16.8.3

1996 Restoration Workshop

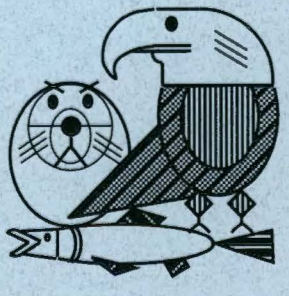
Exxon Valdez Oil Spill Trustee Council

January 16 – 18, 1996
Anchorage, Alaska

Abstracts of 1995 Restoration Project Results

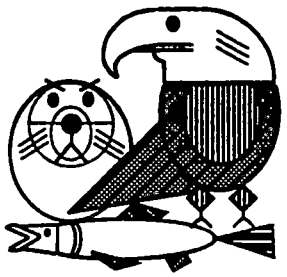
DRAFT

AS OF 1/3/96



16.8.3

Exxon Valdez Oil Spill Trustee Council
Restoration Office
645 G Street, Suite 401, Anchorage, Alaska 99501-3451
Phone: (907) 278-8012 Fax: (907) 276-7178



January 3, 1996

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 1995 Work Plan and are compiled here for the benefit and information of participants in the 1996 Restoration Workshop and the public. Any abstracts submitted after January 3 will be available at the workshop, which is scheduled for January 16-18, 1996.

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
Executive Director

MM/kh

Index of Projects by Subject

[Note: This index lists projects by number under which they were grouped for purposes of the Fiscal Year 1995 Work Plan]

Seabird/Forage Fish Interaction (APEX)
163-A, -B, -C, -D, -E, -F, -G, -J, -K, -L

Subsistence
009-D, 027, 052, 131, 138, 244, 266, 279, 428

Index of Projects by Author

[Note: This index lists authors' names in alphabetical order, followed by the project number or numbers associated with each name.]

Project Number and Title: 95001 - Recovery of harbor seals from the *Exxon Valdez* oil spill: condition and health status

Principal Investigators: Michael A. Castellini, Brian S. Fadely, Tania Zenteno, and J. Margaret Castellini, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, PO Box 757220, Fairbanks, AK 99775-7220 (MAC telephone: 907-474-6825)

Abstract: Harbor seal (*Phoca vitulina*) populations had already been declining in Prince William Sound prior to the *Exxon Valdez* oil spill, and effected populations have shown no signs of recovery. The primary objective of this study was to assess and interpret harbor seal body condition and nutritional status data to help resolve the multiple hypotheses proposed to explain these declines, and to determine whether seals from EVOS-impacted areas were different in their health status compared to seals from non-EVOS areas. To perform these comparisons, we collected morphometric and hematological data from harbor seals that were captured live in the Kodiak Island archipelago, Prince William Sound and southeast Alaska during Spring through Fall seasons. Additional analytical tests of morphometric condition indices were conducted utilizing a historical database provided by Alaska Department of Fish and Game. Morphometric indices of body condition were generally poor indicators of blubber content, but improved if blubber thickness was incorporated into the model. Adult female seals exhibit large seasonal variation in body mass and composition related to the reproductive cycle, while adult males were relatively stable in body mass, but varied in composition throughout the year. Differences in body shape and the scaling of core and blubber compartments with body mass suggest the possibility of changed body condition or age structure between the 1970's and 1990's. Regional and interannual comparisons of hematogical parameters were complicated by variability attributable to sex, age, handling technique and seasonal effects. There were no significant differences among seals from the three sampling regions in plasma copper, zinc, or metalothionine, suggesting no problems exist from heavy metal bioaccumulation. However, differences in plasma haptoglobin levels, an acute-phase stress protein, indicate that Prince William Sound seals are subject to some stressor that increases these levels over that found in southeast Alaska seals.

Project Number and Title: 95007-A, Archaeological Site Restoration- Index Site Monitoring

Principal Investigator: Douglas R. Reger, Alaska Department of Natural Resources, Office of History and Archaeology, 3601 "C" Street, Suite 1278, Anchorage, AK 99503-5921, Phone: (907) 269-8725, FAX (907) 269-8908, e-mail address: oha@alaska.net

Abstract: Vandalism of archaeological sites during the period of cleanup after the *Exxon Valdez* Oil Spill prompted land managers to monitor the affected sites as a restoration effort. Additionally, the potential for oil to adversely effect their research value made monitoring intertidal sites for intrusion by buried or intrusive remanents of the spill another priority of land managers.

During 1995, the State monitored status of three sites on Shuyak Island, AFG-046, AFG-081, and AFG-098. A site in Port Dick, SEL-178, was also monitored for vandalism and presence of oil in the deposits. The National Park Service monitored condition of the McArthur Pass Site, SEL-188, and collected intertidal sediment samples for test for presence of oil. The U.S. Forest Service monitored the condition of the site, SEW-440. The U.S. Fish and Wildlife Service visited the Chief Cove Site, KOD-177, to assess the condition of that site. Vandal damage at most sites appears to have ceased however, long term monitoring is planned on an intermittent basis. Presence or absence of petroleum hydrocarbons are being determined for sediment samples from AFG-046, AFG-098, SEL-178, and SEL-188 using the Hanby Field Test kit procedures.

The 1994 Spill Area Site and Collection Plan, Final Report, Restoration Project 94007-1, was completed and accepted for placement in the OSPIC. It is currently being printed in the required quantity for distribution. Recommendations were: 1) a regional archaeological repository should be supported, 2) small, local storage and display facilities should be supported, 3) site monitoring should continue and a site stewardship program should be encouraged, and 4) public education in support of archaeological site protection should be supported.

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

Principal Investigator:
Linda Finn Yarborough 907-271-2511
Chugach National Forest
3301 C St., Suite 300
Anchorage, Alaska 99503

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. Standard archaeological methods, materials, and equipment were used to test the sites and recover data. Each site's condition was assessed and hydrocarbon samples were taken from their intertidal zones. No revegetation work was done, as it was determined that the sites were revegetating well naturally. The data recovery requirements of the mitigation are considered to have been met, with the completion of the 1995 field season. Data collection was oriented towards determining the nature of the sites, their age and the depth of cultural deposits. Cultural and environmental data was recovered, and pollen, wood, tephra, and radiocarbon samples have been submitted to various labs for analysis. Preliminary analysis points to at least intermittent occupation of the sites over the past 1000 years, and possibly longer. Initial study of the faunal data indicates dependence on a variety of non-salmonid fish in the prehistoric diet. The artifactual materials show the importance of local botanical and mineral resources as well as resources which could only be procured through long-distance travel or trade. The presence of tephras indicates infrequent ashfall from distant volcanic eruptions. There is also some evidence of tsunamis, which could have more seriously disrupted occupation at the sites. Restoration as measured by the mitigation specifications will be completed with the finalization of the project report. Analysis of the excavation results and syntheses of specialists' reports on coastal geomorphology, palynology, tephrology, and radiocarbon analysis are currently on-going.

Project: 95009-D - Survey of octopus in intertidal habitats

Principal Investigator: D. Scheel (Prince William Sound Science Center, Box 705, Cordova, AK 99574; tel: 907-424-5800).

Abstract: Giant Pacific Octopus are an injured, non-recovering species under the general headings of Subtidal Organisms and Intertidal Organisms. Subsistence use of these octopus in Prince William Sound has led to reports that this species has declined in abundance. Reduced octopus availability comprises a part of the decline in subsistence services. This project was designed to identify suitable study sites for octopus through initial surveys and use of local knowledge, to estimate local density of octopus, and to identify the characteristics of good nearshore octopus habitat in the Sound.

Because of the interest in octopus as a subsistence resource, surveys were conducted in the northeast Sound (around Tatitlek) and in the southwest Sound (around Chenega Bay). Individual survey sites were chosen based on expert opinion and the published literature on octopus. The experts consulted were fisherman and village residents who had experience collecting octopus for subsistence use and a Seattle collector of octopus for aquaria trade. Fifty-eight sites were surveyed using either beach surveys at low tide, SCUBA surveys from -3 to -70 feet, or pot sampling. Survey sites ranged in area from 200 to 18,000 square meters.

Octopus were generally sparse except in some intertidal samples. SCUBA surveys never located more than one individual per site; the maximum found at a single site in the intertidal was six. Three octopus were caught in pots near Tatitlek at depths of 40, 500 and 500 feet. All individuals were juveniles of a single species, *Octopus dofleini*, the Giant Pacific Octopus. The population was 80% females (N=29) and ranged in size from 0.07 to 8.7 kg (average 2.54 kg; N=32).

Octopus densities ranged from 0 to 1.8 individuals per 1000 square meters searched, although densities greater than 0.5 individuals/1000 m^2 only occurred at sites where the sampled area was very small. Densities appeared lower in the subtidal than the intertidal; and were substantially lower than densities of 5-13 individuals/1000 m^2 reported from 1978 and 1984 studies in Clayoqout Sound, British Columbia.

Sites with greater numbers of octopus (a) included boulders or broken outcrops on a cobble substrate, (b) were adjacent to Zostera beds and Laminarian kelps, (c) had shallow slope. Of these three characteristics, boulder fields are suspected to be the most important to octopus and slope the least. Octopus were perhaps more abundant in the intertidal and in these habitats because such areas serve as refuges from marine predators (e.g. sea otters). Future work will focus on the dynamics of nearshore octopus and testing the model of preferred habitat patches.

Project Number and Title: 95012 : Comprehensive Killer Whale Investigation in Prince William Sound, Alaska

Principal Investigators:
Craig O Matkin, NGOS, P.O. Box 15244, Homer, AK 99603 (907) 235-6590
Dr. David Sheel, PWSSC, 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, 3) determination of the potential separation of killer whale populations.

Continued within this new project is the monitoring of killer whales *(Orcinus orca)*, a species currently considered injured and recovering from the Exxon Valdez Oil Spill. However, since 1993, five additional mortalities have been confirmed in AB pod and only one calf has been recruited. Some of the new mortalities may be linked to the EVOS . Two were calves orphaned at the time of the spill, one a mature male whose fin collapsed at the time of the spill, one a reproductive female who lost most of her close relatives at the time of the spill. The final mortality was a calf less than 1 year old. Subgroup structure and relationships within the injured AB pod and the non-injured AJ pod are being examined and compared using observed associations, known relationships, and Cole's association index dendrograms. The nine transient AT1 whales missing since 1990 remain missing. One is known dead and the others are believed dead . At this time AB pod and the AT group do not appear to be recovering.

A spatial killer whale database (GIS) is being developed using data from about 560 encounters (360 post spill) during more than 12,000 hours of field effort. Analyses of these data will help evaluate recovery, recognize changes in behavior, and estimate killer whale impact on harbor seals. A review of field data collection procedures resulted in the development of new data sheets in 1995 that has increased the usefulness of data for spatial analysis. Boat paths and whale paths are entered as graphical objects with data attached regarding search effort, weather, and details of killer whale encounters such as , biopsy samples taken, whale behaviors, whale identifications and predation events. Entry has been completed for seven years (1984-85, 1989, and 1992-95) and all data will be entered by February 1996. A preliminary analysis of search effort for the years entered indicates the greatest effort in 1989. Search success (encounters per mile searched) was highest in 1985 and lowest in 1994 and 1989. Predation events and evidence of predation have been summarized for the years entered. Harbor seals (damaged/non-recovering) appear to be an important prey for transient killer whales.

Genetic analysis is being used to clarify the degree of separation of proposed killer whale populations in the Sound. These populations appear ecologically dissimilar. Good quality DNA has been obtained from over 50 killer whale skin samples using proteinase K digestion, phenol-chloroform extraction and alcohol precipitation. Two approximately 2.5 kb regions of the mitochondrial genome were amplified by the polymerase chain reaction using custom primers that were designed based on conserved sequences in other cetacean species. The amplified DNA was then digested with restriction ensymes and analyzed for restriction fragment length polymorphism. The enzymes used initially had proven to be informative in discriminating mitochondrial differences between British Columbia killer whale populations. To improve resolution of the analysis, a suite of novel restriction enzymes are being tested. Preliminary results suggest that the method will effectively and efficiently discriminate genetic difference between resident and transient killer whale populations in Prince William Sound.

Project Number and Title: 95021 - Seasonal movements and pelagic habitat use by common murres and tufted puffins

Principal Investigators: Scott A. Hatch, Paul M. Meyers, Daniel M. Mulcahy, and David C. Douglas, National Biological Service, Alaska Science Center, 1011 East Tudor Rd., Anchorage, AK 99503 (SAH telephone: 907-786-3529)

Abstract: Common murres (*Uria aalge*) were the bird species most heavily impacted by the *Exxon Valdez* oil spill. The failure of this species to recover 6 years after the event may be related to a long term decline in the availability of suitable forage. Elsewhere in the restoration program, tufted puffins (*Fratercula cirrhata*) are being used as samplers of the forage fish community and as indicators of changes that may be affecting murres and other injured resources. Tests of hypotheses concerning food limitation on murre population recovery and the application of puffins as fish samplers require information on the foraging ranges and feeding areas of birds from specific colonies. The primary objectives of this project are: (1) determine the foraging ranges and principal feeding areas of common murres and tufted puffins from the Barren Islands, including assessment of individual and temporal variation, and (2) locate important nursery and/or wintering areas of common murres and determine the timing of use of those critical habitats. In 1995, work at the Barren Islands was conducted in conjunction with a similar project, independently funded, on the foraging of common murres and thick-billed murres (*Uria lomvia*) at two colonies in the Chukchi Sea, Cape Thompson and Cape Lisburne. To track the movements of birds at sea, we are using small (35-gram) implantable satellite transmitters compatible with the ARGOS Data Collection and Location System. In July and August, 10 transmitters were deployed in murres and 5 transmitters in puffins at the Barren Islands, and 20 transmitters were deployed in murres from the two northern colonies. By mid October, more than 500 locations had been obtained for murres and puffins from the Barren Islands. Murres primarily foraged south to Kodiak Island waters at distances of 40-100 km from the release site. This area included nearshore waters off Shuyak Island and the north shore of Afognak, southeast to Marmot Island. One tufted puffin stayed within 20 km of the Barren Islands before departing the colony and moving to a relatively small area of open water some 100 km east of Marmot Island. Both concentrated use areas identified for murres and puffins may be associated with cold, upwelled water conspicuous on infrared satellite images of the region. Murres from Capes Thompson and Lisburne commuted up to 100 km from the colony while breeding, then migrated to apparent wintering areas in the southeastern Bering Sea near the Pribilof Islands. The accuracy of location data obtained in this study is sufficient to satisfy both of our primary objectives. The main problems encountered are shorter than expected battery life, and the apparent inability of some birds to survive the procedure. Overall survival of murres appeared to be 40% at the Barren Islands and Cape Lisburne, compared to a more encouraging 80% at Cape Thompson. Birds carrying devices that transmitted more frequently seemed particularly susceptible to mortality, suggesting possible physiological effects of the radio transmission itself. Studies are planned to address this issue and increase the prospects for longer-term data acquisition in the future.

Project Number and Title: 95025-- Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators (NVP)

Chief Scientist: Leslie Holland-Bartels[1]

Principle Investigators: Brenda Ballachey[1], James Bodkin[1], Terry Bowyer[2], Tom Dean[3], Larry Duffy[4], Dan Esler[1], Stephen Jewett[2], Lyman McDonald[5], Chuck O'Clair[6], Alan Rebar[7], Dan Roby[8], Paul Snyder[7], Glenn VanBlaricom[9]

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3 Coastal Resources Associates, Inc., 1185 Park Center Dr., Suite A, Vista CA 92083, 619-727-2004
4 Department of Chemistry and Biochemistry, Box 756160, University of Alaska, Fairbanks, 907-474-7525
5 Western Ecosystems Technology, Inc., 2003 Central Ave., Cheyenne, WY 82001 307-634-1756
6 National Marine Fisheries Service, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, AK 99801, 907-789-6016
7 Department of Veterinary Pathobiology, Purdue University, 1243 Veterinary Pathology Bldg, West Lafayette, IN 47907-1243, 317-494-7617 (Rebar), 317-494-9676 (Snyder)
8 National Biological Service, Oregon Cooperative Fish and Wildlife Research Unit, 104 Nash Hall, Oregon State University, Corvallis, OR 97331-3803, 503-737-1938.
9 National Biological Service, Washington Cooperative Fish and Wildlife Research Unit, School of Fisheries, WH-10, University of Washington, Seattle, WA 98195 206-685-7471

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 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), first funded in 1995, focuses on the status of system recovery and 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*) and takes a multispecies, integrated approach to assess several potential key mechanisms constraining recovery of the nearshore system. For our test species, the 1994 EVOS workshop suggested mechanisms that may be constraining recovery: 1) recruitment processes; 2) initial and/or residual oil in benthic habitats and in or on benthic prey organisms; and 3) EVOS induced changes in populations of benthic prey species. We ask "are vertebrate populations recovering, and if so, are they recovering as quickly as possible given potential rates of population increase?" by measuring population density and demographic factors (e.g., size and age distributions, birth rates, survival rates) at both oiled (Naked and Knight Islands) and unoiled sites (Montague Island and Jack Pot Bay) in western PWS to examine possible reasons for **lack** of recovery, and assess **progress** toward recovery given demographic restraints. In conjunction with this "recovery monitoring" approach, we ask "
is it oil?" or **"is it food?"** that limits recovery. This is addressed through evaluation of demographic measures, health assessments, biomarkers of oil exposure, and availability of prey for the four nearshore vertebrate predators in oiled and unoiled areas of Prince William Sound. NVP was approved in March, 1995 and a pilot field season was initiated during the summer to develop statistically valid sampling protocols for invertebrate and fish prey items and describe subtidal study area habitats through sidescan sonar technologies so that fine protocols could be developed for the first full field season (1996). In addition to these preliminary efforts, full field seasons were initiated for sea otter and harlequin duck components. A full aerial survey to estimate sea otter abundance was completed, mortality surveys were conducted to estimate age class distribution of sea otters dying as compared to pre- (1976-84; 1989) and post- (1989-94) spill age distributions, 6 adult sea otters were captured to obtain blood for preliminary investigations of immune response and hydrocarbon exposure, and reproduction surveys were completed to estimate reproductive output of sea otters in the two study areas. Over 200 harlequin ducks from Montague Island and 160 from Knight Island were captured. Body condition of all birds was determined and total body electrical conductivity (TOBEC) was measured on 267 individuals to develop a noninvasive condition index. Finally, ninety-six of these birds (all females) were implanted with radio telemetry transmitters and are being monitored regularly to determine comparative survival between oiled versus non-oiled populations. Research on river otters and pigeon guillemots were not initiated in 1995, but will begin in spring, 1996. Although NVP began late in the fiscal year, significant progress was made on an integrated approach to this project. A common data management and quality assurance plan has been implemented; equipment and personnel are shared; and finally, data are centrally served to project investigators through an NBS file server at the Alaska Science Center. FY 1996 will be the first full field season for this project and we expect significant progress on our stated hypotheses.

Project Number and Title: 95027 -- Kodiak Shoreline Residual Oiling Assessment.

Principal Investigators: James C. Gibeaut, Dianne Munson, Ernest Piper, Alaska Department of Environmental Conservation, 555 Cordova Street, Anchorage, Alaska 99501 (907 269 7632)

Abstract: A shoreline survey team visited 30 sites in the Kodiak archipelago that had measurable and or reported oiling in 1990 and 1991 to determine the persistence of that oiling through the summer of 1995. The survey team concentrated on Shuyak and northwest Afognak Island, selected areas between Sturgeon Head and Chief Cove (Spiridon Bay) on the Shelikof Straight coast of Kodiak Island, and several sites of community concern near the village of Larson Bay inside Uyak Bay. This survey used shoreline survey methods developed and refined during the *Exxon Valdez* response, and was intended to complement a similar project conducted in Prince William Sound in 1993. Surveyors found no oil at sites south of Chief Cove, trace amounts at Chief Cove, and widely spaced trace amounts at the sites on Shuyak Island. Traces consisted primarily of tar splatter or coat <5cm in diameter, with a few small (<2m x 20m) areas within which friable, weathered surface oil residue was scattered. No subsurface oil was found. Chemical analysis of samples of surface oil residue identified the residual oiling as *Exxon Valdez* oil. The oiling in the Kodiak archipelago is not persisting as it is at sites in Prince William Sound due to the higher energy settings on the islands, the state of the oil when it came ashore, and the smaller concentrations of intial oiling relative to the Sound.

Project Number and Title: 95031 - Reproductive Success as a Factor Affecting Recovery of Marbled Murrelets (*Brachyramphus marmoratus*) in Prince William Sound, Alaska.

Principal Investigator: Katherine J. Kuletz, U.S. Fish and Wildlife Service, 1011 E. Tudor Rd., Anchorage, Alaska 99503 (phone 907-786-3453).

Abstract: Marbled murrelets are the most abundant seabird in Prince William Sound (PWS) in the summer, and the species was injured in the *Exxon Valdez* oil spill. Previous restoration work described murrelet nesting habitat and foraging range to assist land acquisition. We are now investigating the possibility that food is limiting recovery by affecting murrelet reproductive success. However, murrelet productivity can not be measured, due to their non-colonial and secretive nesting behavior. Our goal is to develop a murrelet productivity index (MPI) that would allow comparison to oceanic conditions and forage fish abundance. Our objectives were (1) to begin development of a MPI and (2) determine what factors influence abundance and distribution of adults and juveniles at sea.

We conducted at-sea surveys to track adult murrelet abundance over the summer in PWS and to obtain juvenile:adult ratios, using 25 ft. vessels. We surveyed 2 sites in 1994 (the pilot study) and 6 sites in 1995. The sites, each with 45-65 km of shoreline, were separated by >20 km, the mean distance radio-tagged birds foraged in 1994, and farther than a radio-tagged juvenile traveled its first 2 weeks at sea. We conducted 4 surveys per site 1-17 June and 7-10 per site 17 July - 28 August. At all sites, the total number of murrelets declined throughout August, to 5% of July numbers. Peak juvenile abundance was greater and 1 week earlier in 1995, with the plateau of fledging between 4-20 August. Among sites, there was no correlation between juvenile and adult density in July/August. However, there was a positive correlation between the June density of adults at a site and the July/August density of juveniles (R^2= 0.87, P=0.006). We conclude that the June population is most representative of local breeders, and due to adult movement after breeding, August numbers of adults at a site are not reliable for an index of relative juvenile abundance. There were significant differences among sites in juvenile abundance and proportions, suggesting differential productivity among sites. We will investigate what site-specific features may be responsible.

Using digitized locations of juveniles, and transect densities for adults, we are using GIS coverages of bathymetry, shoreline, landform, and forage fish distribution to model marine habitat use. In preliminary analyses, there was a positive, significant correlation between murrelet density and underwater relief. There were negative correlations with distance from shore, exposed shoreline and choppy seas. Murrelets selected shallow water more than available, with the exceptions of areas of upwelling, such as near underwater sills and land points.

