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Proposal No 52 **Date Submitted** November 29, 2007 **Date Received**

Project Title: Walrus Distributional and Foraging Response to Changing Ice and Benthic Conditions in the Chukchi Sea

Project Period: from June, 2008 to May, 2010

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Research Priority:

Pacific Walrus in the Chukchi Sea

Summary of Proposed Work: Walruses make foraging trips from sea ice and land to feed on benthic organisms. During ice-free conditions in the Chukchi Sea, their access to offshore foraging areas is reduced and they become more dependent on nearshore resources. We propose to compare the foraging range and effort of walruses using land haul-outs as a consequence of shelf-free ice conditions to walruses using ice haul-outs in the Chukchi Sea. We predict that foraging effort will be greater, and foraging range will be less, when walruses use land haul-outs than when they are able to use ice haul-outs. The foraging costs due to increased travel time to food patches from land may be significantly higher than the costs from sea ice haul-outs and result in reduced energy stores before wintering in the Bering Sea. We will also compare nearshore to offshore infaunal and epifaunal walrus prey communities and changes in these communities that may have occurred from retrospective analysis of archived benthic data. We predict that changing ice conditions over the past decade has resulted in a redistribution of productive areas and community structure. In addition, we predict that the community structure of prey that is accessible to walruses from land haul-outs will be different than that in offshore areas where they can be accessed by walruses using sea ice haul-outs. This project will provide insights into environmental mechanisms responsible for changing distributions and foraging behaviors in walruses from climate change that can ultimately impact benthic communities and walrus vital rates.

Total Funding Requested From NPRB:

$ 91,423.00	USGS Alaska Science Center
$ 84,926.00	Chesapeake Biological Laboratory (CBL)
$ 176,349.00	

Total Other Support:

$ 81,755.00	USGS Alaska Science Center
$ 81,755.00	

Legally Binding Authorizing Signature and Affiliation:

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RESEARCH PLAN

A. Project Title

Walrus Distributional and Foraging Response to Changing Ice and Benthic Conditions in the Chukchi Sea

Walrus Foraging Response to a Changing Chukchi Sea

B. Proposal Summary

Walruses make foraging trips from sea ice and land to feed on benthic organisms. During ice-free conditions in the Chukchi Sea, their access to offshore foraging areas is reduced and they become more dependent on nearshore resources. We propose to compare the foraging range and effort of walruses using land haul-outs as a consequence of shelf-free ice conditions to walruses using ice haul-outs in the Chukchi Sea. We predict that foraging effort will be greater, and foraging range will be less, when walruses use land haul-outs than when they are able to use ice haul-outs. The foraging costs due to increased travel time to food patches from land may be significantly higher than the costs from sea ice haul-outs and result in reduced energy stores before wintering in the Bering Sea. We will also compare nearshore to offshore infaunal and epifaunal walrus prey communities and changes in these communities that may have occurred from retrospective analysis of archived benthic data. We predict that changing ice conditions over the past decade has resulted in a redistribution of productive areas and community structure. In addition, we predict that the community structure of prey that is accessible to walruses from land haul-outs will be different than that in offshore areas where they can be accessed by walruses using sea ice haul-outs. This project will provide insights into environmental mechanisms responsible for changing distributions and foraging behaviors in walruses from climate change that can ultimately impact benthic communities and walrus vital rates.

C. Project Responsiveness to NPRB Research Priorities or Identified Project Needs

This proposal responds to NPRB's 2008 RFP under section 1.d.III. Pacific Walrus in the Chukchi Sea, seeking "research to investigate the effects of changing environmental conditions, particularly sea ice and benthic habitats, and/or the effects of coastal and offshore human activities and disturbance on the distribution and population dynamics of Pacific walrus in the Chukchi Sea". Our project will provide information on the foraging range and behavior of walruses using land haul-outs along the Alaska coast in the Chukchi Sea in fall. In 2007, thousands of walruses hauled out along the Alaska coastline because of the lack of sea ice over the continental shelf. This atypical haul-out behavior could result in more restricted access to foraging areas and benthic prey species, poorer body condition from altered foraging behaviors adversely affecting vital rates, and increased predation risk and disturbances from human contact. Similar behaviors have been observed by Russian colleagues in northern Chukotka with dramatic impacts to walruses in fall of 2007. Our proposal will demonstrate how reduced sea ice conditions impacts walrus distribution and foraging behaviors in context to a changing benthic environment.

D. Soundness of Project Design and Conceptual Approach

Background

The Pacific walrus (*Odobenus rosmarus divergens*) is a large predator of the Arctic benthos. Females and males weigh about 850 and 1250 kg, respectively, and during much of the year, consume 3-5% of their total body mass per day (~34-50 kg/d). During pregnancy and lactation, females increase their average energy intake by 40-50% above these levels. Calves are born in spring (twins are rare), are provided high parental care, and suckle for 1-2 years (Fay 1985).

Walrus prey represent over 60 genera and 10 phyla, ranging from sipunculids to seals and seabirds (Fay 1982, Sheffield et al. 2001); however, walruses are predominately benthic foragers and feed mostly on mollusks (Fay 1985). SCUBA observations in shallow waters indicate that walruses are capable of feeding at a rate of 6-8 clams per minute and can take over 53 clams in a single dive (Oliver et al. 1983, Born et al. 2003). Although walruses are capable of deep diving (> 250 m, Born et al. 2005), they usually feed in waters < 80 m deep over the continental shelf where their prey are in highest density (Fay and Burns 1988).

After the breeding period in winter, most adult female and young walruses migrate in spring with the receding ice into the Chukchi Sea, while most adult males remain in the Bering Sea and move to land haul-outs along the coast of Russia and Bristol Bay, Alaska. Because female and young walruses reside in the Chukchi Sea for roughly six months of the year (Fay 1982), benthic production and the spatiotemporal distribution of walrus prey in the Chukchi Sea are very important.

Relevant benthic studies in the Chukchi Sea include an infaunal survey of the Chukchi and Bering Seas by Stoker (1981), surveys associated with the Outer Continental Shelf Environmental Assessment Program (Hood and Calder 1981a, b), studies within the NSF Shelf-Basin Interactions project (Grebmeier and Harvey 2005), and studies in the southern and northern Chukchi Sea (Grebmeier et al. 1988, Grebmeier et al. 1989, Grebmeier 1992, Grebmeier et al. 2006a, Grebmeier and Barry 2007). Feder et al. (1994a, 1994b) describes infaunal and epifaunal mollusk communities as well as general benthic populations in the northeastern Chukchi Sea based on samples collected in 1986 and 1990. Grebmeier et al. (2006a) reviewed ecosystem dynamics in the northern Bering and Chukchi Seas and down slope to the Arctic Basin and incorporated data from pertinent benthic research cruises from 1974-2004. Foraging areas of walruses in the Chukchi Sea are poorly defined. Side-scan sonar products from 1970-80's have been used to delineate some large-scale feeding areas in northeastern Chukchi Sea from the detection of walrus foraging furrows (Nelson et al. 1994).

