of depth with an instrument lowered from the ship called a CTD. Potential density was calculated from temperature and salinity. Mean values of temperature (T), salinity (S), and potential density at each station were calculated for the upper 20 meter water layer.

Both temperature and salinity were fairly homogeneous in April 1996 (T = 3.6 - 4.8 C, S = 31.3 - 31.8), and of similar magnitude to values in April 1995 (T = 4.1 - 4.4 C, S = 31.3 -31.7), although horizontal temperature gradients were larger in April 1996. In June 1996, upper layer temperatures ranged from 9.0 to 10.8 C, and were significantly higher than those in June 1995 (T = 8.0 - 9.2 C). June salinities ranged from 30.3 to 31.2 in 1996, and from 29.6 to 31.2 in 1995. The higher salinity water (S = 31.2) occupied a much larger region of the Sound in June 1996 than in June 1995. September temperatures in the upper 20 meter layer were warmer in 1996 (T = 12.2- 13.0 C) than in 1995 (T = 10.7 - 11.2 C). The layer was saltier in eptember 1996 (S = 27.0 - 29.5) than in 1995 (25.5 - 27.5). Vertical profiles of potential density showed near zero stratification in April of both years, and maximum stratification in September. No significant differences in mixed layer depths were observed between 1995 and 1996. So in both June and September, the upper 20 meter layer was warmer and saltier in 1996 than in 1995. The resulting potential densities were also higher in June and September 1996 than in 1995. April conditions were roughly the same. Dynamic height contours (0/100 m) suggest much more inflow from the Gulf of Alaska through Hinchinbrook Entrance occurred in June and September 1996 than in June and September 1995. The impact of the higher temperatures and salinities, and the increased Gulf of Alaska inflow on the distributions and abundances of phytoplankton and zooplankton in 1995 and 1996 will be examined.

[1]**Restoration Project 96320N**: Sound Ecosystem Assessment: Nekton-Plankton Acoustics (SEAFISH)

Principal Investigator: G.L. Thomas, Prince William Sound Science Center, P.O. Box 705, Cordova, Alaska 99574, tele: (907) 424-5800, fax: (907) 424-5820, email: loon@grizzly.pwssc.gen.ak.us.

Abstract: The inability to forecast the small runs of Prince William Sound pink salmon in 1992 and 1993, and the collapse of the herring population in 1993, prompted the EVOS Trustee Council to initiate the Sound Ecosystem Assessment Program (SEA), a coordinated group of ecosystem-level projects, to improve existing predictive tools. Within the SEA program, the purpose of the Nekton-Plankton Acoustics project (SEAFISH) is the evaluation and application of new acoustic measurement technology to collect fine- and large-scale, quasi-continuous information on fish and macrozooplankton distribution and abundance synoptically with physical measurements. This information is used to test the river-lake and prey-switching hypotheses[2] and the development/verification of predictive numerical models.

First, annual variability in physical conditions combined with the abundance and distribution of nekton predators and macrozooplankton prey during the spring in Prince William Sound, alter the survival of juvenile pink salmon. As a surrogate for direct measurement of the pink salmon, we are measuring the abundance and distribution of key macrozooplankton prey (Calanoid copepods) and predators (pollock and herring) synoptically with physical conditions along the out-migration path of fry to identify and quantify over-spring, pink salmon fry survival mechanisms.

Second, we believe that mortality of herring juveniles as they recruit and rear in nearshore habitats may be affecting the numbers of juveniles that recruit to adults. Unlike the difficulties in assessing the abundance of rapidly declining larvae and fry numbers during the spring to fall seasons, a time series of direct measurements of juvenile herring abundance and distribution and physical conditions can be made synoptically during the fall and winter to evaluate over-summer and winter survival mechanisms. As with the pink salmon sampling, both fine and large scale data are needed to develop population level understanding of survival.

