PART I - Progress Report on Activities
A. Abstract or summary of project work to date.

Chief among the goals of OSRI research program is the attainment of a four-dimensional (time and 3-dimensional space) understanding of Prince William Sound and the Copper River Delta necessary to detect and predict oil spill related impacts and recovery. Central to achieving this goal is the support of environmental studies of ecological and economic resources at risk to potential oil spills. The vast expanse of intertidal sand/mudflats formed by the Copper River serve as a critical link in the food web of nearshore communities along the southcentral Alaska coastline. The tidal flats of the Copper River Delta provide foraging habitat for a variety of migratory (shorebirds and salmonid fish) and resident demersal species (e.g., dungeness crabs, Pacific halibut, lingcod). Over 4 million shorebirds, the largest spring concentration of shorebirds in the Western Hemisphere visit the Copper River flats annually between late April and mid-May on their way to breeding grounds in western Alaska. The Delta also supports a substantial commercial and subsistence fishery that is an integral element of the local economy: some 549 gillnet fishers commercially harvest 3 species of salmon in the estuarine waters of Copper River Delta. Equally important, subsistence fishing provides a significant food source for residents of Cordova and the upper Copper River watershed.

Many of the factors that contribute to the high biological productivity of intertidal systems also result in their heightened sensitivity to natural and anthropogenic change. Annual or decadal changes in atmospheric pressure and global warming can cause short and long-term alteration in sea level and tidal inundation which in turn can alter the location of the land-sea interface. Changes in habitat boundaries may also result from subsidence and/or elevation of tidal flat areas resulting from tectonic activity (e.g. the Alaska 1964 Good Friday Earthquake). Spatial and temporal variation in coastal circulation patterns or upwelling/downwelling intensity can result in shifts in temperature regimes or delivery of oceanic nutrients and significantly modify species distributions, primary production and trophic transfer. Patterns of freshwater inputs, which affect both nutrient levels and ambient salinities, can vary in response to climatic oscillation that in turn effect precipitation levels and transgression or regression of glaciers. A variety of direct and indirect effects on marine community structure may result from the propagation of these changes up or down coastal food chains.

Adding to the heightened sensitivity of intertidal habitats is the fact that these areas are often the repository for contaminants released in coastal areas. As with changes caused by variation in natural
forcings, a host of direct and indirect effects may result from acute and chronic exposure to contaminants that ultimately modify the complex ecological network of a coastal system. Consequently, a comprehensive understanding of the biotic and abiotic factors that regulate the biological community of the Delta is critical.

Our overall hypothesis is that the distribution, abundance and production of benthic invertebrates residing in intertidal sediments of the Copper River Delta are controlled by a combination of top-down (predators) and bottom-up (nutrient and primary production) processes. To evaluate the central predictions of this hypothesis, a comprehensive sampling program was adopted (Fig. 1) to address four objectives. All of these objectives are designed under the assumption of a multi-year project that leverages OSRI funding with Exxon Valdez Oil Spill Trustee Council funding from their Gulf of Alaska Ecosystem Monitoring (GEM) program. We were pleased when in November 2003, the EVOS Trustee Council approved funding for FY2004-2006 for the Copper River Delta project. Without both OSRI and EVOS funding we could not perform the comprehensive study the Delta’s ecosystem requires. In successfully competing for EVOS funding, we have also been responsive to the instructions of the OSRI board to seek partners to leverage OSRI funding.

In response to the OSRI Chief Scientist’s request, we moved our fiscal year and reporting requirements by 1 quarter, shortening our 2004 contract year to 9 months only. Below we provide a brief summary of results by objective through December 31, 2004, the start date for the 2005 project period.

1. Characterize the spatial abundance of macrobenthic species inhabiting intertidal sediments within the Copper River Delta and Orca Inlet, Southeast Prince William Sound.

Objective 1 of the project is funded primarily from EVOS-GEM. Core sampling (10-cm diameter) for invertebrates were conducted in April and September 2004. Areas sampled included low, mid-and high-tide plots near the outflows of Eyak River and Pete Dahl Slough, and low, mid, upper mid and high tide plots at Hartney Bay. All 90 core samples from April 2004, and approximately one-half of the 90 core samples from September 2004 have been sorted, with all marine invertebrates identified, measured, and enumerated. Despite its low diversity (4 species account for the majority of animals and 1 species, Macoma balthica, account for >80% of the biomass), mudflats of the Copper River Delta support high densities of Macoma clams (~4,000 clams/m2), amphipods, and polychaetes that serve as prey for numerous species of migratory and resident species. Diversity of benthic invertebrates is significantly higher within mudflats of Orca Inlet compared to the Copper River Delta. This higher diversity likely results from the more saline conditions within Orca Inlet and the lower frequency of ice scour. Once the 2004 analysis is completed, we will have a 4 year record of invertebrate densities at these sites. This data set will allow us to examine the question of inter-annual variation in recruitment.