Project Number and Title: 95038 - Pacific Seabird Group *Exxon Valdez* Oil Spill Seabird Restoration Workshop

Principal Investigators: Kenneth I. Warheit, Pacific Seabird Group, P.O. Box 178, Tenino, WA 98589 (Telephone: 360-902-2595, email: warheit@u.washington.edu). Craig S. Harrison, Pacific Seabird Group, 4001 North 9th St., Arlington, VA 22203

Abstract: The Pacific Seabird Group (PSG) received funding from the *Exxon Valdez* Oil Spill (EVOS) Trustee Council to implement a workshop designed to provide recommendations on restoration options for seabird species injured by the spill. This workshop took place September 29 - October 2, 1995, in Girdwood, Alaska, and was composed of roughly 47 participants 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" (Common Murre, Harlequin Duck, Marbled Murrelet, and Pigeon Guillemot), discussions were not limited to these species or to the EVOS situation. We achieved the workshop goal by discussing seabird restoration first from a general or generic (i.e., not oil-spill specific) perspective, and then applied these general discussions and conclusions to EVOS.

The workshop produced comprehensive results and a series of recommendations for the EVOS Trustees. 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 set down 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 over 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 are 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 recommended that 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), habitat or nest site creation or enhancement (e.g., habitat preserves; land purchases; improve quality of habitat), and predator control at colonies were the most promising of restoration techniques. Of particular interest were our discussions on the feasibility of enhancing food resources for seabird through altering fisheries management practices. We determined that these techniques may be very useful in restoring seabird populations, but that not much is known about the logistic feasibility of these techniques or their population- or community-level effects. We recommended that funds be made available to research these techniques. We also recommended that the EVOS Trustees fund research on the effects of gillnet bycatch, nearshore community structure, and predation on Marbled Murrelets at or near nest sites. Finally, among a series of general recommendations, we advocated that the EVOS trustees enlarge the "spill-impact area" to reflect the biological reality of the spill (i.e., birds outside the "spill-zone" were injured, and restoration outside spill zone may benefit populations within the zone).

Project Number and Title: 95041 - Predator Removal From Islands (Removal of introduced foxes: A restoration method for seabirds injured by the T/V *Exxon Valdez* oil spill)

Principal Investigators: G. Vernon Byrd, Edgar P. Bailey, and Steven M. Ebbert, U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, 2355 Kachemak Bay Drive, Suite 101, Homer, AK 99603 (GVB telephone: 907-235-6546)

Abstract: The purpose of this project was to restore populations of black oystercatchers (*Haematopus bachmani*) and pigeon guillemots (*Cepphus columba*), 2 species that were injured by the T/V *Exxon Valdez* oil spill. These species occur on islands throughout southwestern Alaska, a region where populations have been reduced by predation from introduced foxes (*Alopex lagopus or Vulpes vulpes*). Elimination of alien foxes from islands is one method of restoring reduced populations, so fox were removed from Simeonof and Chernabura islands in the Shumagin group near the western edge of the oil's path.

The outer Shumagin Islands, which include 4,000-ha Simeonof and 3,000-ha Chernabura, originally had no terrestrial mammals except river otter (*Lutra canadensis*). The avifauna of these treeless islands primarily included species that were susceptible to extirpation (e.g., oystercatchers) or reduction to low population levels (e.g., guillemots) by predation from introduced foxes.

Foxes were removed from these islands in 1994 and 1995 by trapping and shooting. Populations of oystercatchers and guillemots were estimated on Simeonof and Chernabura and on nearby fox-free islands. Oystercatchers were surveyed by conducting nearshore boat surveys and subsequently walking beaches to look for nests and defensive pairs. For guillemots, we made replicate boat surveys of birds on shore and on the sea within 100 m of shore during early-morning hours. We estimated the amount of oystercatcher and guillemot breeding habitat on Simeonof and Chernabura and on nearby Atkins, Herendeen, and Bird islands to compare densities of birds on islands with and without foxes.

A total of 33 foxes was removed from Simeonof Island in 1994; 5 additional animals were killed in 1995. Three foxes were killed at Chernabura, all in 1994. When crews departed in July 1995, careful surveys of primary use areas indicated no foxes remained.

No oystercatchers successfully nested on Simeonof or Chernabura in 1994 when foxes were present. Nevertheless, failed or non-breeding birds, including some "pairs", were recorded on both islands. Apparently, oystercatchers periodically attempted to nest on islands with foxes but usually lost their eggs or chicks to these predators. Following fox removal, these pairs could successfully nest. Indeed, we found 2 oystercatcher nests on Simeonof and 3 nests on Chernabura in 1995, the first breeding season following fox removal. Furthermore, breeding densities on nearby fox-free islands, suggested that ultimately Simeonof could support 21-88 pairs of oystercatchers and Chernabura could support 16-65 pairs.

Pigeon guillemot populations apparently were depressed at Simeonof and Chernabura by fox predation. Densities on nearby fox-free islands suggested that restored populations of guillemots will eventually fall within the ranges of 136-314 birds on Simeonof and 245-567 guillemots on Chernabura.

It is clear that removal of introduced foxes is an effective restoration tool for oystercatchers and guillemots. Future surveys will reveal the magnitude of the increases in populations of these injured species.

Rocky Creek Cutthroat Trout Habitat Enhancement
EVOS Restoration Project 95043
1995 Project Work

Principal Investigators: Ken Hodges, David Schmid. Cordova Ranger District, Chugach National Forest. USDA Forest Service. P.O. Box 280 Cordova, AK. 99574. (907) 424-7661.

Abstract

Studies by the Alaska Department of Fish and Game indicate that anadromous cutthroat trout (*Oncorhynchus clarki*) were adversely impacted by the *Exxon Valdez* oil spill. Since most of the cutthroat trout populations in Prince William Sound are quite small, they may be especially sensitive to environmental impacts. Furthermore, there is little information on cutthroat genetics in this area. Since Prince William Sound is the northern limit of the range of cutthroat trout and the populations are relatively isolated, it is quite possible that unique genetic stocks are present. Rocky Creek, which flows into Rocky Bay at the northern end of Montague Island, has a small anadromous population. It was felt that if the cutthroat habitat could be enhanced, the population would increase and could better withstand adverse impacts in the future. In addition, the genetic stock could be preserved until more is known about cutthroat trout genetics in the Sound.

Surveys indicated that spawning and first-year rearing areas were the habitat features limiting cutthroat trout production in the Rocky Creek system. In 1994, 18 log and boulder structures were built in two small tributaries to create pools and spawning area. In 1995, the structures were monitored to see how well the structures created the desired habitat and to determine use by cutthroat trout. The structures created 1,074 sq. ft. of pool area and 14 sq. ft. of undercut bank for rearing area. Spawning gravel is still accumulating above the structures and in the tailouts of the pools, so the increase in spawning area cannot be calculated yet. In May, one cutthroat trout redd was observed in the tailout of a pool created by one of the structures. In September, pink salmon (*Oncorhynchus gorbuscha*) and coho salmon (*Oncorhynchus kisutch*) were observed spawning at some of the structure sites.

It appears that the structures are creating the spawning and rearing area as desired. It will take a few years for the gravels to accumulate and for the pools to fully develop. It will also take a few generations for the cutthroat trout population to respond to the increase in habitat. However, given the use of the newly created areas by trout and salmon, it appears that the structures will be effective. Although EVOS funding for this project is now complete, the US Forest Service will continue to monitor the structures and provide updated reports on the response of the cutthroat trout population.

ABSTRACT
Cutthroat Trout and Dolly Varden Habitat Improvement Structures
(Project Number: 96043 - B)

In 1989 the oil tanker *Exxon Valdez* ran aground on Bligh Reef, the ensuing oil spill damage assessment identified oil spill related injuries to the cutthroat trout (*Onchorhynchus clarki*) and Dolly Varden char (*Salvelinus malma*) populations among other species in PWS. Information collected in 1989-1991 by the Natural Resources Damage Assessment (NRDA) studies documented lower growth rates for cutthroat trout and Dolly Varden char in oiled areas than in unoiled areas. The reduced growth rates persisted into 1991 when studies were discontinued. 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.

During the 1995 field season Glacier Ranger District crews installed a total of sixty habitat improvement structures at Otter Lake, Gunboat Lakes, Red Creek and Billy's Hole to improve cutthroat trout and Dolly Varden habitat in PWS. The distribution and densities of cutthroat trout, Dolly Varden and coho salmon were monitored at these locations using standard mark recapture techniques. Project area streams were surveyed and habitat units classified using a modified Hankin and Reeves (1988) methodology both prior to and after structure installation for comparison. Mark recapture and stream survey data are currently being analyzed for the preparation of a project completion report.

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Date prepared: 12/06/95

Project Number and Title: 95052 - Community Interaction and Use of Traditional Knowledge

Principal Investigator: Rita A. Miraglia, Alaska Department of Fish and Game, Division of Subsistence, 333 Raspberry Road, Anchorage, AK 99518 (telephone: 907-267-2358)

Abstract: The objective of this project was to increase the involvement of spill area communities in the restoration efforts of the Trustee Council, and to improve the communication of findings and results of restoration projects to spill area inhabitants.

While scientific studies aimed at restoring the resources and services damaged by the oil spill have occurred throughout the spill area, most of the researchers work for agencies or institutions based in Anchorage, Fairbanks, or outside Alaska. Spill area residents complained of a lack of involvement by in the restoration efforts, and incomplete communication of study proposals and results. At the same time, researchers recognized that local residents have traditional knowledge that could help them answer questions they have not been able to answer through conventional scientific means. This project was designed to make optimal use of the complementary nature of scientific data and traditional knowledge, while increasing the involvement of spill area communities in oil spill restoration. The project was coordinated by the Trustee Council's Director of Operations, and implemented by the Alaska Department of Fish and Game's Division of Subsistence. The project goals were to be achieved through community meetings, and informal networking (i.e., telephone calls, letters, and household visits).

An additional means proposed to improve the involvement of the impacted communities in restoration activities was to provide funding to allow local people to serve as facilitators. To assess how effective such a program could be, a pilot study was conducted. Local facilitators were funded in three communities, Chenega Bay and Tatitlek in Prince William Sound, the area most impacted by the oil spill, and Port Graham, as a representative community for the lower Kenai Peninsula.

Discussions with Chugach region organizations and community residents and officials indicated that the most effective way to fund the local facilitators was to contract with each village council and allow the village council to hire and supervise its local facilitator. In this way the facilitator would answer to the locally elected government and the village council would be responsible for submitting reports, as opposed to an individual, who may or may not be able to represent the community.

The following is a general outline of the function of the local facilitators:

I. Work with the pilot project coordinator and Trustee Council staff to identify those restoration projects for which a community outreach component would be appropriate.
II. Work with the principal investigators of those projects identified to design and implement community outreach components.
III. Communication of traditional knowledge and local interests to project researchers.
IV. Coordination of local hire and facilitating local logistical support such as boat rentals, and lodging.
V. Assess community attitudes and keep the Trustee Council appraised of upcoming community issues and problems through the pilot project coordinator.
VI. Attend Trustee Council functions and meetings to represent their community

In FFY '95, cooperative agreements were negotiated with the village councils of the three pilot communities. Each village council appointed a local facilitator as follows: Gary Kompkoff for Tatitlek, Mike Eleshansky for Chenega Bay and Walter Meganack, Jr. for Port Graham. A coordinating meeting was held with the pilot project coordinator and the three local facilitators. The group discussed the role of the local facilitators, and how Subsistence Division and the Trustee Council Staff could help the facilitators do their jobs. The facilitators decided their first task should be to coordinate their communities' response to the 1996 Draft Restoration Work Plan. An issue of the Subsistence Restoration Project Newsletter was issued to inform community residents of the Community Involvement project and the pilot project as well as restoration projects related to subsistence.

This project has been expanded in scope in FFY '96 and continues under the direction of the Chugach Regional Resources Commission, with the cooperation of other Chugach region organizations, the Chugach region communities, and the Bristol Bay Native Association and the Kodiak Area Native Association.

Project Number and Title: 95058 - LANDOWNER ASSISTANCE PROJECT

Principal Investigators: Ken Holbrook, U.S.D.A. Forest Service, 3301 C Street, Suite 300, Anchorage, Alaska 99503, (907) 271-2819. Mark Kuwada, Habitat and Restoration Division, Alaska Department Of Fish and Game, 333 Raspberry Rd., Anchorage, Alaska 99518, (907) 267-2277.

Abstract: On March 16, 1994, the three *Exxon Valdez* Trustees representing the State of Alaska formally requested that the Executive Director establish a project to facilitate development of a cooperative restoration and enhancement program on private lands scheduled for timber harvest and other development activities. To that end, the Executive Director requested that representatives be assigned form The Alaska Department of Fish and Game, The Alaska Department of Natural Resources, and The U.S.D.A. Forest Service to develop a proposal for the 1995 *Exxon Valdez* restoration program. The project was to provide assistance to private landowners in the oil spill area during development activities on their lands. This assistance would allow the Trustee agencies to help interested landowners reduce the impacts of their land use activities on injured resources and services. The proposal was subsequently funded for three months as a pilot project.

The objective of the project in 1995 was to determine interest in this type of service. If sufficient interest existed the project would be continued in 1996. To inform the public and private landowners of the project and the services that might be offered, public notices were placed in local news papers and an article was presented in the *Exxon Valdez* news letter. In addition, 58 letters were sent to private landowners and development contractors informing them of the project and requesting they contact us if they were interested in the assistance offered by this project.

Only six requests for assistance were received. Although the number of interested landowners has been limited, there may be a good opportunity for increasing involvement in the future. It is likely that the response may be the result of the timing of the public notices. Notices were released in April and by that time most development projects for the 1995 season were already planned. Also, the uncertainty of future funding for the project might have discouraged potential participants.

The Landowner Assistance program has great potential for helping landowners who are interested in providing additional protection for injured resources and services on their property. This program is the logical compliment to the Trustee Councils habitat protection and acquisition program, since only a small percentage of the private lands in the oil spill area can be protected with acquisition of habitat or conservation easements. Since timber harvest along with other development activities are scheduled throughout the oil spill area, this project can provide protection besides that resulting from the habitat protection program.

Project Number and Title: 95064 - Monitoring, Habitat Use and trophic Interactions of Harbor Seals in Prince William Sound

Principal Investigators: Kathryn J. Frost, AK Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701-1599 (phone 907-459-7214, fax 452-6410, e-mail kfrost%fishgame@state.ak.us)

Abstract: More than 300 harbor seals (*Phoca vitulina richardsi*) were estimated to have died in Prince William Sound (PWS) because of the Exxon Valdez oil spill. In addition, harbor seals in PWS as a whole had been declining at about 11% per year prior to the spill. 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 1989-1994 showed a continuing decline in the number of seals counted during the molt. Statistical analysis showed that the primary factors influencing seal counts were date, time relative to midday, and time relative to low tide. When adjusted for these factors, molting counts showed a highly significant decline of about 6% per year. Power analysis showed that adjusted molting counts have a high likelihood of detecting population recovery if at least 6 replicate counts are made each year over a 5 year period. Pupping surveys were more variable and not as useful for determining trend.

Twenty-eight seals were captured, sampled, and tagged in 1993, 36 in 1994 and 42 in 1995. Thirty-eight of these were instrumented with satellite-linked time-depth recorders (SLTDRs). Seals equipped with SLTDRs remained within PWS, mostly near the locations where they were tagged. Several subadult seals made feeding trips into the Gulf of Alaska, one as far south as Yakutat, but later returned to PWS. Dive depth and duration varied by seal and by location. Some seals dove more at night, and others during the day. Most seals made deeper dives in winter than at other times of year.

Blubber biopsies were taken from all seals caught in 1994 and 1995. Fatty acids signatures of seals from the northeastern Sound (Gravina Island) were quite different from those of seals in the southern Sound (Channel Island, Port Chalmers, and Stockdale Harbor). Seals from Channel Island and Port Chalmers also were distinguishable based on fatty acids in blubber. The first fatty acids analyses of prey were completed in fall 1995. Fatty acid signatures of major prey (such as pollock and herring) were very different, and should make it possible to determine the types of prey eaten by seals based on the fatty acids in their blubber. Blood was collected from all seals that were captured. Viral screening of blood serum indicated that seals have been exposed to phocine herpesvirus and phocine distemper virus, but serum titers indicated that there had been no recent outbreaks of disease.

It is clear based on the results of monitoring studies by this project and from discussions with local residents of PWS, that the decline of harbor seals in PWS has continued since 1989. For this reason it is important to try to identify the causes for the decline and take any actions necessary to reverse it. For this reason, the principal investigator is working closely with the Alaska Native Harbor Seal Commission to share and discuss results, develop a biosampling program to provide information about important life history parameters, and to discuss future research and management needs.

Project Number and Title: 95074 - Herring Reproductive Impairment.

Principal Investigators: Mark G. Carls, Scott W. Johnson and Stanley D. Rice. Auke Bay Fisheries Laboratory, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau AK 99801. 907-789-6019 (Carls)

Abstract: A three-part study conducted in 1994 and 1995 was designed to 1) determine if exposure of mature herring (*Clupea harengus pallasi*) to oil would cause genetic damage in progeny, 2) determine impacts on herring eggs exposed to oil during incubation, and 3) survey Prince William Sound (PWS) herring stocks for evidence of reproductive impairment due to the *Exxon Valdez* oil spill (EVOS).

In 1994, polycyclic aromatic hydrocarbons accumulated in tissues of exposed mature herring, mixed function oxidase activity was induced, and immune functions were suppressed, thus prevalence of viral hemorrhagic septicemia virus increased. Parental exposure to oil did not cause genetic damage in progeny.

In 1995, eggs were exposed either to several treatments of crude oil for 16 d (plus unexposed controls) or for 0 to 8 d to a single treatment. Exposure to oil induced early hatch; hatching success, larval swimming, survival, and size were reduced, and morphological abnormalities increased. Frequency of chromosomal aberrations was significantly elevated in the pectoral fins of exposed larvae. Effect gradients existed among oil treatments and exposure times. Two day exposures[1] occasionally elicited significant responses; responses were frequently significant after 4 d exposure. These results imply that relatively brief exposure to modest concentrations of oil in PWS could have adversely affected herring eggs spawned in oiled areas shortly after the EVOS. The implications of chromosomal aberrations in mitotic cells is not clear; it is likely most affected individuals died due to concomitant morphological abnormalities, but the question of whether observed chromosomal damage could be heritable remains unanswered.

In the field surveys, mature herring collected from four PWS sites were artificially spawned and resultant eggs were reared in a laboratory until hatch. These eggs were compared to similarly collected eggs from three unoiled sites in southeast Alaska (SE). Observed response parameters included fertilization success, hatch timing, hatch success, larval swimming ability, and larval spinal abnormalities. Within site, responses of progeny from the 1989 year class (most likely impacted by the oil spill), generally did not differ significantly from responses of any other year class. Responses of all year classes combined or restricted to the same year class did not differ signficantly between PWS and SE sites ($P > 0.50$); the best and worst responses generally occurred in SE. Based on the parameters examined in this study, evidence of reproductive impairment of herring stocks by the EVOS was not detected in 1995, and the chances of detecting any oil related effects against the natural background variation appears negligible.

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[1]At an estimated initial PAH concentration of 36 ppb; final analysis of hydrocarbon concentrations is not complete.

Project Number and Title: 95076 - Effects of Oiled Incubation Substrate on Straying and Survival of Wild Pink Salmon

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

Abstract: This project examines the effects of oil exposure during embryonic development on the straying, survival to spawning, and gamete viability of pink salmon *Oncorhynchus gorbuscha*. The objectives for 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 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. In 1996 several hundred thousand pink salmon fry from wild and experimental treatment groups will be marked with coded-wire tags or fin-clips. Fry from the oil-exposed and control groups will be tagged to identify treatments when they emigrate from the incubators, and emigrating wild fry from two streams will be captured and tagged. Returning adults will be examined for marks in 1997 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 determine if oil exposure decreased the gamete viability of the exposed fish.

In FY95, the objectives of the project were (1) to set up the incubation and oil exposure array, and expose pink salmon embryos from the 1995-brood to oiled gravel; and (2) test fry capture and adult sampling and enumeration techniques. 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 were detected, however, even at nominal dosages as low as 0.4 g oil per kg of gravel. Fry capture and adult sampling and enumeration techniques were successfully tested.

Project Number and Title: 95086C - Herring Bay monitoring and restoration studies

Principal Investigators: Raymond C. Highsmith and Michael S. Stekoll, Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775-1090 (Phone: 907-474-7836)

Abstract: Intertidal habitats in Prince William Sound are dominated by the brown alga, *Fucus gardneri*, interspersed with beds of the mussel, *Mytilus trossulus*, and barnacles (*Balanus glandula*, *Semibalanus balanoides*, and *Chthamalus dalli*). The *Exxon Valdez* oil spill and associated clean-up activities had negative effects on all of these species, especially in the high intertidal zone where both oil and cleaning were concentrated. This study monitored mechanisms of recovery of intertidal habitats in Herring Bay on the north end of Knight Island in Prince William Sound. For organisms with slow or no recovery, the project sought to determine the factors that have limited recovery and possibly to experiment with active restoration techniques.

Fucus seems to have recovered from the oil spill at all tidal levels originally observed, Mobile invertebrates are also mostly recovered, but there continues to be differences in the high intertidal for the limpet, *Tectura persona* and littorine snails, *Littorina sitkana*. In contrast, if only the very high intertidal area is considered limpet, littorine, and *Fucus* populations are lower at oiled sites compared to unoiled sites on shores facing west, east, or south.

Oiled sites generally had higher recruitment of barnacles and mussels which may be related to the higher water flows measured at oiled sites. In general, higher recruitment of mussels onto filamentous algae was observed on oiled sites. In addition, mussel beds on oiled sites tended to have higher proportions of smaller individuals. Some invertebrates seem to use *Fucus* as habitat, so their recovery may be linked to the recovery of *Fucus*. Many invertebrates, especially limpets and littorines utilize *Fucus* plants as habitat, living on and within the fronds. Thus, when *Fucus* is removed from the shoreline, these invertebrates are also removed. In addition upon removal, mobile invertebrates that were utilizing substrates beneath the *Fucus* canopy were reduced significantly within days. Recovery of these invertebrates seems to hinge on the recovery of *Fucus*.

