PROPOSAL FORM

THIS FORM MUST BE SUBMITTED BY THE PROPOSED PRINCIPAL INVESTIGATOR (S) AND SUBMITTED ALONG WITH THE PROPOSAL.

By submission of this proposal, I agree to abide by the Trustee Council's data policy (*Trustee Council Data Policy**, adopted March 17, 2008) and reporting requirements *(Procedures for the Preparation and Distribution of Reports***, adopted June 27, 2007).

PROJECT TITLE: Lingering Oil on Boulder-Armored Beaches in the Gulf of Alaska 22 Years after the *Exxon Valdez* Oil Spill

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* www.evostc.state.ak.us/Policies/data.cfm
** www.evostc.state.ak.us/Policies/reporting.cfm

FY11 INVITATION
PROPOSAL SUMMARY PAGE

Project Title: Lingering Oil on Boulder-Armored Beaches in the Gulf of Alaska 22 Years after the *Exxon Valdez* Oil Spill

Project Period: FFY2011-2012

Primary Investigator(s): Dr. Gail Irvine (USGS), Dr. Daniel Mann (Mann's Environment), Mark Carls (NOAA, NMFS)

Study Location: Gulf of Alaska, (Katmai National Park & Preserve, Kenai Fjords NP&P)

Abstract: We want to continue long-term monitoring of lingering oil at six Gulf of Alaska sites where we have tracked the fate and persistence of stranded *Exxon Valdez* oil over the last 22 years. It has been six years since our last survey revealed that relatively unweathered oil still persisted at some sites. Interestingly these sites have less weathered oil (e.g., contains more *n*-alkanes) than similarly aged oil from Prince William Sound. All five of our monitoring sites on the Katmai National Park coast are boulder beaches with high wave energies. Accepted knowledge predicted that rapid natural weathering of stranded oil would occur in such settings. This was not the case, and we are still figuring out why. We think it is because the boulder armors that cover these shorelines protect the underlying oil. In addition to resampling our monitoring plots, we will be testing to see if oil is leaking out from these beaches. By extending our long term study of oil stranded on this little understood shoreline type, we will contribute important new data useful for predicting the geographic distribution of lingering oil, assessing its potential for continued pollution, and designing methods for its remediation.

Estimated Budget: $203.8k
EVOS Funding Requested:
FFY2011: $178.2k, FFY2012: $25.6k
Non-EVOS Funds to be used:
FFY2011: $31.6, FFY2012: $4.0k

Date: Jan. 7, 2011

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Lingering Oil on Boulder Armored Beaches in the Gulf of Alaska 22 Years after the *Exxon Valdez* Oil Spill

PROJECT PLAN

I. NEED FOR THE PROJECT

A. Statement of Problem

Contrary to the predictions made by oil-spill experts in 1989, significant amounts of *Exxon Valdez* oil remain in the spill region 20 years later. Short et al. (2004) estimate there are 7.8 hectares of oiled shorelines left in Prince William Sound (PWS) containing some 56,000 kilograms (kg) of lingering oil in the subsurface. Furthermore, Short et al. (2007) assert that the areal extent of oiled beaches in PWS did not change significantly between 2001 and 2005, which implies that the rate of decline in lingering oil has slowed. There have been no detailed studies of the amount of lingering oil in the Gulf of Alaska; however, long-term monitoring of oiled sites shows persistence of relatively unweathered oil in Kenai Fjords National Park and Katmai National Park (Irvine et al., 1999; 2006; 2007). Is that oil still there on high wave energy beaches in the Gulf of Alaska? Has its chemical weathering changed significantly? Is it leaking from the beach, thereby potentially posing biological threat? If it is still there, what factors are causing it to persist?

1)Background

a) Lingering Exxon Valdez Oil

Our knowledge about lingering oil in the spill region has become much more complete over the last 20 years, but large gaps still exist. Some of these gaps involve geographical differences in oiling and geomorphology/exposure within the spill region. For example, in PWS oil reached shorelines in a more fluid or less viscous form than the emulsified water/oil form (mousse) that landed on GOA shores. Also, PWS is in general a more protected environment than the GOA, and this basic fact has widespread implications for the coastal geomorphologies of the two areas. We know now that in PWS much of the remaining oil is found at a lower level in the intertidal zone than was thought immediately after the spill (Short et al., 2006). On the other hand, this is not a universal pattern, since lingering oil in the GOA tends to be located high in the intertidal zone (Irvine et al., 2006). A modeling study designed to predict the location of lingering subsurface oil within the spill area, including both Prince William Sound (PWS) and the Gulf of Alaska (GOA), was begun in 2007 (Michel et al., 2010). This ground-breaking work has developed geospatial models that identify areas where subsurface oil is still present on the shorelines of PWS and the GOA and estimate the relative quantities of subsurface oil remaining at different sites. One of the most significant results of this work is its prediction that a significant number of as-yet-unsurveyed sites in PWS and the GOA still contain subsurface oil. On the down side, this geospatial model has been developed primarily based on data from PWS and so has limited applicability to GOA sites. Furthermore, it is implicit in multi-variable models that while overall predictive success may be high (as in PWS), the linkages between the data used and the physical phenomena that drive oil persistence remain unclear (Michel et al., 2010). In other words, the model may work, but we still do not understand the geomorphic and geochemical processes that allow the persistence of stranded oil.

