A 6,300-Year Old Window into the Past: Retrospective Analysis of Nearshore Marine Communities Based on Analysis of Archeological Material and Isotopic Analysis

Project Number:	02656
Restoration Category:	Research

Proposers:	Dr. Gail Irvine USGS-BRD Alaska Biological Science Center 1011 E. Tudor Rd. Anchorage, AK 99503
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Lead Trustee Agency:	DOI--USGS
Cooperating Agencies:	
Alaska SeaLife Center:	No
Duration:	2 years
Cost FY 02:	$ 109.9
Cost FY 03:	$ 28
Geographic Area:	Gulf of Alaska
Injured Resource/Service:	Intertidal communities, clams

ABSTRACT

The primary purpose of this proposal is to investigate long-term (6,300 year) patterns of productivity and relative species abundances in nearshore, intertidal communities via retrospective analyses. These analyses will focus on excavated midden remains of a very rich, well-dated archeological site along the Katmai National Park and Preserve coast. Changes in nearshore marine communities will be assessed through examination of relative species abundances, size-frequency analysis, and other indicators of habitat changes. Isotopic analysis of shells will provide an assessment of long-term productivity patterns in the nearshore marine environment as related to major periods of climate change.

INTRODUCTION

Changes in marine ecosystems occur on multiple scales of space and time. In the near-term, recent biological information suggests that patterns in the abundances of marine organisms and productivity of their associated systems may change in a low-frequency cyclical manner (e.g., regime shifts; Francis et al., 1998; Hare and Mantua, 2000), or may undergo longer-term directional change (e.g., Bering Sea; Schell, 1998, 2000). Long-term changes may reflect changes in climate that have spanned decades, centuries or millenia. Such changes are known for coastal regions from a variety of data. Within Alaska, the coastal paleoenvironments and climate of the late Pleistocene and Holocene have been reviewed by Mann and Hamilton (1995) and Mann et al. (1998, 1999).

Long-term changes in marine ecosystems are difficult to investigate, and the entrees into such data are limited. Cores, isotopic analyses, pollen-grain analyses, tree-ring data, and archeological investigations have been used to examine long-term biological data. A combination of data may provide a multi-faceted approach that allows integration and interpretation of changes and processes occurring in nearshore marine environments.

A tremendous opportunity to gain long-term perspective on biological change in nearshore marine communities bordering the Gulf of Alaska is afforded by recent excavations of a coastal archeological site along the Katmai National Park and Preserve coast. This exceptionally rich site, excavated by a team lead by Dr. Jeanne Schaaf, has midden material dated to at least 6,300 radiocarbon years before present (BP). This site is unusual in its long history, excellent organic preservation, and well-defined stratigraphy, which allows layers to be related to dated occupation surfaces. The material at the site is quite abundant. The non-mixed nature of the material contributes to the clarity of the stratigraphy. There are at least 50 ^{14}C values for the site, determined from occupation surfaces and associated midden materials. The site appears to have been occupied pretty continuously over the last 6300 years except for a gap from approximately 2,000 to 4,000 years before present. This same gap has been noted from other sites across the whole region (the northern Alaska Peninsula and Kodiak). What sets this site apart from other sites along the Kenai Peninsula coast and SE Alaska is the abundance of the biological material and its excellent preservation. It is both the oldest identified and most extensively excavated site along the northern Alaska Peninsula.

In addition to the suite of ^{14}C values from the site, there are at least 50 other values from the Katmai coastal area that provide a broader context for the site. Paleoclimate data have been collected in nearby areas, including analysis of a peat deposit that spans 10,000 years and that contains a tephra (volcanic ash) stratigraphy and vegetational history of the entire Holocene (Hilton, 2000). The combination of radiocarbon dates and paleoclimate information provides a context within which a more detailed analysis of nearshore species found in midden remains can be made.

We propose a retrospective analysis of midden material to determine long-term patterns in nearshore productivity, their relation to climate changes, and ecological changes in composition of nearshore marine communities.

NEED FOR THE PROJECT

A. Statement of Problem

The GEM program is focused on monitoring species and processes in order to describe and understand changes in the oceanic and nearshore environments of the Gulf of Alaska. As an early part of the program, it has espoused the need for retrospective analyses in order to enrich our understanding of long-term changes in this region. The shorter-term cyclical patterns in species abundances and climate that are a focus of much of GEM, must be understood against the broader spectrum of truly long-term (century to millenial) changes and more directional climate change (e.g., global warming). Retrospective analyses of archeological sites may allow development of such a perspective. The goals of the proposed project are to develop long-term patterns of productivity and relative species abundances in the nearshore and investigate their relationship to climate change.