Only a few observational data sets exist that robustly describe walrus distributions in the Chukchi Sea, and include four U.S./Russian Joint Surveys, which were conducted every 5-years beginning September 1975 (Gilbert 1999). The migration of walruses through the Chukchi Sea is known generally from a compilation of published and unpublished historical accounts of walrus sightings from land, ship, and aircraft (Fay 1982, Fay et al. 1984). A large number of walruses migrate northward along coastal leads between Point Hope and Point Barrow, Alaska, in summer, and typically occupy an area from about 170º W to Point Barrow in the eastern Chukchi Sea (Fay et al. 1984). Years of intermediate ice are perhaps optimal ice conditions for walruses, because the unconsolidated ice is widely distributed and allows walruses to access many feeding areas (Fedoseev 1990). In fall, walruses are generally distributed within a band of open ice within about 150 km of the southern ice edge (Gilbert 1999). Little is known of their southward migration routes in late autumn.

Introduction and Proposed Work

The Chukchi Sea is an area of particular interest relative to walrus population dynamics and management. The potential impact of climate warming on the walrus population is of immediate concern. From 1953 to 2006, Arctic summer sea ice extent has decreased sharply, and the decline may be occurring faster than forecasted (Stroeve et al. 2007). The continental shelf in the Chukchi Sea was effectively ice-free in 5 of the last 6 years (2002-2007), but only once in the previous 23 years (1979-2001) (unpubl., passive microwave satellite imagery, NSIDC data). Because walruses use sea ice to rest, molt, and give birth, and sea ice provides walruses access to offshore foraging areas and refuge from predation and disturbance (Fay 1982), reduced sea ice conditions could have large impacts on the walrus population, although causal mechanisms that are not fully understood. During fall 2007, Russian colleagues observed tens of thousands of female and young walruses on land haul-outs on the northern coast of Chukotka with reports of thousands of mortalities from stampeding adults during disturbances at the haul-outs and malnourished individuals.

Regulatory agencies are also interested in knowing more about walrus distributions in the Chukchi Sea in order to mitigate impacts to walruses from resource development. In August 2006, Minerals Management Service (MMS) released a proposed oil and gas leasing program for 2007-2012 (U.S. Minerals Management Service 2006). The program includes consideration of whole or partial blocks in the Chukchi Sea Planning Area, covering about 34 million acres. The migration routes and foraging areas of walruses in the Chukchi Sea are of keen interest to the oil and gas industry and government regulators for mitigating potential impacts to walruses from offshore exploration and development. The MMS 2008 Annual Study Plan identifies the need for information on migration routes and foraging areas because movement and habitat utilization by walruses might be affected by oil and gas exploration (U.S. Minerals Management Service 2007). Ship-based geophysical seismic surveys were initiated by industry in 2006 and are projected to continue for the next several years. U.S. Fish and Wildlife Service is responsible for management and conservation of the Pacific walrus, and similar to MMS, needs information on the movement and foraging areas of walruses in the eastern Chukchi Sea for impact assessments and to develop mitigation regulations under the authority and guidance of the Marine Mammal Protection Act. Policy decisions will likely consider potential impacts to essential walrus habitat, such as important foraging areas, and actions that may alter significant walrus behaviors, such as foraging.

Sea ice and benthic habitats

Recent reductions in sea ice in the Arctic have the potential to cause broad ecosystem change that may shift the benthic-oriented system to one more dominated by pelagic processes. The vulnerability of the ecosystem to environmental change is thought to be high, particularly as sea ice extent declines and seawater warms (Grebmeier et al. 2006b). The duration and extent of seasonal sea ice, seawater temperature, and water mass structure are critical controls on water column production, organic carbon cycling, and pelagic–benthic coupling. Because the productive areas in the Chukchi Sea are associated with short food chains and shallow depths, changes in lower trophic levels can rapidly impact higher trophic organisms such as walruses (Grebmeier et al. 2006a).

Benthic infaunal biomass reflects interannual carbon deposition to the seafloor on the shallow Chukchi Sea continental shelf (Stoker 1981, Grebmeier et al. 1988, Grebmeier et al. 1989, Grebmeier and Barry 1991, Grebmeier 1992, Feder et al. 1994a, Feder et al. 1994b, Grebmeier et al. 2006a and references therein, Grebmeier and Barry 2007). The persistent location of walruses in the summer off the NW coast of Alaska are suggestive of high food resources in sediments of this region. The NE outer continental shelf of the Chukchi Sea and head of Barrow Canyon are at the interface of the Chukchi and Beaufort Seas outer shelf and slope regions and are clearly a key conduit for transformed Pacific water and associated organisms that transit to the deep Arctic Basin (Grebmeier and Harvey 2005). It is likely that large-scale changes on the shelf, forced by environmental change to Pacific inflow and ice dynamics, will cascade to higher trophic organisms in this region. In addition to food supply and community composition, sediment grain size reflects local current speed. Sediment grain size is the major factor in structuring benthic faunal community composition; by comparison, organic carbon drives biomass itself (Grebmeier et al. 1995, Grebmeier et al. 2006a and references therein).

Bivalves, polychaetes, and sipunculids dominate the general infaunal community of the northern Chukchi Sea, where average infaunal benthic biomass is 5-15 g C m^{-2} (200-400 g wet wt m^{-2}; Fig. 1, left and right panels; figure modified from Grebmeier et al. 2006a; Sheffield and Grebmeier, in revision). This benthic community changes to a low biomass, foraminifera-based structure on the upper slope (200-1000 m depth), with benthic biomass <5 g C m^{-2} (<200 g wet wt m^{-2}), that extends down into the Canadian Basin (Fig. 1, left and right panels; figure modified from Grebmeier et al. 2006a; Sheffield and Grebmeier, in revision). Notably, the NE Chukchi Sea upstream and including the upper Barrow Canyon is a “hotspot” for the entire Chukchi Sea, with a rich community of suspension feeding infauna and epifauna (e.g., bivalves, barnacles, basket stars, and tunicates) attached to rocks and cobble and mixed sediments, and suggesting the presence of strong currents (MacGinitie 1955, Feder et al. 1994a, Feder et al. 1994b, Grebmeier et al. 2006a). In areas with interspersed silt, clay, and gravel, the suspension-feeding mussel *Musculus discors* is abundant, with station biomass values up to ~150 g C m^{-2} (~4000 g wet wt m^{-2}; Fig. 1, right panel). This benthic biomass maximum at the head of Barrow Canyon coincides with extremely high sediment oxygen uptake, an indicator of carbon supply to the benthos (Moran et al. 2005, Grebmeier et al. 2006a, Lepore et al. 2007).

