Stakeholder-Based Regional Marine Research Plan for the Aleutian Islands

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Abstract

Stakeholder input was used to identify and prioritize research and information needs for the Aleutian Island region. Stakeholders suggested research needs under six societal themes 1) improving ecosystem health; 2) marine transportation and security; 3) the ocean's role in climate; 4) enhancing human health and safety; 5) stewardship of natural and cultural ocean resources; and 6) increasing resilience to natural hazards. An expert panel rated research priorities for level of importance and a variant of the analytical hierarchy process was selected as the group decision-making technique for ranking research need priorities. Outcomes for the top twenty ranked research and information need priorities are detailed in the report below. Robustness of the ranked research priorities was checked with a sensitivity analyses. Research priorities identified in this report could be useful to support ecosystem-based management for the Aleutian Islands.

Introduction

The Aleutian Islands Region

The United States (US) portion of the Aleutian Island archipelago stretches more than 2,200 kilometers between Alaska and Russia and separates the Bering Sea from the North Pacific Ocean (Fig. 1). The Aleutian Islands consist of hundreds of small volcanic islands formed by the subduction activity of the North American and Pacific tectonic plates. The openings between the islands form passes that allow exchange of water between the North Pacific Ocean, Gulf of Alaska and the Bering Sea. An ecological division occurs between regions east and west of Samalga Pass, as indicated by changes in weather and species composition including cold-water corals, zooplankton, fish, marine mammals, and foraging seabirds (Hunt and Stabeno 2005, Fig. 1).

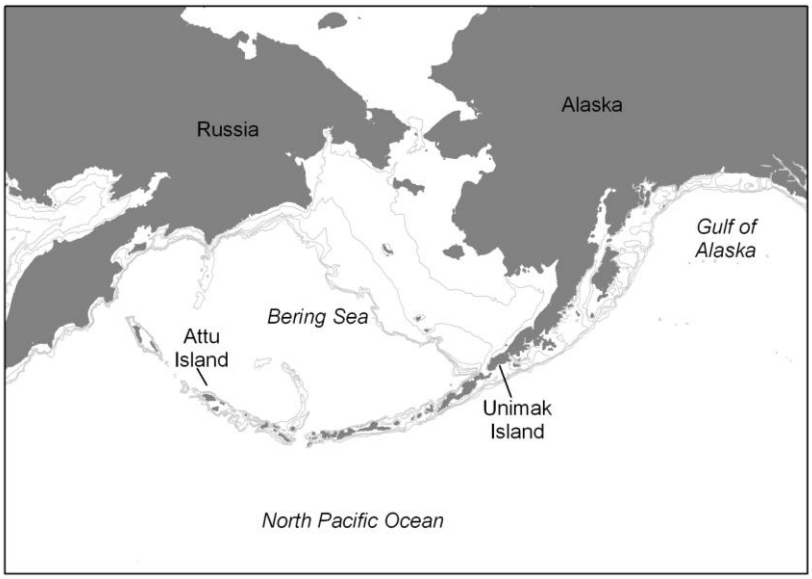

Figure 1 The Aleutian Islands regional marine research plan boundary extends from Unimak Island to Attu Island. Contour lines represent 50 meter isobaths. Source: ArcGIS Version 9.3.1

The Aleutian Islands are a biologically diverse and productive ecosystem valuable for commercial and subsistence fishing as well as for supporting large seabird and marine mammal populations. The Aleutian Islands combined with the Bering Sea and Gulf of Alaska support the world's largest groundfish fisheries. Additional marine species such as salmon, halibut, scallop, king and tanner crab are important for commercial and subsistence fisheries. The Alaska Maritime National Wildlife Refuge, established by

the Alaska National Interest Lands Conservation Act of 1980, includes most of the Aleutian Islands within its boundary. More than 10 million seabirds of 26 species breed in the Aleutian Archipelago (USFWS 2000). The Aleutian Islands provide residence or seasonal habitat for a variety of marine mammals including Steller sea lions, northern fur seals, harbor seals, sea otters, and various cetacean species (NPFMC 2007).

Human factors that have shaped the Aleutian Island marine ecosystem include fishing, hunting of marine mammals and seabirds, shipping, and military activities, including the dumping of hazardous materials (Anthony et al. 2007, Ricca et al. 2008). Changes in marine mammal populations include the extinction of the Steller's sea cow (*Hydrodamalis gigas*), near extirpation, recovery and recent declines of northern sea otters (*Enhydra lutris*) (Doroff et al. 2003), and substantial declines in the western distinct population segment of Steller sea lions (Eumetopias jubatus) (Braham et al. 1980, NMFS 2010). Changes in commercially fished species include the depletion of economically valuable species such as Pacific Ocean perch (*Sebastes alutus*) and red king crab (*Paralithodes camtschaticus*) (Schumacher and Kruse 2005, NPFMC 2007). Unangan (i.e., Aleut) people have inhabited the Aleutian Islands for over 9,000 years (Veltre and Smith 2010). Cultural influences on the Unangan people occurred in the mid-1700s with Russian occupation for fur trade purposes, and later with US military presence, beginning in World War II. Today, five communities in the Aleutian Islands are inhabited, with a total population level of approximately 4,884 individuals. Communities are heavily dependent on commercial and subsistence fishing (Sepez et al. 2005). Fishing for Atka mackerel and cod in the Aleutian Islands has recently been closed out of concern for the slow recovery of Steller sea lions in this region (NMFS 2010).

Although the region is remote and sparsely populated, shipping through the Aleutian Islands is increasing, and the natural resources of the region continue to be heavily exploited for commercial fisheries. The Aleutian Islands region remains difficult to access for research purposes, and significant data gaps exist for ocean related research. The need to better understand the marine ecosystem is essential to properly manage and address future risks.