Other recent EVOS-funded studies focus on smaller-scale processes related to subsurface oil persistence. M. Boufadel and collaborators are studying factors that limit the degradation rate of oil in PWS beaches including nutrient and oxygen concentrations and water flow (Boufadel et al., 2010; Li and Boufadel, 2010). A. Venosa et al. (2010) have researched the factors limiting biodegradability of oiled sediment. Both these small-scale, process studies emphasize the importance of oxygenation, nutrient availability, and hydraulic conductivity in the subsurface of oiled beaches. Certainly, these small-scale variables are influenced at larger spatial scales by the nature and stability of the overlying armor layers.

b) Boulder Armored Beaches

Boulder armors develop naturally when the finer particles (silt, sand, pebbles, and cobbles) are winnowed away by waves, deflating the pre-existing sediments until a layer of boulders remains that prevents further winnowing. Natural boulder armors are little studied despite their wide distribution on shorelines around the world and despite the widespread use of artificial boulder armors to stabilize eroding beaches (Dean and Dalrymple, 2004). Natural and artificial armors are distinctly different phenomena, and the stability formulae used to design artificial armors have little relevance to natural armors (Oak, 1986). A recent review of armored, gravel beaches on paraglacial coastlines is given by Hayes et al. (2010).

Boulder beaches are often intricately packed or fitted together with the projections of one boulder accommodated in the concavities of its neighbors (Shelley, 1968). Smaller boulders are often imprisoned amongst larger ones (Hills, 1970). The fitting together of boulder armors occurs by boulders shifting in place, rubbing against their neighbors until achieving a packing of maximum stability. Tracking of the positions of individually marked boulders on the Katmai coastline shows that while individual boulders regularly roll and shift in place, few ever move out of their niches within the surrounding armor (Irvine et al., 2006; 2007). Armors form tightly fitted fabrics that are highly resistant to wave attack and may be stable for thousands of years (Bishop and Hughes, 1989). Hence boulder armors represent equilibrium geomorphic features; that is, they develop into progressively more stable entities to the point where most wave events cannot disturb them or the sediments (and oil) they cover. Boulder armors are ubiquitous on Gulf of Alaska shorelines (Hayes et al., 2010). Exceptions are shorelines where sea-level changed radically during the Great Alaskan Earthquake in 1964 and shorelines experiencing rapid progradation by glacial outwash.

In summary, naturally occurring boulder armors are widespread on rocky shorelines. Because they are created through waves, armors are most common and best developed on high energy shorelines like many in the GOA and on exposed shorelines in PWS. The dynamics of boulder armors have been little studied relative to sandy and gravel beaches, which tend to be more widespread at lower latitudes. As a result, the processes important in the development and maintenance of boulder armors remain poorly known, though it is clear that boulder beaches are quite different from sand and gravel beaches with a unique set of formative processes (Oak, 1984; Hayes et al., 2010). Another thing that is clear is that boulder-armored shorelines can harbor slightly weathered oil for long periods of time (Irvine et al., 2006; 2007; Short et al., 2007). It seems likely that if there is still *Exxon Valdez* oil in the environment of southern Alaska 50 years hence, it will be associated with boulder armors.

c) Our Long Term Monitoring Study of GOA Shorelines

Since 1994, we have monitored the status of *Exxon Valdez* oil at six sites in the Gulf of Alaska (Irvine et al., 1999; 2006; 2007; Short et al., 2007). These sites are now the most consistently studied, long-term monitoring sites of stranded oil in the spill region. Sixteen years post-spill, surface oiling had declined markedly at all sites, but subsurface oil remained abundant. The oil collected from beneath the boulder armor at three of the four sites surveyed was still compositionally similar to eleven-day old *Exxon Valdez* oil (Short et al., 2007). Remarkably, this oil still contained *n*-alkanes, which normally would be degraded by microbes within weeks of a spill. When the composition of *Exxon Valdez* oil from the GOA was compared to that from PWS, the GOA oil was less-weathered (Short et al., 2007). These findings indicate that our GOA study of the long-term persistence of stranded oil may provide insights not possible from PWS studies and that may apply to some of the extensive coastline that was oiled outside of PWS.