It may appear that heavy recruitment of barnacles on oiled shores enhances recovery of *Fucus*. Barnacles may increase the chances of *Fucus* recruitment by decreasing desiccation stress and herbivory, and *Fucus* recruits are frequently seen on barnacles. Reproductive *Fucus* adults, however, are almost never seen growing on barnacles, suggesting that there is a long-term disadvantage for *Fucus* to recruit onto barnacles. In fact, survival and the breaking strength of *Fucus* is less on barnacles compared to rock surfaces. Recovery of *Fucus* has been slow in the upper intertidal due to low dispersal distances, low densities of reproductive plants leading to low settlement rates, and high desiccation stresses. These factors combine to make conditions difficult for *Fucus* to establish. North facing shores that are rarely subjected to direct sunlight, seem to have recovered more fully. If plants are able to recruit, growth is as fast or faster at oiled sites compared to unoiled sites.

Biodegradable fabric was used to ameliorate desiccation stress as a means of active restoration of *Fucus*. *Fucus* germlings recruited heavily onto the fabric and occurred higher on the shore than other recruits. Once these plants become fertile, they may act to seed the natural rock substrate of a site denuded by the oil spill and clean-up.

Project Number and Title: 95090 - 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, Patricia M. Harris, and Stanley D. Rice. Auke Bay Fisheries Laboratory, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau AK 99801. 907-789-6018 (Babcock)

Abstract: Many mussel (*Mytilus trossulus*) beds oiled by the *Exxon Valdez* oil spill were not cleaned because the beds physically stabilized the intertidal area and provided food for higher consumers. However, natural cleaning was slow and contamination remained high in the beds. In 1992 and 1993, the Auke Bay Laboratory documented 31 mussel beds in Prince William Sound with underlying sediment concentrations greater than 10,000 µg/g total petroleum hydrocarbons (TPH). The high hydrocarbon concentrations measured in mussels in these beds caused concern that contaminated mussels could be impacting their predators.

To aid return to pre-spill hydrocarbon levels, in 1994, in cooperation with the Alaska Department of Environmental Conservation and residents of Chenega, Alaska, we restored twelve mussel beds at five sites. Oiled mussels and underlying sediments were removed and replaced with clean sediment; the mussels were rinsed and replaced onto the clean sediment. Restored beds ranged in size from 9 m^2 to 35 m^2.

The main objectives of this project in 1995 were to 1) evaluate the success of 1994 mussel bed restoration by measuring hydrocarbon levels in the underlying sediments and mussel densities, and 2) sampling mussels and sediments from other documented, but untreated, beds. Companion work along the Kenai and Alaska Peninsulas is presented separately.

Concentrations of petroleum hydrocarbons in replacement sediments in all restored beds have remained low, showing little recontamination, so potential chronic exposure of the mussels to oil has been much reduced. In August of 1994 hydrocarbon levels (TPH) in replacement sediments were an average of 88% (range, 66-100%) lower than the sediments there before restoration. By May of 1995 they averaged 89% (49-100%) lower, and by August of 1995 were 98% (range, 94-100%) lower. Preliminary evaluation of sediment data from untreated beds indicated reductions in hydrocarbons but levels were still not as low as in the restored beds. Mussel chemical data has still to be evaluated.

The effect of restoration on densities of mussels in the beds is not clear. Densities in four restored beds (at the same site) were similar to pre-restoration densities when last sampled in August 1995, but in eight beds, densities were significantly lower than pre-restoration levels. In some untreated beds at restoration sites, however, densities showed significant decreases as well, indicating that factors other than transplanting could be responsible.

Further monitoring of the untreated and restored beds will be proposed for 1997 or 1998.

Project Number and Title: 95090 - Geographical Extent and Recovery Monitoring of Intertidal Mussel Beds in the Gulf of Alaska Contaminated by the Exxon Valdez Oil Spill.

Principal Investigator: Gail V. Irvine, National Biological Service, Alaska Science Center, 1011 E. Tudor Rd, Anchorage, AK 99503, tel 9077863653.

Abstract: The Exxon Valdez oil spill resulted in the stranding of huge volumes oil in the intertidal, directly affecting intertidal communities, including beds formed by the mussel, Mytilus trossulus. Studies of oiled mussel beds were begun in Prince William Sound by NOAA's Auke Bay Lab, but were extended to other areas of the spill zone through the initiation of this project in 1992. The objectives of this study were to: 1) investigate the geographical extent of oiled mussel beds in the Gulf of Alaska, outside of Prince William Sound, and 2) to determine the degree of hydrocarbon contamination of these beds through time. Numerous sites were surveyed for the presence of oiled mussel beds in 1992 and 1993 along the outer Kenai Peninsula coast, the Alaska Peninsula, and the Kodiak Archipelago. Sampling was conducted in 1992, 1993 and 1995. Within beds, both mussels and underlying sediments were collected for analysis by ultraviolet fluorescence (uvf-a screening method), and, for a smaller subset, by gas chromatography/mass spectroscopy (GC/MS). The values for samples from the Gulf of Alaska sites are generally lower than for PWS mussel bed samples. Values for both total petroleum hydrocarbons (TPH -as determined by uvf) and total polynuclear aromatic hydrocarbons (TPAH - determined from GC/MS analyses) declined from 1992 to 1993. By 1993, TPAH concentrations at most beds were approaching background levels, however, at two sites (both in Morning Cove, on the outer Kenai Peninsula coast), substantial TPAH and TPH concentrations persisted. Results of uvf analysis of 1995 samples have just been received, and indicate further reductions in hydrocarbon (TPH) concentrations. When comparing mussel versus sediment concentrations of TPAH's in earlier samples, it was found that sediment concentations were much greater than those found in mussels and there was no direct relationship between the values. This suggests a complex relationship - sediments may act as a reservoir of hydrocarbon contamination that episodically becomes available to mussels. The persistence of oiled mussel beds provides an opportunity for transfer of hydrocarbons to consumers (e.g., harlequin ducks, young sea otters, humans, etc.).

Project Number and Title: 95106 - Subtidal Monitoring: Eelgrass Communities

Principal Investigator: Stephen C. Jewett, Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, AK 99775-1080, 907-474-7841

Abstract: This study has focused on the injury to, and recovery of, shallow (< 20 m) subtidal eelgrass communities in western Prince William Sound following the Exxon Valdez oil spill (EVOS). Effects were assessed in 1990, 1991, 1993, and 1995 primarily by examining differences in population parameters (e.g., abundance, biomass) of dominant taxa within the subtidal eelgrass habitat. It is anticipated that 1995 is the final sampling year for this investigation.

In 1990, we noted significant differences between oiled and control sites with respect to a number of taxa. Among the differences noted were greater densities of eelgrass flowers and shoots, amphipods, trochid snails, *Telmessus* crabs, and *Dermasterias* sea stars at the control sites. Other taxa, including small epifaunal mussels, (*Musculus*) and spirorbid worms, a variety of infaunal polychaetes, and juvenile cod were more abundant at oiled sites. The infaunal benthic community within the deeper portion (3 to 20 m) of the eelgrass habitat appeared especially affected by the EVOS, as there was a decline in diversity as well as reductions in a number of dominant taxa. On the other hand, the benthic community in shallower portions of the habitat, within the eelgrass bed, showed a general enhancement of both diversity and abundance of several dominant taxa. The notable exception was for amphipods, which declined in all habitats. By 1991 there was strong evidence of recovery at eelgrass by fewer differences in community parameters and dominant taxa than observed in 1990. Although some recovery was still evident by 1993, e.g., large epifaunal crabs (*Telmessus*) and sea stars (*Dermasterias*), many infaunal and small epifaunal taxa were more prevalent in oiled eelgrass sites, resembling 1990.

Polycyclic aromatic hydrocarbon (PAH) concentrations in sediments were generally higher at oiled than control sites and in the deeper portions of the habitat. The highest concentrations observed were greater than 1000 ng g^{-1} at several eelgrass sites in 1990. PAH concentrations declined to less that 100 ng g^{-1} by 1993, but were still somewhat higher at oiled sites.

Many of the observed effects appeared related to the effects of oil. The reduction in the abundance of amphipods were presumably due to the acute toxicity of oil. However, most other declines in population density were probably related to either the sublethal effects of oil or to indirect effects such as increased predation. Increased abundance of most taxa at oiled sites appeared related, either directly or indirectly, to organic enrichment from either oil or from bioremediation.

Benthic biological and hydrocarbon samples collected in 1995 are scheduled to be completed by mid-January and late March 1996, respectively. Therefore, no statement can be made on the recovery status of these components. As for the large epifaunal organisms in 1995, preliminary examination of the data suggests that no differences are apparent between oiled and control sites.

Project Number and Title 95110 and 95126: - Habitat Protection Data Acquisition and Habitat Protection Negotiation and Acquisition Support.

Principal Investigators: Catherine Berg, Tom Gerlach, Jess Grunblatt, Ken Holbrook, Mark Kuwada, and Art Weiner, US Dept. of Interior, Fish & Wildlife Service, US Forest Service, AK Dept. of Fish & Game, and AK Dept. of Natural Resources.

Abstract: Habitat protection is a major component of the Exxon Valdez oil spill restoration process. The acquisition of private lands, or partial interests in private lands, is intended to promote natural recovery of spill-injured resources and services by removing the threat of additional development impacts. The Comprehensive Habitat Protection Process is the method that was designed to achieve this objective. Over one million acres within the oil spill affected area were evaluated, scored and ranked by a multi-criteria evaluation process. Initially, lands were divided into large parcels encompassing entire bays and watersheds. Criteria were then used to assess the habitat and human use values associated with each parcel and the protection benefit that acquisition would provide for nineteen injured resources and services. This process has been the basis for the acquisition of 41,549 acres of land on Afognak Island, 23,800 acres on the Kenai Peninsula, protection of 267,724 acres within Kodiak National Wildlife Refuge and agreements that, if consummated will result in the acquisition of fee or lesser rights on over 320,000 additional acres of land in the Kodiak Archipelago, Kenai Peninsula and Prince William Sound. These rights, if acquired, will be incorporated into parks or refuges or otherwise managed in a manner that will facilitate the recovery of resources and services injured by the oil spill..

PROJECT NUMBER AND TITLE: 95115 - The Sound Waste Management Plan

PRINCIPAL INVESTIGATORS: Paul A. Roetman, Executive Director, Prince William Sound Economic Development Council, 128 Pioneer Drive, Post Office Box 2358, Valdez, Alaska, 99686

ABSTRACT: The Sound Waste Management Plan is a comprehensive plan to identify and remove the major sources of marine and solid waste pollution generated in five Prince William Sound communities: Chenega Bay, Cordova, Tatitlek, Valdez, and Whittier. Complete restoration from the oil spill requires permanent protection from on-going chronic pollution sources in these communities that may be degrading the quality of marine habitat for injured fish, wildlife, and human uses. The primary objective of the project is to make practical progress in reducing pollution to the environment through identifying pollution sources, developing solutions, and obtaining funding for implementation of the solutions. The project is based on a regional approach to planning, whereby coordination among communities during the planning and implementation stages increases the opportunity for and feasibility of a wide range of environmental management alternatives.

Anticipated outcomes of the project include the initiation of a regional household hazardous waste management program, increased recycling of cardboard and aluminum, recommendations on how solid implementation of a comprehensive used oil management system in each of the communities. The communities have also identified enhanced communication and understanding of each other's environmental management issues as a significant benefit of the project. The communities plan to continue coordination of their solid and marine waste management activities after the project is completed.

The solutions recommended by the plan are likely to be funded from a variety of sources, including the communities themselves, agencies, and the private sector. In addition, a request to fund some solutions is expected to be submitted to the Trustee Council for fiscal year 1997.

Project Number and Title: 95131 - Nanwalek, Port Graham and Tatitlek subsistence clam restoration

Principal Investigators: Carmen Young, 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.

1995 was the first year of the project. Its goal is to provide the project villages with safe, reliable, easily accessible sources of clams for subsistence use. 1995 objectives were to identify clam species to use in the restoration effort, identify and clear clam broodstock for hatchery use, demonstrate hatchery and nursery capabilities by producing 10 mm seedstock from at least one of the selected clam species and identify enhancement/restoration sites near the project villages.

After consultation with the Native villagers, experts in clam production techniques and a literature search, littleneck clams (*Protothaca staminea*) and cockles (*Clinocardium nuttalli*) were selected as the species that will be used in the restoration effort. The butter clam *(Saxidomus giganteus)*, a popular species with the Native villagers, was rejected because of its slow growth characteristics and propensity to retain the Paralytic Shellfish Poison toxin for extended periods. Littleneck clam broodsource for both Port Graham/Nanwalek and Tatitlek have been cleared for use in the Qutekcak Shellfish Hatchery in Seward. A Nanwalek/Port Graham broodsource of cockles has been cleared for hatchery use, but clearance for a Tatitlek cockle broodsource is being withheld pending further analysis by the state fish pathologist. Several batches of 5 mm littleneck clam seed have been produced in the Qutekcak Shellfish Hatchery and a small batch of 10 mm littleneck clams was produced in the adjoining nursery system. No hatchery work has yet been done with cockles. Beach surveys near the Port Graham, Nanwalek and Tatitlek villages were conducted this summer. Several sites near each village were identified as suitable for use in this project.

Project Number and Title: 95138 - Community Conference on Subsistence and the Oil Spill

Project Leader: Bill Simeone, Alaska Department of Fish and Game, Division of Subsistence, 333 Raspberry Road, Anchorage, Alaska 99518 (telephone: 907-267-2309).

The Trustee Council provided funding to the Alaska Department of Fish and Game, Division of Subsistence to organize a conference on subsistence and the oil spill (Project Number 95138). The project leader was William E. Simeone. The Trustee Council's purpose in sponsoring the conference was to "promote the recovery of injured resources and subsistence uses of natural resources of the oil spill area through a conference that will involve elders, youth, and other representatives of spill area communities as well as selected scientists involved in spill area research." Goals that emerged during the planning of the conference were:

- To provide elders, youth and other subsistence users from 20 communities a chance to talk to one another about their common experiences related to the oil spill and subsistence.
- To facilitate communication between communities, regions and resources managers/EVOS Trustee Council.
- To identify how communities can be more involved in the restoration of subsistence resources.

Funding provided for four people from each of the following 20 communities to travel to Anchorage to attend the conference: Akhiok, Chenega Bay, Chignik Bay, Chignik Lagoon, Chignik Lake, Cordova, Ivanof Bay, Karluk, Kodiak, Larsen Bay, Nanwalek, Old Harbor, Ouzinkie, Perryville, Port Lions, Port Graham, Seward, Seldovia , Tatitlek, Valdez.

Through panels and working groups six **Themes and Actions** emerged from the conference:

1. Coordination between communities and between regions. The principal action listed under this theme was the formation of a steering committee with 2 representatives from each of the 4 regions. Formation of this committee was the major outcome of the conference. Members of the committee are Pete Kompkoff (Chenega Bay), Monica Reidel (Cordova), Walter Meganack Jr. (Port Graham), Lillian Elvssas (Seldovia), Hank Eaton (Kodiak), Robert Katelnikoff (Ouzinkie), Priscilla Skonberg (Chignik Bay) and Virginia Alek (Chignik Lake).
2. Recovery of resources and the health of the ecosystem. Actions suggested under this theme included better communication between villages and regions, and with western scientists; more projects for shellfish restoration, and better communication between villages involved in the abnormalities project and organizations that conduct tests on the samples provided by the villages.
3. The role of local knowledge in resource recovery. Actions listed under this theme included: involving local people in research by: consulting with local people and community organizations on research designs, training and employing local people to conduct research, using elder's knowledge to shape scientific research, communicating research results to the community, using local knowledge to create sensible regulations.
4. Involve young people and address their concerns. Actions suggested under this theme were holding more spirit camps and giving young people a voice on councils and commissions.
5. Actions to restore confidence in people's decisions about subsistence food safety. These actions included: acquiring better, more frequent reporting of test and research results; train locals to use western science in addition to traditional knowledge to evaluate food safety; develop a system in villages to rely on local knowledge and observations about food safety; develop more restoration projects aimed at shellfish, re-establishing clambeds.
6. Legal considerations. Actions suggested under this theme included: get the human element accounted for in damage assessment; put a native trustee on the EVOS trustee council now; pursue compensation for mental health damages; create mechanisms for extensive local involvement in any proposal process that effects village people; protect the confidentiality of the Native people sharing information of wildlife resources and pursue actions related to the court system and judges selected to hear Native cases.

(95138, continued)

The conference began with a review of people's experiences during the oil spill and its effects on subsistence. People discussed the changes they saw and felt and what they are currently doing to heal the wounds created by the spill.

Panel the on Research and the Status of Resources and Ecosystems - chaired by Gordon Pullar - reported by Robert Spies EVOSTC Chief Scientist, Stan Senner, EVOSTC Science Coordinator and Tom Nighswander, Oil Spill Health Task Force & Alaska Area Native Health Service.

Conference participants divided into working groups composed of people from the communities and scientists involved in restoration research.
Question addressed at this first working group
How do you integrate local knowledge into resource recovery?

On the second day conference began with participants breaking up into working groups.
The question addressed by these groups was
Should communities re-invigorate subsistence?

PROJECT NUMBER AND TITLE: 95139A1 - 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. Data from these surveys indicated that Little Waterfall Creek contained a significant amount of spawning habitat that was under utilized 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 upstream of the barriers to allow full utilization of spawning habitat.. The priorities of the project were to renovate the bypass to reduce the gradients and to design resting pools to minimize water velocity. In conjunction with the renovation work, pink and coho salmon production data were further assessed to determine pre-project status. This included escapement, egg-to-fry survivals, and rearing abundance (coho) upstream and downstream of the barrier. 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. Juvenile sampling for egg-to-fry survival as well as adult coho salmon escapement surveys were completed in 1994 and juvenile coho salmon rearing relative abundance was surveyed in 1995.

EVOS RESTORATION WORKSHOP
JANUARY 15-16, 1996
ANCHORAGE, ALASKA

ABSTRACT

PORT DICK TRIBUTARY RESTORATION AND DEVELOPMENT PROJECT (96139A2)

The Lower Cook Inlet (LCI) outer Kenai Peninsula has many important estuarine and intertidal nursery areas that are critical to pink and chum salmon production. Harvests of pink and chum salmon in this area provide an important contribution to the southern Kenai Peninsula economy, but in 1989, this area was affected by the Exxon Valdez Oil Spill (EVOS). Although no quantitative damage assessment surveys were funded or conducted in this outer Gulf Coastal area, studies in Prince William Sound indicated significant increases in pink salmon egg mortality and decreased growth in the early marine life stage. Restoration surveys were initiated in FY/91 and FY/92, by the Alaska Department of Fish and Game (ADF&G) to select potential fish habitat restoration projects in the Oil Spill area. The survey resulted in the selection of Port Dick Creek, on the Outer Gulf Coastal area of the Kenai Peninsula.

The Port Dick system was chosen because it is considered one of the most important pink and chum production streams in the LCI area and it was moderately to heavily oiled by the EVOS. The restoration survey also identified optimal methods of salmon spawning habitat rehabilitation and enhancement methods.

The proposed salmon spawning habitat improvement project would help restore Port Dick Creek pink and chum salmon stocks by improving former spawning habitat of two tributaries by excavation down to a stable ground water source. This project would ultimately make available an additional 2,100 sq.m. of stable spawning habitat. Actual construction is scheduled for June, 1996.

Montague Island Riparian Rehabilitation
EVOS Restoration Project 95139C1
1995 Project Work

Principal Investigators: Ken Hodges, David Schmid. Cordova Ranger District, Chugach National Forest. USDA Forest Service. P.O. Box 280 Cordova, AK. 99574. (907) 424-7661

Abstract

In 1994 and 1995 riparian restoration work was undertaken in four watersheds on Montague Island where logging had occurred in the 1960's and 1970's. Although this work would not deal directly with the habitat oiled by the *Exxon Valdez* oil spill, it was felt that the restoration of these watersheds would improve conditions throughout the stream systems and contribute to the overall restoration of chum salmon (*Oncorhynchus keta*) and pink salmon (*Oncorhynchus gorbuscha*) in Prince William Sound.

The project was conducted in the watersheds of Hanning Creek, Quadra Creek, Swamp Creek, and an unnamed creek, all on the western coast of Montague Island. When the areas were logged, no buffer strips were left around the streams and large woody material was removed from the creeks in the belief that it would help salmon migration. As a result, there was increased bank erosion, erratic flows, a loss of pools, increased bedload movement, and a loss of habitat for juvenile coho salmon (*Oncorhynchus kisutch*) and Dolly Varden char (*Salvelinus malma*). Chum and pink salmon redds in downstream spawning areas are subject to sedimentation, dewatering, or displacement during high flows.

In 1994, 32 log and boulder structures were built to create pools, reduce water velocities, protect banks from erosion, reduce bedload movement, and provide fish habitat. Essentially , the structures act as large woody material would in a natural system. In addition, 15 acres of small, crowded Sitka spruce (*Picea sitchensis*) were thinned to accelerate the growth of the remaining trees. Eventually these trees will provide a natural source of woody material for the streams. In 1995, two additional acres were thinned along Quadra Creek.

Although the structures held up to bankfull flows in 1994, floods in 1995 destroyed 10 structures, mostly in the main branch of Hanning Creek. The structures in smaller tributaries were more successful, creating 1,798 sq. ft. of pool habitat and 740 sq. ft. of cover area for juvenile fish at normal water levels in June. Low flows in August reduced the amount of habitat considerably, however. Monitoring of the thinned areas showed there was no sunburn, windthrow, or other adverse effects to the trees. Main stem and whorl growth was analyzed using a single classification ANOVA. Growth was significantly greater in thinned areas than in untreated areas, but the sample sizes were small.

In 1996, some of the structures can be repaired using better anchoring techniques. More extensive monitoring of growth in the thinned areas will also be conducted.

ABSTRACT APEX 95163 A

Forage Fish Studies in Prince William Sound

Ken Coyle, Lewis Haldorson, Thomas Shirley - University of Alaska
Richard Thorne - Biosonics Inc.

The abundance and distribution of forage fishes was estimated in three areas (north, central, south) of Prince William Sound during July and August using downlooking and sidelooking hydroacoustic sampling. The species composition of forage fish aggregations was assessed by midwater trawl. Most forage fish biomass was concentrated in the central region east of Knight Island where dense schools of young-of-the-year walleye pollock occurred below 30 m; also, small schools of capelin occurred in the upper 20 m near Naked Island. Biomass in the north and south study areas was substantially lower than in the central region, and consisted primarily of juvenile herring in the upper 20 m. The most common invertebrate species in trawl samples were euphuasiids, or krill, of five species. Krill samples from the north and south study sections were dominated by different species, and no krill were found in the central area. Side-looking echograms indicated that the central area had the fewest individual targets (probably salmon) and also the fewest large schools (over 20 m width) near the surface. The north area had the highest abundance of schools near the surface, mainly in Port Fidalgo. The water column in July and August was highly stratified, with low surface salinities (< 30 ppt) and high surface temperatures (> 12° C.) It appears that in the summer of 1995 most of the small pelagic fish biomass in PWS was comprised of walleye pollock that were too deep to be available to most foraging seabirds; however, some areas such as the Naked Island nearshore and Port Fidalgo had capelin or herring available near the surface.