A comprehensive research plan was developed to addresses interactions between society and the ocean. The Aleutian Island regional marine research plan focuses on six national ocean research priority themes: 1) improving ecosystem health; 2) marine transportation and security; 3) the ocean's role in climate; 4) enhancing human health and safety; 5) stewardship of natural and cultural ocean resources; and 6) increasing resilience to natural hazards. These ocean research priority themes were outlined in a national report entitled: Charting a course for ocean science in the United States for the next decade: an ocean research priorities plan and implementation strategy (JSOST 2007). Research priorities overlap between the themes and also within themes, and therefore, compliment and address each other. The research priorities detailed in this report are intended to inform potential funding entities of stakeholder-based ocean research priorities for the Aleutian Islands.

The Regional Marine Research Plan

Initiation of the Aleutian Islands regional marine research plan occurred after various research programs and management reports led to a call for national development of regional marine research plans. In response to these reports, the National Oceanic and Atmospheric Administration (NOAA) provided funding to the National Office of Sea Grant, who issued a request for proposals in 2006 calling for the development of regional marine research plans. Eight regional ecosystems were designated for the development of these plans; the North Atlantic shelf, Southeast Atlantic, Caribbean, Gulf of Mexico, California Current, Alaska, Pacific Islands, and Great Lakes.

Because of the extent and diversity of Alaska's marine ecosystems, the Alaska Sea Grant program narrowed the regional marine research plan to focus on the Aleutian Island region. This region includes the state and federal waters, and the federal exclusive economic zone surrounding the Aleutian archipelago, from Unimak Island to Attu Island (Fig. 1). The model selected for Alaska was a

combination of a bottom-up and top-down approach that is similar to the approach adopted for the California Current regional marine research plan. Development of the Aleutian Islands regional marine research plan has been guided by approaches from similar projects in other Sea Grant programs, and by the ocean research priorities plan and implementation strategy report (JSOST 2007).

Methods

The initial phase of the Aleutian Islands regional marine research plan consisted of a scoping process to collect a breadth of perceptions relating to management-critical research and information needs. From January to April 2008, paper and web-based questionnaires were used to gather stakeholder input under the six ocean research priorities plan themes (Appendix A). Research needs are defined as requiring the discovery of new knowledge about coastal and ocean processes and resources. Information needs are defined as requiring the synthesis or translation of existing knowledge. Input from 118 individual and group respondents provided 1,007 suggestions of research and information needs. Responses were received from representatives of state and federal resource management agencies (agencies), non-governmental organizations (NGOs), individuals associated with the fishing and processing sectors, community development corporations, local governments, university faculty and students (academic), representatives of Alaska native organizations, and the public at large. The raw responses were consolidated to eliminate redundancies; responses that called for actions outside the scope of this project were dropped from consideration.

A variant of the analytical hierarchy process (AHP) was selected as the group-decision making technique for ranking research and information need priorities. The AHP was developed in the 1970s as a formal decision making method that provides a standard for solving discrete multiple criteria problems (Schmoldt et al. 2001). The AHP has been used extensively to address planning, conflict resolution, and prioritization in such areas as policy development, economics, engineering, medical, and military science, and has more recently been applied to fisheries research and management (Merritt and Criddle 1993; Mardle and Pascoe 1999; Merritt and Quinn 2000). The AHP structures a problem into a hierarchy and evaluates preferences among group members to find priorities among choices.

The final list of 314 research and information needs was organized for each theme using a hierarchical structure, with categories at the top representing the broad topic areas, subcategories representing more specific topic areas, with specific research and information needs listed under their corresponding subcategories (Appendix B-G). An expert panel was assembled to rate the categories, sub-categories, and research and information needs for each of the six themes.

To begin the expert panel rating process, a workshop was convened in Anchorage on July 15 and 16, 2008. The panelists included 18 professionals and interested persons of varying expertise across the six themes of the Aleutian Islands regional marine research plan. Panelists rated the level of importance on a scale of one through nine, with one indicating a low level of importance, and nine indicating a high level of importance. Panelists developed a set of six criteria to use as guidance for rating each category, subcategory, and research or information need. The six criteria developed by expert panel participants as guidance are: (1) the lack of information jeopardizes the ability to ensure sustainable development/management/use of the resource (e.g., endangered or threatened species status, sentinel species, keystone species); (2) feasibility and cost effectiveness; (3) probability that research will successfully address a need; (4) information aids a broad swath of people (e.g., maintains and enhances human benefits); (5) there is a sequential order, whereby one need must be addressed before research can begin on another; and (6) there is a potential for synergy (i.e., research projects will address multiple missions and encompass multiple disciplines).

By the end of the 2008 workshop, priorities for theme (5) stewardship of natural and cultural ocean resources, and (2) marine transportation and safety were completed, and partial priorities were obtained for categories and sub-categories of theme (1) improving ecosystem health. On July 12, 2010, the 18

original workshop participants with the exception of one replaced participant were contacted and asked to complete a web-based survey for prioritizing subcategories and research and information needs under theme (1) improving ecosystem health. Because panel members were not in the same location to discuss ratings for each survey question, the method used for the web-based surveys was a variant of the analytical hierarchy process. The organized lists of research and information needs for the remaining themes were sent for expert panel rating approximately one per month in fall 2010. A web-based survey for the (2) marine transportation and safety theme was also sent for comparison to the 2008 survey rating. The results of the expert panel ratings were presented to the panelists in April 2011, and they were given the opportunity to revise their ratings. Panelists were asked to pay particular attention to research and information needs where there are large differences in scores, but were told that they do not need to reach consensus.