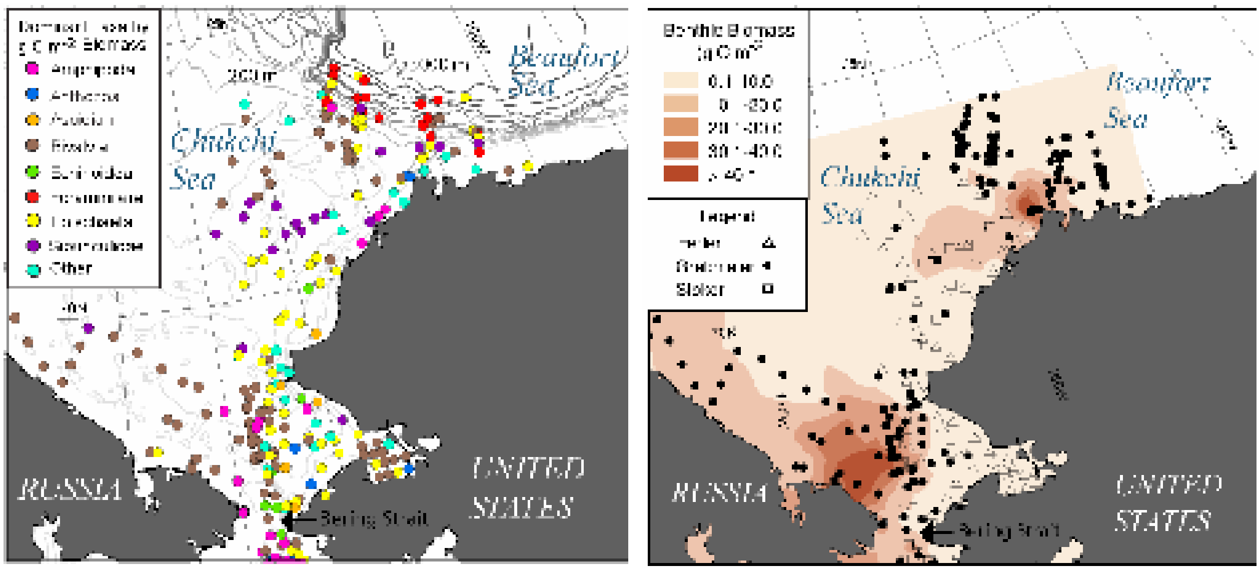

Fig. 1. Distribution of dominant benthic infauna (by biomass, left panel) and associated station benthic biomass (right panel) in the proposed study area using Inverse Distance Weighting Prediction modeling (ESRI GIS software). Note that the different symbols in the benthic biomass map are based on different data sets, with lead authors identified in the paper. Maps modified from Grebmeier et al. (2006a).

As is the case with infauna, the epifauna of the Chukchi Sea is also influenced by the overlying water mass properties. Infauna are prey for many epifaunal species, and the numerous epifaunal scavenger-predators present reflect an abundant infaunal food resource (Feder et al. 1994a, Feder et al. 1994b, Grebmeier et al. 2006a and references therein). Epifaunal biomass is clearly high in this region, based both upon past studies (e.g. MacGinitie 1955, Feder et al. 1994a, Feder et al. 1994b) as well as new video footage we acquired while participating in an International Polar Year (IPY) cruise aboard the Canadian Coast Guard Service (CCGS) Sir Wilfrid Laurier in July 2007 as part of the Canada's Three Oceans (C3O) project.

Sea ice and walruses

Not only is the distribution of walruses in the Chukchi Sea influenced by the distribution and density of prey patches, but they are also affected by the quality and proximity of sea ice because they use sea ice as a platform on which to rest between foraging trips. As a consequence, access to offshore foraging areas by walruses is likely to decrease with decreasing availability of sea ice. As the Chukchi Sea shelf becomes ice free during extreme ice minimum conditions, walruses can either follow the ice over deep water, which would leave them with virtually no access to prey until new ice is formed over the shelf in late fall-winter, or they can move to land haul-outs. During the 1990 joint Russia-U.S. survey, atypically large concentrations of walruses and polar bears aggregated at Wrangel Island due to extreme ice minimum conditions. The polar bears gradually occupied the haul-outs and often deterred walruses from hauling out (Gilbert et al. 1992). Extreme ice minimum conditions over the past several years may have caused tens of thousands of walruses, including adult females with calves, to haul out on land along northern Chukotka (Ovsyanikov 2003, Kochnev 2004). Observers at some of these haul-outs recorded the death of many calves that suffered trauma from stampeding adults when the herd was disturbed by hunters or polar bears. In addition, extreme ice minimum conditions in 2004 were associated with observations of calf abandonments in areas far offshore in the northeastern Chukchi Sea (Cooper et al. 2006).

Fay (1982) suggests that the foremost advantage to walruses using sea ice haul-outs (in contrast to land) is the constant movement of sea ice over new sources of food and the refuge it provides from predation and disturbance. Hauling out on land could result in decreased access to foraging areas and increased foraging effort. The foraging costs due to increased travel time to food patches from land may be significantly higher than the costs from sea ice haul-outs (Orians and Pearson 1977). These in turn could affect the individual fitness of walruses, including lactating and pregnant females, before they migrate to their wintering areas in the Bering Sea, with the resultant outcome of decreased survival of young and lower reproductive rates in adult females. Our current understanding of free-ranging walrus dive behavior is largely limited to male walruses using land haul-outs (Born and Knutsen 1992, Wiig et al. 1993, Born and Knutsen 1997, Gjertz et al. 2001, Jay et al. 2001). Little is known of the haul-out behavior of adult females using ice or land haul-outs.

We propose to compare the foraging range and effort of walruses using land haul-outs as a consequence of shelf-free ice conditions to walruses using ice haul-outs in the Chukchi Sea in the summer and fall of 2008. We predict that foraging effort will be greater, and foraging range will be reduced, when walruses use land haul-outs compared to their use of offshore ice haul-outs. The foraging costs due to increased travel time to food patches from land may be significantly higher than the costs from sea ice haul-outs and result in reduced energy stores before wintering in the Bering Sea.