Observations of Near-Surface Fish using Side-looking Acoustics

Richard E. Thorne

Side-looking capability was included in the acoustic acquisition system used in forage fish surveys in July/August and October. Preliminary analysis has been completed for the first survey of all three regions during the July/August cruise. The side-looking system consistently detected both schools and larger individual fish to ranges of at least 50 m. There were some clear indications of size differences among schools that were related to the fish species. Both diving birds and fish schools could be detected on the side-looking system during intensive observations on foraging flocks.

Project Number and Title: 95163B Seabird/forage fish interactions

Principal Investigator: William D. Ostrand and John M. Maniscalco, U.S. Fish & Wildlife Service, 1011 E. Tudor Rd., Anchorage, Alaska 99503 (Telephone 907-786-3849)

ABSTRACT: We sought to determine whether forage fish characteristics and/or interactions among seabirds limit availability of seabird prey. We monitored seabird/forage fish interactions by conducting systematically arranged transects in three areas of Prince William Sound from 21 July-11 August 1995. The study sites were located at Valdez arm, Naked and Knight islands, and Jackpot and Icy bays. Down- and side-looking hydroacoustic and bird-observation data were collected simultaneously. We collected separate data on foraging behavior and kleptoparasitism on 22 foraging flocks encountered during the survey. Walleye pollock (Theragra chalcogramma) made up a high proportion of the forage fish biomass; however, schools were at depths greater than 25m, and few seabirds were associated with these schools. Black-legged kittiwakes (Rissa tridactyla), pigeon guillemots (Cepphus columba), and marbled murrelets (Brachyramphus marmoratus) were observed in shallow water, near shore (<2 km). Tufted puffins (Fratercula cirrhata) and glaucous-winged gulls (Larus glaucescens) were observed significantly farther from shore. We attempted to correlate the presence of forage fish schools observed in side viewing sonar with seabirds and found that no relationship. Foraging flocks were associated with capelin (Mallotus villosus), sand lance (Ammodytes hexapterus) , and juvenile herring (Clupea harengus). Marbled murrelets and black-legged kittiwakes were both present in 20 foraging flocks, suggesting that kittiwakes utilize marbled murrelets as a mechanism to concentrate and drive forage to the surface. We found that while foraging in mixed species flocks, kittiwakes lost 12% of their food catches to piracy; 6% to intraspecific, 6% to interspecific kleptoparasitism. We concluded that most of the forage fish biomass was made up of walleye pollock schools that were too deep to be available to seabirds. Additional data and analysis is needed to determine if kleptoparasitism and aggressive behavior is limiting access to available forage. Rather than continuing to use correlations to describe the relationship between seabirds and forage, future analysis will take a multivariate approach using fish schools as the sampling unit, in the development of a resource selection function.

Project Number and Title: APEX 95163C - Diet Overlap of Forage Fish Species

Principal Investigator: Molly Sturdevant. Auke Bay Fisheries Laboratory, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau AK 99801. 907-789-6041

Abstract: The food habits of forage fish collected by trawl in Prince William Sound in summer, 1995 for the Alaska Predator Ecosystem Study (APEX), and in fall, 1994 during a pilot study, were examined. The diet study is one of several components of APEX, which is examining trophic interactions of seabirds injured by the *Exxon Valdez* Oil Spill, (e.g., black-legged kittiwakes and pigeon gillemots), and their forage species. Forage fish diet composition as percent biomass of pooled prey categories and diet overlap as Percent Similarity Index (PSI) calculated from biomass of prey taxa are presented in these preliminary results. Diets were described for multiple age-classes (as suggested by mean preserved fork lengths (FL)) of herring and pollock and for juvenile sandlance, capelin and eulachon. Samples analyzed to date from summer (n = 90) included young-of-the-year (YOY) pollock (56 mm FL), herring (76 mm FL) and sandlance (80 mm), older herring and pollock (143 and 181 mm FL, respectively), and capelin (135 mm FL). Samples analyzed from fall (n = 90) included YOY herring and pollock (94-111 mm FL), two size classes of older herring (170 mm and 215 mm FL), and juvenile eulachon (84 mm FL).

Most dietary biomass was contributed by few prey categories and differences were observed between seasons, species, age-classes, and areas. In summer, small calanoids were consumed by all except large pollock, forming 29-70% of YOY species and 43% of older herring prey biomass. Hyperiid amphipods comprised 21-23% of YOY prey biomass, while teleosts and barnacle larvae were unique (20% biomass) in YOY pollock and sandlance, respectively. Large calanoids comprised approximately 45% of prey biomass of both older herring and older pollock, while euphausiids (24%) and chaetognaths (20%) were unique in older pollock diets. In the fall, euphausiids were consumed by all species, forming 30-81% of prey biomass. In contrast to summer diets, hyperiids and small calanoids contributed little to YOY fish diets; however, small calanoids remained in older herring diets (33-50% biomass). In southern PWS, YOY pollock diets differed by including 49% biomass from large calanoids and larvaceans combined. Most capelin and eulachon stomachs were empty.

Diet overlap ranged from approximately 32% to 59% PSI between YOY species pairs and for combinations involving herring < 175 mm FL in both spring and fall. Overlap was highest between YOY pollock and herring collected in the same locations in northern PWS in the fall, and lowest for 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 Title: 95163C - Forage Fish Influence on Recovery of Injured Species: fish diet overlap

Principal Investigators: Mark Willette[1], Molly Sturdevant[2], Steve Jewett[3], [1]Alaska Department of Fish and Game, P.O. Box 669, Cordova, Alaska 99574 (907-424-3214); [2] National Marine Fisheries Service, Auke Bay Laboratory, P.O. Box 210155, Juneau, Alaska 99821; [3] University of Alaska Fairbanks, Institute of Marine Science, Fairbanks, Alaska 99775.

Abstract:

The goal of this component of 95163 was to estimate the degree of prey resource partitioning among important forage fish species in Prince William Sound. Juvenile walleye pollock (*Theragra chalcogramma*), Pacific herring *(Clupea harengus pallasi*), pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*) were found to be widely distributed in the upper 20 m of the water column in western Prince William Sound during August and September. Principal components analysis identified a prey species complex that is associated with prey resource partitioning among these four fish species. Two fish species pairs (juvenile walleye pollock and Pacific herring; and juvenile pink and chum salmon) exhibited a relatively high degree of diet overlap within each species pair and little overlap between species pairs. Schoener's proportional diet similarity index was 33% for Pacific herring and walleye pollock and 25% for pink and chum salmon. Prey resource partitioning was associated largely with differences in the amounts of *Pseudocalanus spp.*, small calanoid copepods, and fish larvae consumed by the two species pairs. Juvenile Pacific herring and walleye pollock consumed *Pseudocalanus spp.* and small calanoid copepods; whereas, pink and chum salmon consumed fish larvae. Diet composition and diet overlap among walleye pollock, Pacific herring, chum salmon, and pink salmon also changed significantly over a diel period. Juvenile chum salmon preferred gelatinous prey such as ctenophores, cnidaria, and *Oikopleura spp.*

Project Number and Title: 95163D - Diet and Growth of Tufted Puffin Chicks in Prince William Sound

Principal Investgators: John F. Piatt(1), Daniel D. Roby(2), Laird Henkel(2), and Kriss Neuman(1); ((1) National Biological Service (NBS), 1011 E. Tudor Rd, Anchorage AK 99503; and (2) NBS, Cooperative Research Unit, University of Alaska, Fairbanks AK; Telephone (JFP): 907-786-3549.

Diet and growth of Tufted Puffin chicks were studied on Seal Island, Prince William Sound, between 17 July and 2 September, 1995. After thorough searches, only 112 burrows (71% active) were located on the island. Of 95 accessible burrows, 54% were typical earthen burrows whereas the remainder were atypical for the species, e.g., associated with tree roots. Chick growth was monitored at 14 nest sites. Hatching success (78.6%) and fledging success (>81%) were high. Peak hatching occurred on 20 July. Chick growth rates (mean=17.7 g/day) were also high, as were fledgling weights (mean=563 g). Weekly blind observations between 28 July and 27 August of chick feeding activity at 4-6 nest-sites revealed meal delivery rates of 3.0-7.0 (mean=4.7) meals/chick/day, which is above average for puffins in the Aleutians. Chick meals were collected by placing screens in burrows and retrieving prey dropped by adults at the burrow entrance. A total of 42 chick meals, comprising 125 individual prey, were collected from 31% of burrows screened (n=67). Meal loads weighed 13.7 g on average, and were comprised of pollock (54% and 12% by number and weight, respectively; mean length=61 mm), herring (40%, 27%, 77 mm), prowfish (8%, 32%, 117 mm), salmonids (5%, 20%, 140 mm), capelin (1%, 4%, 147 mm), sandlance (2%, 1%, 89 mm), and squid (1%, 4%, 100 mm). Taken together, data suggest that Tufted Puffins are nest-site limited at Seal Island, but feeding and growth of chicks there in 1995 was above average compared to other colonies in Alaska. The dominance of herring, prowfish and salmonids in diets is atypical for the species throughout its range in Alaska, but reflects local fish abundance as determined from hydroacoustic and trawl surveys.

Project Number and Title: 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 objective of this component was to determine relative food availability to kittiwakes at determined by foraging and reproductive parameters. Two sites in Prince William Sound (PWS) and one at the Barren Islands were compared. In 1995 we radio-tagged 60 kittiwakes and followed them during foraging trips with a boat. From this we located foraging areas that were used by birds breeding at specific colonies and exact locations where feeding took place. Birds from the Shoup Bay colony had a mean foraging trip duration of four hours and traveled more than 40km from the colony. Birds from Eleanor Island had a mean foraging trip duration of only two hours and traveled only 5km from the colony. Most foraging occurred within one kilometer of shore.

Birds at Shoup Bay ate mostly sandlance and herring, while birds at Eleanor Island and Seal Isalnd ate more herring and less sandlance. Birds at the Barren Islands ate mostly sandlance and capelin. These data support the prediction that birds at close colonies have more overlap in their diets than birds at distant colonies.

By combining the foraging data and the bird productivity data we see evidence that birds have flexible foraging behavior that can buffer their chicks against periods of food shortage. Birds from Shoup Bay had much longer foraging trips than birds at Eleanor, but chick growth rates were very similar at the two colonies. However, Irons has data from 1989 and 1990 that suggest a threshold beyond which the adults cannot buffer there chicks. These data suggest the relationship between forage fish abundance and seabird productivity is not linear, but is buffered by the adults.

We have historical data for Shoup Bay and all colonies in PWS which help put 1995 in perspective. Kittiwake productivity declined in PWS in 1990 and has remained low through 1995. By looking at reproductive parameters for all these years we concluded that kittiwake productivity in PWS has declined because of a decrease in available food and a increase in predation. Knowing that herring and sandlance are important prey species for kittiwakes, we suggest five possible reasons why food has declined in PWS since 1990: (1) the oil spill (2) disease in herring (3) competition with pink salmon smolt (4) an ecosystem shift in PWS that favors walleye pollack (5) a large-scale climatic shift in the Gulf of Alaska. We suggest that predation may have increased because the prey (pink salmon and herring) of a major predator, bald eagles, has decreased since the spill and bald eagles switched to preying more on kittiwake young.

Project Number and Title: 95163F - Recovery monitoring of pigeon guillemot (*Cepphus columba*) populations in Prince William Sound

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

Abstract: Over 600 oiled guillemot carcasses were recovered in the four months following the *T/V Exxon Valdez* oil spill. Current estimates of the number of guillemots (ca. 5,000) in Prince William Sound are only about one third of what they were in the early 1970s. However, there is evidence that this population was already declining before the spill. One of our primary objectives was to test the hypothesis that the composition and amount of prey items in the diet of guillemot chicks reflect changes in the relative abundance and distribution of forage fish at relevant scales around colonies. We studied the breeding and feeding ecology of guillemots nesting on Naked and Jackpot Islands in the western part of Prince William Sound. Feeding observations were made from boats or blinds between 0500 and 2300 Alaska Daylight Time throughout the chick-rearing period. In 1979-1981 and 1994-1995 the proportions of nearshore demersal fish (blennies, sculpins, gadids) caught in traps around Naked I. were quite similar to the proportions of those same types of fish in the diet of guillemot chicks at nearby colonies. Also, in 1995 there was agreement between the types of forage fish detected and sampled by hydroacoustic surveys and the types delivered to guillemot chicks on Naked and Jackpot Islands. Herring accounted for 43 and 29% of the chick diet at Jackpot I. in 1994 and 1995. Herring or capelin accounted for only two and 12% of the chick diet at Naked I. in 1994 and 1995. Nearshore demersal fish such as blennies, sculpins, and gadids composed at least 70% of the chick diet at Naked I. and at least 50% of the chick diet at Jackpot I. during the last two years. The proportion of sand lance in the diet of chicks at Naked I. has decreased from 60% in 1979 to 10% in 1994 and 1995. Guillemots appear to be opportunistic foragers, probably feeding on sand lance, herring, and capelin when they are available. These changes in the relative proportions of benthic and schooling fish in the diet of guillemot chicks might represent a key change in the ecosystem. Recent and historical data, plus some circumstantial evidence, suggest that the diet of guillemot chicks can serve as a good indicator of the availability and abundance of nearshore demersal and forage fish. The number of breeding pairs of pigeon guillemots at a particular colony might be related to the availability of forage fish as an abundant and reliable source of food for their chicks.

Project Number and Title: 95163G - Diet Composition, Reproductive Energetics, and Productivity of Seabirds Damaged by the Exxon Valdez Oil Spill

Principal Investigator: Daniel D. Roby, Oregon Cooperative Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331-3803 (telephone: 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 EVOS 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 to be tested is that differences in the nutritional quality of forage fishes is a primary determinant of energy provisioning rates to seabird nestlings, which influences not only the growth and survival of young, but also other factors (e.g., post-fledging survival, recruitment rates) that regulate seabird populations. During the 1995 breeding season, we collected samples of nestling meals and measured nestling growth rates, provisioning rates, and nesting success in relation to diet for (1) Pigeon Guillemots at Naked Island (oiled site), Jackpot Island (nonoiled site), and Kachemak Bay (reference site); (2) Black-legged Kittiwakes (*Rissa tridactyla*) at Eleanor and Seal islands (oiled site), Shoup Bay (nonoiled site), and the Barren Islands (reference site); (3) Tufted Puffins (*Fratercula cirrhata*) at Seal Island (oiled site) and the Barren Islands (reference site). The primary factor determining the energy density of forage fishes was lipid content (% of dry mass). This varied from as much as 48% in some juvenile Pacific herring (*Clupea harengus*) to as low as 3% in some juvenile walleye pollock (*Theragra chalcogramma*). Sand lance (*Ammodytes hexapterus*) was second only to herring in lipid content and energy density, and capelin (*Mallotus villosus*) was third. Juvenile gadids (pollock, Pacific cod [*Gadus macrocephalus*], tomcod [*Microgadus proximus*]) were generally low in lipids and thus had the lowest energy density of the sampled forage fishes. The lipid content and energy density of herring, sand lance, and capelin, though generally high, was highly variable depending on age, sex, and reproductive status (pre- or post-spawning). Nestling growth performance of guillemots was highest when herring predominated in the diet and lowest when pollock predominated, with intermediate growth performance on sand lance diets. These trends are in agreement with measured energy densities for these forage fishes. We hypothesize that recovery of Pigeon Guillemots at Naked Island (oiled site) is limited by low availability of high quality schooling forage fishes (specifically sand lance or herring), which are apparently crucial for maintaining high densities of breeding guillemots. As with Pigeon Guillemots, productivity of Black-legged Kittiwakes in the EVOS area appears limited by the availability of sand lance, herring, and capelin. Results from the first season of field work support the hypothesis that productivity of Pigeon Guillemots and Black-legged Kittiwakes in the EVOS area is determined in part by differences in nutritional quality of forage fishes.

Project Number and Title: APEX 95163J - Using Predatory Fish to Sample Forage Fish

Principal Investigators: David G. Roseneau and G. Vernon Byrd, U.S. Fish and Wildlife Service, Alaska Maritime NWR, 2355 Kachemak Bay Dr. (Suite 101), Homer, AK 99603 (DGR telephone 907/235-6546)

Abstract: This pilot project was conducted to test the feasibility and effectiveness of obtaining low cost spatial and temporal information on two important species of forage fish, capelin *(Mallotus villosus)* and Pacific sand lance *(Ammodytes hexapterus)*, in the northern Gulf of Alaska through cooperation with local sport fish charter-boat operators. Several hundred Pacific halibut *(Hippoglossus stenolepis)* stomachs were obtained from fish caught by charter vessels in the Kachemak Bay - lower Cook Inlet and Chiswell Islands regions during late May - early September 1995. The stomachs were collected when the fish were cleaned and filleted at the various charter boat facilities, and the contents were identified shortly afterward with the aid of photographs and standard taxonomic keys. Basic fish categories included capelin, sand lance, herring, flatfish, sculpin, cod, greenling, and other species (e.g., rockfish, salmon). Invertebrates were also divided into several general groups: crab, shrimp, squid, octopus, mollusks, and other species (e.g., starfish). Data, including dates and information on where the halibut were caught, were entered into a previously prepared data base. Analysis included sorting records by categories and previously designated sampling areas, and calculating frequencies of occurrence of items in stomachs and percentages of total numbers of fish and invertebrates.

Although poor weather prevented vessels from fishing in Barren Islands waters during most of July and August, data obtained from other sectors of the study area demonstrated the value of the technique in providing information on general composition, presence/absence, and relative abundance of species over time that can be integrated with seabird studies. Results of the work indicated that sand lance were most numerous in the Homer and Kennedy Entrance sectors (41% and 63% by number, respectively), and that capelin were particularly abundant in the Point Adam area near the southern tip of the Kenai Peninsula (85% by number). The work also confirmed that large numbers of capelin were present in Barren Islands and Shuyak Island waters during June (94% and 100% by number, respectively; observations of feeding seabirds and whales also indicated that these fish were abundant in the Barren Islands region during July and August). By analyzing numbers of capelin and sand lance per stomach in the Point Adam data set (the data set containing the best time series of samples), it was also apparent that changes in the relative abundance of the two target species could be detected over time. Sand lance averaged about two fish per stomach in this area during June, but were completely absent in the July and August samples. In contrast, capelin increased markedly after late June, rising from an average of only about one specimen per stomach that month, to about two in July and more that eight by early August. Based on the favorable outcome of the study to detect the presence/absence of key forage fish species and seasonal changes in their relative abundance, we believe the technique should be fully developed and used as a sampling tool in regions where charter vessel sport fishing fleet operations and seabird foraging areas overlap.

Project Number and Title: APEX 95163K - Barren Islands Seabird Studies

Principal Investigators: David G. Roseneau, A.B. Kettle, and G. Vernon Byrd, U.S. Fish and Wildlife Service, Alaska Maritime NWR, 2355 Kachemak Bay Dr. (Suite 101), Homer, AK 99603 (DGR telephone 907/235-6546)

Abstract: This pilot project was designed to collect data on black-legged kittiwakes *(Rissa tridactyla)*, tufted puffins *(Lunda cirrhata)*, and common murres *(Uria aalge)* at the Barren Islands for use in a multispecies analysis of seabird productivity and energetics. The work was integrated into the larger APEX seabird - forage fish project because large numbers of capelin were present in Barren Islands waters during 1993-1994. The reoccurrence of this important forage fish species in the region during 1995 would provide a prime opportunity to study seabird - forage fish relationships that could help explain why some seabird species were not recovering in Prince William Sound (PWS). The work was also initiated because it could be integrated with a Minerals Management Service - National Biological Service (MMS-NBS) seabird ecosystem project in Kachemak Bay - lower Cook Inlet (KBCI). Sharing data with the larger MMS-NBS study would help provide additional insight into the recovery of seabirds in PWS and at the injured Barren Islands colonies.

Large numbers of capelin were present at the Barren Islands in 1995, and all proposed study objectives were met. Murre and kittiwake data collected during 15 June - 9 September included information on productivity, nesting chronology, feeding rates and types of prey fed to chicks, and time-budgets of adults. To collect these data, several sets of study plots were monitored from observation posts every few days. Information was also obtained on meal sizes and growth rates of kittiwake nestlings. These data were acquired by visiting nests, weighing and measuring chicks, and collecting regurgitated prey. Information on puffin burrow occupancy rates, productivity, nesting chronology, and nestling growth rates and meal sizes was obtained from historical plots and transects. Active nesting burrows were visited to weigh and measure chicks, and other sets of burrows were temporarily blocked with wire screens to obtain food items brought to nestlings. Preserved kittiwake and puffin prey items were identified by A.M. Springer, University of Alaska-Fairbanks (UAF) and A.B. Kettle, AMNWR, respectively.

All data were obtained by methods that allow maximum utilization by other components of the APEX project and the MMS-NBS study (e.g., productivity data can be analyzed in several ways to meet the needs of other investigators and allow comparisons to be made with historical information). Kittiwake and puffin data were shared with D. Irons and J. Piatt for comparison with PWS information. These and similar data on murres were also supplied to J. Piatt for comparison with KBCI information. Data relevant to energetics studies were sent to D. Roby, UAF. In addition to supplying information for direct comparisons with PWS and KBCI data, the types of information collected during the Barren Islands seabird project helped link APEX PWS studies with historical data from these and other northern Gulf of Alaska colonies.

Productivity of kittiwakes and murres was high in 1995, compared with data from previous years and other colonies (about 1.0 kittiwake fledglings per nest vs. 0.0 and 0.7-0.8 in 1993 and 1994, respectively, and 0.8 murre fledglings per egg vs. 0.6 and 0.7 in 1993 and 1994, respectively). Although reproductive data on puffins have not been completely analyzed, these birds appeared to produce average numbers of chicks in 1995, compared with information from previous years. Growth rates of kittiwake nestlings were high (about 19 grams/day), but puffin growth rates were lower than 1994 values (about 12 vs. 17 grams/day, respectively). Capelin dominated murre chick diets (86% by number), while both capelin and sand lance were important food items for kittiwake nestlings (about 60% and 35% by number, respectively). Puffin chicks were given a somewhat wider variety of prey dominated by capelin, pollock, prowfish, and sand lance (28%, 24%, 22%, and 13% by weight, respectively). *[Some results are preliminary and may change slightly during final analyses. Data on chick feeding rates and adult time budgets are still being analyzed.]*

APEX 95163 L

Historical Review of Small-Mesh Trawl Sampling in the Gulf of Alaska With Special Reference to Forage Species

by
Paul J. Anderson
James B. Blackburn
and
Alan B. Johnson

Abstract

This report includes a preliminary historical review of information and data from small-meshed 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 1994. Nearly 9,000 individual sampling tows are in the current data base of the two agencies (ADF&G -- 4,636; NMFS -- 4,352). For preliminary analysis, the entire region sampled was divided into six sub-areas representing geographical, oceanographic, and biological domains. Where possible, the occurrence and relative abundance of five major species or species groups was studied to detect change in the ecosystem over the four decades of past sampling with small-mesh trawls and beam trawls.