The persistence of oil at high wave-energy sites in the GOA seems to be related to the presence of stable boulder armors. Though not initially chosen for this reason, all five of our monitoring sites on the Katmai National Park and Preserve coast in the GOA possess such boulder armors. The prediction that oil persistence correlates with armor stability has been borne out over the last 16 years. Analysis of movements in the boulder armors reveals that only minor shifts have occurred since 1994. These findings suggest that boulder armors, combined with the stranding of oil mousse high in the intertidal zone, results in the unexpectedly lengthy persistence of only slightly to moderately weathered oil within otherwise high-energy wave environments on GOA coastlines. The three-dimensional matrix provided by boulder-armored beaches allows oil to penetrate into finer sediments lying beneath stable, boulder lags. Previously it was thought that oil would be rapidly removed from such geomorphic settings by the vigorous wave action (Vandermuelen, 1977). Instead, these surface armors attenuate wave energy and reduce wave reworking of the underlying substrates and the included oil. Additionally, oil on boulder-armored beaches is sheltered by the boulders from sun exposure (Irvine et al., 1999). Similar inferences about the importance of boulder armors in allowing oil to persist for long periods on exposed shorelines comes from observations made inside PWS (Michel and Hayes, 1993a, b; 1995; 1999; Hayes and Michel, 1999; Hayes et al., 2010). Understanding the dynamics of armored shorelines is basic to understanding what determines the distribution of persistent, subsurface oil.

The persistence of this oil in the GOA raises questions about it potential or realized biological effects. In PWS a number of studies have examined biological effects of the spill over the years (e.g., Bodkin et al., 2002; Esler and Iverson, 2010), but these types of studies are lacking in the GOA except for more limited temporal sampling of oiled mussel beds (Babcock, et al., 1996; Carls, et al., 2001, Irvine et al., 2007). Thus the ability to tie lingering oil to biotic effects is limited. We propose to examine whether oil is being released from these sites as a first step in addressing this particular gap in our understanding of biological effects of lingering oil.

B. Relevance to 1994 Restoration Plan Goals and Scientific Priorities

Our proposed work will address the physical and chemical processes responsible for the persistence of lingering oil in the spill region within the GOA and seeks to understand the reasons why this long lingering oil has failed to degrade. Additionally, we are investigating whether the oil is being released and may be affecting biota. Of particular significance is the fact that five of our long-term monitoring sites are located within a designated wilderness area in Katmai National Park and Preserve. Our findings will provide direct evidence of the recovery status of these special-value lands and will assist in the evaluation of remediation options that could lead to restoration of these injured natural resources. Our proposed study of lingering subsurface oil on boulder armored beaches in the GOA will fill a geographical gap in our understanding of the distribution of lingering oil and directly complement recent or ongoing studies of oil biodegradation at finer spatial scales.

II. PROJECT DESIGN

Objective #1. What is the status of oiling at our long-term monitoring sites, 22 years after the *Exxon Valdez* spill? Specifically, how chemically weathered is the oil today, and how have the extents of surface and subsurface oiling changed?

Objective #2: How much of the subsurface oil preserved under boulder armors at our GOA monitoring sites is presently leaking into the surrounding environment?

Objective #3: How stable have the boulder armors on our study beaches been over the last 22 years and how does this relate to the findings from Objectives #1 and 2?

B. Procedural and Scientific Methods

1) What is the status of oiling at our long-term monitoring sites, 22 years after the *Exxon Valdez* spill? Specifically, how weathered is the oil and how have the extents of surface and subsurface oiling changed?
We will reassess the extent of both surface and subsurface oil using the same methods we have used since 1994 at these sites. Additionally, we will collect two oiled sediment samples from each site for hydrocarbon analyses. These samples will be analyzed via gas-chromatography/mass-spectrometry (GCMS) by NOAA's Auke Bay Laboratory.

2) **Is the subsurface oil preserved under boulder armors presently leaking into surrounding environment?**
Although oil has persisted at our GOA monitoring sites for at least 16 years, we do not know if oil is presently leaking from the subsurface into the environment. If it is occurring, such leakage could be having biological impacts. To ascertain if oil is leaking out, we will deploy low density polyethylene strips (LDPEs), which we refer to here simply as "plastic strips." These plastic strips function like the better known semi-permeable membrane devices (SPMDs) (Chapman, 2006), but are superior when the hydrocarbon signal is low (e.g., in relatively unpolluted environments), since they record less background 'noise' than do SPMDs (Jeep Rice, pers. comm.). Polynuclear aromatic hydrocarbons (PAHs) are adsorbed onto the plastic strips, but not alkanes or particulate oil. We will deploy the plastic strips, in their protective containers, in radiating patterns near boulder armors that still shelter remnant oil, and also at control sites. Our plan is to place the plastic strips at two of our long-term monitoring sites on the Katmai coast and at two un-oiled control sites relatively near these oiled sites. At each oiled site, we will deploy 10 plastic strips, while at each control site we plan to deploy 4 plastic strips. Trip and field blanks will be collected and analyzed for control purposes. At all sites, the plastic strips will be

left in place for up to 30 days, then collected for analysis of hydrocarbons. We also plan to collect mussels (*Mytilus trossulus*) near these same sites - where they are present - and analyze them for hydrocarbons as well, since they are better indicators of particulate hydrocarbons (Jeff Short, pers. comm.).