We will also compare nearshore and offshore infaunal and epifaunal walrus prey communities and changes in these communities that may have occurred from retrospective analysis of archived benthic data. We predict that changing ice conditions over the past decade has resulted in a redistribution of productive areas and altered community structure. We predict that the community structure of benthic prey that is accessible to walruses from land haul-outs will be different than that in offshore areas where they can be accessed by walruses using ice haul-outs. Satellite radio-tagging of adult female walruses in fall of 2007 in northern Chukotka by Russian colleagues, in a collaborative study with USGS and FWS, revealed that walruses from land haul-outs foraged at distances less than 65 km from the coastline. The community structure of infauna in the late 1980's differed at a boundary corresponding to about this same distance from shore, with more productive communities found offshore (Feder et al. 1994a). In contrast, adult males in Bristol Bay, Alaska, traveled up to 125 km from land haul-outs to foraging areas (Jay and Hills 2005).

This project will provide data that will compliment movement and behavior data collected earlier in the summer season from other funding sources and allow for a comparison of foraging behaviors between walruses using different haul-out platforms. It will also provide base maps of benthic production and community structure in the Chukchi Sea. It will provide insights into environmental mechanisms responsible for changing distributions and foraging behaviors in walruses from climate change that can ultimately impact their condition and demographic rates. This information is necessary to MMS and FWS for oil and gas lease sales, MMPA authorizations, NEPA analyses, and as documentation in the approval of exploration and development plans. It will also help the oil and gas industry meet regulatory requirements while pursuing oil and gas development and Alaska Native organizations in considering the potential impacts of oil and gas industrial activities on subsistence hunting.

Relation to other work

This proposal seeks funding to extend the scope of work that was initiated by the principal investigator (USGS) in 2007. In summer of 2007, USGS attached satellite radio-tags to nine walruses in the eastern Chukchi Sea while the ice edge was still over the shelf in June-July to examine where walruses go when the ice edge retreats off the shelf and over deep waters of the Arctic Basin. As the main ice edge retreated over deep water, the tagged walruses remained over the eastern Chukchi Sea shelf, using remnant ice floes to haul out. This behavior suggests that walruses will exploit very sparse ice (too sparse to be detected by passive microwave imagery) to maintain access to preferred foraging areas. However, in addition to this, for the first time recorded in Alaska, thousands of walruses were reported using land haul-outs in September along the northwestern coast of Alaska, presumably after the remnant floes melted. Hauling out on land could result in restricted access to foraging areas, increased calf mortality, and increased disturbances from human contact.

Relative to the 2007 tagging by USGS in northeastern Chukchi Sea, Russian colleagues, in collaboration with USGS and FWS, deployed similar radio-tags on female walruses in northern Chukotka in fall 2007 to obtain initial movement data from female walruses using land haul-outs in that region. Additional observations at those haul-outs by Russian observers suggest high levels of calf mortalities due to trampling, abandonment, and starvation.

In 2007, FWS coordinated with Shell Inc. to obtain data from coastal aircraft surveys on the number of walruses hauled out along the Alaska coast north of Cape Lisburne on a weekly to bi-weekly basis. In 2008, FWS will again coordinate with industry to obtain similar walrus count data, but will strive to obtain more detailed information on the sex and age structure of the walrus herds on shore. Those data will add context to the findings we derive from telemetry data from walruses hauled out on land.

In 2008, Grebmeier will participate in two oceanographic research cruises in the Chukchi Sea: 1) continuation of time series benthic work as part of the Canadian IPY project C30 (Canada's Three Oceans) as in 2007, with July sampling both in the southern and northern Chukchi Sea, and 2) participation in a joint Russian-US RUSALCA (Russian American Long-term Census of the Arctic) oceanographic cruise in the western and eastern Chukchi Sea in August-September. Standard hydrographic measurements, along with infaunal and epifaunal sampling, are included in this NOAA-Russian Academy of Sciences collaborative program.

Methods

Walrus foraging areas and behavior relative to sea ice and land haul-outs

USGS has recently modified a remotely deployed satellite radio-tag that allows identification of walrus foraging areas and behaviors. Collecting these kinds of foraging data requires satellite telemetry because walruses range widely and recapturing individuals to recover data-logging tags is generally impractical. USGS previously developed a satellite-linked radio-tag that is deployed by crossbow to circumvent difficulties associated with animal capture, and have successfully deployed many of these tags to obtain information about walrus haul-out behavior (Jay et al. 2006). Recently, USGS incorporated a pressure transducer to the tag design to allow determination of foraging status on an hourly basis. Foraging activity is classified, by an on-board algorithm, based on the frequency of depth readings (once every second) greater than a threshold depth. The frequency and depth thresholds were established from free-ranging dive profile data from a previously published study (Jay et al. 2001). The algorithm correctly classified foraging status with $< 3\%$ error rate ($n = 4$ walruses and 2084 hours). USGS successfully deployed a prototype of the tag on a walrus in Bristol Bay in September 2007 and it yielded a continuous chronology of foraging status that clearly identified foraging habitat and behaviors consistent with those described in previous studies. Because the tag provides a continuous chronology of location and foraging behavior, distances from the haul-out can be determined (e.g. Fig. 2), and foraging effort (h/day) can be calculated for each foraging trip.

We will collect data on the foraging behavior of adult females using sea ice and land haul-outs by tagging 30-45 walruses from 15 May through about 7 August in sea ice in the Chukchi Sea, and tagging 30 walruses in the first week of September on land haul-outs on the Alaska coast as outlined in Table 1. The tagging dates are staggered temporally by 6 weeks because that is the average functional longevity of the tags. Tagging is staggered spatially from south to north synchronous to the northward migration of walruses. Tagging from land haul-outs will be conducted in collaboration with local Native communities and we will provide a flow of information back to the villages and the Eskimo Walrus Commission following tag deployments. All tagging will be conducted in accordance with a Research Permit issued to USGS (Fish and Wildlife Permit #MA801652-4).