Project Number and Title: 95163L - Seabird and Forage Fish Population Dynamics in the Gulf of Alaska

Principal Investigator: John F. Piatt, National Biological Service, 1011 E. Tudor Rd., Anchorage, Alaska, 99503

Abstract:

For more than a decade, seabirds in the Gulf of Alaska (GOA) and Prince William Sound (PWS) have shown signs of food stress: population declines, decreased productivity, changes in diet, and large-scale die-offs. These prevailing conditions may hamper recovery of seabird populations damaged by the 1989 Exxon Valdez oil spill (EVOS). To address this concern, EVOS Trustees initiated a 5-year, $10 million research program in 1995 to examine historical data on forage fish and current relationships between seabirds and forage fish in PWS and the GOA. Small-mesh trawls (ca. 12,000) conducted during the past 40 years reveal that a major shift in community composition occurred in the late 1970's: some forage species (e.g., capelin, shrimp) virtually disappeared, while predatory fish populations (e.g, gadids, flatfish) increased dramatically. These changes correlate with long-term cycles in seawater temperature. In 1995, productivity, diets, and foraging behavior of 6 seabird species (murre, puffin, guillemot, gull, kittiwake, cormorant) were studied at 6 colonies ranging over 600 km from PWS to Cook Inlet. Oceanographic measurements, seabird and hydroacoustic surveys, trawls, and seines were conducted in waters around each colony. Forage fish were analyzed for energy content and condition (sex, age, maturity). In 1995, PWS was characterized by relatively warm, stratified waters in summer, whereas Cook Inlet contained cold, tidally-mixed water upwelled from the GOA. Pelagic waters were dominated by juvenile (0+,1+) pollock and capelin, important prey for puffins and murres. Nearshore waters were dominated by sandlance, which were consumed by all seabirds in proportion to their local abundance. Forage fish school densities ranged from 10's fish/m3 (pollock) in PWS and upper Cook Inlet, to 100's and 1000's fish/m3 (sandlance) in lower Cook Inlet. Correspondingly, seabird productivity ranged from low, to moderate, to high, in areas with low, moderate and high forage fish densities. Capelin and sandlance had much higher energy loads than gadids, and where they were observed in high densities, seabirds consumed large quantities and had the highest breeding success. Investigations will continue for 4 more years to assess temporal and geographic variation in seabird-forage fish relationships.

Project Number and Title: 95165 - Prince William Sound Herring Genetic Stock Identification

Principal Investigators: James E. Seeb, Lisa W. Seeb, and Sue Merkouris, Alaska Department of Fish and Game, Genetics Laboratory, 333 Raspberry Rd., Anchorage, AK 99518 (JES phone 907-267-2385); Paul Bentzen, Marine Molecular Biotechnology Laboratory, University of Washington, 3707 Brooklyn Ave NE, Seattle, WA 98105, (phone 206-685-9994); Jonathan Wright, Marine Gene Probe Laboratory, Dalhousie University, Halifax, Nova Scotia, Canada, B3H 4J1 (phone 902-494-3515).

Abstract: The timing of the *Exxon Valdez* oil spill (EVOS) in Prince William Sound (PWS) overlapped the annual spring migration of *Clupea pallasi* (Pacific herring) spawners to nearshore staging areas. Over 40% of the herring spawning, staging, and egg deposition areas and over 90% of the documented summer rearing and feeding areas were lightly to heavily oiled prior to spawning events. In 1993, the total observed spawning population was less than one-third of preseason predictions and only limited commercial herring fishing occurred. As in 1993, the 1994 spawning population was below preseason predictions and no commercial fishing was allowed. Incorporating genetically derived population structure is crucial to the success of the Trustee Council restoration program. Efforts to collect herring samples for genetic analyses were not successful in PWS during the 1994 spawning return. During the 1995 season, collections of herring (N=100) were achieved from four sites in PWS: St. Matthews Bay, Fish Bay (late run), Rocky Bay (late run), and Pt. Chalmers. In addition, collections of Pacific herring from three out-groups were made for genetic comparison: Togiak Bay, Norton Sound, and Kodiak Island.

Previous surveys of herring using the genetic techniques of allozyme electrophoresis have generally revealed differentiation over broad geographic regions; however, an explosion of new techniques has occurred in recent years as a result of recent advances in molecular techniques. We are using a combination of mitochondrial and nuclear DNA techniques to more accurately define the stock structure of herring from the EVOS-affected area. Efforts are underway using techniques of restriction fragment length polymorphism (RFLP) analysis of mitochondrial regions amplified by polymerase chain reaction (PCR) and analysis of microsatellite loci (analysis of regions with variable number of tandem repeats, VNTR). These methods are being used to evaluate the null hypothesis that a single panmictic population of Pacific herring exists in PWS. Further, the genetic structure of PWS herring will be evaluated within the context of the structure of three adjacent spawning aggregates, including two populations from across the known genetic barrier of the Alaska Peninsula.

Project Number and Title: 95166 - 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 1995 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 20,021 tons with a 95% confidence interval ranging from 12,577 tons to 27,465 tons. The biomass of herring migrating to Prince William Sound spawning grounds was also estimated acoustically in the spring of 1995 using echointegration techniques. Net sampling was conducted to estimate species, size and age composition of the insonified fish. The biomass estimate from the spring of 1995 acoustic survey was 13,227 tons. The acoustic biomass estimates are being compared with spawn deposition biomass estimates to evaluate the cost effectiveness and accuracy of each method. These estimates of spawning biomass 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. The proportion of eggs lost through physical removal and the mortality rate of remaining eggs 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 values recommended in the literature. Results indicate that egg loss rates are highly variable, site specific and are generally higher than previously estimated. Depth and wave exposure accounted for much of the variation in instantaneous egg loss rates in the Montague Island area. Results from this study will be incorporated with the 1994 results to build an embryo survival model.

95320 I (2)

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

Principal Investigators: Donald M. Schell, Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775 (DMS telephone: 907-474-7978)

Abstract: Harbor seal (*Phoca vitulina*) populations in Prince William Sound were declining prior to the 1989 oil spill and declined even further as a direct result of the spill. Other marine populations, e.g. Steller sea lions (*Eumetopias jubatus*), sea otters (*Enhydra lutris*) and marine birds, and their prey were heavily impacted as a result of the spill. The trophic interactions and status of these mammals and their prey are being studied to help determine the reasons for the continuing decline of seals and sea lions in Prince William Sound. Stable isotope ratios are natural tracers of carbon and nitrogen as they pass through a food web. Stable isotopes are acquired in proportion to assimilated food and are reflected in body tissues. Continuously growing tissues, e.g. whiskers and claws, provide temporal and spatial information about the pinnipeds within the ecosystem. Harbor seals, Steller sea lions and prey species have been collected at various locations within and outside the Sound to determine where isotopic gradients occur. Of ninety-eight (98) harbor seals sampled within the Sound, seventy-one (71) animals have been analyzed. A calibration experiment to determine the growth rate of harbor seal vibrissae has been initiated on captive animals at Mystic Aquarium. A similar experiment, using a different technique, is being conducted at Memorial University on captive harbor seals and at the University of British Columbia on captive Steller sea lions.

To test the hypothesis that the decline in harbor seal numbers is a result of a major regime shift in the ecosystem, we analyzed archived tissues sampled from harbor seals in the 1970s and 1980s along with current samples. They suggest that no major shifts in trophic status have occurred during the past twenty years. A larger sample size will be needed for conclusive results. Preliminary results seem to indicate harbor seals are not utilizing adult pollock as a primary food source. Unexpectedly large enrichments in pinniped carbon isotopes have consistently been found and cannot be explained with our current data. The source of this enrichment is being investigated.

Project Number and Title: 95191A - Oil-related pink salmon embryo mortalities

Principal Investigators: James E. Seeb, Mark Willette, Brian Bue, Christopher Habicht, Andrew Craig, Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, 333 Raspberry Rd., Anchorage, Alaska 99518-1599 (JES telephone 907-267-2385).

Abstract: We examined pink salmon embryo mortality and survival from embryo to preemergent fry 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 falls of 1989, 1990, 1991, 1992 and 1993 ($P<0.023$ for all years). However, no difference in survival of embryo to preemergent fry was detected for the 1989, 1990, 1991, 1992, or 1993 brood years ($P>0.550$). 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 unimpacted streams, and matings were conducted at a hatchery. The resulting embryos were incubated in controlled environmental conditions; those originating from oil-contaminated streams showed elevated mortalities when compared to the embryos from unimpacted streams ($P=0.012$). Flow cytometric analysis of individuals of known oiling history did not detect genetic damage in the form of macrolesions.

Project Number and Title: 95191B - Injury to Pink Salmon Eggs and Pre-emergent Fry Incubated in Oiled Gravel (Laboratory Study)

Principal Investigator: Ron Heintz; co-investigators: Stanley Rice, Robert Bradshaw and Jeffrey Short. Auke Bay Fisheries Laboratory, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau AK 99801. 907-789-6058 (Heintz)

Abstract: Data collected from mature pink salmon that incubated in oiled gravel demonstrated long-term effects of oil on growth and offspring survival. Developing pink salmon embryos were incubated in oiled gravel beginning in September 1993. After emerging in April 1994, surviving fry representing the control and 3 different doses of oil (3.7, 7.8 and 17 ppb polynuclear aromatic hydrocarbons (PAH) in water) were coded-wire tagged and released from the NMFS hatchery at Little Port Walter. In September 1995, 342 mature fish returned to the hatchery where their growth and gamete viability were evaluated.

Male pink salmon that incubated in the most heavily oiled gravel grew significantly slower than the control males. Body weight at maturity for control males averaged 1304 g, compared to 1150 g for males exposed to 17 ppb PAH in water during incubation. These data support earlier observations of reduced growth among pink salmon exposed to oil during incubation. No growth differences were detected between the control males and males that incubated in either 3.7 or 7.8 ppb PAH in water.

Offspring of parents exposed to 17 ppb PAH in water during incubation had lower survival than offspring of control parents. Three experiments revealed the same pattern to offspring survival. In the first experiment, equal numbers of eggs from similarly dosed females were mixed and fertilized by males with the same exposure history. Aliquots were withdrawn and incubated in clean water. The second experiment had a similar design, but females contributed disproportionate numbers of eggs. In both experiments, the average number of embryos surviving through development of the eye was lowest among the progeny of parents that incubated in the highest dose of oil. The same trend was observed in the third experiment which consisted of single pair matings between males and females with similar exposure histories.

Project Number and Title: 94244/95244: Harbor Seal and Sea Otter Cooperative Harvest Assistance

Project Leader: James A. Fall, Alaska Department of Fish and Game, Division of Subsistence, 333 Raspberry Road, Anchorage, Alaska 99518 (telephone: 907-267-2359)

Populations of harbor seals and sea otters were injured as a result of the *Exxon Valdez* oil spill and have not recovered. Both species are taken for subsistence uses by Alaska Native hunters. Under the Marine Mammal Protection Act, subsistence uses of harbor seals and sea otters may be restricted only if populations are declared depleted. Neither population has been so classified. Consequently, any conservation actions on the part of Alaska Native hunters must be voluntary. The goal of this project was to work with subsistence hunters to involve them in marine mammal management, and to develop an ongoing exchange of information and consensus building between hunters, scientists, and agencies. Objectives were to compile the available information on harbor seal and sea otter populations and trends; hold workshops for marine mammal biologists and subsistence users to exchange, review, and discuss this information; produce an informational video; collect new information regarding harbor seal harvest locations and traditional ecological knowledge about harbor seals and sea otters; and develop recommendations for subsistence users of harbor seals and sea otters based upon the study findings and workshop results.

The compilation of existing information was accomplished through a cooperative agreement between the Alaska Department of Fish and Game and the Alaska Sea Otter Commission (ASOC). The report concluded that subsistence harvests of harbor seals currently take about four to eight percent of the total population of Prince William Sound and lower Cook Inlet annually. A healthy harbor seal population would be able to grow despite this level of harvest, but because the harbor seal population of the Gulf of Alaska is declining for unknown reasons, these harvests add to the decline. Because of incomplete data, the actual effect of the subsistence harvest on the population cannot be determined. Regarding sea otters, annual subsistence harvests are about one to three percent of the population of lower Cook Inlet and Prince William Sound. This level of subsistence harvest is sustainable.

ADF&G Division of Subsistence staff interviewed hunters and mapped harbor seal harvest locations. The results of these interviews were incorporated into data bases. This work is continuing.

Four workshops took place. Among the topics and consensus points were the following:

- There was a consensus that the harbor seal populations of spill region remain severely depressed. In addition to oil spill effects, subsistence users suggested other causes, including food shortages, commercial fisheries-related mortalities, and killer whale predation.
- While sea otter populations of Prince William Sound are not yet classified as recovered by the Trustee Council, most hunters and users have concluded that sea otters are abundant and have recovered from any spill effects.
- Substantial traditional knowledge is held by Alaska Natives. Although sometimes dismissed by western scientists as "anecdotal," such information is vital to a full understanding of marine mammal populations and trends. Procedures need to be developed so that this traditional knowledge can be appropriately collected, organized, and accessed. Alaska Natives must be full participants in such an endeavor.
- The National Marine Fisheries Service has identified three stocks of harbor seals in Alaska. Alaska Natives need to participate in marine mammal stock assessment programs.
- Hunters also need to be meaningfully involved in biological research. There is a tremendous potential for furthering knowledge about harbor seal and sea otter populations through a biological sampling program that involves subsistence hunters.
- A strong need exists to establish positive working relationships between Alaska Native communities and government agencies. This need is being addressed for sea otters through the Alaska Sea Otter Commission, but no such organization existed until 1995 to represent subsistence users of harbor seals. Development of recommendations for harbor seal hunters is hindered by the lack of such an organization. Following the third workshop, the Alaska Native representatives agreed to work to form a harbor seal commission.

(94244/95244, continued)

Portions of the second workshop were video taped and incorporated into the "Alaskan Harbor Seals: Science and Subsistence" video. Also included were interviews with two marine mammal biologists and the chair of the Alaska Native Harbor Seal Commission (ANHSC). Topics include the impact of the oil spill on harbor seal populations, current research, biosampling, and co-management.

The objectives for this project in FY 1996 are based on the recommendations of the workshops. It was decided to focus in the future on harbor seal restoration. Meeting recovery objectives for harbor seals will be enhanced by continuing the dialogue between scientists and subsistence users, involving subsistence hunters in research efforts, implementing biosampling programs, integrating traditional knowledge into scientific studies, and collaborating in developing recommendations for conservation actions. In FY 1996, the ANHSC will be a major participant in this project. The creation of the ANHSC as a formal co-management body increases the likelihood that a consensus can be reached on ways to restore the injured harbor seal population.

Project Number and Title: 95255 - Kenai River Sockeye Salmon Restoration

Principal Investigators: Lisa W. Seeb[1], James E. Seeb[1], K. E. Tarbox,[2] Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, [1]333 Raspberry Road, Anchorage, AK 99516 and [2] 34828 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669 (LWS telephone: 907 267-2249)

Abstract: Genetic data from sockeye salmon (*Oncorhynchus nerka*) were collected from all significant spawning populations contributing to mixed-stock harvests in Cook Inlet. A total of 68 allozyme loci were resolved from 37 populations. Mitochondrial DNA data from the NADH subunits 5 and 6 were collected from 19 of the populations. Both allozyme and mtDNA reveal a substantial amount of genetic diversity among populations and suggest that significant local adaptation has occurred. Mixed-stock analyses using maximum likelihood methods with 27 loci were evaluated to estimate the proportion of Kenai River populations in Central District drift fisheries. Simulations indicate that Kenai River populations can be identified in mixtures at a level of precision and accuracy useful for restoration and fishery management. Mixed-stock samples from Cook Inlet drift net fisheries were analyzed both inseason (48 hr) and post-season. The contribution of Kenai River populations varied from 88.2% to 52.7%. Samples from fish wheels from the Kenai, Kasilof, Yentna, and Susitna River systems were also analyzed. Inclusion of mtDNA data in the analysis is being investigated to determine if it improves precision and accuracy. In addition, this study collected hydroacoustic information from Cook Inlet. The hydroacoustic survey was used successfully to estimate salmon abundance inseason in the marine waters of Cook Inlet. Results from this study are currently being used in the management and restoration of Kenai River sockeye salmon injured in the 1989 *Exxon Valdez* oil spill.

Project Number and Title: 96258 - Sockeye Salmon Overescapement

Principal Investigators: Dana Schmidt(1), Ken Tarbox(1), and Charles Swanton(2), Alaska Department of Fish and Game, (1)34828 Kalifornsky Beach Road, Suite B, Soldotna, Alaska 99669 (907-262-9368);(2) 211 Mission Rd., Kodiak, Alaska 99615 (907-486-1850)

Abstract: The Exxon Valdez oil spill resulted in fishery closures in Upper Cook Inlet and on Kodiak Island. As a result sockeye salmon, *Oncorhynchus nerka*, spawning escapements into these systems exceeded escapement goals by two-three times. Investigations were initiated in 1992 to evaluate the impact of these larger escapements on the limnological and biological characteristics of the juvenile sockeye salmon rearing lakes. These studies included measurements of adult returns, juvenile fry and/or smolt numbers, sockeye salmon prey abundance estimates and feeding preferences, and physical/chemical parameters. Results in 1995 indicated that poor smolt production from Red and Akalura Lakes on Kodiak continued. In the Kenai River the adult return of 1.3 sockeye salmon was significantly below expected levels. Spawner abundance from the mainstem Kenai River were correlated with fall fry size measured during the subsequent year. In addition, fall fry/spawner is highly correlated with spring and summer *Cyclops* abundance. The spring *Cyclops* abundance is dependent upon the overwintering cohort from the previous fall. Biological data collected on juvenile sockeye fry and copepods documented behavioral adaptation for feeding and survival in these glacial lake systems. These data suggest a density dependent relationship with escapement into the Kenai River system. The effect of this density dependence on smolt production and subsequent adult return will be further refined with data from returning adults in 1996 and the 1996 fall fry production from the 1995 escapement.

Project Number and Title: 96259 - Restoration of Coghill Lake sockeye salmon (*Oncorhynchus nerka*).

Principal Investigators: Gary Kyle, Dana Schmidt, and Pat Shields, Alaska Department of Fish and Game, Limnology Unit, 34828 Kalifornsky Beach Road. Suite B, Soldotna, Alaska 99669 (telephone 907-260-2908).

Abstract: Prior to its recent decline, Coghill Lake was an important sockeye salmon producer in western Prince William Sound (PWS). Although limnological and juvenile fisheries data are not available before the decline, it has been suggested that consecutive years of high escapements 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 were present through large escapements or hatchery fry releases. Following the 1989 *Exxon Valdez* oil spill, Coghill Lake was selected as a system for sockeye salmon restoration to replace fishery stocks damaged by the oil spill. In 1993, a 5-year plan to treat Coghill Lake with nutrient additions was implemented to increase lake productivity. During the first three years of treatment, 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 in the fall. Increases in primary and secondary production benefited rearing sockeye juveniles as exemplified by the relatively large number of smolts produced in 1994 and 1995 (average of 1.4 million) compared to about 275,000 before nutrient treatment.. While productivity has increased during nutrient treatment, restoring the run is contingent upon obtaining adequate fry recruitment. The current sockeye escapement goal (25,000) has been met twice in the last six years. In 1995, 30,382 sockeye returned to the lake and was partially due to the recently adopted management strategies (implementation of a migration corridor) to reduce the interception of Coghill sockeye in the PWS commercial fishery. Finally, in-lake fry densities via juvenile recruitment from escapement and/or hatchery releases need to be balanced with the existing forage base, which should expand with continued nutrient treatment in order to achieve restoration of Coghill Lake sockeye salmon.

Key Words: *Oncorhynchus nerka*, nutrient enrichment, zooplankton, glacial, meromictic lake, restoration

Project Number and Title: 95266: Experimental Shoreline Oil Removal

Principal Investigator: Ernie Piper, Restoration Chief, Alaska Department of Environmental Conservation; 555 Cordova Street; Anchorage, Alaska 99501 (Phone 907-269-7632)

Abstract: The objective of this project was to review available technologies and determine whether additional treatment of residual shoreline oil is effective and beneficial, and to determine the likely financial and environmental cost.

A workshop on this subject was held on November 1 and 2, 1995. Over 50 people participated in the workshop, including 14 people from the Village of Chenega. The 14 people from Chenega represents a significant portion of that village's adult population. The participation of so many Chenega residents indicated the importance of the issue to people of Chenega, and made an important impression on Trustee Council staff and other workshop participants.

Information presented at the workshop from previous Trustee Council shoreline assessments indicated that surface and subsurface oil remains at specific locations, mostly within Prince William Sound, and that the oil is likely to remain for many years. The workshop also determined that appropriate treatment at appropriate sites could significantly reduce the amount of surface and subsurface oil on many beaches. Chenega residents at the meeting indicated that they strongly believe that the treatment for a limited number of beaches near the community would provide significant benefits to the residents. Scientists indicated that the treatment of the oil is unlikely to significantly benefit area-wide populations of injured resources, but that it could benefit local populations in some instances. Scientists also indicated that if conducted appropriately a program to treat a limited number of beaches could be conducted without significant environmental cost, but that treating a large number of beaches could set back intertidal recovery.

The workshop report is being written and should be distributed in late January 1996.

Project Number and Title: 95266 - The Fate and Persistence of Oil Stranded on National Park Coasts along the Gulf of Alaska by the 1989 *Exxon Valdez* Oil Spill.