2. Determine and quantify those factors that best serve as predictors for primary production in the overlying water and within the sediments of tidal flat communities.

For the 2004 field season we collected the second year of oceanographic observations for the inside waters of the Copper River Delta. From April to October, in conjunction with our monthly fish trawls, we conducted a series of conductivity-temperature-depth (CTD) profiles and fluorescence at 11 sites in the major channels of the western Copper River delta and close to our benthic invertebrate core sampling areas. These data document the temporal and spatial influence of the Copper River’s freshwater discharge on the intertidal waters and on adjacent water masses (Gulf of Alaska and Prince William Sound). Surface (Fig. 2) and bottom water salinities (Fig. 3) throughout the Delta and Orca Inlet are significantly reduced during the summer in response to the large input of freshwater from the Copper River Delta. At the Delta sites, lowest salinity values for both surface and bottom were recorded during August 2004. Comparisons of data between 2003 and 2004 reveal temporal variability in the temporal of the Copper River Delta.
As of 1 January 2005, we analyzed all nutrients and chlorophyll a samples from monthly samples obtained from March through October 2004. Still remaining to be analyzed are the freshwater samples collected in November and December samples. The Copper River is the principle source of nitrate to the Delta ecosystem as well as a source of nitrates to the Gulf of Alaska through exchanges between Egg Island and Pete Dahl channels (Fig. 4). Phosphate concentrations appear to be influenced by both oceanic and riverine sources, whereas silicate appears to be delivered in large quantities primarily from riverine sources (Fig 5 and 6). Chlorophyll a concentrations in surface waters (Fig. 7) appear to reflect input of phytoplankton from the Gulf of Alaska and Prince William Sound. Sediment chlorophyll a patterns show elevated concentrations at mid tidal elevation, a location which generally demonstrates benthic biomass maximum. Compared with 2003 when chlorophyll a inputs were recorded from the Gulf of Alaska from April through June, during 2004 we recorded inputs only during May.
Figure 2. Interpolated surface salinity maps by month, April – October 2004, for the Copper River Delta study area. Note the large influence of the Copper River outflow from July through August, the period of peak outflow.
Figure 3: Interpolated bottom salinity maps by month, April – October 2004, for the Copper River Delta study area. Note the large influence of the Copper River outflow from July through August, the period of peak outflow.
Figure 4. Interpolated surface nitrate concentrations from March through September 2004. Large inputs of nitrate enter the Delta through the Copper River with highest concentrations occurring in late spring and late summer/fall.
Figure 5. Interpolated surface phosphate concentrations from March through September 2004 for the Copper River Delta study area. Phosphate concentrations appear to be influenced by both oceanic and riverine sources.
Figure 6. Interpolated surface silicate concentrations from March through September 2004 on the Copper River Delta study area. Silicate appears to be delivered in large quantities primarily from riverine sources.
Figure 7. Interpolated surface chlorophyll a concentrations from March through September 2004. Maximum chlorophyll a concentrations are associated with higher salinity waters entering Pete Dahl Channel and in Orca Inlet in May. Large inputs of freshwater and high suspended solids may decrease photosynthesis from June-August.
3. Quantify the spatial and temporal abundance of demersal and avian predators and assess the role of epibenthic predation on recruitment of intertidal macroinvertebrates.

In an effort to document the abundance and distribution of demersal fish and crabs we conducted replicate otter trawl surveys every 3 weeks around our study areas for a total of 8 trawl surveys between March and October 2004. All animals caught in trawls were identified and measured for TL (total length) and weighed. Distinct spatial variation (Fig. 8) are evident in the demersal fish and crab distributions: CPUE is highest near the outflows of Pete Dahl and Eyak River. A strong spatial pattern repeated in all three trawl years (2002-2004) is the absence of Dungeness crabs west of the Seal Bar site, and the high quantities of shrimp east of the Seal Bar site. Examination of three years of trawl data also reveal distinct differences in the recruitment of three two important commercial species (Pacific Halibut and lingcod). Pacific halibut recruitment was highest in 2002 and lowest in 2003 (Fig 9). Lingcod recruitment was low in 2002 and 2003 but showed substantial increase in 2004 (Fig 10). In an effort to learn more about fish movement patterns, we also tagged more than 155 large (>200mm) starry flounder, Pacific halibut, and Pacific staghorn sculpin. In 2004, we received no returns compared with two returns in 2003 from a recreational and a commercial fisher.