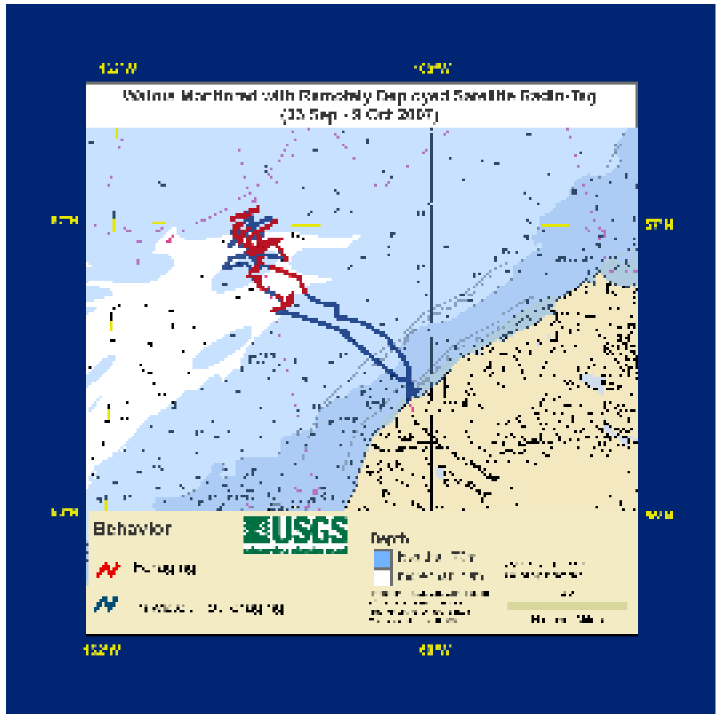

Fig. 2. A newly modified remotely deployed satellite radio-tag that identified the foraging locations (red) of an adult male walrus during a foraging trip from a land haul-out at Cape Seniavin in Bristol Bay, Alaska, in fall 2007.

Walrus location and dive data will be downloaded from the Argos Data Collection System. The foraging status of tagged walruses and their locations will be entered into a GIS data base. Foraging areas and areas of use will be identified using a kernal estimator using independent relocations only. Maximum foraging distance from the last used haul-out will be compared between walruses using sea ice and land haul-outs. These distances will be used to buffer the coastline with a maximal foraging distance exhibited by the tagged walruses and thereby identifying nearshore benthic resources that are accessible to walruses using land haul-outs. Foraging and haul-out status data will be used to test for differences in dive behavior between walruses using sea ice and land haul-outs. Variables used in the comparison will include dive parameters such as trip duration, haul-out duration, and proportion of time spent foraging.

Table 1. Dates, logistics, and source of support for walrus tagging in 2008. This proposal seeks funding from NPRB for tags to conduct tagging in the fall on land haul-outs (**bold**).

	Tagging Date	Logistics/Location	# of Tags	Source of Support
Tagging summer-fall in sea ice	15-May-08	42' boat from Nome to tag at southern boundary of Chukchi Lease Sale area	15	Boat and tags from USGS
	26-Jun-08	Nearshore tagging from small boats with help from North Slope Borough	15	Field costs and tags from USGS
	7-Aug-08	125' ship to tag offshore in northeastern Chukchi	15	Ship funds donated to National Fish and Wildlife Foundation from Shell Inc. and ConocoPhillips; will seek additional funds for the 15 tags from another source
	18-Sep-08	*Last of data collection*		
Tagging fall on shore after sea ice retreats off shelf	1-Sep-08	2 land haul-outs along Alaska coast; potential sites include Cape Lisburne, Icy Cape, and Peard Bay	30	**Seeking 15 tags from NPRB in this proposal;** will seek additional funds for the remaining 15 tags from another source
	13-Oct-08	*Last of data collection*		

Sea ice and benthic habitats

The benthic component will undertake a benthic ecological analysis of the shallow continental shelf regions of the NE Chukchi in the area of nearshore and offshore walrus foraging through retrospective analysis of benthic infaunal and epibenthic data from previous studies. These data will be analyzed in coordination with walrus feeding studies in order to relate prey fields to walrus foraging ranges. Coincident collections made of hydrographic and sediment data will be evaluated in the context of benthic community structure and standing stock to evaluate forcing functions for faunal community structure and to determine select factors to be studied in future field campaigns to monitor the ecosystem.

For our retrospective analysis, we will use infaunal samples collected using a standard 0.1 m^2 van Veen grab in the NE Chukchi during past studies (Feder et al. 1994b, Grebmeier et al. 2006a), including data sets collected during SBI in 2002-2004, cruises on the CCGS Sir Wilfrid Laurier in 2005 and 2007, and data sets collected during the 1990's US-Russian BERPAC (Bering-Pacific) program, the 2004 RUSALCA cruise, and the upcoming 2008 RUSALCA cruise. We are also currently interacting with Dr. Boris Sirenko, a RUSALCA collaborator from the Zoological Institute in St. Petersburg, Russia, to identify select data sets in the Russian archive that could be utilized in our retrospective study. SBI data sets are available from the Earth Observing Laboratory (EOL) archive (http://www.eol.ucar.edu/projects/sbi/), as are some benthic data from 2005 and eventually 2007 as part of the C30 program. As part of our synthesis effort for the Progress in Oceanography paper with Howard Feder and Boris Sirenko (Grebmeier et al. 2006a), PI Grebmeier has access to benthic taxonomic data that can be used in this retrospective analysis.

We will utilize similarity cluster analyses, multi-dimensional scaling, and environmental parameter analyses with multivariate ecological analysis software (PRIMER v6, Plymouth Routines in Ecological

Research, Plymouth, UK; http://www.primer-e.com) using methodologies similar to Cusson et al. (2007). This statistical package facilitates the determination of grouping patterns of association among infaunal animals, bottom types, and environmental factors. Shannon-Weaver indices of diversity (H') and eveness (J) will be determined for stations and station cluster groups of the four-five grabs collected for benthic population studies. In addition, a non-metric multi-dimensional scaling analysis of station faunal composition similarity (Bray-Curtis) will be undertaken, along with multiple regression analysis. We will also input data into a GIS database for Geospatial GIS analyses using Inverse Distance Weighting Prediction modeling (ESRI GIS software) to map different data benthic and environmental sets with the coincident walrus foraging location data obtained through the walrus tagging portion of this proposal.

E. Timeline and Milestones

Project Duration: 2 years, June 1, 2008 – May 31, 2010

2008	**Completion Date**	**Outcome**
Order radio-tags	June	
Deploy radio-tags on walruses	September	Provide near real-time tracking data to public via USGS website after deployments
Compile walrus tracking and behavior data and pertinent benthic data into GIS database	December	
2009		
Graphically summarize walrus benthic faunal data; Presentation at annual NPRB symposium	January	Progress report to NPRB
Draft analysis of walrus and benthic data	June	
Final analysis	December	Present results to Eskimo Walrus Commission, FWS, and MMS
2010		
Presentation at annual NPRB symposium and/or AGU/ASLO Oceans meeting	Jan. or Feb.	
Draft report	February	
Final report	May	
Prepare manuscripts for journal submissions		

F. Project Management

This project will be led by Dr. Chadwick Jay (USGS, PI) and Dr. Jacqueline Grebmeier (U. of Maryland, PI) under separate contracts for each investigator.