Because individuals may rate level of importance on a consistently high or a consistently low range of numbers, ratings from each panelist were normalized. Normalized ratings were calculated using:

$$N = \frac{y_i - \bar{y}_i}{s_{y_i}} \bar{s} + \bar{y} \quad ,$$

where

N = normalized ratings for a panel member,
y_{ij} = individual rating for a particular question in a theme,
$\bar{y}_i$ = geometric mean for an individual panelist's ratings for all questions in a theme,
s_{y_i} = standard deviation for an individual panelist's ratings for all questions in a theme,
$\bar{s}$ = arithmetic mean of s_{y_i} for all panel members, and
$\bar{y}$ = arithmetic mean of $\bar{y}_i$ for all panel members.

Scores for each category, subcategory and research and information need were calculated using:

$$T_m = W_k N_m \,,$$

where

T_m = the total weighted score for research and information need *m*,
W_k = the weighted average score for category (and subcategories) *k*, and
N_m = the weight for research and information need *m*.

Scores for research and information needs were used to rank research priorities within each ocean research priority theme.

To address the non-random selection of panelists to participate in the ranking process, sensitivity analyses were used to assess the robustness of the results. Responses by blocks of panelists were compared to examine the changes in ranked priorities when scores from blocks of panelists were excluded from the analysis. Blocks were defined as panel members affiliated with agencies, NGOs, academics, and the fishing industry. Blocks of fewer than 3 panelists were not included in the comparisons. Spearman rank correlation tests were used to test the null hypothesis of no association between interest groups (α=0.05). Exclusion tests were conducted for blocks of panelists and differences in rank ordering of five or greater for the top twenty priorities were evaluated and discussed in the results for each theme.

Results

I. Improving Ecosystem Health

The Aleutian Islands are a biologically diverse and productive marine ecosystem that supports valuable fish and invertebrate stocks as well as large seabird and marine mammal populations. Due to unique habitat features such as cold-water corals and sponges, Bowers Ridge, Ulm Plateau, and Bowers Seamount, the region was designated a habitat conservation zone in 2005 with a majority of the area closed to bottom trawl fishing. Submerged marine vegetation found in the Aleutian Islands, such as kelp forests and eelgrass beds, support various life stages of federally-managed fish and invertebrates.

Although the Aleutian Islands support large and diverse marine resources, population declines and extinctions have occurred in the region. Several species of seabirds, marine mammals and whales that reside in or utilize the Aleutian Islands are listed under the Endangered Species Act. Severe economic consequences have resulted from the collapse of economically valuable species, such as the red king crab (Wooster 1992).

In order to better manage for improved ecosystem health, more research and information is needed to understand previous changes and predict future changes in the Aleutian Islands. Since the region is poorly studied, there is a lack of data required to better understand ecosystem health, such as understanding why populations have declined and continue to decline. Improving ecosystem health requires interdisciplinary research that can provide the necessary information to manage various activities in the marine environment. As described in the ocean research priorities plan (JSOST 2007), research from the other societal themes will complement an understanding of ecosystem health.

Stakeholder suggested research and information needs were organized into a hierarchy of common topics including categories, sub-categories, and 115 research and information needs (Appendix B). Scores that reflect expert panel ratings are shown in the hierarchy. The top twenty research and information need priorities were ranked with mean and standard deviation lines (Table 1, Fig. 2). Lettered codes (Table 1, Fig. 2) represent the category (first letter), subcategory (second letter) and research and information need (third letter) shown in the improving ecosystem health hierarchy (Appendix B).

Table 1 Top twenty research and information needs for *Improving Ecosystem Health*

Rank	Research/information need	Code
1	Monitor species distribution and abundance indices.	Aaa
2	Identify and map the foraging, spawning and nursery habitats of marine species.	Aba
3	Study the role of deep passes in limiting the distribution of species.	Dbb
4	Study the temporal and spatial distribution and abundance of pollock in Steller sea lion Critical Habitat.	Aad
5	Examine the links between fish and invertebrate populations in the Aleutian Islands to the open ocean ecosystem and to the Bering Sea and Gulf of Alaska.	Dbe
6	Study the linkages between the nearshore habitat and pelagic ecosystems.	Dbd
7	Examine the relationship between deep ocean ecosystems of the Western Aleutian Islands and shallower Bering Sea.	Dba
8	Develop high resolution maps of seafloor geology, morphology and habitat.	Abb
9	Improve identification and classification of invertebrates caught in trawl surveys.	Aac
10	Determine the winter distribution of seabirds in the Aleutian Islands.	Aae
11	Identify Essential Fish Habitat (feeding and spawning habitat) for Atka mackerel.	Abe
12	Determine if the Aleutian Islands are a separate ecosystem.	Dbc
13	Identify Pacific Ocean perch spawning sites.	Abd
14	Identify and map the distribution of kelp and other macroalgae.	Abc
15	Identify which species west of 160 have connections to North America and which are more closely connected to Asia.	Aab
16	Determine the best scale for evaluating movements of fish and other marine life.	Cba
17	Examine the functional roles of commercial species in marine food webs.	Dag
18	Monitor indicators of ecosystem change.	Bbb
19	Identify critical habitat for endangered species (e.g., Northern Right Whale).	Cbd
20	Determine the trophic effects of depleting a target species.	Dad