Figure 8. Spatial changes in the demersal fish community from March to October 2004. Stations on the x-axis are arranged from west to east from Hartney Bay (Orca Inlet) to Pete Dahl (near the Copper River). Each data point represents the average catch per unit effort (CPUE) for trawls collected over all sampling dates. One of the most striking patterns is the absence of Dungeness crabs west of the Seal Bar site, and the high quantities of shrimp east of the Seal Bar site.
Figure 9. Length-frequency diagrams for Pacific halibut captured in 2002 – 2004. Ages are based on otolith examination performed by the International Halibut Commission. Age 0 halibut are more abundant in 2002 than any other year, whereas age 1 halibut are more common in 2002.

Figure 10. Length-frequencies for lingcod captured in 2002-2004. Catches increased from 2002 to 2004. Two distinct cohorts are evident in the graph 80-120 mm TL (young of the year fish) and 130-220 mm TL (age 1 fish). The 20-40 mm TL fish represent post-hatchling juveniles.
4. Develop a cost-effective strategy and sampling design for long-term monitoring of the intertidal sedimentary habitats.

Objective 4 requires completion of the three years of field collections according to the observation program detailed in figure 1. We have had limited discussions with the OSRI Science Director and OSRI Executive Director on monitoring priorities after 2006. We will continue to discuss future monitoring activities as data from the current OSRI/GEM program is analyzed.

Other accomplishments:

Monica Dozier, an OSRI fellow for the project is also analyzing a subset of the demersal fish data in order to prepare a manuscript on habitat partitioning by flounders. This manuscript is currently under review by the PI's and should be submitted this summer.

The Prince William Sound Regional Citizens’ Advisory Council (RCAC) awarded Bishop and Powers a grant in November 2003. The grant allowed Dr. Erica Clesceri, a post-doc at the University of South Alabama, to finish collecting and analyzing samples for stable isotope analyses. The isotope analyses will allow us to document major sources and pathways of energy in the intertidal foodweb. These same paths would apply if any contaminants were released into the intertidal ecosystem. A final report is being submitted to PWRCAC in March 2004 and will be submitted to a journal for publication late this summer.

Publications resulting from the project:

Previous publications:


Reporting year & current publications (in press or published):


Publications in Preparation


Reports

Presentations:

Apr 2004    Spring migration strategies of shorebirds along the eastern Pacific Flyway. 
            Prince William Sound Science Center Board of Directors. Cordova, Alaska. Powers, 
            Bishop, & Peterson.

Public Outreach Activities:

April 2004  Presentation, The Copper River Delta’s mudflats. By Bishop & Powers 
            for the Prince William Sound Science Center, Community Program in conjunction with the 
            Earth Day celebration.
April 2004  Collected and prepared fish specimens for public display at Cordova’s Earth Day fair.
April 2004  Aerial tour of Copper River Delta mudflats to Gail Phillips, Executive Director of Exxon 
            Valdez Oil Spill Trustee Council.
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Part II - Annual Financial Statement Project 04-10-14 Powers, Univ. S. Alabama
(budget information is reported separately by the office of contracts and grants)

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Intertidal Resources at Risk to Oil Spills: Ecology of the Copper River Delta, Alaska

**ABSTRACT**

*Society for Conservation Biology Annual Meeting New York City, New York July 2004*

**Conservation of Sub-Arctic Tidal Flats: Copper River Delta Alaska.**

Mary Anne Bishop and Sean P. Powers

Prince William Sound Science Center, PO Box 705 Cordova, AK 99574 USA (MAB), mbishop@pwssc.gen.ak.us; University of South Alabama & Dauphin Island Sea Lab, 101 Bienville Blvd., Dauphin Island, AL 36528 USA