- Dr. Jay has been involved in walrus research since 1995 and is leader of walrus research for USGS. He has considerable experience in developing novel radio-tag designs and walrus telemetry projects on land and sea ice in the U.S. and Russia. He will be responsible for the overall work and coordination with UM, supervise all walrus field operations, maintain wildlife permits, participate in data analyses, and report and manuscript writing. He will coordinate this project with existing Chukchi Sea tagging projects under USGS Base funds and funds originating from industry.
- Dr. Grebmeier has been involved in benthic and ecosystem studies in the northern Bering and Chukchi Seas and Arctic Ocean since the early 1980s. Her specialty is pelagic-benthic coupling, benthic carbon cycling, and benthic population dynamics in polar regions, focusing most of her career in studies of Bering/Chukchi continental shelf ecosystems. She will be responsible for undertaking the benthic retrospective data collections and analyses in the context of walrus-prey studies. She will supervise all

benthic data statistical and GIS graphic data analyses, and report and manuscript writing.

- Ms. Vera Metcalf is Director of the Eskimo Walrus Commission. She will collaborate on the project to help involve coastal communities in walrus tagging and communicate results to EWC and Native villages.

References

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Grebmeier, J. M., J. E. Overland, S. E. Moore, E. V. Farley, E. C. Carmack, L. W. Cooper, K. E. Frey, J. H. Helle, F. A. McLaughlin, and S. L. McNutt. 2006b. A major ecosystem shift in the northern Bering Sea. Science **311**:1461-1464.

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Moran, S. B., R. P. Kelly, K. Hagstrom, J. N. Smith, J. M. Grebmeier, L. W. Cooper, G. F. Cota, J. J. Walsh, N. R. Bates, D. A. Hansell, W. Maslowski, R. P. Nelson, and S. Mulsow. 2005. Seasonal changes in POC export flux in the Chukchi Sea and implications for water column-benthic coupling in Arctic shelves. Deep-Sea Research II **52**:3427-3451.

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NPRB BUDGET SUMMARY FORM

PROJECT TITLE:	Walrus Foraging Response to a Changing Chukchi Sea				Annual cost category breakdowns will be requested for other support only if project is funded
PRINCIPAL INVESTIGATOR:	Chadwick V. Jay - USGS, Alaska Science Center				
FUNDING SOURCE	**YEAR 1**	**YEAR 2**	**YEAR 3**	**TOTAL**	
NPRB Funding	88,523	2,900	0	91,423	
Other Support				81,755	
TOTAL	88,523	2,900	0	173,177	

Cost Categories	**NPRB Year 1**	**NPRB Year 2**	**NPRB Year 3**	**NPRB TOTAL**	**Match/In kind TOTAL (all years)**
1. Personnel Salaries				0	
2. Personnel Fringe Benefits				0	
3. Travel (include 1 trip to review mtg in Anchorage each year plus for the year following project conclusion)				0	
4. Equipment	61,050			61,050	
5. Supplies				0	
6. Contractual/Consultants				0	
7. Other (Include $2000 for education and outreach)		2,000		2,000	
Total Direct Costs	**61,050**	**2,000**	**0**	**63,050**	**0**
Indirect Costs	27,473	900		28,373	
TOTAL PROJECT COSTS	**88,523**	**2,900**	**0**	**91,423**	**0**

NPRB BUDGET SUMMARY FORM

PROJECT TITLE:	Walrus Foraging Response to a Changing Chukchi Sea				Annual cost category breakdowns will be requested for other support only if project is funded
PRINCIPAL INVESTIGATOR:	Jacqueline M. Grebmeier, Chesapeake Biological Laboratory/University of Maryland Center for Environmental Sciences				
FUNDING SOURCE	**YEAR 1**	**YEAR 2**	**YEAR 3**	**TOTAL**	
NPRB Funding	40,804	44,122	0	84,926	
Other Support				0	
TOTAL	40,804	44,122	0	84,926	

Cost Categories	**NPRB Year 1**	**NPRB Year 2**	**NPRB Year 3**	**NPRB TOTAL**	**Match/In kind TOTAL (all years)**
1. Personnel Salaries	17,625	18,506		36,131	
2. Personnel Fringe Benefits	6,169	6,477		12,646	
3. Travel (include 1 trip to review mtg in Anchorage each year plus for the year following project conclusion)	1,500	1,500		3,000	
4. Equipment	0	0		0	
5. Supplies	1,000	1,000		2,000	
6. Contractual/Consultants	0	0		0	
7. Other (Include $2000 for education and outreach)	1,370	2,430		3,800	
Total Direct Costs	**27,664**	**29,913**	**0**	**57,577**	**0**
Indirect Costs	13,140	14,209		27,349	
TOTAL PROJECT COSTS	**40,804**	**44,122**	**0**	**84,926**	**0**

NPRB BUDGET SUMMARY FORM - MULTIPLE ORGANIZATIONS

PROJECT TITLE:	Walrus Foraging Response to a Changing Chukchi Sea				
PRINCIPAL INVESTIGATOR(S):	Chadwick V. Jay - USGS, Alaska Science Center; Jacqueline M. Grebmeier, Chesapeake Biological Laboratory/University of Maryland				
FUNDING SOURCE	**YEAR 1**	**YEAR 2**	**YEAR 3**	**TOTAL**	
NPRB Funding	129,327	47,022	0	176,349	
Other Support				0	
TOTAL	129,327	47,022	0	176,349	

Annual cost category breakdowns will be requested for other support only if project is funded

Cost Categories	**NPRB Year 1**	**NPRB Year 2**	**NPRB Year 3**	**NPRB TOTAL**	**Match/In kind TOTAL (all years)**
1. Personnel Salaries	17,625	18,506	0	36,131	0
2. Personnel Fringe Benefits	6,169	6,477	0	12,646	0
3. Travel (include 1 trip to review mtg in Anchorage each year plus for the year following project conclusion)	1,500	1,500	0	3,000	0
4. Equipment	61,050	0	0	61,050	0
5. Supplies	1,000	1,000	0	2,000	0
6. Contractual/Consultants	0	0	0	0	0
7. Other (Include $2000 for education and outreach)	1,370	4,430	0	5,800	0
Total Direct Costs	**88,714**	**31,913**	**0**	**120,627**	**0**
Indirect Costs	40,613	15,109	0	55,722	0
TOTAL PROJECT COSTS	**129,327**	**47,022**	**0**	**176,349**	**0**