B. Rationale/Link to Restoration

In order to understand the effects of the *Exxon Valdez* oil spill and other perturbations, we need to have an increased understanding of how species are changing through time. This project focuses on the nearshore environment, an area that was heavily injured by the *Exxon Valdez* oil spill. Developing an understanding of long-term change in nearshore marine communities and investigating the relationship between productivity and climate will aid in the development of the GEM monitoring plan.

C. Location

Study is focused on the Mink Island archeological site on the Katmai National Park and Preserve coast, bordering the Gulf of Alaska.

COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

Retrospective analysis of archeological specimens involves the revealing of human use patterns of resources. This could enrich the cultural history of local native groups. Additionally, querying local groups about findings may reveal whether similar use of nearshore species is made now or was in the recent past. We will be happy to discuss our findings with native groups.

PROJECT DESIGN

A. Objectives

1. Assess long-term patterns in nearshore productivity via isotopic analysis of shells of selected invertebrate taxa found in different, dated layers of middens.

2. Evaluate the paleoecology of the assemblages found in the middens via relative species composition, abundances, etc., and compare to patterns of productivity.

B. Methods

The hypotheses and methods used to address them are outlined below.

> H1: Changes in nearshore productivity, as evidenced by isotopic signatures of invertebrate shells, have changed in relation to major climate changes or trends in the Holocene.
>
> H2: Changes in species composition, sizes, etc., of midden species assemblages reflect changes in climate, habitat, or human use patterns.

The methods used to test each of these hypotheses are given below.

H1: Changes in nearshore productivity, as evidenced by isotopic signatures of invertebrate shells, have changed in relation to major climate changes or trends in the Holocene.

Recent analyses of stable isotope ratios of baleen of bowhead whales suggest declining productivity in the Bering Sea (Schell, 1998, 2000). In this case, analysis of carbon isotope ratios provided a means of indirectly assessing relative primary production. The bowhead whales feed on zooplankton that they filter with their baleen, and are thus one step removed from the phytoplankton primary producers. Bivalve molluscs, the dominant constituents of the middens at the Mink Island site, are also filter feeders, but feed more commonly on phytoplankton, thus responding more directly to patterns in primary productivity. Although the relationship of short-term changes in primary productivity may be reflected in annular growth rates of bivalves, this type of analysis is not appropriate for archeological material where the dating of the material is not sufficiently precise.

Thus, we propose a combination of carbon and nitrogen isotopic analyses ($\delta^{13}C$, $\delta^{15}N$, ^{14}C) of bivalve shells from the Mink Island midden to examine long-term changes in nearshore primary productivity. Carbon is transferred relatively conservatively in food webs and stable isotopic analysis of $\delta^{13}C$ gives excellent information on sources and magnitudes of productivity. Recent studies of the relationships between stable carbon isotope ratios in phytoplankton and the growth of diatoms (Laws et al., 1995) and for haptophytes inhabiting differing ocean productivity regimes (Bidigare el al., 1997) indicate a close relationship between $\delta^{13}C$ and algal growth rates (Schell, 1998, 2000).

These findings provide a mechanism for linking $\delta^{13}C$ values and the magnitude of primary production, which can then be expressed in higher order consumers.

The addition of $\delta^{15}N$ analysis may allow finer discrimination of productivity differences, as changes in stable nitrogen isotope ratios also are related to productivity patterns, with higher $\delta^{15}N$ values related to higher productivity patterns (D. Schell, pers. comm.; Altabet and Francois, 1994). It must be recognized that these relationships and linkages are in their early stages of development. However, the approach here is to look for patterns in isotopic values that correlate with major climate periods experienced in the Gulf of Alaska (Fig. 2).

Another measure of productivity (via upwelling), and one that has broader implications for the dynamics of deep ocean circulation is ^{14}C analysis. Comparison of the ^{14}C age differences revealed by analysis of paired wood (terrestrial) and marine shell samples reveal differences in ^{14}C age of atmospheric and surface marine carbon reservoirs. In regions of upwelling, this is indicative of global thermohaline circulation. In subpolar regions, reservoir ages can provide information on the intensity of upwelling and mixing processes (Southon et al., 1990).