The unique interface of land, sea and air characteristic of intertidal habitats serves to promote high biological productivity. Many of the factors that contribute to the high biological productivity also result in heightened sensitivity of intertidal systems to natural and anthropogenic change. The Copper River Delta in southcentral Alaska includes extensive (500 km2) tidal flats that are critical to many taxa including migratory shorebirds and salmonids. These tidal flats are vulnerable to petroleum spills, both from offshore tankers and the Trans-Alaska pipeline. To more effectively protect the Delta, we investigated the intertidal soft-bottom community and its predators. We determined that the benthic invertebrate community is characterized by low species diversity, dominated both in biomass and numerical abundance by Macoma balthica, a slow-growing and long-lived bivalve. The predator community is dominated by shorebirds in spring and a large, demersal-fish community dominated by flatfish, Crangon shrimp, sculpin, snake prickleback and crabs. Many of the species captured are of significant fisheries value (Pacific halibut, Dungeness crab, lingcod). Natural or human-induced changes to M. balthica populations could impact the food web of the delta, which could cascade to larger geographic impacts because of the importance of the delta to migratory species.
Spring migration strategies of shorebirds along the eastern Pacific Flyway

Nils Warnock, PRBO Conservation Science, Stinson Beach, CA, 94970, USA; Mary Anne Bishop, Prince William Sound Science Center, Cordova, AK, USA; John Y. Takekawa, BRD, US Geological Survey, Vallejo, CA, USA

Since Frederick Lincoln first proposed the general flyway concept for migratory birds in North America in 1938, much progress has been made in describing migratory pathways of waterbirds in the four flyways, especially for larger game birds like ducks and geese. However, progress in describing the migration ecology of small waterbirds (less than a few hundred grams) over large distances has lagged. We will provide an overview of how shorebirds (waders) use the eastern Pacific Flyway during migration, the importance of the flyway to shorebird populations, and we will identify important migratory stopover sites. Additionally, we will present migration data on individually radio-marked shorebirds tracked over different parts(sections) of the 7,000 km stretch of the Pacific Flyway of North America between wintering grounds in Mexico and California and breeding grounds in Alaska. We will present data on spring-time travel routes, stopover ecology, and travel rates of Western Sandpipers (Calidris mauri), Dunlin (C. alpina), and Short-(Limnodromus griseus) and Long-billed Dowitchers (L. scolopaceus).
Spring migration patterns in migrating Western Sandpipers *Calidris mauri*

Mary Anne Bishop, Nils Warnock & John Y. Takekawa

We radiomarked 132 Western Sandpipers *Calidris mauri* at two Pacific Coast sites in North America, San Francisco Bay, California and Grays Harbor, Washington and at an interior, western Great Basin wetland, Honey Lake, California. We monitored their northward migration at a network of 12 major stopover sites and 4 breeding areas. We relocated 88% of the birds at 10 stopover sites and 2 breeding areas between San Francisco Bay and the Yukon-Kuskokwim Delta, Alaska (~4,200 km). On average birds were relocated at < 2 sites, with the Copper River Delta Alaska the single most important stopover site. We documented that migrant birds radiomarked at the interior, western Great Basin stopover site shifted to the coast between Oregon and Washington, and then continued migration along the Pacific Coast. Individual birds used a wide variety of migration strategies. At the population level, we observed heterogeneity in phenology and site use, a strategy well adapted to the changing landscape that Western Sandpipers must navigate during migration, especially in interior regions.
Migration and stopover strategies of individual Dunlin along the Pacific coast of North America

Nils Warnock, John Y. Takekawa, and Mary Anne Bishop

Abstract: We radio-marked 18 Dunlin, Calidris alpina (L., 1758), at San Francisco Bay, California, and 11 Dunlin at Grays Harbor, Washington, and relocated 90% of them along the 4200 km long coastline from north of San Francisco Bay to the Yukon–Kuskokwim Delta, Alaska. The Copper River Delta, Alaska, was the single most important stopover site, with 79% of the marked birds detected there. Our second most important site was the Willapa Bay and Grays Harbor complex of wetlands in Washington. The mean length of stay past banding sites ranged from 1.0 to 3.8 days. Controlling for date of departure, birds banded at San Francisco Bay had higher rates of travel to the Copper River Delta than those banded at Grays Harbor. The later a bird left a capture site, the faster it traveled to the Copper River Delta. Length of stay at the Copper River Delta was inversely related to arrival date. We did not find any effect of sex on travel rate or length of stay. Combining the results of this study with our previous work on Western Sandpipers, Calidris mauri (Cabanis, 1875), reveals variation of migration strategies used within and among shorebird species along the eastern Pacific Flyway.
Radio-tagged Pacific Golden-Plovers: Further insight concerning the Hawaii-Alaska migratory link