Since the goal of model development is to predict population change in pink salmon and herring, there is a need to have accurate assessments of the adult and juvenile populations wherever possible to serve as a starting (initiation) and ending (verification) points for predictions. Currently, we depend upon Prince William Sound Aquaculture Corporation for the numbers of pink salmon fry released and the Alaska Department of Fish & Game (ADF&G) for the numbers of returning adult pink salmon, but both of these assessment techniques could use error assessment and improvement. We have developed assessment methods for adult herring and have attempted to find matching funds from ADF&G and the fishing industry for fall and spring assessments.

Some management and public information spinoffs have occurred from the SEA Nekton and Plankton Assessment Project. Acoustic measurement and estimation of the size of the dominant predator populations in the Sound, adult walleye pollock and adult Pacific herring, have contributed to establishing commercial harvest guidelines. The tracking of the size of these populations is very popular public information since the these fisheries have significant economic impact on the region. With new, rapid, cost-effective stock assessment techniques management becomes more affordable and less risky. Also, as the quality of the data on commercial stocks improve, alternate management practices such as in-season measurement and multiple species approaches become feasible.

A poster of this project will be presented.

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[1] C:\seafish\abs1996

[2] River-lake and prey switching hypotheses are primary mechanisms in the Sound Ecosystem Assessment modeling effort (SEA 1994)

Project Number and Title: 95320T-SEA-Juvenile Pacific Herring Growth and Habitat

Principal Investigators: Brenda L. Norcross, Associate Investigators: Kevin D. E. Stokesbury, Evelyn D. Brown, Bob Foy, Institute of Marine Science, University of Alaska - Fairbanks, P.O. Box 757220, Fairbanks, Alaska, 99775 (phone 907/474-7990)

Abstract: This project is a component of the Herring Recruitment group of SEA, initiated to provide information on the herring population in Prince William Sound and restoration measures required after the *Exxon Valdez* oil spill. The Herring Recruitment group is examining the physical and biological mechanisms affecting the survival of juvenile Pacific herring (*Clupea pallasi*) and providing indices of recruitment into the fishing stock. To do this a model addressing three objectives: 1.) overwintering survival model, 2.) summer habitat model, 3.) monitoring strategy, has been created. The Growth and Habitat project addresses each of these objectives in coordination with the other members of the Herring Recruitment group. We are determining: 1.) horizontal and vertical spatial distribution of juvenile herring, using hydroacoustic and aerial surveys, and the underlying biological (predator distribution, prey distribution) and physical variables (oceanographic conditions, substrata) influencing this distribution, 2.) survival rate of juvenile herring based on densities and yearclass distribution, 3.) summer growth rates in different areas, 4.) habitat quality, based on oceanographic conditions, energetics, growth rates and prey availability, 5.) a larval drift model based on the SEA oceanographic model, 6.) assist in the field collection of data for the overwintering survival model.

In 1996 we completed 2 broadscale surveys, sampling the majority of coastline in Prince William Sound in March and July; 4 diel surveys, sampling Eaglek, Whale, Ziakof, and Simpson Bays in May, June, August and October; and 2 winter surveys sampling Whale, Ziakof and Simpson Bays in November and December. Four or five vessels were used during the 10-12 day broadscale and diel surveys: an acoustic vessel, a trawler, a seiner, a processing boat which also supported the inshore frye skiff, and an oceanographic vessel. Aerial surveys were completed in May, June, July and August. One vessel was used during the winter surveys to collect herring for energetic measurements.

Preliminary results suggest some key factors of Pacific herring life history and influential environmental parameters. Adult and juvenile herring distributions appear to differ. Adult herring were found in large schools in Zaikof Bay in March and in the Latouche Passage area during July. Juvenile herring recruited into the bays throughout the sound. We collected very small post-metamorphose herring ranging in size from 15 to 74 mm in August. Each bay supported a large density of juvenile herring from August throughout the fall. During March, May and June we found young-of the-year herring in these bays. This suggests that juvenile herring overwinter in the bays and use them as a nursery until they are near maturity (age 1 $^{1}/_{2}$ to 2). Further, it appears that juvenile herring grow faster in some areas than in other areas of the sound. The relative importance of prey also seems to vary spatially and seasonally. Aerial survey techniques appear to provide an accurate means of estimating juvenile herring densities and distributions. Although preliminary, these results are critical to understanding the life history of Pacific herring in Prince William Sound.