Our first hypothesis is that patterns of change in primary productivity, as evidenced by isotopic analyses, are correlated with changes in climate. Mann et al. (1998) have detailed the climatic history along the Gulf of Alaska (Fig. 1). We will select samples to analyze for natural stable isotopes ($\delta^{13}C$, $\delta^{15}N$) based on occurrence of radiocarbon dates (Fig. 2; Hilton, 2000) relative to the major climate periods. The well-defined stratigraphy of the Mink Island site, coupled with the abundance and fine-preservation of the material makes possible analytical approaches that tie ^{14}C dates closely to biological material. Bivalve material is extremely abundant through time. Bivalve shells tightly associated with the targeted radiocarbon dates will be analyzed. During the excavation of the Mink Island site, fine-grained recovery techniques were used to ensure that the occupations surfaces were linked to the faunal refuse outside the lived-upon surfaces. All excavation surfaces, artifacts, and select faunal elements were 3-point provenanced for tight control, leading to an extremely well-defined stratigraphy. The abundance of the biological material, and the presence through time of some abundant modern species (e.g., *Saxidomus giganteus* and *Mytilus trossulus*) should facilitate consistent analytical approaches. We estimate that 20 different time strata will be targeted, with an estimate of 20 bivalves analyzed for each radiocarbon date. Sample sizes will be based on the variability revealed by the isotopic analyses, coupled with availability of material. Preliminary testing of techniques will target recent material. Cross-sections of shells will be analyzed in order to integrate the temporal isotopic signal, since shells cannot be dated precisely (e.g., radiocarbon dating of house floors has some error associated with it [approx. ± 50-100 years], and variously shaped shell fragments may need to be analyzed). Additional preparation of shell material prior to isotopic analysis will be needed to remove inorganic carbonate. This makes the analyses more difficult, but still feasible (Schell, pers. comm.).

^{14}C Analysis: Information obtained by Southon et al. (1990) from radiocarbon dating of shells and associated wood from coastal sediments in British Columbia suggest similar values to the present for reservoir age for most of the samples. However, data from a radiocarbon age of around 6,400 BP give a markedly different reservoir age than the older samples, suggesting that Holocene ocean circulation was much more variable than previously thought. Analysis of shell data from the exposed Mink Island site, when compared with associated charcoal dating of occupied surfaces (the latter ^{14}C data already obtained), would provide another time series of ocean mixing variability and the relationship of upwelling patterns across changing climate patterns of the Holocene. Additionally, such a time series, when compared with the British Columbia data would provide a broader view of long-term ocean circulation and its variability. This type of analysis cannot be done except at exposed sites, such as the Mink Island site bordering the Shelikof Strait, that are affected by coastal upwelling. A set of bivalve samples (estimated n=40) that are closely linked to radiocarbon-dated charcoal (from occupied surfaces) will be analyzed for ^{14}C via accelerator mass spectroscopy (AMS).

H2: Changes in species composition, sizes, etc., of midden species assemblages reflect changes in climate, habitat, or human use patterns.

An ecological analysis of the archeological midden material may reveal changes in the species composition and structuring of the populations through time. The temporal patterns in relative species composition of shell material at the site will be examined. Based on review of the relative abundance of the most common species (Foster, 1998, 2000) and the condition of the material, size-frequency data will be collected on one or a few species. These patterns will then be compared to known climate trends and productivity information provided by the isotopic analyses. Since many of the species abundant at the site (e.g., *Mytilus trossulus*, *Saxidomus giganteus*) are common present-day organisms, an ecological analysis of species shifts may suggest changes in climate, changes due to habitat shifts (perhaps due to sea level changes wrought by tectonic activity), or changes in human use patterns. Analysis of midden fauna in other locales (e.g., relative species abundance or size structure of abalones in the Channel Islands) has revealed changes thought to be caused by shifting ocean climate (Glassow, 1993) or alterations in predation intensity (Douros, 1993). Interpretation of the human use patterns of the site will be incorporated into the analysis of climate, species abundances, and habitat changes in order to evaluate the observed biological changes as comprehensively as possible.

Cooperating Agencies, Contracts, and Other Agency Assistance

We will continue interaction and cooperation with researchers doing natural stable isotope analyses (Dr. Tom Kline, Prince William Sound Science Center; Dr. Don Schell, University of Alaska, Fairbanks). Contracts for natural stable isotope analysis are expected with the University of Alaska, Fairbanks. Another contract will be arranged for ^{14}C analysis via accelerator mass spectroscopy (AMS).