3) How stable are the boulder armors?
We will resurvey the locations of the marked boulders at each site, using the same methods as previously. The deviations from the previous locations will be calculated and used to determine if individual boulders have moved significantly over time. The degree of boulder movement on each beach will be used to interpret the data gathered in Objectives #1 and #2 on the extent, chemical composition of oiling and whether oil is being released into the environment. If boulder armors are responsible for the long term persistence of EVOS oil, we expect to see the most oil and the least weathered oil at sites whose armors have moved the least.

C. Data Analysis and Statistical Methods

Surface oiling at our GOA monitoring sites is reassessed in marked quadrats by estimating oil percent cover. Percent cover data for individual quadrats will be compared through time (1994, 1999, 2005, and 2011) via pair-wise tests. As for all tests discussed here, the data will be tested for normality and the appropriate parametric or non-parametric test chosen. Data from previous years (1994, 1999 and 2005) were compared in our latest report and manuscript via Wilcoxon signed-rank tests.

Subsurface oiling is assessed through the sampling of "dip stones" at each site. These are naturally occurring cobbles that extend from the sub-armor surface of the substrate downwards through the zone of subsurface oiling. Means and ranges of the depth of oiling for each site will be compared through time.

Hydrocarbon analyses:
Oil composition and weathering: As in our previous studies, chemical analysis of sediment, mussel and LDPE samples will be conducted via gas-chromatography/mass-spectrometry (Short et al., 1996a). We will compare the presence and relative abundance of polynuclear aromatic hydrocarbons (PAH) within samples, and compute a weathering index based on a first-order kinetic loss rate model of Short and Heinz (1997), which will be used to compare the degree of weathering of different samples at the same and different sites. Additionally, the proportion of *n*-alkanes and PAHs remaining through time will be compared among samples and sites. These analyses permit identification of the source of the oil.
LDPE data: The concentration and distribution of PAHs in these samples will be compared between oiled and non-oiled (control) armored beaches.

Boulder movement: We will use the same combination of survey methods employed in our earlier surveys. Measurement of boulder movement will be compared between years, by site. Various measures of movement, e.g., horizontal and vertical displacements, changes in angular orientation of the marker bolts, will be considered separately. Measurement error is determined through repeated measurements of selected marked bolts. The significance of displacements for the boulder armoring will be evaluated in relation to the size classes of the boulders on the beach.

Variations between beaches will be contrasted, especially in relation to the extent of chemical weathering of oil samples.

D. Description of Study Area

As detailed above, we are proposing to continue monitoring of six sites located on the GOA coastline, in Katmai National Park & Preserve and Kenai Fjords National Park and Preserve (Irvine et al., 1999; 2006; 2007; Short et al., 2007). We have monitored oiling conditions and boulder movements at these sites since 1994. Maps with the location of the study sites and details of site morphology and sampling have been included in previous reports submitted to the EVOS Trustee Council.

E. Coordination and Collaboration with Other Efforts

NOAA is a cooperating agency, and Mark Carls, the head of the analytical lab at NOAA's Auke Bay Fisheries Laboratory, is a principal investigator on the project. We have been in communication with the NPS regarding this project, and most closely there with Bud Rice. We plan to have NPS staff with us in the field, and will be training staff in our sampling procedures. The NPS continues to be interested in and concerned with the persistence of oil on the Katmai and Kenai Fjords National Park coastlines.

III. SCHEDULE

A. Project Milestones

Objective 1. Determine status and extent of persistent oiling at the long-term GOA study sites.
To be met by March 2012

Objective 2. Determine if oil is leaking from GOA armored beaches.
To be met by March 2012

Objective 3. Determine the stability of the boulder armors.
To be met by February 2012

B. Measurable Project Tasks

FFY 11, 2nd quarter (January 1, 2011-March 31, 2011)
February: *Project funding approved by Trustee Council*

FFY 11, 3rd quarter (April 1, 2011-June 30, 2011)
Contracting, hiring, preparation for field work

FFY 11, 4th quarter (July 1, 2011-September 30, 2011)
Field work
Shipment of hydrocarbon samples to Auke Bay Labs

FFY 12, 1st quarter (October 1, 2011-December 31, 2011)
December 15: *Begin data and hydrocarbon analyses*

FFY 12, 2nd quarter (January 1, 2012-March 31, 2012)
January 18: *Annual Marine Science Symposium*
March 1: *Complete hydrocarbon analyses*
Write report/manuscript

FFY 12, 3rd quarter (April 1, 2012-June 30, 2012)
April 15: *Submit final report. This will consist of a draft manuscript for publication to the Trustee Council Office.*

FFY 12, 4th quarter (July 1, 2012-September 30, 2012)
Present findings at national conference (during FFY12 or FFY13)

C. Publications & Reports

The study results will be submitted to EVOS TC as a manuscript that will later be submitted for publication in a peer-reviewed journal. We are requesting funding for the writing of this manuscript and its publication in a peer-reviewed journal. The tentative title of one manuscript is: "Oil persistence 22-years after the *Exxon Valdez* spill on boulder-armored beaches distant from the spill origin." We plan to target the journal, Marine Environmental Research, with a submission date planned for Dec. 2012.