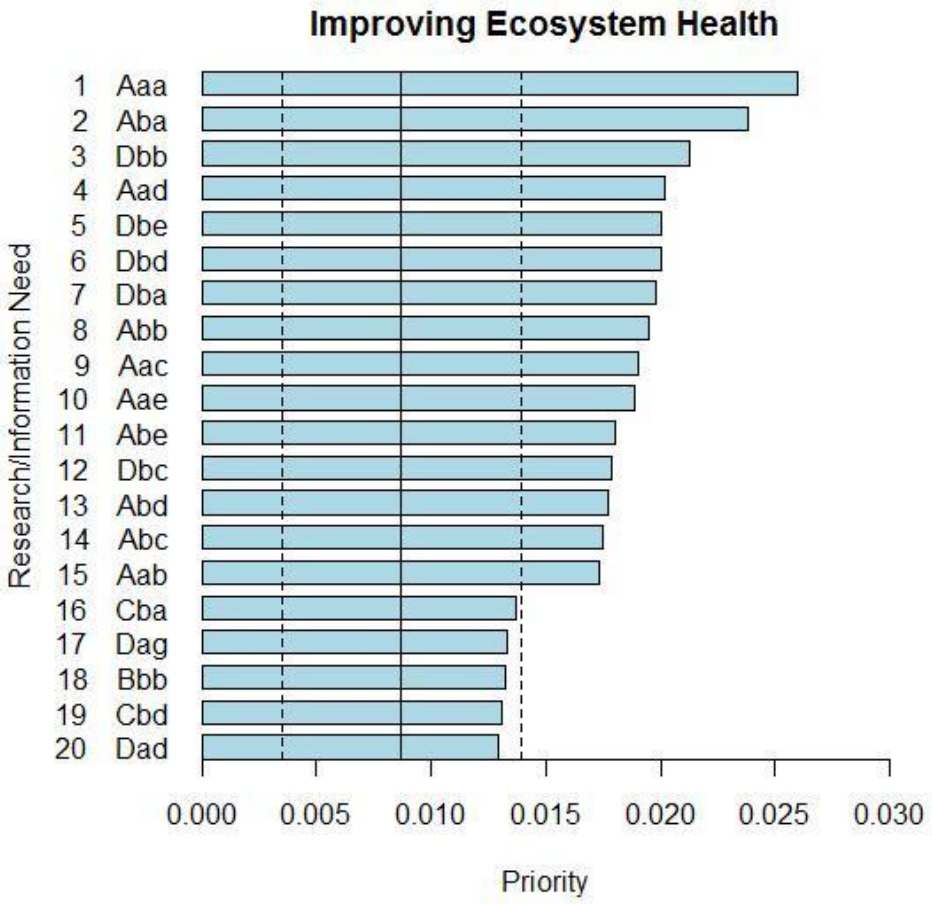

Figure 2 Top twenty research and information needs for ecosystem health with mean (solid) and standard deviation (dashed) lines

Top Twenty Priorities

The number one research priority was to "monitor species distribution and abundance indices." Although this priority does not specify which species to monitor, it is indicative of the need for more information on species distribution and abundance in the Aleutian Islands. The NMFS groundfish bottom trawl surveys currently occur on a biennial basis and provide general information on the summertime distribution and abundance of groundfish and invertebrate species that occur in trawlable habitats in the Aleutian Islands (Von Szalay et al. 2011). This research priority supports continuation of the trawl survey as well as more frequent or expanded trawl surveys and surveys of non-trawlable habitat.

The second research priority was to "identify and map the foraging, spawning and nursery habitats of marine species." For fish and invertebrate species managed under Fisheries Management Plans (FMPs), Congress defines essential fish habitat (EFH) as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity". For Aleutian Island groundfish and crab species, EFH information is based off general distribution information available for some life stages of species, and is described in the FMPs (NPFMC 2008, 2009). EFH information for life stages including eggs, larvae, and early juvenile are largely unknown for many species. For marine species not managed under FMPs, habitat information is poorly studied and largely unknown. Various habitat features in the Aleutian

Islands are designated as areas of particular concern under EFH due to importance of ecological function and vulnerability to human-induced degradation. Further research on these habitat types could provide a better understanding of species distribution and abundance. This research priority also overlaps with the first research priority to "monitor species distribution and abundance indices", and could be integrated in similar research.

The third research priority was to "study the role of deep passes in limiting the distribution of species." The Aleutian archipelago passes west of Samalga Pass are characterized as deeper and wider than those passes to the east of Samalga Pass (Hunt and Stabeno 2005). An ecological division occurs to the west of Samalga Pass, which is used for management boundaries in the Aleutian Island Fisheries Ecosystem Plan (Hunt and Stabeno 2005, NPFMC 2007). The Passes Project consisted of two research cruises in 2001-2002 to the east and west of Samalga Pass that used interdisciplinary research to gain a better understanding of the Aleutian passes (Hunt and Stabeno 2005). Based on changes in demersal fish communities and characteristics, it has been hypothesized that other ecological divisions could occur around Buldir Island and Amchitka Pass (Logerwell et al. 2005). Since previous cruises occurred several years ago and did not extend throughout the entire archipelago, additional research could expand on previous studies by sampling additional passes along the archipelago, and integrate interdisciplinary research including oceanography, fisheries, marine birds, and mammal species distributions. Important management implications could arise if additional ecological divisions occur along the archipelago.

The fourth research priority was to "study the temporal and spatial distribution and abundance of pollock in Steller sea lion critical habitat." Pollock is an important prey species for Steller sea lions in the Aleutian Islands (Tollit et al. 2009). Because competition from commercial fishing could affect Steller sea lion populations, fishing is prohibited in Steller sea lion critical habitat (NMFS 2010). Further research could specifically address temporal and spatial distribution information for pollock in critical habitat.

The fifth research priority was "to examine the links between fish and invertebrate populations in the Aleutian Islands to the open ocean ecosystem and to the Bering Sea and Gulf of Alaska." Because of the relatively narrow shelf and slope habitats in the Aleutian Islands, the nearshore and offshore marine environments are closely coupled. The Aleutian Islands are linked to the Bering Sea and Gulf of Alaska by three major currents; the Alaska Stream, the Alaska Coastal Current, and the Aleutian North Slope Current. The Alaska Coastal Current carries freshwater runoff from coastal regions in the Gulf of Alaska along the Aleutian Islands and moves through Unimak Pass and also through Samalga Pass. The Alaska Stream connects waters from the Gulf of Alaska to the Aleutian Islands, and then through the passes to the Bering Sea connecting to the Aleutian North Slope Current. Links between fish and invertebrate populations could be studied using various techniques, such as genetics or tagging studies to investigate species origins and movements between the different ecosystems. Similar research was conducted where geographic distribution of demersal fishes was linked to biological and physical oceanographic environment (Logerwell et al. 2005). Understanding linkages has important management implications because, depending on a species relationship to other ecosystems or processes, actions such as stock management could be influenced.