SCHEDULE

A. Measurable Project Tasks for FY02 (October 1, 2001- September 30, 2002)

Oct 1– July 31:	Set up contracts
Oct. 1- March 31:	Evaluation of climate record, midden materials for selection of target dates and shells for analysis
Oct 1 - July 31:	Evaluate isotopic techniques, preliminary assessments of recent material, test archeological material
Nov 30– Sept 30:	Isotopic analysis of shell material.
Jan 14-23 (2 days):	Participate in EVOS Annual Restoration Workshop
February 1- Sept 30:	Ecological analyses of midden materials
August, 2002	Present project results to Ecological Society of America
April 15, 2003	Draft final report

B. Project Milestones and Endpoints

FY02: Natural stable isotopic analyses of recent (test) bivalves and archeological midden shells
Radiocarbon (^{14}C) analysis of selected clam shells
Data analysis
Ecological analyses of composition/size structure of selected midden species

FY03: Data analysis and synthesis, draft final report (April 15, 2003), manuscript preparation

C. Completion Date

A draft final report will be produced April 15, 2003.

PUBLICATIONS AND REPORTS

A draft final report will be produced April 15, 2003. Manuscripts for publication will be produced in FY03. Three manuscripts are planned: one focused on the relationship between isotopic composition of shells and major climate patterns over the last 7,000 years, a second focused on the ecological analysis of the midden material through time, and a third examining the implications of the ^{14}C analysis for long-term ocean circulation.

PROFESSIONAL CONFERENCES

I plan to present the ecological analysis of midden materials to the Ecological Society of America (FY02); these meetings are held in August of each year. In FY03, I plan to present a paper on the isotopic analyses to the annual meeting of the American Society of Limnology and Oceanography in Albuquerque, NM.

NORMAL AGENCY MANAGEMENT

The work involved in this project is not part of normal agency management.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

As the research proposed is very multidisciplinary in nature, we will be coordinating and integrating information with other researchers using stable isotopic analyses, especially those involved in retrospective analyses. Additionally, we will integrate our paleoecological analyses with available information from other appropriate archeological sites bordering the Gulf of Alaska.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

N/A

PROPOSED PRINCIPAL INVESTIGATORS

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PRINCIPAL INVESTIGATORS

Dr. Irvine is a Marine Ecologist with the Alaska Biological Science Center. She has extensive experience in coastal ecosystems in Alaska, the Pacific Northwest and the tropics. Her primary research interests have focused on population and community ecology of nearshore systems, oil effects, the design of long-term monitoring programs and associated research, plant-herbivore interactions, succession, and life history dynamics. She is also interested in broad-scale and long-term research. Gail has been a Principal Investigator on several EVOS-funded studies involving oiled mussel beds and the residual oiling of coastlines and has been involved in publishing results from both projects. Recently she was invited to author a chapter on "Persistence of Spilled Oil on Shores and its Effects on Biota" for The Seas at the Millenium, a three-volume assessment of the state of the world's oceans published by Elsevier Scientific Press. Over the last 4 years, she has also been involved in designing protocols for broad-scale, inferential monitoring of intertidal assemblages in Glacier Bay National Park and Preserve, then adapting the design for the small coastline of Sitka National Historical Park.

Dr. Schaaf is Director of the Lake Clark-Katmai Studies Center of the National Park Service. She has organized and spearheaded the archeological excavations occurring over the last four years at Mink Island, Katmai National Park and Preserve. In her previous position as an archeologist in the Regional Office of the NPS, she was responsible for managing the Shared Beringian Heritage Program, the National Archeological Survey Initiative Gulf of Alaska Coastal Survey and the Alaska region Cultural Sites Inventory. Jeanne has been both editor and author of publications concerning cultural traditions and archeological studies in Alaska.

Dr. Mann is a Research Associate at the University of Alaska, Fairbanks, with degrees in Anthropology, Forest Entomology, and Soil Science and Quaternary Studies. His research has focused on Holocene glacial histories, paleoclimate reconstructions, dynamics of coastal systems (geologic), dynamics of developing plant assemblages, and oil spill studies. He has published at least 12 papers on the paleoclimate of Alaska, with additional publications having different geographic focus. His CV is attached.