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V. RESUMES

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A. Education

Ph.D. 1983 University of California, Santa Barbara, Biological Sciences
Emphasis – Aquatic and Population Biology
M.S. 1973 University of Washington, Seattle; Zoology
B.A. 1969 University of California, Santa Barbara; Zoology (Honors)
Attended 1965-66 Alaska Methodist University

B. Professional Positions

Research Ecologist, U.S. Geological Survey, Alaska Science Center, 1995 – present
Coastal Resources Specialist, National Biological Survey/U.S.Geological Survey, 1993-1995
Coastal Resources Specialist, National Park Service, 1991-1993
Marine Biologist/Fisheries Scientist, Minerals Management Service, 1984-1991

Assistant Research Biologist, Marine Science Institute, University of California, Santa Barbara, 1983

C. Scientific Involvement

Editorial Board of Marine Systems Domain, online journal, TheScientificWorld*, 2001-present*

Member, Non-indigenous Species Working Group, PWS RCAC

D. Five Recent Publications Related to the Lingering Oil Project

Irvine, G.V., Mann, D.H., Short, J.W. **S**ixteen-year persistence of slightly weathered *ExxonValdez* oil under boulder armors on beaches distant from the 1989 spill. (***in revision***)

Short, J.W., Irvine, G.V**.**, Mann, D.H., Maselko, J.M., Pella, J.J., Lindeberg, M.R., Payne, J.R., Driskell, W.B., and Rice, S.D. 2007. Slightly weathered *Exxon Valdez* oil persists in Gulf of Alaska beach sediments after 16 years. Environmental Science and Technology 41:1245-1250.

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E. Other Publications

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Carls, M.G., M.M. Babcock, P.M. Harris, G.V. Irvine, J.A. Cusick, and S.D. Rice. 2001. Persistence of oiling in mussel beds after the *Exxon Valdez* oil spill. Marine Environmental Research 51(2001): 167-190.

F. Persons with whom Dr. Irvine has collaborated on a project or publication with over the last four years

Scott Carpenter, Dept. of Geosciences, University of Iowa, Iowa City, Iowa
Sandra Lindstrom, Dept. of Botany, University of British Columbia, Vancouver, B.C., Canada
Dan Mann, Institute of Arctic Biology, University of Alaska, Fairbanks
Anne Pasch, Dept. Biology, University of Alaska, Anchorage

Jeanne Schaaf, Director, Lake Clark-Katmai Studies Center, National Park Service, Anchorage, AK

Nora Foster, NF Taxonomic Services, Fairbanks, Alaska

Jeff Short, Auke Bay Lab, NOAA, Juneau, Alaska
John Southon, Earth System Science Dept., University of California, Irvine, CA
Bernd Schoene, University of Mainz, Germany
Nadine Hallman, University of Mainz, Germany
Jacqui Michel, Research Planning, Inc., South Carolina
Zach Nixon, Research Planning, Inc., South Carolina
Miles Hayes, Research Planning, Inc., South Carolina

DANIEL H. MANN

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PROFESSIONAL CREDENTIALS

1983-1985 Post-Doctoral Fellow, Quaternary Research Center, University of Washington: Sea-level history and soil development in Svalbard.

1978-1983 PhD. Quaternary Science, College of Forest Resources, University of Washington: Quaternary History of the Lituya Glacial Refugium, Alaska.

1976-1978 MSc. Entomology, University of Washington: Ecology of Snowfield-Foraging Arthropods on Mount Rainier

1971-1975 B.A. Social Anthropology, University of Washington

EMPLOYMENT HISTORY

2008-present Associate Professor, Geography Program, School of Natural Resources University of Alaska, Fairbanks, Alaska

1994-2008 Research Associate, Institute of Arctic Biology, University of Alaska

1991-2006 Research Associate, Alaska Quaternary Center and Institute of Arctic Biology, University of Alaska

1988-1991 Research Associate, Quaternary Research Center, University of Washington

1985-1988 Director, School for Field Naturalists, University of Vermont

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FIVE RELATED PUBLICATIONS

Mann, D.H. and Streveler, G.P. (2008). Relative sea level history, isostasy, and glacial history in Icy Strait, Southeast Alaska. *Quaternary Research* 69, 201–216.