The sixth research need was to "study the linkages between the nearshore habitat and pelagic ecosystems." Compared to the eastern Bering Sea and Gulf of Alaska, the transition from nearshore habitat to the open ocean occurs within a short distance in the Aleutian Islands, which enables a tighter coupling between nearshore and offshore environments. Research could investigate how nearshore habitat and pelagic ecosystems influence one another through various oceanographic, biological or chemical studies. Various research techniques could be used to measure linkages such as recruitment, environmental variables, chemistry, productivity, etc.

The seventh research priority was to "examine the relationship between deep ocean ecosystems of the Western Aleutian Islands and shallower Bering Sea." This research priority has some overlap with other research priorities such as research needs five and six. Research to address this research priority could

focus on how currents and nutrient transport affect both of these ecosystems. Sampling methods could include research cruises that include interdisciplinary components, such as those conducted for the Passes Project.

The eighth priority was to "develop high resolution maps of seafloor geology, morphology and habitat." Before mapping occurs it will be important to prioritize which locations could best address research and management needs. The Aleutian Island region is large and contains complex habitat such as deep-sea corals and underwater volcanoes. Improved habitat information could contribute toward a better understanding of fish habitat that could overlap with research priority two. Mapping techniques could include remotely operated underwater vehicles, submersibles, acoustic remote sensing, etc.

The ninth priority was to "improve identification and classification of invertebrates caught in trawl surveys." Currently, NMFS trawl surveys report invertebrate species caught in trawls (von Szalay et al. 2011). However, development of better taxonomic keys could help improve classification information. Training observers on non-research vessels to identify invertebrates to a finer taxonomic level could also contribute to a better understanding of the prevalence of various species.

The tenth research priority was to "determine the winter distribution of seabirds in the Aleutian Islands." The Alaska Maritime National Wildlife Refuge conducts seabird monitoring at representative sites on the Aleutian Islands. While those surveys are useful for monitoring population trends, they do not provide information on variation in seasonal distributions which could affect how seabirds are impacted by commercial fisheries. Linking winter distribution studies with existing monitoring could address this research priority. Research methods could include visual surveys and/or tagging studies.

The eleventh research priority was to "identify Essential Fish Habitat (feeding and spawning habitat) for Atka mackerel." The current EFH description for Atka mackerel (*Pleurogrammus monopterygius*) states that little is known about their distribution before they are caught in trawl surveys at ages two to three (NOAA 2005). Recent research on spawning and feeding habitat indicates that Atka mackerel utilize trawl exclusion zones in the Aleutian Passes (Cooper and McDermott 2011, Rand and Lowe 2011). This information could contribute to improved EFH description for Atka mackerel when EFH information is evaluated on the five year cycle. Further studies could investigate Atka mackerel habitat use in other locations.

The twelfth research priority was to "determine if the Aleutian Islands are a separate ecosystem." Currently, the Fisheries Management Plans (NPFMC 2008, 2009) combine the Bering Sea and the Aleutian Islands into one management area. However, the Aleutian Islands are unique from the Bering Sea in many ways including habitat, current influences, etc., that may warrant further discussion on managing the Aleutian Islands separately. Determining if the Aleutian Islands are a separate ecosystem would be supported by further research studies in various disciplines including oceanography, biology and geology. Research related to many of the research needs identified in this report would contribute toward a better understanding of how the Aleutian Islands are a separate ecosystem.

The thirteenth priority was to "identify Pacific Ocean perch spawning sites." In the groundfish FMP, essential fish habitat for Pacific Ocean perch is poorly defined for eggs and early juvenile stages. Based on larval distributions, it is believed that adults spawn near the shelf break in the spring (NPFMC 2009, Rooper and Boldt 2005), although this has not been well studied. For juvenile life stages, studies have correlated juvenile Pacific Ocean perch to coral and sponge habitat (Rooper and Boldt 2005). Further research could investigate spawning habitat through tagging studies or habitat related research.

The fourteenth research priority was to "identify and map the distribution of kelp and other macroalgae." Submerged aquatic vegetation, such as kelp and macroalgae, are important to various life stages of fish and invertebrates, and are designated habitat areas of particular concern due to ecological value and vulnerability to human induced degradation. Kelp and vegetated areas are identified as EFH for yelloweye rockfish and Atka mackerel (NPFMC 2010). Although it is known that substantial macroalgal

habitat occurs in the Aleutian Islands, such as kelp beds and eelgrass, little information is available regarding the distribution of these habitats and variations over time. In 2007, a new genus of kelp (*Aureophycus aleuticus*) was collected near Kagamil Islands (Kawai et al. 2008). Mapping macroalgal distribution could also contribute toward the second research priority to identify and map the foraging, spawning and nursery habitats of marine species, since this habitat commonly supports fish and invertebrate populations.

The fifteenth research priority was to "identify which species west of 160 have connections to North America and which are more closely connected to Asia." The Aleutian archipelago extends out to the Kamchatka Peninsula of Russia and 160 W is start of the Aleutian Island region at the Alaska Peninsula. The Aleutian Islands are an important corridor for migratory species, therefore, some species found in the Aleutian Islands, such as marine birds, mammals and fish, may have closer connections to Asia. For example, genetic analysis has indicated that migratory chum salmon off the Aleutian Islands are predominantly Asian in origin (McCraney et al. 2010, 2011). Studies to address this research priority could be conducted using genetic techniques or archeological evidence.