LITERATURE CITED

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2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002	PROPOSED FY 2002 TRUSTEE AGENCIES TOTALS ADEC	ADF&G	ADNR	USFS	DOI
							$109.9
Personnel	$0.0	$48.4					
Travel	$0.0	$3.4					
Contractual	$0.0	$47.5					
Commodities	$0.0	$0.0					
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS				
Subtotal	$0.0	$99.3			Estimated FY 2003		
General Administration	$0.0	$10.6					
Project Total	$0.0	$109.9			$28.0		
Full-time Equivalents (FTE)	0.0	0.7					
	Dollar amounts are shown in thousands of dollars.						
Other Resources	$0.0	$0.0			$0.0	$0.0	

Comments:

FY02

Revised: 7/9/01

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Lead Agency: DOI--USGS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002
Personnel		$44.2
Travel		$3.4
Contractual		$47.5
Commodities		$0.0
Equipment		$0.0
Subtotal	$0.0	$95.1
General Administration		$10.0
Project Total	$0.0	$105.1
Full-time Equivalents (FTE)		0.7
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

Dollar amounts are shown in thousands of dollars.

FY02

Revised: 7/9/01

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Agency: DOI-USGS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Personnel Costs:		GS/Range/	Months	Monthly		P
Name	Position Description	Step	Budgeted	Costs	Overtime	
Gail Irvine	Marine Ecologist	GS 12/9	2.0	8.3		
Vacant	Biologist	GS 9/1	6.0	4.6		
	Subtotal		8.0	12.9	0.0	
					Personnel Total	

Travel Costs:	Ticket	Round	Total	Daily	F
Description	Price	Trips	Days	Per Diem	
Consult with Dr. Don Schell, University of Alaska, Fairbanks;					
review lab and procedures	0.2	1	2	0.2	
Present results to Ecological Society of America, Annual Meeting,					
August 4-8, 2002; Tuscon, AZ	1.3	1	6	0.2	
Registration	0.3	1			
				Travel Total	

FY02

Revised: 7/9/01

Project Number: 02656
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Agency: DOI-USGS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

Contractual Costs:	P
Description	
Research Work Order to UAF, Dan Mann Natural Stable Isotopic Analyses, 500 samples @ $26/sample AMS analysis of shell material, 40 samples @ $600/sample	
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	

Commodities Costs:	I
Description	
Commodities Total	

FY02

Revised: 7/9/01

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Agency: DOI-USGS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

New Equipment Purchases:		Number	Unit	P
	Description	of Units	Price	

Comments:

ew Equipment Total

Number
of Units

FY02

Revised: 7/9/01

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Agency: DOI-USGS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002
Personnel		$4.2
Travel		$0.0
Contractual		$0.0
Commodities		$0.0
Equipment		$0.0
Subtotal	$0.0	$4.2
General Administration		$0.6
Project Total	$0.0	$4.8
Full-time Equivalents (FTE)		0.0
	Dollar amounts are shown in thousands of dollars.	
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

FY02

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Agency: DOI-NPS

Revised: 7/9/01

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Personnel Costs:		GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	P
Name	Position Description					
Jeanne Schaaf	Archeologist	GS 12/9	0.5	8.3		
	Subtotal		0.5	8.3	0.0	
					Personnel Total	

Travel Costs:	Ticket Price	Round Trips	Total Days	Daily Per Diem	F
Description					
				Travel Total	

FY02

Revised: 7/9/01

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Agency: DOI-NPS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

Contractual Costs:	P
Description	
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	

Commodities Costs:
Description
Commodities Total

FY02

Revised: 7/9/01

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Agency: DOI-NPS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Personnel Costs:				Months	Monthly		P
	Name	Position Description		Budgeted	Costs	Overtime	
	Dan Mann	Quaternary geologist: paleoclimates and geomorphology		1.0	9.1		
			Subtotal	1.0	9.1	0.0	
						Personnel Total	

Travel Costs:		Ticket	Round	Total	Daily	P
	Description	Price	Trips	Days	Per Diem	
					Travel Total	

FY02

Revised: 7/9/01

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Lead Agency: USGS contract to UAF

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

Contractual Costs:	P
Description	
Contractual Total	

Commodities Costs:	P
Description	
Commodities Total	

FY02

Revised: 7/9/01

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Lead Agency: USGS contract to UAF

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

New Equipment Purchases:	Number of Units	Unit Price	P
Description			
Those purchases associated with replacement equipment should be indicated by placement of an R. **New Equipment Total**			

Existing Equipment Usage:	Number of Units
Description	

FY02

Revised: 7/9/01

Project Number: 02656
Project Title: A 6,300-Year Old Window into the Past...
Lead Agency: USGS contract to UAF