Irvine, G.V., Mann, D.H., Short, J.W. **S**ixteen-year persistence of slightly weathered *Exxon Valdez* oil under boulder armors on beaches distant from the 1989 spill. (***in revision***)

Short, J.W., Irvine, G.V**.**, Mann, D.H., Maselko, J.M., Pella, J.J., Lindeberg, M.R., Payne, J.R., Driskell, W.B., and Rice, S.D. 2007. Slightly weathered *Exxon Valdez* oil persists in Gulf of Alaska beach sediments after 16 years. Environmental Science and Technology 41:1245-1250.

Irvine, G.V., Mann, D.H., Short, J.W. 2006. Persistence of ten-year old *Exxon Valdez* oil on Gulf of Alaska beaches: the importance of boulder armoring. *Marine Pollution Bulletin* 59(9): 1011-1022.

Irvine, G.V., D.H. Mann, J.W. Short. 1999. Multi-year persistence of oil mousse on high energy beaches distant from the *Exxon Valdez* spill origin. Marine Pollution Bulletin, 38(7): 572-584.

FIVE OTHER SIGNIFICANT PUBLICATIONS

Mann, D.H., Groves, P., Reanier, R.E. and Kunz, M.L. (2010). Floodplains, cottonwood trees, hillslopes and peat: What happened the last time climate warmed suddenly in arctic Alaska? *Quaternary Science Reviews* 29, 3812-3830.

Mann, D.H., Reanier, R.E., Beck, W., and Edwards, J. (2008). Drought, vegetation change, and human history on Rapa Nui (Isla de Pascua, Easter Island). *Quaternary Research* 69, 16–28

Mann, D.H., Crowell, A.L., Hamilton, T.D., and Finney, B.P. (1999). Holocene Geologic and climatic history around the Gulf of Alaska. *Arctic Anthropology* 35, 112-131.

Crowell, A.L. and Mann, D.H. (1996). Human populations, sea level change, and the archaeological record of the Northern Gulf of Alaska coastline. *Arctic Anthropology* 33, 16-37.

Mann, D.H. and Hamilton, T.D. (1995). Late Pleistocene and Holocene Paleoenvironments of the North Pacific Coast. *Quaternary Science Reviews* 14, 449-471.

COLLABORATORS AND CO-AUTHORS (Last 4 years)

Suzanne Anderson (Department of Geography, University of Colorado)
James Edwards (Department of Surgery, Oregon Health Sciences University)
John Edwards (Department of Zoology, University of Washington)
Bruce Finney (Institute of Marine Science, University of Alaska)
Pamela Groves (Institute of Arctic Biology, University of Alaska)
Thomas Hamilton (US Geological Survey, Alaska Branch)
David Meltzer (Department of Anthropology, Southern Methodist University)
Scott Rupp (School of Natural Resources, University of Alaska)
Ronald Sletten (Department of Geology, University of Washington)
John Stone (Department of Geology, University of Washington)
Gail Irvine (US Geological Survey, Alaska Science Center)
Jeffrey Short (NOAA, Auke Bay Laboratory)
Jacqui Michel (Research Planning, Inc., South Carolina)
Zach Nixon (Research Planning, Inc., South Carolina)

Curriculum Vitae for Mark G. Carls

National Marine Fisheries Service, Auke Bay Laboratories email: **mark.carls@noaa.gov**
17109 Pt. Lena Loop Road Phone: (907) 789-6019
Juneau, AK 99801 FAX: (907) 789-6094

Education

M.Sc., 1978, biological oceanography, Dalhousie University, Halifax, Nova Scotia.
B.A., 1975, biology; Magna cum laude, Gustavus Adolphus College, St. Peter, Minnesota.
Additional coursework (30 semester hours), University of Alaska Southeast (statistics, genetics, fish, and misc)

Professional Experience

Fisheries Biologist, 1979-present, Auke Bay Laboratory.
Principal Investigator for *Exxon Valdez* Oil Spill Trustee Council

- Embryo toxicity: pink salmon, Pacific herring, zebrafish
- Pink salmon habitat
- Herring Synthesis
- Mussel and sediment contamination
- Hydrocarbon chemistry: sampling, interpretation, modeling

Biological Review Teams

- Pacific herring, Lynn Canal, Alaska (chairman)
- Status of Pacific herring in Puget Sound, Washington

Habitat and Ecological Processes Team

Recent related publications (lead author only)

Carls MG, Meador JP. 2010. A perspective on the toxicity of petrogenic PAHs to developing fish embryos related to environmental chemistry. Human and Ecological Risk Assessment 15:1084-1098.
Carls, M.G. 2006. Nonparametric identification of petrogenic and pyrogenic hydrocarbons in aquatic ecosystems. Environ Sci Technol. 40:4233-4239.
Carls, M.G., S.D. Rice, G.D. Marty, and D.K. Naydan. 2004. Pink salmon spawning habitat is recovering a decade after the *Exxon Valdez* oil spill. Trans Am Fish Soc 133:834-844.
Carls MG, LG Holland, JW Short, RA Heintz, SD Rice. 2004. Monitoring polynuclear aromatic hydrocarbons in aqueous environments with passive low-density polyethylene membrane devices. Environ Toxicol Chem 23:1416-1424.
Carls MG, Thomas RE, Rice SD. 2003. Mechanism for transport of oil-contaminated water into pink salmon redds. Mar. Ecol. Prog. Ser. 248:245-255.