The sixteenth research priority was to "determine the best scale for evaluating movements of fish and other marine life." Because there are various scales to evaluate movement on, identifying what scale is most useful will depend on management needs and specific research questions. This research priority could be addressed by reviewing various research efforts to determine what scale is most effective and useful for specific purposes.

The seventeenth priority was to "examine the functional roles of commercial species in marine food webs." Because large biomass removals occur every year from the Bering Sea Aleutian Island management area, it is important to understand the consequence of removing commercial species. Food web interactions are not well understood in the Aleutian Islands; therefore, it is important to use available information and to investigate data gaps to gain a better understanding of how commercial species affect food webs.

The eighteenth priority was to "monitor indicators of ecosystem change." The Ecosystem Considerations section of the annual Stock Assessment and Fishery Evaluation document includes trends of ecosystems change such as physical and environmental trends, ecosystem trends and fishing and fisheries trends (Zador and Gaichas 2010). This information contributes toward monitoring ecosystem changes, however, more data sampling from the Aleutian Island region would contribute toward better monitoring of ecosystem changes. Overlap with research needs in theme (3) the ocean's role in climate, including species distribution, ocean acidification, weather changes, and regime changes could also contribute toward improved monitoring for ecosystem change.

The nineteenth priority was to "identify critical habitat for endangered species (e.g., northern right whale)." Although critical habitat for the North Pacific right whale (*Eubalaena japonica*) was designated by NMFS in 2008, there is lack of information related to the habitat requirements for this species. For example, migratory information, calving and nursery areas for the North Pacific right whale remain unknown (Shelden et al. 2005); therefore, it is difficult to ensure that the designated critical habitat encompasses the entire region necessary the species. Since critical habitat may be revised if new information becomes available, more research on the habitat needs for the North Pacific right whale could address this research priority.

The twentieth priority was to "determine the trophic effects of depleting a target species." Since a large removal of groundfish biomass is occurring in the Bering Sea and Aleutian Islands, the trophic effects of depleting a target species such as pollock, Pacific cod, Atka mackerel, king crab, halibut, sablefish, and Pacific Ocean perch should be evaluated. The Aleutian Island Fisheries Ecosystem Plan (NPFMC 2007) conducted a risk assessment for various fishing effects interactions. However, trophic effects of depleting a target species were not specifically addressed. The risk assessment (NPFMC 2007) describes indicators from the Ecosystem Consideration chapter (Zador and Gaichas 2010) along with

additional indicators and needed indicators to monitor fishing effects. These indicators should be monitored to assess effects of fishing.

Sensitivity Analysis

The sensitivity analysis failed to find statistically significant differences between ranked priorities when all panelists were included and ranked priorities when compared to blocks of panelists affiliated with particular interest group (i.e., agency, NGO). Similarly, there were no statistically significant differences between interest groups when compared to one another.

However, there were some substantial differences in the ranking of the top twenty priorities when agency input was excluded and when academic input was excluded. For example, when agency input was excluded, the research need to "research the movement patterns of nearshore fishes" increased in rank order by eight places and into the top twenty priorities. This subsequently moved research priorities 19 and 20 out of the top twenty priorities. Because the rank order increased when agency input was excluded, this indicates that agency panel members did not consider these research priorities as important as the other panelists. There are several reasons why agency affiliated panelists could consider these to be less of a priority. Based on the criteria developed by the expert panel, agencies could consider cost and feasibility to be an issue for these research needs. Agency employees tend to be more familiar with technical reports and grey literature and could be under the impression that research needs have already been addressed. Panelists affiliated with other interest groups could be unaware of these studies, indicating a communication lapse between agencies and other interest groups. Alternatively, other interest groups could have considered the existing research inadequate because it was not asking the right questions or approaching research from the appropriate angle. Comments made by panelists for this survey give some indication of why people rated research needs in a particular way. However, comments were not made for every research need, and therefore it is difficult to interpret reasons for panelists rating one research priority higher or lower than another.

Similarly, research priority 15, "identify which species west of 160 have connections to North America and which are more closely connected to Asia," increased in rank order by seven places when agency input was excluded. Research priority 10, "determine the winter distribution of seabirds in the Aleutian Islands," increased in rank order by six places. These research priorities are both under the subcategory for the general topic of map abundance and distribution.

Research priorities 5, "examine the links between fish and invertebrate populations in the Aleutian Islands to the open ocean ecosystem and to the Bering Sea and Gulf of Alaska," and 6 "study the linkages between the nearshore habitat and pelagic ecosystems" both decreased in rank order by five places when agency input was excluded.

Because these research priorities decreased in rank order without agency input, this indicates scientists considered these research priorities a higher priority than the other panelists. There are several reasons this may have occurred. All three of these research priorities are under the subcategory "ecosystem linkages", under the general category "understand factors that influence and control ecosystem dynamics." Since ecosystem linkages have implications to management of marine species, agency affiliated panelists could consider these research priorities applicable to their jobs. For example, if a nearshore habitat is affected by natural or anthropogenic impact, it would be important to understand how this may link to the open ocean. Ecosystem-based management requires knowledge of linkages in order to properly manage marine species. Linkages between the Aleutian Islands and other marine ecosystems such as the Bering Sea and Gulf of Alaska are important for predicting changes in the ecosystem.