Principal Investigators: Gail V. Irvine, Daniel H. Mann, and Jeffrey Short (GVI: National Biological Service, Alaska Science Center, 1011 E. Tudor Rd, Anchorage, AK 99503, tel. 907-786-3653; DHM: Alaska Quarternary Center, University of Alaska Museum, 907 Yukon Drive, Fairbanks, AK 99775; JS: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, AK 99801)

Abstract: The fate of oil stranded on the shoreline after the 1989 *Exxon Valdez* spill was followed at six moderately to heavily oiled sites on the Gulf of Alaska coasts of Kenai National Park and Katmai National Park and Preserve. Study sites were chosen in 1992 on the basis of having persistent amounts of surface oil. Geomorphologically, all six sites are characterized by boulder armoring, a lag of boulders resulting from progressive winnowing of smaller clasts by storm waves. This boulder lag armors the underlying substrate, protecting it from further wave erosion. It also protects from weathering the oil mousse that penetrated into the subsurface after stranding. While largely cleaned of surface oiling compared to their initial condition following the oil spill, all six study sites retain poorly described amounts of subsurface oil. In 1994 we refined our methodology for monitoring surface oil by discarding a photographic method of assaying oil cover that was made inaccurate by the effects of shadows and surface wetting and developed a visual technique of oil cover using quadrats whose positions are permanently marked by rock bolts. These same rock bolts enable us to revisit the study sites and document the frequency of shifts in the surface boulder armor. At one of the six sites revisited in 1994, the surficial oil had been buried by a deposit of cobbles that had been deposited since the last visiti in 1992.

Chemical results from the 1994 samples became available this past fall, and revealed that very little weathering of the oil had occurred since 1992. In fact, for those sites where we had obtained historical samples taken by other parties in 1989, the oil had shown remarkably little weathering from 1989 to 1994. There was some variation in the weathering shown by the 1989 historical samples, but that pattern in weathering was maintained through time.

Project Number and Title: 95279 - Subsistence Restoration Project, Resource Abnormalities Study

Principal Investigators: Karen Shemet and Rita Miraglia, Alaska Department of Fish and Game, Division of Subsistence, 333 Raspberry Road, Anchorage, AK 99518 (telephone 907-267-2358)

Abstract: As demonstrated by data collected by the Alaska Department of Fish and Game's Division of Subsistence, subsistence uses of fish and other wildlife were injured by the *Exxon Valdez* oil spill. Annual per capita subsistence harvests declined dramatically (from 4 percent to 77 percent decline compared to pre-spill averages) in 10 of the communities in the path of the spill during the first year after the event.

In 1993 and 1994 the *Exxon Valdez* Trustee Council provided funding to test resources from subsistence harvest areas for the presence of hydrocarbons. Samples of species cited in community meetings as being of continued concern were collected with community representatives assisting in site selection, and the collection of samples. The samples were analyzed at the National Marine Fisheries laboratory in Seattle. Test results were reported to the communities in an informational newsletter and community visits.

In subsequent years, levels of subsistence harvests, ranges of uses, harvest effort, and the sharing of resources have gradually increased in the affected communities. However, a view persists in the communities in the oil spill area, that the natural environment has changed in ways that still pose a potential threat to their health and their way of life. This view is partly fueled by observed abnormalities in resource species. Frequently, subsistence users asked where they could send samples of abnormal animals that they had harvested, to find out what could have caused the abnormalities.

There is little we can learn about subsistence food safety from additional hydrocarbon testing. The FFY 1995 project was designed to continue efforts to communicate information on subsistence food safety to the communities. In addition, we set out to put in place a system for getting samples of abnormal resources from subsistence users to biologists and pathologists for study and reporting the findings of the scientists to subsistence users. All samples are to be taken from animals harvested by local hunters or fishers for subsistence use.

This project answers the need to continue to monitor the risks to human health from the oil spill, and in part, the need to involve residents of the spill area as full partners in restoration activities. Additionally, the project will give biologists and pathologists the opportunity to see examples of abnormalities that they might not other-wise encounter given their limited time in the field.

A total of 61 volunteers were trained to preserve, package and ship the different types of samples. Training sessions were held in the communities of Chenega Bay, Tatitlek, Cordova, Valdez, Nanwalek, Port Graham, Seldovia, Seward, Larsen Bay, Karluk, Old Harbor, Akhiok, Ouzinkie, Kodiak City, Chignik Lake, Chignik, Chignik Lagoon, Perryville and Ivanof Bay. A videotape version of the training session was left in each community to serve as a refresher course for the volunteers, and allow for the training of additional community residents. Sampling kits and instructions were placed in each community, and accounts were set up with air carriers to transport samples to Anchorage.

A resource abnormality hotline (1-800-267-2552) was established, and posters were placed in each participating community listing the names of the local volunteers and the hotline number.

As of this writing (12-7-95), there have been three calls to the hotline, only one of which has resulted in a detailed analysis and formal report (the other two were a puffin which had been dead too long to get any useful information from an autopsy, and a complaint of too much algae in a fishing area). Juanita Kelly of Kodiak collected a sample of a cod with abnormal growths in a gill cavity. The sample was examined by Jill Follett, a Fish Pathologist with the Alaska Department of Fish and Game. Follett identified the growth as a xenoma, which is caused by a one-celled animal called a protozoan. It is not likely this growth was caused by oil or other pollution. This type of growth is fairly common, and in some places is found in nearly three-quarters of all Bering Sea Pacific Cod. A fish with such a growth is still safe for people to eat, although the growth itself is pretty unappetizing.

Although this project was only funded for one year, the Trustee Council has provided funding to the Division of Subsistence to support the continuation of the hotline, the transport of samples and the replacement of sampling kit components as part of the Community Involvement and Use of Traditional Knowledge project (96052).

Project Number and Title: 95285 - Subtidal Monitoring: Recovery of sediments in the northern Gulf of Alaska

Principal Investigators: Charles E. O'Clair, Jeffrey W. Short and Stanley D. Rice. Auke Bay Fisheries Laboratory, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau AK 99801. 907-789-6016 (O'Clair)

Abstract: In the 5 years following the *Exxon Valdez* oil spill (EVOS), we sampled subtidal sediments at 45 locations in Prince William Sound (PWS) and at 10 locations in the northern Gulf of Alaska (NGOA) to determine the geographical, bathymetric, and temporal distribution of oil in benthic sediments. We sampled sediments at mean lower low water (0 m) and at five subtidal depths (3, 6, 20, 40 and 100 m). Triplicate, composite sediment samples were collected at each station by beach teams, divers (0-20 m) and grabs (40 and 100 m). Our results are based on 1589 sediment samples analysed by gas chromatography/mass spectrometry.

In the first year after the spill, at locations in PWS with oiled shorelines, sediments from 0 m had the greatest concentrations of total polynuclear aromatic hydrocarbons (TPAH, excluding perylene) found in benthic sediments. An average concentration (n = 3) of 12,729 ng/g occurred at 0 m at Disk Island in July 1989. Shallow subtidal sediments (3-20 m) showed a PAH composition pattern characteristic of weathered *Exxon Valdez* oil (EVO-PAH) at 80% of oiled locations in PWS in 1989. Contamination of subtidal sediments by EVO reached a depth of at least 20 m at five oiled locations sampled in 1989. The greatest concentration of EVO was at shallow depths. We found little evidence of EVO in sediments from great depths (≥40 m). Sources other than the EVOS probably accounted for the petroleum hydrocarbons at these depths.

In the NGOA, EVO-PAH pattern was found at Chugach Bay, Hallo Bay, Katmai Bay, and Windy Bay in the summer of 1989. The TPAH concentration was highest in intertidal sediments (Hallo Bay, 348 ng/g; Katmai Bay, 339 ng/g). The weathered EVO pattern also appeared in subtidal samples at 6 m and 20 m at Chugach Bay (TPAH, 80.6 ng/g and 362 ng/g) and at 3 m at Windy Bay (TPAH, 224 ng/g).

After 1989, hydrocarbons often matched the EVO-PAH pattern less closely, EVO was more patchily distributed, and EVO concentrations decreased in benthic sediments. By 1993, sediments in PWS at 0 m at both assessment and reference sites showed no evidence of EVO. Subtidal sediments showed the EVO-PAH pattern at three sites (Herring Bay, Northwest Bay and Sleepy Bay). The EVO was found as deep as 20 m at Northwest Bay and Sleepy Bay in 1993, the last year PWS was sampled. By 1994 no evidence of the EVO-PAH pattern was found in NGOA.

The EVO-PAH concentration in subtidal sediments has decreased with time and routine or periodic monitoring is no longer justified. Any subtidal monitoring to be done in the future should be driven by site and study specific needs. The year 1995 was the closeout year of this project.

Project Number and Title: 95290 - 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, Ron A. Heintz and Bonita Nelson. Auke Bay Fisheries Laboratory, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau AK 99801. 907-789-6065 (Short)

Abstract: The Trustee hydrocarbon database is a catalog of hydrocarbon samples taken in support of *Exxon-Valdez* damage assessment and restoration programs. This database provides a record of: 5400 tissue, 4000 sediment, 350 water and 650 other samples collected since 1989, and analyzed for the presence of hydrocarbons. The database will continue to grow and support trustee research.

Samples cataloged in the database have been examined for systematic bias and the presence of Exxon Valdez crude oil. In FY 95, the database has been manipulated and simplified to be more user friendly. An electronic copy of the of the contents has been released for public inspection. The copy is accompanied by a hard-copy users guide that explains the structure of the database, instructions for querying the data, and an introductory guide to the interpretation of hydrocarbon data based on patterns of relative analyte abundances.

Project Number and Title: 95320A - Sound Ecosystem Assessment - Salmon Growth and Mortality

Principal Investigators: Mark Willette, Greg Carpenter, Ed Debevec, Penny Saddler, Margaret Powell, Alaska Department of Fish and Game, P.O. Box 669, Cordova, Alaska 99574 (907-424-3214)

Abstract:

This project collected data needed to test several hypotheses related to predator-prey interactions affecting the mortality of pink salmon (*Oncorhynchus gorbuscha*) in Prince William Sound. Several other projects within the Sound Ecosystem Assessment (SEA) program also contribute to this hypothesis testing effort. These hypotheses include the following concepts (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) spatial patterns of adult pink salmon production are related to the distribution of large calanoid copepods and walleye pollock during the early marine period. This project was designed to achieve the following objectives (1) estimate the daily foraging times of juvenile pink salmon, (2) estimate prey abundance and composition in nearshore nursery habitats utilized by juvenile pink salmon, (3) estimate the diet composition of juvenile pink salmon, and (4) estimate the size composition and mean growth rate of juvenile pink salmon. Diel feeding studies were conducted at 4 sites during both May and June. Juvenile salmon were sampled with a purse seine and tow net every three hours during a 24-hour period in nearshore and offshore habitats at each site. Four thousand and six hundred juvenile pink and chum salmon were collected to estimate size composition, condition, daily foraging times and the proportion of the diet comprised of large calanoid copepods. Stomach sample processing was initiated in December, 1995 and no data is yet available from these samples. An additional 1,800 samples of fish (<150mm FL) from seven species were collected to estimate species/size composition of nearshore fish assemblages. Stomach contents analysis will be conducted on a portion of these samples to examine diet overlap among species. This work will be conducted under project 95163 'Forage Fish Influence on Recovery of Injured Species'. Coded-wire tagged juvenile salmon released from the Wally H. Noerenberg Hatchery were sampled in June to estimate growth rate. Mean growth rate was significantly different (P=.010) among three treatment groups, but not different from the mean growth of juvenile salmon in 1994. Laboratory studies have shown that the feeding rate of juvenile pink salmon is at least 4 times greater when feeding on large rather than small calanoid copepods. In the present study, zooplankton samples were collected every three hours to test for differences in plankton abundance between nearshore and offshore habitats. The abundance of large calanoid copepods was significantly greater (P=.005) in offshore (159 m^{-3}) than in nearshore (95 m^{-3}) habitats in May. In June, large calanoid copepods were again significantly (P=.004) more abundant in offshore (70 m^{-3}) than in nearshore (31 m^{-3}) habitats. Thus, the growth potential of juvenile pink salmon may be 50% greater in offshore than in nearshore habitats. However, predation by walleye pollock and squid (*Berryteuthis spp.*) was apparently high in offshore habitats in May (project 94320E). The modelling component of SEA (95320J) will further investigate this apparent trade-off between growth potential and predation risk as it relates to mortality processes and recruitment.

Project Number and Title: 95320B - 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 1994 were recovered in the returning adults in the summer of 1995. 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 in the eastern portion. Preliminary return numbers based on coded wire tags indicate that 80% of the return was produced by hatchery released pink salmon. Cannery Creek and Solomon Gulch hatcheries had ocean survival rates near 5% while W.H. Noerenberg and A.F. Koernig hatcheries had rates near 1%. An exceptionally high tag loss rate occurred in the Cannery Creek returning adult fish averaging 56%. Fish that were released from A.F.Koernig and W.H.Noerenberg hatcheries in mid June of 1994 at approximately 1.5 grams had survivals over 19 times greater that other release groups.

Project Number and Title: 95320C - Otolith mass marking of hatchery 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: 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 the fishery managers in mixed stock fisheries in Prince William Sound. All pink salmon hatcheries in Prince William Sound installed water heating devices to allow rapid and sustained temperature changes to the incubation water on their pink salmon eggs. Thermal marks were applied on the otolith of all hatchery pink salmon in Prince William Sound in 1995. Each hatchery has its own distinct thermal mark to allow for separation of hatchery stocks from injured wild stocks from the *Exxon Valdez* oil spill and between hatcheries. Marking 100% of hatchery produced pink salmon with a non-intrusive mark will enable biologists to study hatchery straying to wild systems and possibly predict stock composition in the following year's return by sampling out migrating smolt in the southwestern passages.

Project Number and Title: 95320-D - 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: Wild-stock pink salmon in Prince William Sound (PWS) suffered both direct lethal and sublethal injuries as a result of the *Exxon Valdez* oil spill (EVOS). Embryos and alevins suffered increased mortality, diminished growth, and a high incidence of somatic cellular abnormalities as a result of spawning ground contamination and rearing in oiled areas. 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. Historical biological and genetic data clearly indicate that PWS populations are divided into temporal and spatial isolates, but the scale of division is not well understood. 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 collections. Also, haplotype data were collected from the NADH subunits 5 and 6 from 40 fish from each of 28 even-year collections. These initial collections included five comparisons of upstream and inter-tidal spawners within the same streams, and collections represented all of the physiographic regions within PWS. A majority of the samples were from the 1994 brood year, but an assortment of 1992 collections were compared for inter-annual stability of allele and haplotype frequencies. The allozyme analysis indicated that most variation occurred within populations (99.34%), however, significant ($P < 0.0001$) heterogeneity was found among the ADFG management regions (0.09%), between upstream and tidal collections within one stream ($P < 0.0001$), and between 1992 and 1994 collections at one site ($P = 0.0029$). The mtDNA analysis also showed regional heterogeneity ($P < 0.001$) but showed no differences between upstream and tidal collections within two streams tested ($P < 0.05$) and showed inter-annual stability within sites tested. Pink salmon appear to be regionally structured and in some cases divergent between upstream and tidal sites within streams. This snap shot of population structure will be expanded to include two complete sets of observations for the even-year populations and two complete sets of observations for the odd-year populations. Collections are also being made to investigate temporal genetic differences within stream of sampling.

Project Number and Title: 95320E - Sound Ecosystem Assessment - Salmon and Herring Integration

Principal Investigators: Mark Willette, Mark Clapsadl, Ed Debevec, Jay Johnson, Penny Saddler, Margaret Powell, Alaska Department of Fish and Game, P.O. Box 669, Cordova, Alaska 99574 (907-424-3214)

Abstract:

This project collected data needed to test several hypotheses related to predator-prey interactions affecting the mortality of pink salmon (*Oncorhynchus gorbuscha*) and Pacific herring (*Clupea harengus pallasi*) in Prince William Sound (PWS). Several other projects within the Sound Ecosystem Assessment (SEA) program also contribute to this hypothesis testing effort. These hypotheses include the following concepts (1) predation on juvenile salmon and herring 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) spatial patterns of adult pink salmon production in PWS are related to the distribution of large calanoid copepods and walleye pollock during the early marine period. This project was designed to achieve the following objectives (1) estimate the juvenile salmon consumption rate of fish predators in PWS, (2) estimate the species/size composition of fish predators, and (3) identify fish species that prey on juvenile herring. Diel feeding studies focusing primarily on juvenile salmon were conducted at 4 sites during both May and June in northwest PWS. Sampling over a 12-hour period was conducted at 3 additional sites utilized by juvenile herring in southeastern PWS during both May and June. Fish predators were sampled with a mid-water trawl, purse seines, gill nets, hoop traps, and fyke nets every three hours in nearshore and offshore habitats at each site. Sixteen thousand stomach samples were collected and approximately 60% of these have been analyzed to date. The fish species assemblage occupying pelagic habitats was comprised largely of walleye pollock, herring and squid (*Berryteuthis spp.*). The fish species assemblage in nearshore benthic habitats was comprised of various species of sculpin, greenling, rockfish, and cod. Catches of walleye pollock and squid declined and became much more variable during June. Catches of nearshore benthic fish were significantly greater at night. Juvenile salmon comprised 2.3% and 1.2% of the diet of the pelagic and benthic fish assemblages, respectively. Predation on juvenile salmon was generally greater at night and in the morning. Pacific herring exhibited strong feeding periodicity in May with a significant increase in stomach fullness in the morning. Stomach fullness of nearshore benthic fishes also increased in the morning during May. Walleye pollock exhibited strong feeding periodicity in June with an apparent increase in feeding activity in the morning. The mean length of juvenile salmon consumed in nearshore (31 mm) and offshore (36 mm) habitats was significantly different. Pacific cod and walleye pollock were important predators on juvenile herring. Pacific cod consumed primarily age 1 herring; whereas, walleye pollock consumed age 0-2 herring. Tests of predator\prey hypotheses will be conducted after all samples have been analyzed.

Project Title: 95320 G Sound Ecosystem Assessment (SEA): Phytoplankton and Nutrients

Principal Investigators: C. Peter McRoy and David L. Eslinger, Institute of Marine Science, School of Fisheries and Ocean Science, University of Alaska Fairbanks, Fairbanks AK 99775 (CPM phone: 907-474-7783; DLE phone 907-4747797)

Abstract: The populations of pink salmon and herring declined abruptly in the years following the Exxon Valdez oil spill in Prince William Sound. This is a field project, designed in concert with the suite of SEA research studies, with the primary objective of determining the influence of regional and inter annual variations in phytoplankton stocks and productivity on the food webs of restoration target species. Data describing the phytoplankton spatial and temporal fields were collected from shipboard on monthly cruises (March through June plus September) in Prince William Sound and from the AFK Hatchery. Additional data were gathered from the CFOS permanent ocean buoy. Data from these platforms provide adequate spatial and temporal coverage to quantitatively describe the major events in the phytoplankton cycle in the sound. We describe the phytoplankton cycle using measurements of biomass (chlorophyll and other pigments, carbon and nitrogen) and water column dissolved, inorganic nutrients (nitrate, ammonia, phosphate and silicate). Cell counts and species identifications provide direct analysis of the plant community. The increase in phytoplankton biomass occurs in mid to late April; the exact timing of the bloom is governed by ocean conditions (i.e. storms and upper layer mixing). The 1993 bloom was more than 2 weeks earlier than that in 1994 and one week earlier than 1995. The spring phytoplankton community is dominated by Skeletonema sp. and Thalassiosira sp., but the number of picoplankton cells (i.e. flagellates) is about 30-50% of the abundance. Phytoplankton productivity is driven by light , through mixing processes, and nutrients, with nitrate being a principal limit to growth. The spatial pattern of phytoplankton biomass in the sound modifies the "lake" vs. "river" hypothesis proposed by SEA; new data indicate that these two phases occur simultaneously but spatially separated. In spring the bloom appears in the region dubbed "lake" while "river" waters have consistently lower biomass. The waters entering from the Gulf of Alaska have low phytoplankton stocks and high nitrate; these waters would dilute the phytoplankton stock but, paradoxically, enhance the overall productivity of the sound. The seasonal increase in zooplankton biomass lagged that of the phytoplankton by about 2 weeks in all years (see 95320-H) reflecting the close coupling of these seminal events in the food web. The data are incorporated into the SEA database and are used to verify the biological models (see 95320-J).

Project Number and Title: 95320H - The Role of Zooplankton in the Prince William Sound Ecosystem

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

Abstract: Losses of juvenile pink salmon and herring to predators in Prince William Sound appear to be related to the kinds and amounts of alternative prey available to predators each year. Juvenile and adult walleye pollock, adult herring, squid, and other large fishes and birds adopt planktivory at times and places where macrozooplankton populations are abundant and available. This behavior presumably reduces the consumption of the smallest juvenile fishes at these same times and locations.

The large, late stage copepodites (C4 and C5) of Neocalanus plumchrus/flemingeri have been implicated as alternative prey for most predators that also consume small fishes like juvenile pink salmon and herring. In years and seasons when Neocalanus spp. are abundant, mortality on the early life stages of pink salmon and herring may be significantly reduced. The goal of this study is to describe the oceanographic and biological processes that force interannual variability in stocks of macrozooplankton during the springtime in Prince William Sound. This information is being incorporated in models predicting the annual recruitment of pink salmon and herring.

Neocalanus plumchrus/flemingeri appear in the surface waters of the Sound in late February and early March. Successive molts to larger sizes produce the first C5 stages by late April and early May. To arise from local overwintering populations, the developmental stages must remain in the region for roughly 60 days. If the retention of upper-layer water parcels and plankton is less than 60 days, the resulting mid-May biomass bloom will have origins in populations outside Prince William Sound, and interannual differences will be forced by external factors. This issue is being examined jointly with the observational and modelled physical oceanography programs of SEA.

Our observations, and those of others, confirm that adult pollock are capable of filter feeding in zooplankton layers and swarms near the surface during the spring and summer. Combined net, optical plankton counting and acoustic measurements were used this spring to measure horizontal and vertical layering of macrozooplankton and planktivorous fishes (adult pollock) as a means to evaluate Sound-wide overlaps in these distributions. These studies investigate the application of such measurements to predictions of future salmon run strength.

Our most recent observations suggest that Neocalanus spp. C4 stages tend to swarm in the upper 20 m. This behavior probably establishes the layering of near-surface zooplankton responsible for drawing adult filter-feeding pollock into that zone in late April and early May over broad areas of Prince William Sound.

Project Number and Title: 95320I - Sound Ecosystem Assessment: Confirming Fish Food Web Dependencies in the Prince William Sound Ecosystem Using Natural Stable Isotope Tracers (SEA-FOOD).