Project Number and Title: SEA 320U - Fish Energetics.

Principal Investigator: Dr. A. J. Paul, University of Alaska, Seward Marine Center, POB 730, Seward, AK 99664 (Phone 907-224-5261)

Abstract: This project describes the interannual and seasonal somatic energy content (SEC) of juvenile *Clupea pallasi* in Prince William Sound. Calorimetric measurements of their fall and spring nutritional status are used to determine if starvation during the over-winter period is important in regulating recruitment of age 0 herring. SEC samples were collected in the spring and fall of 1995, and 1996, plus the summer months of 1996 from several sites. The fall field sampling showed large geographical differences in the nutritional status of recruiting herring. This is also true for fish at individual collection sites. The SEC measurements made to date suggest that food availability frequently limits growth in age 0 recruits. Age 0 herring that recruited in 1994 ended the over-wintering phase in good nutritional condition. In contrast, many 1995 recruits did not have enough energy reserves to fast through the winter of 1995-96. Collections for this part of 320U will be made in the fall of 1995, 1996 and 1997 with spring samples in 1996, 1997 and 1998 so that the percentage of age 0 fish having enough stored energy to fast through the winter can be calculated for three year classes.

Young herring were held in captivity to quantify the energy they need to survive the winter fast. In 1996-97 there will be periodic winter sampling to measure the nutritional status of fish in nature. These *in situ* measurements will be used to verify the energy use model derived in the laboratory and to measure energy intake during the winter months.

This project also measures fall and spring somatic energy content of juvenile pollock (*Theragra chalcogramma*) to compare their nutritional status to that of competitors like juvenile herring and pink salmon fry. Samples of age 0 pollock from the fall of 1995 and spring of 1996 indicate that for the 1995 year class SEC values were lower than would be expected if food was not limiting growth. The collection schedule for this part of the project is for fall collections in 1995, 1996 and 1997 with spring collections in 1996, and 1997. Analysis of the 1996 fall samples are in progress.

Measurements of the spring SEC of pink salmon fry (*Oncorhynchys gorbuscha*) removed from predatory fish stomachs will be analyzed. These values will be compared to those from the general population to see if weaker fry are more subject to predation. These measurements are part of the SEA effort to understand the role predation plays in the recruitment process of this injured species.

Pollock and herring are a major prey of many species injured by the oil spill. Our energetic measures will be useful in estimating fish and bird consumption rates when these forage fishes are prey. The information gathered by this project is being related to SEA zooplankton surveys, habitat studies, prey selection studies and trophic isotopic studies through the SEA modeling effort. The energetic data is also available to APEX and other EVOS trophic studies.

Project Number and Title: 96320-Y (closeout)- Sound Ecosystem Assessment (SEA): Estimating Local Avian Predation Rates on Hatchery-Released Fry

Principal Investigators: David Scheel & Kathy R. Hough, Prince William Sound Science Center, Cordova, AK (ph 907/424-5800)

Abstract: We estimated the mortality of hatchery-raised pink (Oncorhynchus gorbuscha) and chum (Oncorhynchus keta) salmon fry as a result of seabird predation near a Prince William Sound salmon hatchery. Field counts of seabirds and observations of feeding rates for several piscivorous seabirds were obtained from a skiff during April, May, and June 1995. Several 100 birds of seven piscivorous species aggregated in front of the hatchery. Aggregations were largest early in the study period and declined by early June. Consumption rates were determined from focal animal sampling and by calculation of energetic demand for all of the piscivorous birds observed at the hatchery. Most of the per capita consumption rates based on behavioral data were lower than those calculated from energetic considerations. The use of energetic models and estimated fry movement rates provided a range of 2.7 to 5.9 million juvenile salmon (1.1% to 2.4% of released fry) consumed during the study period. Sixty-four percent of this range was attributed to differences between the energetics models; the remainder to the assumptions about fry movement rates. Early marine mortality of salmon fry resulting from seabird predation may increase in years of higher seabird abundance; however, mortality may be reduced by releasing fry later in the season when bird numbers have declined.