Discussion

Because research and information needs were grouped into similar categories and subcategories of related topics (Appendix B), there is overlap between some priorities that may allow for collaboration in similar studies, such as an interdisciplinary research cruise. Research and information need priorities one through 15 were more than one standard deviation above the mean (Table 1). This indicates that the expert panel considered these research and information needs to warrant a substantially higher priority compared to the others in the theme. All research and information needs under category A, "catalog organisms and identify habitats," were included in the top 15 priorities. This indicates that panelists agreed on the need for additional basic information on the occurrence and abundance of species and habitats in the Aleutian Islands. The category D, "understand factors that influence and control ecosystem dynamics" and subcategory b "ecosystem linkages" had five research needs in the top 15 priorities. Priorities 15 through 20 were above the mean, but less than one standard deviation above the mean. These research priorities were in category C "determine the function and inter-relationship of organisms in the ecosystem" and subcategory b "movement and distribution," and category D "understand factors that influence and control ecosystem dynamics" and subcategory a "energy flow: nutrient cycling, trophic/food chain dynamics."

II. Marine Transportation and Security

The Aleutian Islands are located along the North Pacific great circle shipping route between East Asian and North American ports. Shipping traffic along this route passes through the western Aleutian Islands and through Unimak pass (Fig. 1). Based upon automated tracking data collected from October 2005 through June 2006, approximately 3,100 ships a year pass through the Aleutian Islands (Nuka Research and Planning Group, LLC. and Cape International 2006). Due to commonly adverse maritime weather conditions and proximity to valuable fishing grounds and sensitive wildlife refuge areas, the Aleutian Islands are vulnerable to oil and cargo spills that result from foundered vessels. For example, in 2004, the M/V *Selendang Ayu* went aground on Unalaska and spilled 336,000 gallons of fuel oil and marine diesel oil and 60,000 tons of soybeans (Transportation Research Board 2008). Transportation activities have been expanding and are likely to continue with changes such as the opening of the Arctic and increased oil and gas development. Improved knowledge necessary for safe and secure marine transportation is essential.

Twenty stakeholder-suggested research and information needs were organized into a hierarchy of four categories, including expert panel scores for each level in the hierarchy (Appendix C). Research and information needs were ranked with mean and standard deviation lines (Table 2, Fig. 3). Lettered codes shown with each research and information need (Table 2, Fig. 3) represent the category (first letter), and research and information need (second letter) that correspond to the marine transportation and security hierarchy (Appendix C).

Table 2 Top twenty research and information needs for *Marine Transportation and Security*

Rank	Research and information need	Code
1	Develop a regional oil spill response plan.	Ad
2	Is current infrastructure (tugs, booms, refueling, marine services, etc.) sufficient to respond to shipping accidents and oil spills?	Ac
3	Is an inter-island marine transportation system feasible for transportation of goods and people?	Db
4	Would changes in mandatory landing locations for fisheries in the region will reduce transportation costs?	Da
5	Determine the socioeconomic impacts of increased transit shipping.	Dc
6	Develop shipping traffic maps for anticipated changes in shipping and fishing activity.	Ab
7	Examine methods to control shipping (e.g., require VMS or emergency transponders and sailing plans on all transiting vessels).	Ba
8	Determine if island passes are bottlenecks that warrant additional shipping regulation (e.g., designated shipping lanes, tug boat escorts).	Bb
9	Provide training/education for vessel operators and communities for risks involved in response to fuel/oil spills and downed vessels.	Be
10	Improve reporting and forecasting of sea conditions.	Bd
11	Regularly update bathymetric maps of the seafloor and currents models through the AI passes to increase transportation safety.	Bc
12	Determine incentives to attract private investment in infrastructure needed for emergency response.	Aa
13	Identify transportation routes that cross sensitive habitats.	Cd
14	Assess the risks and impacts of ballast water and small fuel discharges on the environment.	Cg
15	Determine how traffic related to anticipated Outer Continental Shelf (OCS) exploration and development will impact the Aleutian Islands.	Cc
16	Examine alternatives for managing environmental impacts of shipping (e.g., traffic lanes, no transit zones around critical habitat, speed limits).	Cf
17	How does disturbance to marine life and habitat differ in areas of occasional versus steady marine traffic?	Ce
18	Assess marine shipping impacts with attention to anticipated effects of changes in lanes and routes.	Cb
19	Map habitats and the effects of shipping, fishing and marine debris on those habitats.	Ch
20	Estimate the frequency and causes of collisions with whales with increased shipping.	Ca