Principal Investigator: Thomas C. Kline, Jr., Ph. D., Prince William Sound Science Center, P. O. Box 705, Cordova AK99775, 907-424-5800

Abstract: The failure of several Prince William Sound (PWS), Alaska vertebrate species to recover from population crashes following the 1989 T/V *Exxon Valdez* oil spill (EVOS), has raised concerns that shifts in food web structure may have occurred. Of particular concern are post-EVOS declines in the abundance of *Clupea pallasi* (Pacific herring), and *Oncorhynchus gorbusha* (pink salmon). It is hypothesized that abundance of large herbivorous copepods of the genus *Neocalanus* and other macrozooplankton, primary sources of food for these fishes and their predators, are controlled by oceanographic processes. When planktonic prey are unavailable, predators switch feeding mode from planktivory to piscivory. Confirmation of these hypotheses are being tested in a large-scale multi-disciplinary project known as Sound Ecosystem Assessment (SEA).

Because of their predictable nature, stable isotope ratios of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) are providing an effective method for testing the SEA hypotheses. Natural stable isotope ratios are useful for providing empirical evidence of trophic relationships in marine food webs. Stable Isotopes are providing evidence in three SEA hypotheses: (1)"prey switching" through observations of seasonal isotope shifts in predators in combination with a prey database; (2) "river-lake processes" through measurement of related temporal and spatial isotopic effects within the plankton community (with the goal to trace food web carbon sources through to fishes); (3) "herring overwintering" through comparisons of energetic condition with food web carbon source as determined by stable isotope signatures.

$^{15}N/^{14}N$ and $^{13}C/^{12}C$ natural abundances of PWS pelagic biota were measured in samples collected in 1994 during the spring plankton bloom in April; during the SEA predation study in May to July; and during pre-winter fish population assessments in September and October. The sampling program expanded in size in FFY 1995 to include plankton sampling during PWS-wide oceanographic cruises as well as more intensive sampling during the SEA predation study. More extensive sampling of pre-winter fish was also made in October to November 1995 (FFY 1996).

$^{15}N/^{14}N$ values were used to determine canonical trophic levels (TL) using the copepod *Neocalanus cristatus* as a reference. Macrozooplankton ranged in TL up to 3.4 (i.e., 60% primary carnivore and 40% secondary carnivore) and fishes ranged in TL from 3.4 up to 4.3. Species overlapping at TL = 3.4 included the carnivorous copepod, *Euchaeta elongata* and juvenile *Clupea*. *Theragra chalcograma* (walleye pollock) was found to be abundant and the apex pelagic consumer at TL = 4.3. These TL estimates were greater than that calculated using existing carbon flow box models. A $^{13}C/^{12}C$ gradient is suggested for PWS with increasing ^{13}C in neritic carbon and decreasing ^{13}C in oceanic carbon.

The *Neocalanus cristatus* sample collected in early 1994 had a mixture of oceanic and neritic carbon sources. The interplay of these carbon sources is hypothesized to play a role in PWS food web nutrition through the SEA-hypothesized river-lake processes. In FFY 1995, the focus of analytical work was addressed at resolving the relationship of $^{13}C/^{12}C$ to oceanic (Gulf of Alaska, GOA) versus neritic (PWS) carbon sources. These analyses consisted of extensive isotopic analyses of individuals of the copepod *Neocalanus cristatus* as well as bulk net plankton samples paired to samples collected in the SEA zooplankton project during oceanographic surveys in 1995. Copepods feeding in the GOA were significantly ^{13}C depleted compared to those feeding in PWS consistent with a source isotope effect. Diapausing copepods had a mixture of PWS and GOA carbon consistent with some seeding from outside PWS the previous year. Bulk net plankton samples followed similar patterns as *Neocalanus*. Nitrogen and carbon isotope abundance were significantly correlated suggesting that differences in nutrient depletion was a cause for a portion of the isotope gradient. However, less than 25% of variation was explained suggesting that the remaining variation is due to source effects.

After removing lipid- and trophic level-isotope-effects from $^{13}C/^{12}C$ of higher trophic level organisms, it is possible to assess significance of GOA and PWS carbon sources. These normalized $^{13}C/^{12}C$ of fishes will be monitored to test SEA hypotheses since variation in these carbon sources is expected to play roles in all the SEA hypotheses.

Project Number and Title: 95320-J Sound Ecosystem Assessment (SEA): Information Systems and Model Development (SEADATA).

Principal Investigator: E. Vincent Patrick, Prince William Sound Science Center, Cordova, AK 99574; tel:907-424-5800 fax:907-424-5820 patrick@grizzly.pwssc.gen.ak.us

Abstract:

The Information Systems and Model Development project (SEADATA) is one of thirteen projects in the Sound Ecosystem Assessment (SEA) program. The SEA projects are designed to maximize simultaneous measurement of key ecosystem components and combine information into a common data system. The ultimate objective is quantitative understanding and simulation of the time evolution of processes regulating pink salmon and Pacific herring populations in Prince William Sound (PWS). The role of SEADATA is to provide data management, visualization, data communications and modelling resources to the SEA program. For FY95 there were five SEADATA subprojects: field data communications; information systems; numerical model development; interim modelling products; and sampling technologies.

Field Data Communications: There are now three permanent operational installations in the SEA data radio network: the base station in Cordova and repeater sites on Heney Ridge and Naked Island. This system currently supports routine ASCII file transfer from remote sites. During FY95 a weather station was installed at Applegate Rock and used to monitor air temperature, barometric pressure, and wind speed and direction. This information is stored in a remote data logger and periodically downloaded via the radio network.

Information Systems: Work in FY95 included maintenance of local and wide area computer networks; acquisition and archiving of historical and current meteorological data; development of SEA coordination utilities; and development of a new scientific database system with ecosystem scale query and visualization tools. A prototype data management system was developed, based on *Illustra*™ object-relational technology and incorporating a spatial index over a bounding polygon for all SEA datasets. The innovative architecture in this system uses an archive of datasets in hierarchical data format (HDF) combined with an index of metadata stored in a relational database. Dataset design, HDF coding and data ingestion is largely complete for a number of key datasets including physical oceanographic (CTD and ADCP data), zooplankton and offshore nekton and plankton acoustics. Joint work is underway with collaborators at the University of Alaska Fairbanks and the Alaska Department of Fish and Game to incorporate the existing SEA salmon predator and herring databases. Datasets can be listed and retrieved by SEA collaborators over the Internet via a Netscape interface, and are searchable according to space, time and metadata attribute criteria. An interactive survey cruise planning tool was completed. The SEA Home Page on the World Wide Web was brought online at http://www.pwssc.gen.ak.us, providing a forum for exchange of data and information among the SEA collaborators.

Numerical Model Development: A 3-dimensional eddy-resolving general ocean circulation model for PWS was developed, under forcing of wind, coastal inflow and M2 tide from the Gulf of Alaska. Early model results show: (1) a general circulation which is cyclonic in the upper layer due to inflow at Hinchinbrook Entrance (HE) with a volume transport of around $0.3 \times 10^6 m^3 sec^{-1}$; (2) a deep current that is anticyclonic, due to tidal residual flow; (3) mesoscale eddies developing in the sound in the deep water region: an anticyclonic eddy to the east of the main stream entering from HE and a cyclonic eddy to the west of it; and (4) surface current that is also strongly controlled by wind forcing. The nekton modelling group completed a one-dimensional model of the spatial distribution and feeding rates of salmon fry and walleye pollock, a major predator, in PWS. Results suggest that the apparent prey-switching behavior of pollock hypothesized by the SEA program has both a spatial and a temporal component. Changes in pollock diet and apparent switching may occur under some model scenarios. Evaluation of higher dimensional mesh generators for expansion of the model into 2 and 3-d space is underway. In addition, a bioenergetics model for walleye pollock is currently undergoing final testing and is expected to be complete by the end of 1995. Bioenergetic simulations will then be used to predict pollock consumption of juvenile herring and salmon fry, using SEA field data inputs for diet and temperature.

Interim Products: Work during FY95 has led to attainment of a number of goals related to interim modelling products, including the ability, for a specific time and location in the outmigration channel, to forecast the inshore-offshore distribution of fry and predators, the fry foraging rates, and predator foraging rates on fry and macrozooplankton. In conjunction with the salmon bioenergetics model, this will allow nowcast/forecast of fry size and time to 60mm, and nowcast of the spatial distribution of fry of length greater than 60mm. Progress was also made toward forecasting of relative vertical migration flux of zooplankton as a function of spatial position. Work in FY96 will focus on improved parameterization, and on linking and integrating the outputs of the ocean circulation and trophodynamic models with the nekton population models.

Project Number and Title: 95320-K. Experimental Fry Releases

Principal Investigator: Tim Linley, Prince William Sound Aquaculture Corp. P.O. Box 1110, Cordova, AK 99574

Abstract: Returns of hatchery produced pink salmon to Prince William Sound have been weak to moderate in recent years resulting in economic hardship to fishermen, processors, and communities dependent on this resource. Weak returns may be related to heavy predation during early marine residence because pink fry are typically small (i.e. < 0.5 grams) at the time of release which increases the time spent foraging, and therefore the time of exposure to predators. The purpose of this study was to determine whether releasing larger fry (i.e. 1.5 grams) would reduce the risk to predation and lead to higher ocean survival. Approximately 12 million pink salmon fry were reared to a size of 1.0 - 1.5 grams at Armin F. Koernig (AFK) and Wally Norenberg (WNH) hatcheries and released in mid-June in 1994 and 1995. Coded wire tag data obtained from adult returns in 1995 indicate that the larger fry experienced a survival of approximately 7% and 21%, respectively, from the two hatcheries. This compares to a survival of approximately 0.3% and 0.5%, respectively, for all other releases at AFK and WNH.

Project Number and Title: 95320-M - Seasonal Variability of Water Mass Properties of Prince William Sound

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

Abstract: The observational oceanographic part of the SEA program is aimed at identifying the dominant physical processes that influence pink salmon and Pacific herring production in Prince William Sound (PWS). A specific goal is to determine the seasonal and interannual variability of the large scale water mass properties (temperature, salinity, and density) of the sound, and of the inflowing Gulf of Alaska (GOA) waters. In March through September 1995, five large scale hydrographic surveys were conducted in central PWS. Temperature and salinity were measured as functions of depth, and used to calculate potential density. To illustrate the water mass variability at the 10 and 100 m levels, all three variables were averaged over two depth layers (0 to 20 m and 90 to 110 m), and contoured horizontally for each cruise. The March and April temperature, salinity, and density fields at both the 10 and 100 m levels were more homogeneous than the summer and fall months, indicating a more uniform water mass. In May 1995, the inflow of warm, fresh GOA water through Hinchinbrook Entrance (HE) is first evident at the 10 m level. Also apparent in the May contours at both levels is a doming of the isopycnals, suggestive of cyclonic (counterclockwise) circulation, over a region north of Montague Point. The center of the circulation lies directly over a topographic ridge, and it is hypothesized that the formation of the gyre is in part topographically induced. Upwelling of deep water nutrients often accompanies cyclonic circulations and may contribute to the high biological productivity in this region. The isopycnal doming is better defined at the 10 m level in June, 1995. Inflow from the GOA is still apparent in June; part of the flow appears to go northward and part seems to curve to the west around the cyclonic eddie. Inflow and the cyclonic curvature was not present at either depth level in June 1994. In September 1995, the inflow through HE at both the 10 and 100 m levels appears to have weakened or even reversed direction. The central sound is characterized by a large scale cyclonic circulation (again inferred from the doming of the isopycnals) centered over the deep central basin. Outflow and a less well defined cyclonic circulation was suggested by the September 1994 contours. The formation of the cyclonic gyre north of Montague Island in May and June, and its replacement by a basin scale cyclonic circulation in the central sound in September, seems to be correlated with the presence of inflowing GOA waters through HE. Conditions north of Montague Point are favorable for Pacific herring production. If these conditions are linked to upwelling within the cyclonic gyre, the timing and intensity of GOA inflow into PWS could modulate rates of production of Pacific herring. Further hydrographic observations in 1996, along with direct current measurements, will be used to test this hypothesis.

Project Number and Title: 95320N - Nekton and Plankton Acoustics

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Abstract: A primary assumption of the Sound Ecosystem Assessment program is that predation is a primary mechanism affecting the survival of pink salmon fry as they migrate out of Prince William Sound. We believe that better predictions of the number of returning adult pink salmon can be made by developing a numerical model that accurately predicts the magnitude of fry predation.

In 1994 and 1995, we conducted hydroacoustic surveys along the outmigration route of pink salmon fry *Oncorhynchus gorbuscha* in western Prince William Sound to describe the density and distribution of potential predator and prey populations. In spring of 1994 and 1995, the offshore assemblage was dominated by a nearsurface layer of zooplankton targets (including high densities of copepods), large single fish targets (identified as adult walleye pollock *Theragra chalcogramma)* and an occasional school target (identified as Pacific herring *Clupea harengus).* The pollock densities were much lower in nearshore areas where the bottom depth was less than 100 meters. In contrast, the fish assemblage in nearshore area was characterized much lower densities of fish and plankton, consisting of pelagic herring schools and demersal aggregations of rockfish over hard bottom and gadids over soft bottom.

The walleye pollock was the most abundant large fish predator along the outmigration path but they are primarily offshore during the salmon fry outmigration. Since the fry and walleye pollock feed on the same copepod-prey which is at highest densities offshore, and the fry must cross large expanses of offshore water during their outmigration from the Sound, and fry are found in the pollock stomachs, walleye pollock may represent the major source of predation on salmon fry. If the magnitude of salmon-fry predation in a year is primarily a function of the offshore walleye pollock densities in the upper 50 meters during spring outmigration, a cost-effective monitoring program with acoustics is possible. Given the temporal and spatial dynamics of the pollock population, annual measurements of density and distribution will be required input to the numerical model.

In 1994 and 1995, nearsurface plankton layers were measured acoustically. In 1995, we conducted a Sound-wide survey that showed kilometer-scale patchiness of the surface plankton layer. The presence of nearsurface walleye pollock targets appeared to be dependent upon the presence of the plankton layer. In 1996, analytical techniques to identify and quantify nearsurface plankton layers are being investigated. Since predation is a function of growth rate as well as predator density, estimation of prey abundance is also required input to the numerical model. Given that multiple frequencies can be used simultaneously, one survey could be designed to collect both predator and prey information.

Project Number and Title: 95320-Q - Sound Ecosystem Assessment (SEA) - Avian predation on Herring Spawn

Principal Investigators: Mary Anne Bishop, Copper River Delta Institute, Pacific Northwest Research Station, US Forest Service, PO Box 1460, Cordova, AK 99574 (telephone: 907-424-7212)

Abstract: Pacific herring (*Clupea pallasi*) has been identified as a resource injured by the *Exxon Valdez* oil spill. The primary objective of this study is to assess and document the impact of avian predation on herring spawn in Prince William Sound. In spring 1995 we collected and analyzed stomach contents of the most abundant avian species foraging in spawn areas at northern Montague Island. Herring spawn occurred in 100% of the glacuous-winged gulls (*Larus glaucescens*), mew gulls (*Larus canus*), and surf scoters (*Melanitta perspicillata*) stomachs with percent aggregate wet weights of 99%, 89%, and 98% respectively. Surfbirds (*Aphriza virgata*) and black turnstone *(Arenaria melanocephala)* stomachs contained relatively less spawn with percent aggregate wet weights of 68.99% and 70.40% respectively. To date we have estimated the daily herring spawn intake for each of these five species based on estimated field metabolic rates, energy content of spawn, and the proportion of energy acquired from herring spawn. Estimated herring spawn ingested is 1.27 kg/day per individual glaucous-winged gull, 1.15 kg/day per surf scoter, 0.58 kg/day per mew gull, 0.17kg/day per surfbird, and 0.16 kg/day for black turnstone. These estimates are probably low due to energetic demands for migration and/or breeding for all five species. Using aerial videography for gulls and boat shoreline surveys for all other birds, we documented avian abundance and distribution by both date and location in relation to herring spawn. Glaucous-winged gulls were the most abundant bird in spawn areas. Computer counting of gulls from 1995 aerial videos using standard s-video equipment and Duckhunt-Image 1.45 software was insufficient for target discrimination and resulted in artificially low gull counts. Ten boat surveys conducted between spawn initiation (27 April) and hatch (19 May) determined that the most numerous non-gull species in spawn areas were surfbirds (102,248 bird-days), surf scoters (27,558 bird-days), and black turnstones (12,432 bird-days). Final results from 1994 and 1995 seasons are being integrated into a model relating sound-wide Pacific herring embryo survival to predation, habitat type, egg density, and meteorological conditions (EVOS 95166, Herring Natal Habitats).

Project Number and Title: 95320-S - Investigations of Disease Factors Affecting Declines of Pacific Herring (*Clupea pallasi*) Populations in Prince William Sound: II. Controlled Laboratory Challenge of Herring With and Without Stressors.

Principal Investigators: R.M. Kocan & M.L.Landolt, Box 355100 School of Fisheries, University of Washington, Seattle, WA 98195 and J.R.Winton, National Biological Service, 7500 Sandpoint Way NE, Seattle, WA 98105. ph. (206) 685-2984.

Background: The Prince William Sound Pacific herring (*Clupea pallasi)* spawning biomass began a dramatic decline in in 1993 and was accompanied by the unusual appearance of a disease, Viral Hemorrhagic Septicemia (VHS) and it's associated virus (VHSV). In 1994 the spawning biomass continued to decline and was accompanied this time by the appearance of an unusually high rate of infection by *Ichthyophonus hoferi*, a suspected pathogenic fungus. Since these two potential pathogens had not been previously associated with significant mortality in herring (or any other species) in Prince William Sound, a study was initiated to determine whether they could indeed be responsible for the type of losses observed since 1993, and to determine what environmental conditions might induce them to became overtly pathogenic.

Materials & Methods: In order to establish the causal relationship between a specific microorganism and a specific disease, it is necessary to fulfill a series of criteria known as "Koch's Postulates". Briefly, these criteria are: (1) the organism must be present in every case of the disease, (2) the organism must be isolated from the diseased host and grown in pure culture, (3) the specific disease must be reproduced when a pure culture of the organism is inoculated into a healthy susceptible host, and (4) the organism must be recoverable once again from the experimentally infected host.

The first task was to isolate both the VHS virus and *I. hoferi* from Prince William Sound herring and grow them in pure culture in the laboratory. This was done by using established culture techniques for both organisms. The second task was to grow specific pathogen-free (SPF) herring in the laboratory for use in experimental infections. This was accomplished by removing eggs and sperm from running-ripe herring and incubating the eggs and larvae in filtered UV-sterilized seawater until the larvae were large enough for use in laboratory studies.

Results: Both VHSV and *I. hoferi* were obtained from PWS herring and successfully cultured in the laboratory. SPF herring were successfully reared and when they were >30 mm in length they were used for experimental infections with the two suspect pathogens. Over 40% of the successfully hatched eggs survived with a linear growth rate of 0.233 mm $*$ d^{-1} for the first 90 days. No VHSV, *I. hoferi* or other pathogen was detected in these fish by either *in vitro* culture or histologic examination of tissues.

Koch's Postulates were fulfilled for VHSV in the SPF herring. Fish exposed to increasing concentrations of virus demonstrated a clear dose response with the first mortalities occurring 4 days after initial exposure to the virus. All fish in all exposure concentrations ultimately died by 14 days post initial exposure. It was suspected that the initially infected fish released virus into the water and secondarily infection the remaining fish. This was tested by placing wild VHSV-infected fish into tanks containing SPF herring and observing the SPF herring for signs of disease and mortality. This experiment conclusively demonstrated that infected fish do transmit the virus to susceptible fish and that they developed the same signs of disease and ultimately died from the infection.

Wild 5-month-old herring were brought into the laboratory and maintained in flowing seawater for 45 days. When initially captured, they appeared healthy and no virus could be isolated. By one week in captivity an apparently density-dependant epizootic occurred and over 50% of the fish died with obvious cutaneous hemorrhage similar to VHS; 100% of the fish examined were positive for the virus. By 30 days post-capture the epizootic ceased and virus was no longer detectable.

A PWS herring isolate of *I.hoferi* has been successfully transmitted to 100% of the experimental herring tested by intraperitoneal injection (I.P.) but not by oral exposure. At this time no *I. hoferi*- associated mortality has been observed, but these studies are continuing to determine the long-term pathogenicity of the organism. Studies are also underway to determine the infective stage of the organism, the natural route of infection for wild herring and it's host range in marine fish. Data obtained to date indicate that the PWS strain of *I. hoferi* is not the same species as that found in Atlantic herring (*Clupea harengus*)

Project Number and Title: 95320-S - Disease Impacts on Prince William Sound Herring Populations: I. Field Studies of Disease Prevalence.

Principal Investigators: Gary D. Marty and David E. Hinton, VM-APC, University of California, Davis, CA 95616; Theodore R. Meyers, Alaska Dept. of Fish and Game, Southeast Fish Pathology Laboratory, P.O. Box 25526, Juneau, AK 99802, John Wilcock, Alaska Dept. of Fish and Game, P.O. Box 669, Cordova, AK 99574 (GDM telephone: 916-754-8062)

PURPOSE AND OBJECTIVES: The estimated spawning biomass of Pacific herring (*Clupea pallasi*) in Prince William Sound (PWS), Alaska, has decreased every year (except 1992) since the 1989 *Exxon Valdez* oil spill. In 1993, viral hemorrhagic septicemia virus (VHSV) and no other significant pathogens was isolated from Pacific herring in PWS. Prince William Sound Pacific herring fisheries were severely curtailed in 1993, and were never opened in 1994 or 1995. In 1994 (94320-S), 233 Pacific herring were sampled from Prince William Sound: 29% had the disseminated fungus *Ichthyophonus hoferi*, and VHSV was isolated from 5% of the fish. In 1995, the study included fish from a reference site, Sitka Sound (SS), in which the herring fishery was strong and there was no history of a large oil spill. The primary objective of this study was to determine the role of disease in decline of Pacific herring populations.

METHODS: Spawning fish were sampled from SS (n=240) and subjected to complete necropsy. Similar samples from PWS included 80 prespawning fish from Zaikof Bay (Montague Island) and 180 spawning fish from Rocky Bay (Montague Island).

RESULTS: Severe focal skin reddening or ulcers were more prevalent in spawning fish from PWS (2.8%) than in spawning fish from SS (0.4%), but prevalence of these lesions in 1995 was less than in spawning fish from PWS in 1994 (8.4%). For internal lesions, *Ichthyophonus* prevalence in PWS spawning fish (29%) was the same as in 1994 and no different from the *Ichthyophonus* prevalence in spawning fish from SS (26%). At both sites in 1995, prevalence of *Ichthyophonus* among all fish was higher in 7-year-old fish than in 2- and 3-year-old fish (PWS, 35% vs. 9.6%; SS, 31% vs. 22%). Viral hemorrhagic septicemia virus was not isolated from any spawning fish in PWS or SS, but VHSV was isolated from 6.2% of prespawning fish from PWS. Prevalence of several parasites and subtle inflammatory lesions was greater in spawning fish from PWS than SS. Examples include the testicular coccidian *Eimeria sardinae* (PWS = 85%, SS = 66%) and focal parenchymal leukocytes in liver (PWS = 81%, SS = 49%).