Oscar W. Johnson, Corey D. Adler, Lee Anne Ayres, Mary Anne Bishop, Jodi E. Doster, Patricia M. Johnson, Ronald J. Kienholz, and Susan E. Savage

Abstract.— We radio-tagged a total of 55 Pacific Golden-Plovers (Pluvialis fulva) in spring 2001-2003 on wintering grounds in Hawaii. Following their northward migration (most birds deserted winter territories in late April), we relocated 15 of them in Alaska – some in each of three regions: Copper River Delta, King Salmon, and Kotzebue. One individual made the transpacific flight from Oahu to the Alaska Peninsula in a minimum time of 70 h at a minimum flight speed of 56 km/h. Present findings, together with earlier records, indicate a major Hawaii-Alaska migratory connection for this species, and suggest that plovers wintering on Oahu nest throughout the known Alaska breeding range. Post-breeding, 84% of the sample birds returned to Oahu and reoccupied their previous winter territories.
DIFFERENTIAL SPRING MIGRATION BY MALE AND FEMALE WESTERN SANDPIPERS AT INTERIOR AND COASTAL STOPOVER SITES

MARY ANNE BISHOP, NILS WARNOCK, & JOHN Y. TAKEKAWA

Abstract. Western Sandpipers (Calidris mauri) are differential migrants, with females and adults wintering farther south. Earlier passage of males in the spring has been explained by sexual differences in winter latitude (male-biased sex ratios at more northerly areas) and onset of migration (males departing earlier). We investigated sex differences during the spring migration by radio-marking 132 Western Sandpipers at two Pacific coast sites, San Francisco Bay, California and Grays Harbor, Washington and at a Great Basin interior wetland, Honey Lake, California. We monitored northward migration at a network of 12 major stopover sites and 4 breeding areas. At the banding sites, we observed differences in sex ratios by date and banding site, with males preceding females. We found sex differences in departure time from the banding site, in arrival time at the Copper River Delta (our most important stopover site), and in the likelihood that a stopover was used, although patterns are not consistent. Our data suggest that by mid to late April, migration timing becomes more compressed and sex differences are less pronounced and harder to detect.
Distribution of *Mya arenaria* L. on tidal flats of the Copper River Delta and southeastern Prince William Sound, Alaska

Sean P. Powers, Mary Anne Bishop, Jonathan H. Grabowski and Charles H. Peterson

Abstract

The bivalve *Mya arenaria* L. is a common inhabitant of intertidal sediments along the southcentral Alaskan coastline. Its current distribution along the Pacific coast of the continental USA, Canada and Alaska has resulted from a series of intentional and unintentional introductions as well as larval transport between points of introduction over the previous century. Despite the apparent success of *M. arenaria* in intertidal habitats of coastal Alaska, few studies have examined the abiotic and biotic factors that limit its distribution or potential interactions with native benthic invertebrates. We sampled four times over a two-year period (2001-2002) to document the distribution of *M. arenaria* in intertidal sedimentary habitats of the Copper River Delta and adjacent Orca Inlet (southeastern Prince William Sound), Alaska. Sampling was performed along a gradient of tidal elevations at three sites (Hartney Bay, Eyak and Pete Dahl) chosen to represent the range of physical/chemical settings of protected intertidal sand and mud flats within the study area. Among the three sampling sites, abundance of *M. arenaria* increased on a E-W gradient with abundance increasing as distance from the highly turbid plume of the Copper River increased (Pete Dahl < Eyak < Hartney Bay). Within each of the two sites located on the Copper River Delta (Eyak and Pete Dahl), *M. arenaria* was virtually restricted to low tide plots (+ 0.8 m for Eyak, + 1.2 m for Pete Dahl). For the third site located in Orca Inlet (Hartney Bay), *M. arenaria* was found at all tidal elevations; however, distinct differences in the distribution of newly recruited *M. arenaria* (< 10 mm shell length [SL]) and older juveniles and adults (>10 mm SL) were evident. Newly recruited *M. arenaria* were found almost exclusively at low tide plots, whereas larger *M. arenaria* (> 10 mm SL) were found in greatest abundance at high and mid-tide plots. With the exception of the mussel *Mytilus trossulus*, little spatial overlap was detected between the distribution of *M. arenaria* and native obligate suspension feeding bivalves (e.g. *Mya truncata*, *Siliqua pacifica*, *Protothaca staminea*).