Gulls recorded during aerial surveys were significantly associated with spawning herring and with hatchery sites, but not with linear miles of herring spawn. The correlation of bird aggregations with the presence of small fish (spawning herring and hatchery locations) indicates that concentrations of forage fish have an important influence on the distribution of birds at sea during this time of the year. Bird numbers in all samples (boat counts, volunteer data, and aerial surveys) declined from early May to early June, suggesting that fry released from the hatcheries in April and May face considerably more risk of predation from birds than do fry released in June.

Project Number and Title: 96320-Z Sound Ecosystem Assessment (SEA): Synthesis and integration.

Principal Investigator: R. Ted Cooney, Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, Alaska 99775-1080 (Phone 907-474-7407).

Abstract: Success of the SEA program requires the continuous exchange and debate of information collected by field studies and derived from modelling activities. Principal and senior investigators in SEA represent several different organizations; some reside outside Alaska. Funding for synthesis and integration activities is used to facilitate scholarly exchanges between all investigators in the program. These exchanges take the form of subgroup meetings (salmon, herring, ocean state/plankton), conference calls, and workshops. Funding is also used to prepare and submit an integrated SEA annual report and an integrated DPD each year.

In 1996, SEA was restructured internally to provide working areas for intense collaboration between field ecologists and SEA modelers. Three subgroups were created to focus on developing numerical products for: 1) pink salmon recruitment; 2) Pacific herring recruitment; and 3) ocean state and plankton dynamics. These components of SEA ecosystem modelling structure are assisted in their activities by funds from the Integration and Synthesis project. In 1996, all of these projects used large blocks of conference calls to coordinate and plan activities, and to discuss results.

The SEA program held a 3-day internal workshop in Seward, Alaska in September, 1996, to review the status of the overall investigation and to plan for future activities. The Synthesis and Integration project extended travel to all principal investigators and selected senior staff and students to participate in the workshop. Funds were also used to pay for use of the Seward Marine Center Public Education Building to host the meeting. One important outcome of that gathering was the establishment of formal liaison with the Regional Office of Alaska Department of Fish and Game as the first step in building an interface between SEA research and future management activities in Prince William Sound.

As SEA enters its out-years, the demand for internal coordination, publication, and distribution of results to user communities in Alaska will increase. Most of these activities will be enhanced or directly supported by the Integration and Synthesis project.

Project Number and Title: 96427 - Distribution, abundance, and composition of harlequin ducks in Prince William Sound, Alaska.

Principal Investigator: Daniel H. Rosenberg and Michael J. Petrula, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, Alaska 99518 (Phone 907/267-2453).

Abstract: The primary objective of the project is to determine whether current productivity of harlequin ducks *(Histrionicus histrionicus)* in oiled areas of western Prince William Sound (WPWS) is at a level necessary to maintain a viable population. We conducted annual surveys of harlequin ducks inhabiting oiled areas in WPWS and non-oiled areas in eastern PWS (EPWS) to compare trends in numbers and levels of productivity between locations. Surveys were conducted simultaneously and were repeated at 6 intervals from the breeding (May) through molting periods (September). We used the number of breeding pairs, age and sex composition of the population, chronology of molt and the number of brood observations to determine whether harlequin ducks in WPWS and EPWS exhibit similar demographic characteristics. Variation in these parameters between locations would indicate dissimilar extrinsic influences affecting populations and may explain differences in productivity. Similar trends in numbers and levels of productivity (relative to abundance) would be evidence for recovery by harlequin ducks in WPWS.