CONCLUSIONS: Based on external examination, spawning PWS Pacific herring were in better condition in 1995 than in 1994, and PWS spawning fish were in worse condition than spawning SS fish in 1995. However, *Ichthyophonus* prevalence was similar among all three sample groups. Because VHSV was not isolated from PWS spawning fish in 1995, the outbreak of VHSV in PWS seems to be resolving. The continued high prevalence of *Ichthyophonus* in spawning fish in PWS is a concern. However, because *Ichthyophonus* cases were concentrated among 7-year-old fish, and 2- and 3-year-old fish were infected at historically endemic levels, the *Ichthyophonus* outbreak may soon be subsiding. If younger fish remain relatively free of *Ichthyophonus*, disease is less likely to impair their continued recruitment into the fishery in 1996 and 1997.

Project Number and Title: SEA95320S - The Effects of Viral Hemorrhagic Septicemia Virus, *Ichthyophonus* and Pristane on the Hematological and Immunological Status of Pacific Herring, *Clupea harengus pallasi* and rainbow trout, *Oncorhynchus mykiss*.

Principle Investigator: Sanders, S., A.P. Farrell, R. Kocan and C.J. Kennedy.

Abstract: Declines in Pacific herring populations in Prince William Sound are due to factors or stressors which have reduced either the survival, the performance, or the reproduction of these fish. Coincident with this decline was the exposure of herring to oil following the *Exxon Valdez* spill in 1989. In addition, information gathered in a field monitoring program suggests that other stressors, including Viral Hemorrhagic Septicemia Virus (VHSV) and *Ichthyophonus hoferi* (ITP), may be contributing to present low population levels. In order to determine cause and effect relationships between these stressors and herring fitness, laboratory experiments were initiated using Pacific herring, *Clupea harengus pallasi* and rainbow trout, *Oncorhynchus mykiss*. Hematological and immunological parameters were examined in trout following exposures to VHSV, ITP and pristane (a hydrocarbon known to be a mammalian immunosuppressant) via different routes of exposure.

Herring underwent a natural epizootic in which VHSV was detected in 100 percent of fish examined. Forty percent of the fish survived the epizootic. No virus was detected in these fish, despite the continued presence of overt VHSV symptoms, one month following the onset of the epizootic. VHSV exposure was indicated by lowered hematocrit and leucocrit values. Higher fish densities tended to enhance the magnitude of some observed responses.

Trout treated with ITP showed no differences from control fish in terms of hematocrit or leucocrit although differential white blood cell counts indicated a neutrophilia in ITP-exposed fish. VHSV-exposed fish exhibited a significant decrease in hematocrit. As with VHSV-exposed herring, trout exposed to VHSV or pristane had lowered leucocrits; and both stressors applied simultaneously had an additive effect on lowering leucocrit. Trout exposed to VHSV and pristane also demonstrated a leucopenia with concurrent neutrophilia and lymphocytopenia.

This preliminary study indicates that VHSV, pristane and possibly ITP affect the hematology and immunology of herring and trout. As well, the data indicate that following an epizootic of VHSV, the immune system of herring may continue to be compromised even when the virus is no longer detectable by viral assay. These results are beginning to explain cause and effect relationships between environmental stressors such as oil components and disease and herring fitness.

Project Number and Title: 95320T - Juvenile herring growth and habitat partitioning

Principal Investigators: B.L. Norcross and E.D. Brown, IMS, SFOS, UAF, Fairbanks, AK 99775-7220 (907)474-7990

Abstract: *Exxon Valdez* oil spill injury to the Prince William Sound (PWS) Pacific herring (*Clupea pallasi*) population has been difficult to interpret because little was known about herring early life stages. The herring population crashed in 1993 apparently due to a viral infection, VHSV, of which occurrences are known to increase in fish exposed to oil. In order to decipher early life history stages, and to facilitate restoration of the herring population, research was initiated in 1995 as a component of the Sound Ecosystem Assessment project, an integrated, multi-investigator approach to understanding Prince William Sound. This component of the project focuses on understanding the distribution, feeding and condition of ages 0 - 2 herring (<150 mm) in order to characterize their habitat. Herring were collected as ancillary data from net sampling for salmon conducted April - July 1994 and 1995 primarily on the western side of PWS. Additionally, aerial surveys were conducted specifically to analyze broad scale herring distribution in 1995. Juvenile herring are much more widely distributed than adults, but there are areas where juveniles are more abundant. Though results are not definitive due to the spatial limitations of past net collections, four major areas seemed to have more herring: 1) Port Gravina in eastern PWS, 2) northern Montague Island and Green Island, 3) southwestern PWS, including Whale and Jackpot Bays and Port Bainbridge, and 4) Resurrection and Aialik Bays in the outer Kenai Penisula. Overlap between adults and juveniles occurs mainly in the northern Montague Island area and Port Gravina. In the future, this distribution information will be compared with stomach contents and condition indices taken from the same locations to determine if there are differences between rearing areas which could affect survival and ultimate recruitment to the adult population. The most important result of the 1994 and 1995 distribution data was that it provided insight as to our knowledge gaps about herring distribution and is being used to design an effective spatial and temporal sampling plan for juvenile herring in FY96.

Project Number and Title: SEA 95320U - Energetics of herring, pollock and pink salmon.

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

Abstract: The Exxon Valdez oil spill may have altered the trophic structure of the plankton feeding fish community by injuring intertidal spawning species. This project, begun in April of 1995, has started to describe the interannual seasonal somatic energy cycle of juvenile *Clupea harengus pallasi*. This information was not previously available and is needed to describe feeding success and to determine if the over-winter period is important in regulating recruitment of age 0 herring. Samples from the fall of 1994 and spring of 1995 from 8 sites throughout Prince William Sound showed there was large geographical differences in the nutritional status of recruiting herring. This is also true for fish within a school. This initial survey suggests that many age 0 herring entered the over-wintering phase in poor nutritional status. Samples of juvenile herring were collected from 10 sites in the fall of 1995 and analogous spring sampling will be done in 1996 to compare the energetics of fall fish and those that survived the winter. Young herring are being held in the laboratory for experiments that will quantify the energy needed to survive the winter fast.

This project has started to examine herring ovarian energy indices relative to length and age to understand the populations egg production potential which is the first step in the recruitment process. In 1995 sampling was done in 3 areas, the northeast, northwest and southwest portions of Prince William Sound. Ovaries will be sampled for three years for comparative purposes, since there is no previous information on the variability in the amount of energy allocated to egg production.

This project 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. This energetic profile will aid in the understanding of how pollock compete with these two injured fish species. Pollock are a major prey of many seabird species injured by the oil spill and our energetic measures will be useful in estimating bird energy intake. The first samples were collected from 11 sites in the fall of 1995 and are now being processed. Extensive sampling is scheduled again in the spring of 1996.

Measurements of the spring somatic energy content of pink salmon fry (*Oncorhynchys gorbuscha*) were made from four 1995 collections. We found that energy content of fry was related to their relative abundance, but not to body length. In 1996 energetic measurements of wild and hatchery pink salmon fry will be carried out so comparisons of their nutritional status vs. geography and origin can be made. These measurements are part of the SEA effort to understanding the role energy intake plays in the recruitment process of this injured species.

The information gathered by this energetics project is being related to SEA zooplankton surveys, prey selection studies and tropic isotopic studies through the SEA modeling effort.

Project: 95320-Y Sound Ecosystem Assessment: Estimating local avian predation rates on hatchery released fry.

Principal Investigator: D. Scheel (Prince William Sound Science Center, Box 705, Cordova, AK 99574; tel: 907-424-5800).

Abstract: The 'predator-prey relationship' hypothesis of SEA suggests that predation on early life stages of pink salmon and herring is an important modulator of survival, and that the intensity of this predation depends on the availability of alternative prey such as macrozooplankton. This hypothesis is particularly relevant to predicting and managing the recovery of pink salmon populations from the oil spill, and to the role of hatcheries in restoring these populations. Observations from 1994 suggest that in some cases, predation on young fish by birds may be as important as predation by larger fishes. The goal of this project is to estimate bird predation rates on hatchery-released salmon fry near hatcheries immediately following fry release. This information should indicate whether bird predation on localized concentrations of small fish is a significant source of mortality to these fish.

Seabird aggregations were surveyed around Wally Noerenber hatchery on Esther Island, Prince William Sound, Alaska from April to June 1995. During this period, releases of pink and chum salmon from the hatchery attracted small aggregations of gulls, terns and diving birds. Aggregations of Black-legged Kittiwakes formed and dispersed quickly. Bonaparte's Gulls and Arctic Terns aggregated in the area for several days and then moved on. The number of Red-breasted Mergansers increased gradually from the onset of release through mid-May and then decline by early June. Marbled Murrelet numbers began to increase about one week following the start of releases and continued to increase throughout the period of daily release.

Data from aerial surveys during this same period suggest that large gull aggregations form at food sources such as herring spawn and outmigrating salmon fry at the mouths of streams. I suggest that the timing of spawning by forage fish in relation to salmon fry release or outmigration may be an important regulator of the number of seabirds aggregating to feed on salmon fry.

Project Number and Title: 95427 - Harlequin duck (*Histrionicus histrionicus*) recovery monitoring.

Principal Investigator: Daniel H. Rosenberg, Alaska Dept. of Fish and Game, 333 Raspberry Rd., Anchorage, AK 99518 (907) 267-2453

Abstract: In response to mortality from the 1989 T/V Exxon Valdez oil spill, harlequin duck (*Histrionicus histrionicus*) populations were surveyed in Prince William Sound (PWS) in 1995 to assess the extent of recovery of ducks inhabiting oiled areas and determine if low reproductive success resulted in changes in population structure and productivity. Shoreline surveys monitored abundance, distribution, population structure, and productivity in oiled areas in western PWS and unoiled areas in eastern PWS.

Number of pairs and females declined throughout the spring for both populations while adult males increased. During the survey period from May 10 to May 20, 83% of the females and 65% of the total eastern PWS (epws) population were paired while only 57% of the females and 40% of the total western PWS (wpws) population were paired. By the third spring survey (June 9-16) 28% of the females and 11% of the epws population remained paired while 5% of the females and 2% of the total wpws population were paired. Throughout the spring surveys female numbers declined by 56% for epws and 40% for wpws. Males increased during the spring surveys from 61% to 81% of the epws population and from 65% to 79% of the wpws population. Ratios of adult:subadult males for the three spring survey periods were similar, averaging 3.0:1 for epws and 3.1:1 for wpws. In fall the percentage of males declined from 76% to 59% in epws and from 86% to 66% in wpws. The proportion of flightless females was higher in wpws (75%) than epws (47%) during the first fall survey. Ten broods were observed in epws. We did not observe any broods in the wpws study area.

In spring, a greater proportion of the epws population was paired. This corresponded with a greater movement of females out of the study area, presumably to breeding areas. Fewer paired birds, more unpaired females, more females remaining within the study area, and a greater percentage of flightless females during the early fall surveys indicate less movement to breeding areas by wpws females. Brood surveys indicated greater production in epws. Adult male:subadult male ratios, a potential measure of recruitment, were similar for the two populations.

Project Number and Title: **94428/95428 - Subsistence restoration planning and implementation**

Project Leader: **James A. Fall, Alaska Department of Fish and Game, Subsistence Division, 333 Raspberry Road, Anchorage, Alaska 99518 (Telephone: 907-267-2359).**

Subsistence use of fish and wildlife is a vital natural resource service (a human use) that was impaired as a result of the *Exxon Valdez* oil spill. Although some recovery has occurred, the spill's effects on subsistence remain. The purpose of the Subsistence Restoration Planning and Implementation Project was to design a comprehensive approach to subsistence restoration and implement a planning process to develop subsistence restoration project proposals for consideration by the Trustee Council for federal Fiscal Year 1995, FY 1996, and beyond. Project ideas not approved by the Trustee Council could be considered for funding from the State of Alaska criminal settlement money through grants administered by the Department of Community and Regional Affairs (DCRA). Project objectives included meeting with residents of the subsistence communities in the spill area to identify community needs and subsistence restoration priorities, and working with communities to develop proposals to restore reduced or lost subsistence resources and services.

A planning team was formed consisting of representatives of the Alaska Department of Fish and Game, DCRA, the National Park Service, and the US Forest Service. The planning team met with Trustee Council staff and attorneys to plan the program and develop guidelines for projects. Three rounds of community and regional meetings took place, involving representatives of 19 communities.

Sixteen subsistence restoration project proposals were submitted to the Trustee Council for consideration for funding in FY 1995. Of these, three received funding from the Trustee Council, and an additional seven received criminal settlement funding. For the FY 1996 Work Plan, 22 project proposals were submitted to the Trustee Council, with eight receiving funding in August 1995 and additional four under further consideration. In 1995, three additional projects received criminal settlement funding, for a total of about $3 million of the available $5 million criminal settlement appropriation being committed by September 1995.

The planing team's efforts to develop a "comprehensive approach" to subsistence restoration encountered some obstacles, stemming from the terms of the settlement agreement governing the use of the restoration fund. A restoration plan adopted by the Trustee Council in 1994 clarified that projects to restore or enhance an injured service had to demonstrate a direct connection to an injured natural resource. Given this limitation, the planning team concluded that a comprehensive approach to subsistence restoration that addressed the environmental, social, and cultural dimensions of the subsistence way of life would not be possible. The team emphasized to communities the need to link project proposals to natural resource recovery. The team remained committed to a comprehensive approach in a geographic sense, but participation was greatest in Prince William Sound and lower Cook Inlet, with more frustration expressed in Kodiak and the Alaska Peninsula about lack of familiarity with the restoration process.

Despite the limitations on the scope of eligible projects, the planning effort succeeded in contributing to an enhanced role for subsistence users and communities in the restoration process. The commitment of civil settlement funds to subsistence restoration rose from about $600,000 in FY 94 to over $1,000,000 in FY 95. During the same time, the percentage of subsistence restoration funds supporting community-proposed projects or going to local communities and Alaska Native organizations increased from 23 percent to 34 percent. Of the $878,400 authorized for FY 96 in August 1995, 80 percent will go directly to community-proposed projects or be awarded to communities and Alaska Native organizations through contracts. Action on deferred FY 96 projects may bring the total authorization for subsistence restoration to over $1,500,000. The support of 10 projects by the State of Alaska through grants from the criminal settlement funding broadened the scope of the total package of the subsistence restoration program. A number of these projects, such as a spirit camp and subsistence foods processing facilities, attempted to restore the social and cultural aspects of subsistence uses which could not be directly addressed by the full Trustee Council.

The final report for this project offers several recommendations:

A directed effort should continue to involve subsistence users and communities in restoration activities.

To the maximum extent allowed by law, subsistence restoration projects should strive to address all oil spill impacts on subsistence uses, including those to the natural resource base as well as to the sociocultural foundation which supports subsistence activities in Alaska communities.

There needs to be a recognition in law that for assessing the damages caused by disasters such as oil spills, Alaska is a special case, in that it is the only state with hundreds of communities and tens of thousands of people whose economic, social, and cultural well-being and survival are linked directly to the subsistence uses of natural resources. Future attempts to restore the damaged "natural" environment in Alaska need also to directly address the environmental, social, cultural, and spiritual dimensions of the subsistence way of life. A comprehensive approach to subsistence restoration requires nothing less.

Abstract

Use of Aerial Photograph, Channel-Type Interpretations to Predict Habitat Availability in Small Streams (Restoration Project 95505B).

Anadromous salmon, cutthroat, and dolly varden were injured by the *Exxon Valdez* oil spill of 1989. A fundamental problem facing fishery managers, given that the species migrate widely throughout drainage basins in the oil spill area, is the need to incorporate an ecosystem perspective into protection and restoration planning, while still focusing on the objective of increasing productivity. An ecosystem approach requires an ecosystem-based inventory to develop capabilities for identifying habitat limiting to production. To date, fishery managers have lacked methods to adequately identify representative reaches within streams. As a result, short of cataloguing every habitat feature in an entire stream or drainage basin, our abilities to conduct comprehensive ecosystem based habitat analyses have been somewhat limited.

Over the past ten years hydrologists have developed channel-typing systems to classify streams into hydrologically, and geologically similar reaches. Channel-types incorporate physical features such as gradient, width, sinuosity, incision, and adjacent slopes which can be readily discerned by studying stereo pairs of aerial, and satellite photographs. Features such as beaver dams, and logging, which may alter habitat composition in a stream, are also apparent on the photographs. In its broadest capacity channel-typing can be used to map streams into geographical information system (GIS) data bases, and to divide the streams into similar reaches prior to conducting expensive field surveys. As such, channel-typing provides fishery habitat managers with a valuable tool for: making evaluations of land management decisions; designing habitat and fish sampling schemes; and cataloguing those data into meaningful groupings. In this study, we establish that channel-types can be significant predictors of the kind and area of habitat to be found in the wetted portions of a stream.

In-stream habitat were quantified and qualified for nine channel-types that were identified from interpretations of stereo pairs of color and infrared aerial photographs. A total of 70 sites were sampled for streams located on the northwest portion of the Kenai Peninsula, in south-central Alaska. Channel-types were a significant predictor ($P < 0.05$) of the area (m^2) for 9 of 13 habitat types. When habitats were grouped into 6 categories which roughly describe depth and water flow in the habitat, channel-types accounted for 55 to 92% of the variability observed in the area (m^2) of these habitats. Channel-types that had similar habitat composition, differed in the size and depth of those habitats. Spawning habitat also appeared to be correlated to channel-type, however the within channel-type variability caused the differences to test non-significant at $P < 0.05$. Overall, channel-types appear to be a good management tool for inventorying, cataloguing, and evaluating stream habitat. Channel-types allow for useful comparisons of fish production in similar habitats under different settings.

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16.8.3
Addendum

1996 Restoration Workshop

Exxon Valdez Oil Spill Trustee Council

January 16–18, 1996

Anchorage, Alaska

Abstracts of 1995 Restoration Project Results

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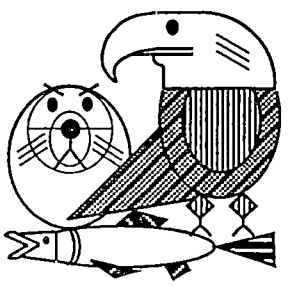
Addendum

DRAFT

AS OF 1/12/96



Project Number and Title: 95102 - Closeout of Project 94102, 'Marbled Murrelet Foraging Patterns and a Pilot Productivity Index for Murrelets in Prince William Sound, Alaska.'

Principal Investigator: Katherine J. Kuletz, U.S. Fish and Wildlife Service, 1011 E. Tudor Rd, Anchorage, Alaska, 99503 (telephone: 907-786-3453)

Abstract: Funding was provided for analysis and report writing of 1994 field work. This is the first phase of a long-term study to determine if food is limiting marbled murrelet (*Brachyramphus marmoratus*) recovery in Prince William Sound. To investigate the food limitation hypothesis, we predicted that birds in Port Nellie Juan (PNJ), a deep water fjord, would travel farther than birds at Naked Island (NI), surrounded by relatively shallow water. In 1994 we radio-tagged 47 marbled murrelets at these two sites, to study their foraging patterns during the breeding season. From 3 June-28 July we tracked 46 birds and mapped 232 relocations made from airplanes and 186 boat-based relocations. Relocations from airplanes for 42 birds were used for analysis of foraging range. Six inland sites ($\bar{x}$ = 1.6 km inland) were assumed to be nests (3 tree nests and 3 cliff/ground nests). From the nests to relocations on water, straight-line distance mean = 16 km (SE = 5, max = 31) and mean distance measured around landforms was 21 km; the bird with the highest average foraged 40 km from its nest.

Foraging range indexes were used to compare all birds. We found no significant differences in foraging range indexes between birds at PNJ (N=32) and NI (N=10). Average straight-line distances for birds at PNJ were 17 km from capture site, 12 km between consecutive sites and 24 km maximum distance. Birds at NI averaged 16 km, 9 km and 26 km, respectively. Although birds from the two areas had equivalent foraging range indexes, they demonstrated different use of available habitat. Birds from NI selected shallower areas ($\bar{x}$ = 52 m deep) proportionally more than available. At PNJ, birds used areas in proportion to their availability, and were found on water that was significantly deeper ($\bar{x}$ >115 m). PNJ birds were often found over deep-water sills and shelf edges, likely sites of upwelling, and may have relied on concentrations of prey caused by local bathymetric and landform features.

A pilot project was initiated to assist development of a murrelet productivity index in 1995 (Project 95031). We surveyed the shoreline of NI (N = 15 surveys) and PNJ (N = 12 surveys) from 16 July to 8 September 1994, using 25 ft whalers. Adults and juveniles at sea showed similar patterns of abundance at NI and PNJ. Juveniles were observed at low levels from 22 July to 8 August. Afterwards they increased and remained high until 1 September, when they began to decline. Concurrently, total numbers of murrelets declined steadily, and by early September they were 5% of July counts. Additional work is required to refine this method of monitoring murrelet productivity, but it appears promising.

We conclude that to investigate food limitation, large areas need to be surveyed for murrelet productivity concurrent with forage fish availability.

POSTER SESSION ABSTRACT: WHISKERS! DATABASE

WHISKERS! is a computerized text database of indigenous local knowledge about Alaskan marine mammals. It was compiled by the Alaska Department of Fish & Game Division of Subsistence from key respondent interviews with Alaska Natives in approximately 60 Alaska coastal communities between 1992 and 1995. It is organized into notes from six geographic regions--Southeast, North Pacific Rim, Kodiak, Alaska Peninsula, Aleutians and Pribilofs, and Bristol Bay.

The purpose for compiling this information is to contribute to scientific knowledge about Alaskan marine mammals, especially harbor seals and Steller sea lions, whose populations have been declining at an alarming rate in Prince William Sound and Kodiak Island--areas impacted by the oil spill. Hopefully, this information will promote better cross-cultural understanding of the importance of these animals to subsistence users and assist in the management and recovery of stressed populations.

The poster session will feature a graphic display (conventional poster) highlighting features of the database. Side by side with this display I will provide a hands-on demonstration of how to access and use WHISKERS!

Equipment provided: 30" x 36" wall poster and a laptop computer hooked up to an overhead viewer.

Equipment needed: small table (chest height if available) and 2-prong electrical outlet. A raised lecturn for the laptop would also be a big help.

Contact person: Craig Mishler at 267-2357 or fax 267-2450