Other significant publications

Carls MG, Thedinga J.F. 2010. Exposure of pink salmon embryos to dissolved polynuclear aromatic hydrocarbons delays development, prolonging vulnerability to mechanical damage. Marine Ecology Research 69:318-325
Carls MG, Holland L, Larsen M, Collier TK, Scholz NL, Incardona JP. 2008. Fish embryos are damaged by dissolved PAHs, not oil particles. Aquatic Toxicology 88:121-127.
Carls MG., PM Harris, SD Rice. 2004. Restoration of Oiled Mussel Beds in Prince William Sound, Alaska. Mar. Environ. Res. 57:359-376.

Carls MG, GD Marty, JE Hose. 2002. Synthesis of the toxicological impacts of the *Exxon Valdez* oil spill on Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska, U.S.A. Can. J. Fish. Aquat. Sci. 59:1-20.

Carls MG, MM Babcock, PM Harris, GV Irvine, JA Cusick, SD Rice. 2001. Mar Env Res 51:167-190.

Recent Collaborators (excluding ABL staff):

Dr. Mace Barron (P.E.A.K. Research)
Frederick C. Funk (consultant, Juneau, AK)
Dr. Jo Ellen Hose (Occidental University, CA)
Dr. John Incardona (NOAA, Northwest Fisheries Science Center)
Dr. John Kern (NOAA Damage Assessment and Restoration Center Northwest, Seattle, WA)
Dr. Gary Marty (Animal Health Centre, Abbotsford, BC)
Dr. Brenda Norcross (University of Alaska Fairbanks)
Dr. James Payne (Payne Environmental Consultants)
Dr. Terrance J. Quinn II (University of Alaska Fairbanks)
Dr. Robert Spies (Applied Marine Sciences, Livermore, CA)
Dr. Katherine Springman (University of California, Davis)
Dr. Bob Thomas (University of California, Chico).

VI. BUDGET JUSTIFICATION

Personnel: amount requested FY11-FY12 - $ 56.8k

The amount of time requested for personnel is concentrated in year 1, due primarily to the demands of getting the project going (hiring, contracts, purchasing), plus field work. The level greatly decreases in FY12 to reflect the emphasis on data analysis and report/manuscript production. In FY11, $23.4k will be to support G. Irvine's involvement in planning, contracting, hiring, supervising, field work, data quality assurance, etc. Her assistant (FY11 cost = $13.8k) will do the bulk of permitting, contracting, purchasing for the field, testing equipment, mobilization and demobilization of field studies, sample management, data management and processing, GIS integration. The assistant and another assistant will be involved in the FY11 field work .

Travel: amount requested FY11-FY12 – $ 8.7k

Travel expenses are largest in FY11 due to multiple field work trips. Travel in FY12 is associated with presentation of the findings at a scientific conference; the conference is not known at the present, and this could mean that the travel could shift to FY13.

Contractual: amount requested FY11-FY12 - $ 118.5k

On this budget form, the apparent contractual costs are elevated, as the costs for NOAA's analysis of our samples for hydrocarbons is included (FY11, $24.8k). The major sources of contracts are for logistics (boat charters, some fixed wing and helicopter time; Total = $59k) and for the support of Dr. Dan Mann's involvement (through contracts with Mann's Environment). Our contract with D. Mann includes his time, travel costs, and some miscellaneous expenses. Minor contract costs are included for shipment of samples and gear.

Commodities: amount requested FY11-FY12 - $ 3.0k

In FY11 the commodities cost, $3.0k, is for various field gear and supportive supplies.