The number and composition of harlequin ducks in PWS varied among survey periods because of seasonal movements by ducks in and out of the study area. The number of ducks declined during the early spring as pairs moved from coastal areas up breeding streams to nest. Numbers increased as the breeding season progressed when males returned to the coast to molt. The proportion of females progressively increased from late summer to early fall as failed breeders, followed by successful breeders, returned to coastal molting areas.

The general pattern of seasonal movements was similar between WPWS and EPWS. Preliminary results, however, suggest that differences in the magnitude and timing of these movements may represent differences between populations in their potential for growth. A lower proportion of paired females in WPWS coupled with a greater poroportion of flightless females earlier in the fall indicates to us that breeding propensity of female harlequin ducks is lower in WPWS than EPWS. Males comprised a greater proportion of the WPWS population during spring and fall surveys suggesting lower survival rates of females in WPWS. Fourteen harlequin broods were observed in EPWS while no broods were observed in WPWS. However, similar proportions of sub-adult males in WPWS and EPWS indicates that recruitment also results from nesting outside of PWS. Fewer breeding females, a higher proportion of males, and no observations of broods for the 3rd consecutive year lead us to conclude that productivity by harlequin ducks is lower in WPWS than EPWS. We cannot yet determine whether the disparity in breeding activity between WPWS and EPWS is related to effects of oil contamination or habitat differences unrelated to the oil spill. Additional years of survey data will enable us to determine whether lower productivity by harlequin ducks in WPWS is responsible for declining harlequin numbers in that area.

Project Title: XXX- The potential importance of jellyfish as predators and competitors of fishes in Prince William Sound.

Principal Investigator: Jennifer E. Purcell, University of Maryland Center for Environmental and Estuarine Research, Horn Point Environmental Laboratory, P.O. Box 775, Cambridge, MD 21613 (Phone 410-221-8431)

Abstract: In July 1996, I participated in one of the SEA cruises in Prince William Sound (PWS). I was invited, as a specialist on jellyfish, to advise on their likely effects on the food web of PWS. SEA and APEX scientists have observed the great numbers and high biomass of jellyfish, which can exceed that of fishes in trawl catches. The scientists recognize the potentially great importance of jellyfish in the food web of PWS.

Jellyfish are predators that eat zooplankton and ichthyoplankton (fish eggs and larvae). In the spring, blooms of small jellyfish (hydromedusae) have been seen at herring spawning grounds in PWS (E. Brown, pers. comm.), and frequently occurred at spawning grounds throughout British Columbia. They may be important as predators of the newly-hatched larvae, as documented for *Aequorea victoria*, which decimated herring larvae in a bay on Vancouver Island. The amounts of ichthyoplankton and zooplankton consumed by jellyfish can be estimated through plankton net sampling of population densities of jellyfish and their prey, and gut content analysis of field-collected jellyfish in combination with experimentally measured digestion times of prey.

Jellyfish also consume the same zooplankton foods as fish larvae and some fishes (e.g. herring, pink salmon). In the summer, I observed very large populations of large jellyfish in PWS -- the scyphomedusae *Cyanea capillata* and *Aurelia aurita*, and the large hydromedusa *Aequorea victoria*. All of these species are documented predators of larval herring and other ichthyoplankton, however, their main negative effect is probably as consumers of zooplankton, thereby reducing the foods available to fishes like herring and pink salmon. These and other jellyfish species are present throughout the summer, feed continuously, and consume prey in direct proportion to the amounts available. They have been shown to reduce zooplankton populations in other locations, therefore, they are potential competitors with fish for zooplankton foods. If forage fish populations are negatively affected by jellyfish, the populations of vertebrate predators of the forage fishes (e.g. piscivorous seabirds, fishes and marine mammals) also may be negatively affected.

My observations suggest that jellyfish are major predators of zooplankton in PWS. Determining the magnitude of their predation on zooplankton could be critical to understanding the ecology of vertebrates in PWS. Such research would contribute toward understanding why some species have not recovered from the effects of the oil spill.