DR. CHADWICK V. JAY

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Ph: 907-786-7414 E-mail: chad_jay@usgs.gov

ACADEMIC CREDENTIALS

Ph.D.	Fisheries Science – Marine	Oregon State University	1990 – 1996
M.A.	Biology – Invertebrate Zoology	Humboldt State University	1982 – 1985
B.S.	Fisheries Science – Limnology	Utah State University	1976 – 1981

PROFESSIONAL CREDENTIALS

Research Ecologist	USGS Alaska Science Center	1994 –
Research Assistant	OSU Dept. of Fisheries and Wildlife	1991 – 1994
Fisheries Biologist	New Zealand Ministry of Agriculture and Fisheries	1987 – 1990

RELEVANT PROFESSIONAL ACTIVITIES

Areas of special interest*:* Wildlife Telemetry, Spatial and Temporal Patterns of Animal Distributions, Marine Mammal and Benthic Ecology

SELECTED RECENT PUBLICATIONS

Jay, C.V., M.P. Heide-Jørgensen, A.S. Fischbach, M.V. Jensen, D.F. Tessler, and A.V. Jensen. 2006. Comparison of remotely deployed satellite radio transmitters on walruses. Marine Mammal Science 22(1):226-236.

Bornhold, B.D., C.V. Jay, R. McConnaughey, G. Rathwell, K. Rhyna, and W. Collins. 2005. Walrus foraging marks on the seafloor in Bristol Bay, Alaska – a reconnaissance survey. Geo-Marine Letters 25:293-299.

Jay, C. V., and S. Hills. 2005. Movements of walruses radio-tagged in Bristol Bay, Alaska. Arctic 58(2):192-202.

Jay, C.V., and G.W. Garner. 2002. Performance of a satellite-linked GPS on Pacific walruses (Odobenus rosmarus divergens). Polar Biology 25:235-237.

Jay, C.V., S.D. Farley, and G.W. Garner. 2001. Summer diving behavior of male walruses in Bristol Bay, Alaska. Marine Mammal Science 17(3):617-631.

OTHER SELECTED PUBLICATIONS

Udevitz, M.S., C.V. Jay, and M.B. Cody. 2005. Observer variability in pinniped counts: ground-based enumeration of walruses at haul-out sites. Marine Mammal Science 21(1):108-120.

Mulcahy, D.M., P.A. Tuomi, G.W. Garner, and C.V. Jay. 2003. Immobilization of free–ranging male Pacific walruses using carfentanil citrate and naltrexone hydrochloride. Marine Mammal Science 19(4):846-850.

Jay, C.V., T.L. Olson, G.W. Garner, and B.E. Ballachey. 1998. Response of Pacific walruses to disturbances from capture and handling activities at a haul-out in Bristol Bay, Alaska. Marine Mammal Science 14(4):819-828.

PROFESSIONAL AFFILIATIONS

Member	Society for Marine Mammalogy	1998-
Member	Arctic Institute of North America	2004-

COLLABORATORS (past 4 years)

Grants: D. Atwood (UAF), D. Douglas (USGS), R. Kwok (NASA), A. Trites (UBC), M. Udevitz (USGS).

Co-authors: B.E. Ballachey, B.D. Bornhold, M.B. Cody, W. Collins, S.D. Farley, A.S. Fischbach, G.W. Garner, M.P. Heide-Jørgensen, S. Hills, M.V. Jensen, A.V. Jensen, R. McConnaughey, D.M. Mulcahy, T.L. Olson, G. Rathwell, K. Rhyna, D.F. Tessler, P.A. Tuomi, M.S. Udevitz.

Biographical Sketch: JACQUELINE MARY GREBMEIER (November 2007)
Department of Ecology and Evolutionary Biology, Marine Biogeochemistry and Ecology Group, 10515 Research Drive, Suite 100, Bldg. A, The University of Tennessee*, Knoxville (UTK), TN. 37996; phone (865) 974-2592; fax (865) 974-7896; email: jgrebmei@utk.edu; websites: http://arctic.bio.utk.edu and http://sbi.utk.edu; relocating to the Chesapeake Biological Laboratory (CBL), University of Maryland Center for Environmental Sciences (UMCES), Solomons, June 2008

Research Interests: Pelagic-benthic coupling on continental shelves, benthic ecology, invertebrate zoology, contaminant distributions, high latitude oceanography

(a) Professional Preparation

Ph.D. Biological Oceanography, December 1987-Institute of Marine Science, University of Alaska, Fairbanks, Alaska
M.A. Marine Affairs, August 1983-Institute for Marine Studies, University of Washington, Seattle, Washington
M.S. Biology, June 1978-Stanford University, Stanford, California
B.A. Zoology, June 1977-University of California, Davis, California

(b) Appointments:

U.S. Delegate (2006-2012) and Vice-President (2006-2010), International Arctic Science Committee (IASC)
Research Professor and Project Director, Dept. Ecology and Evolutionary Biology, UTK, 2002-
U.S. Presidential Appointee, U.S. Arctic Research Commission, 2000-2003
Research Associate Professor, Dept. Ecology and Evolutionary Biology, UTK, 1998-2001
Visiting Scientist, Environmental Sciences Division, Oak Ridge National Lab, TN, 1989-2000
Research Assistant Professor, Dept. Ecology and Evolutionary Biology, UTK, 1989-1997
Teaching Appointment-Dept. Botany/Dept. Ecology and Evolutionary Biology, UTK, 1989-present
Research Associate, Dr. Douglas Hammond, Department of Geological Sciences, Univ. Southern California, Los Angeles, 1988-1989
Research Assistant, Dr. C. Peter McRoy, Institute of Marine Science, Univ. Alaska, Fairbanks (UAF), 1985-1987: NSF-funded Inner Shelf Transfer and Recycling (ISHTAR) project

(c) Ten Relevant Publications (*5 most relevant; next 5 most relevant))

Cooper, L.W., J.M. Grebmeier, I.L. Larsen, V.G. Egorov, C. Theodorakis, and H.P. Kelly, J.R. Lovvorn (2002), Seasonal Variation in Sedimentation of Organic Materials in the St. Lawrence Island Polynya Region, Bering Sea; *Marine Ecology Progress Series* 226: 13-26.