Equipment: amount requested FY11-FY12 - $0k

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 11-FY12

Budget Category:	Proposed FY 11	Proposed FY 12	TOTAL PROPOSED
Personnel	$44.6	$12.2	$56.8
Travel	$5.1	$3.6	$8.7
Contractual	$110.8	$7.7	$118.5
Commodities	$3.0	$0.0	$3.0
Equipment	$0.0	$0.0	$0.0
SUBTOTAL	$163.5	$23.5	$187.0
General Administration (9% of subtotal)	$14.7	$2.1	$16.8
PROJECT TOTAL	$178.2	$25.6	$203.8
Other Resources (Cost Share Funds)	$31.6	$4.0	$41.6

COMMENTS: **In kind contributions:** NOAA - hydrocarbon analytical support (Mark Carls, 2 months @$8k/mo= $16k; Jeep Rice, 1 month @$9k/mo = $9k; Mandy Lindeberg, 1 month @ $7k/mo; Total = $32k); USGS (Gail Irvine, 0.5 mo @$11.7/mo = $6k); NPS - field experience/support ($3.6k) - **NOTE:** because no Multi-Trustee_Multi-year forms were available, costs for NOAA to do the hydrocarbon analyses are included on this form, under Contracts. The total budget amount that should go to NOAA is the cost of the hydrocarbon analyses ($24.8k), plus 9% GA ($2.2k), which totals $27.0k. The USGS portion of the budget should be reduced accordingly. This does not affect total project cost, which is reflected on this form.

FY11-12

Project Title: Lingering Oil - GOA
Lead PI: Irvine
Agency: USGS

FORM 3A
TRUSTEE AGENCY SUMMARY

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 11-FY12

Personnel Costs:		GS/Range/	Months	Monthly		Personnel
Name	Project Title	Step	Budgeted	Costs	Overtime	Sum
						0.0
Gail Irvine	Research Ecologist	GS 13/7	2.0	11.7		23.4
no name at present	Biologist	GS 7/1	3.0	4.6		13.8
no name at present	Biologist/geologist	GS 5/1	2.0	3.7		7.4
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		7.0	20.0	0.0	
					Personnel Total	$44.6

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
					0.0
Anchorage - Homer, RT	0.3	6	9	0.2	3.6
Invitational travel for Auke Bay person (to aid deployment of LDPEs)					0.0
Juneau- Homer RT	0.7	1	4	0.2	1.5
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$5.1

FY11

Project Title: Lingering Oil - GOA
Lead PI: Irvine

FORM 3B
PERSONNEL &
TRAVEL DETAIL

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 11-FY12

Contractual Costs: Description	Contract Sum
Contract with Mann's Environment (Dr. Dan Mann) - time, travel, phone, misc.	
2.0 mo. of Mann's time @$12k/mo = $24k; Travel: 2 trips Fairbanks -Homer RT (2x 0.5 = 1.0); misc = 0.5	25.5
Boat charter, 12 days, Katmai and Kenai Fjords coast @ $4k/day	48.0
Helicopter charters (Homer to Katmai coast) 2 days @ $5k/d	10.0
Air charter from Homer to boat and return; to support limited time of NOAA staff in field	1.0
Shipment of samples, gear	1.5
Hydrocarbon Analyses (NOAA Auke Bay Laboratory): GCMS (and prep and shipping) of LDPEs, 28 @$350 = $9.8k	
GCMS (mussel and sediments), 20 @$750 = $15k	24.8
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$110.8

Commodities Costs: Description	Commodities Sum
Field and sampling supplies (e.g., I-chem jars; rock drill and accessories; misc.)	2.0
Camera/computer accessories, software	1.0
Commodities Total	$3.0

FY11

Project Title: Lingering Oil - GOA
Lead PI: Irvine

FORM 3B CONTRACTUAL & COMMODITIES DETAIL

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 11-FY12

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
		New Equipment Total	$0.0

Existing Equipment Usage: Descriptior	Number of Units	Inventory Agency

FY11

Project Title: Lingering Oil - GOA
Lead PI: Irvine

FORM 3B EQUIPMENT DETAIL

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 11-FY12

Personnel Costs:		GS/Range/	Months	Monthly		Personnel
Name	Project Title	Step	Budgeted	Costs	Overtime	Sum
						0.0
Gail Irvine	Research Ecologist	GS-13/7	1.0	12.2		12.2
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		1.0	12.2	0.0	
					Personnel Total	$12.2

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
					0.0
Travel to present results at conference; estimate	1.8	1	6	0.3	3.6
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$3.6

FY12

Project Title: Lingering Oil - GOA
Lead PI: Irvine

FORM 3B
PERSONNEL &
TRAVEL DETAIL

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 11-FY12

Contractual Costs: Description	Contract Sum
Contract with Mann's Environment (Dr. Dan Mann); includes 0.5 mo Dan's time@ $12k/mo = $6k	6.0
Page charges	1.0
Registration for scientific conference	0.5
Finalizing report/manuscript for EVOS/ARLIS	0.2
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$7.7

Commodities Costs: Description	Commodities Sum
Commodities Total	$0.0

FY12

Project Title: Lingering Oil - GOA
Lead PI: Irvine

FORM 3B CONTRACTUAL & COMMODITIES DETAIL

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 11-FY12

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
		New Equipment Total	$0.0

Existing Equipment Usage: Descriptior	Number of Units	Inventory Agency

FY12

Project Title: Lingering Oil - GOA
Lead PI: Irvine

FORM 3B EQUIPMENT DETAIL