Grebmeier, J.M. and L.W. Cooper (1995). Influence of the St. Lawrence Island Polynya on the Bering Sea Benthos. *Journal of Geophysical Research-Oceans,* 100: 4439-4460.

*Grebmeier, J.M., and K.H. Dunton (2000). Benthic Processes in the Northern Bering/Chukchi Seas: Status and Global Change, in H.P. Huntington (ed), *Impacts of Changes in Sea Ice and Other Environmental Parameters in the Arctic*, Marine Mammal Commission Workshop, Girdwood, Alaska, 15-17 February 2000, pg. 80-93.

*Grebmeier, J.M., and J.P. Barry (2007). Benthic processes in polynyas, pp. 363-390. In: W.O. Smith, Jr. and D.G. Barber (eds), *Polynyas: Windows to the World,* Elsevier Oceanography Series, Volume 74.

Grebmeier, J.M., W.O.Smith, Jr., and R.B. Conover (1995). Biological Processes on Arctic Continental Shelves: Ice-Ocean-Biotic Interactions, in W.O. Smith, Jr. and J.M. Grebmeier (eds), *Arctic Oceanography: Marginal Ice Zones and Continental Shelves*, pp.231-261, Wash., DC.

*Grebmeier, J.M., L.W. Cooper, H.M. Feder, and B.I Sirenko (2006a). Ecosystem Dynamics of the Pacific-Influenced Northern Bering and Chukchi Seas. *Progress in Oceanography* 71: 331-361.

*Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin, and S.L.. McNutt (2006b), A Major Ecosystem Shift Observed in the Northern Bering Sea, *Science* 311: 1461-1464.

Lalande, C., Grebmeier, J.M., Wassmann, P., Cooper, L.W., Flint, M.V., Sergeeva, V.M. (2007). Export Fluxes of Biogenic Matter in the Presence and Absence of seasonal sea ice cover in the Chukchi Sea. *Continental Shelf Research*, 27:2051-2065.

*Lepore, K., S.B. Moran, J.M. Grebmeier, L.W. Cooper, C. Lalande, W. Maslowski, V. Hill, N.R. Bates, D.A. Hansell, J.T. Mathis, R.P. Kelly (2007), Seasonal and interannual changes in particulate organic carbon export and deposition in the Chukchi Sea, *Journal of Geophysical Research,* Vol. 112, C10024, doi:1029/2006JC003555.

Moore, S.E., J.M. Grebmeier, and J.R. Davis (2003), Gray whale distribution relative to forage habitat in the northern Bering Sea: current conditions and retrospective summary, *Canadian Journal of Zoology* 81(4):734-742.

(d) Five Synergistic Activities:

1. U.S. Delegate to the International Arctic Science Committee (IASC), March 2006-Marchh 2012; voted Vice President March 2006-March 2010
2. National Academy committee membership, including (a) USCG Icebreaker Committee (2005-2006), (b) US International Polar Year 07/08 National Committee (2003-2005), (c) National Research Council, Committee on the Alaska Groundfish Fishery and Steller Sea Lions, 2001-2002, (d) Bering Sea Ecosystem Study Panel Member (1993-1996)
4. Director, Project Management Office, Western Arctic Shelf-Basin Interactions (SBI) Program, National Science Foundation Office of Polar Programs, 1999-2008
5. Study of Environmental Arctic Change (SEARCH) Science Steering Comm. member, 2003-2007
6. National Academies, Polar Research Board, appointment: 2003-2006

(e) Collaborators and Other Affiliations, Co-Authors on Publications and Abstracts (not listed above, last four years): N.R. Bates (Bermuda Biological Station), R. Benner (University of South Carolina), R.G. Campbell (University of Rhode Island), L.A. Codispoti (University of Maryland), R. Harvey (University of Maryland), D. Hansell (University of Miami), C. Jay (USGS, Anchorage), S. Moran (University of Rhode Island), G. Sheffield (Alaska Department of Fish & Game), W. Maslowski (Naval Postgraduate School), J.J. Walsh (University of South Florida), T. Weingartner (University of Alaska Fairbanks), T. Whitledge (University of Alaska Fairbanks)

(f) Graduate & Postdoctoral Advisors: C. Peter McRoy (PhD), Howard Feder (PhD), Doug Hammond (postdoc); **Graduate Student Advisor for:** M.S as chair (dates graduated): Adam Humphrey (2006-present), Rebecca Pirtle-Levy (2006), Arianne Balsom (2003), Jackie Clement (2002), and Andrew Reed (1998); PhD as chair: Sherry Cui (2005-present), Catherine Lalande (2006); as committee member for M.S.: Matt Bowles (1998) and Naomi Parker (1996), for PhD: Becky Brown (1998); **International outside PhD examiner**: Steffan Kaltin (Sweden, 2003), Christian Wexels-Riser (Norway, 2007)

(g) Recent Oceanographic Cruises (Plus Over 30 Others, Many As Chief Scientist)

July 1998-2007	CCGC Sir Wilfrid Laurier	Bering and Chukchi Seas
May-June 2006, 2007	USCGC Healy	Northern Bering Sea
July-August 2002, 2004	USCGC Healy	Bering/Chukchi/Beaufort Seas, Arctic Ocean
May-June 2002, 2004	USCGC Healy	Bering/Chukchi/Beaufort Seas, Arctic Ocean
March-April 2001	USCGC Polar Star	Bering Sea

(h) Selected Recent Presentations at Conferences/Invited Workshops

Invited Speaker: IPY PolarPalooza Public Event and Lecturer, November 2007, Baton Rouge, LA

Invited Speaker: 2nd Bush China-US Roundtable, IPY session, October 2007, Washington, DC

Invited Participant: AMAP/CliC/IASC Workshop on Arctic Carbon Cycle, Feb. 2007, Seattle, WA

Invited Speaker: Arctic Frontiers Symposium "Food web dynamics and biogeochemical fluxes in the Arctic Ocean", Jan. 2007, Tromso, Norway

Invited Speaker: International Conference on Arctic Research Planning II (ICARP II) Implementation Planning Workshop, Potsdam, Germany, Nov., 2006

Invited Speaker Minerals Management Service Workshop on Chukchi Offshore Monitoring in Drilling Area (COMIDA), Anchorage, Alaska, Nov. 2006

Invited Speaker: National Academies "Changing Ice Conditions in the Arctic-Implications and Opportunities" workshop, Oct. 2006

Invited Speaker: Pacific Arctic Group (PAG) of the International Arctic Science Committee (IASC), Shanghai, China, Sept. 2006

Invited Speaker, Oceans Meeting Special Session, Honolulu, Hawaii, Feb. 2006