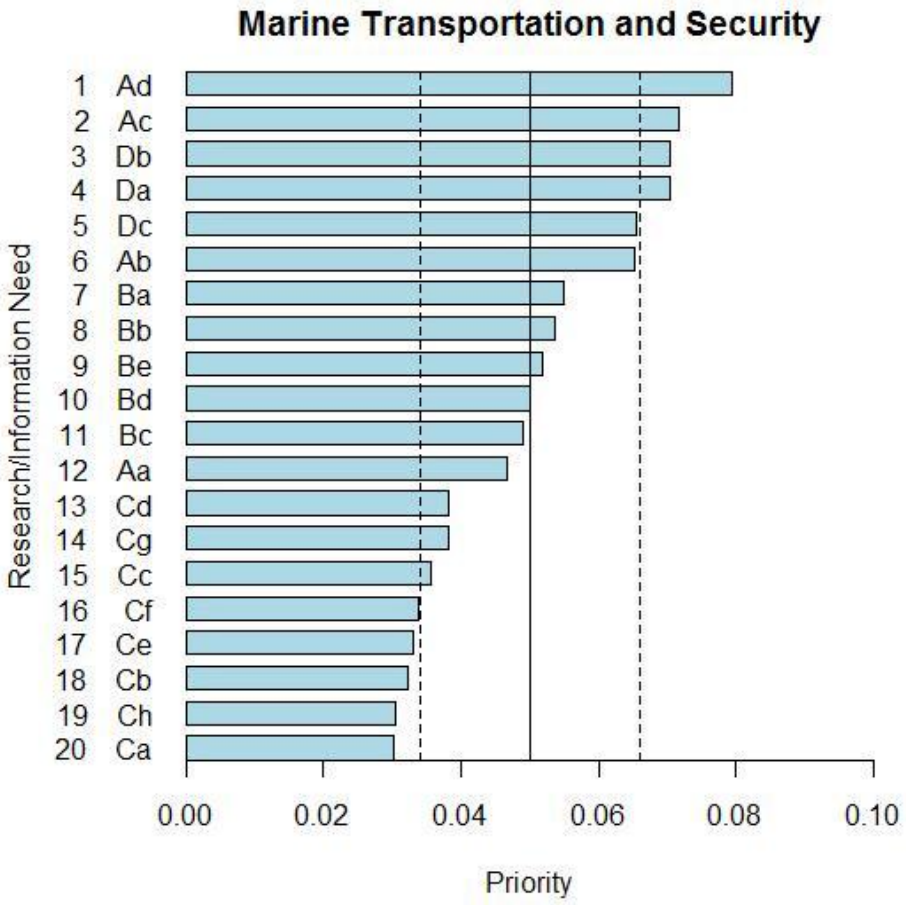

Figure 3 Top twenty research and information needs for marine transportation and security with mean (solid) and standard deviation (dashed) lines

The first priority was to "develop a regional oil spill response plan." In 2008, a guidance document was created to develop a comprehensive risk assessment of ship accidents and spills in the Aleutian Islands (Transportation Research Board 2008). In 2011 an advisory panel completed the first phase of an Aleutian Island risk assessment report that addresses risks facing the region and recommendations for risk reduction measures (AIRA Risk Analysis Team 2011). The second phase of the risk assessment began in 2011 and will address risk reduction measures that require further study, such as increasing spill response capability. Therefore, this priority is currently being addressed.

The second research priority was "is current infrastructure (tugs, booms, refueling, marine services, etc.) sufficient to respond to shipping accidents and oil spills." The Aleutian Island risk assessment report identified infrastructure needs including the need to "enhance towing capabilities on US Coast Guard cutters and increase cutter presence in the Aleutians" (AIRA Risk Analysis Team 2011). That report also identifies the need to "increase rescue tug capability in the Aleutians" (AIRA Risk Analysis Team 2011). An unanswered question that could be addressed by research is how to attract and deploy additional tug capacity in the Aleutian Islands region.

The third priority was "is an inter-island marine transportation system feasible for transportation of goods and people." Few passenger vessels currently travel to or pass through the Aleutian Islands. The Alaska Marine Highway provides infrequent summer service from Homer or Kodiak to False Pass,

Akutan, or Dutch Harbor, and between False Pass, Akutan and Dutch Harbor (Nuka Research & Planning Group, LLC and Cape International, Inc. 2006, Alaska Marine Highway website). However, some communities in the Aleutian Islands such as Adak and Atka do not have ferry terminals. An evaluation of the cost and feasibility of adding ferry terminals to these communities and an evaluation of the costs and benefits of expanded ferry services could be conducted to address this research priority.

The fourth priority was "would changes in mandatory landing locations for fisheries in the region reduce transportation costs." Mandatory landing locations are sometimes included in fisheries management programs. For example, the Bering Sea and Aleutian Islands King and Tanner Crabs crab rationalization program required that a percentage of non-community development quota program total allowable catch be landed in the west region of the Aleutian Islands. Because only one shore-based processing plant existed in Adak, fishermen were not satisfied with this requirement. An amendment to the FMP for Bering Sea and Aleutian Islands King and Tanner Crabs included an exemption to this requirement (NPFMC 2011). Further evaluation of mandatory landing locations could be analyzed for reducing transportation costs.

The fifth priority was to "determine the socioeconomic impacts of increased transit shipping." The Aleutian Island risk assessment project produced a consequence analysis report that analyzed the socioeconomic and environmental effects from sixteen spill scenarios (DNV and ERM-West, Inc. 2011). The report analyzed how spill scenarios could affect socioeconomic factors including commercial and recreational fisheries, subsistence, historic preservation sites, marine recreation and tourism, and coastal development and coastal infrastructure (DNV and ERM-West, Inc. 2011). Additional socioeconomic impacts from increased transit shipping beyond oil spills could be explored through further analysis.

The sixth priority was to "develop shipping traffic maps for anticipated changes in shipping and fishing activity." According to the Aleutian Island Risk Assessment report (AIRA Risk Analysis Team 2011), changes in Arctic routes including the Northern Sea Route and the Northwest Passage route are not likely to become highly transited or to impact the Aleutian Island region (ERM DNV 2011). However, the traffic forecast for vessels including chemical carriers and container ships transit are predicted to more than double in the next 25 years. The report predicted no increase in the fishing fleets, however changes in fishing activity could change due to stock changes and regulations. Shipping traffic maps could be developed to address predicted changes, and fishing activity could be forecasted based on scenarios that project plausible changes in the distribution or abundance of target species, e.g. increased pollock abundance in the Bogoslof or Donut Hole areas.

The seventh priority was to "examine methods to control shipping (e.g., require Vessel Monitoring System [VMS] or emergency transponders and sailing plans on all transiting vessels)." The VMS provides real-time information on vessel location that can be used to inform the deployment of search and rescue assets or to detect violation of sovereign waters or no-transit zones. In 2002, NMFS required VMS on federally licensed groundfish vessels involved in pollock, Pacific cod and Atka mackerel fisheries. The Aleutian Island risk assessment report (AIRA Risk Analysis Team 2011) recommended that enhanced vessel monitoring and reporting program be established for the Aleutian Island Subarea. Decisions regarding new monitoring requirements could benefit from feasibility and cost-benefit analyses.

The eight research priority was "determine if island passes are bottlenecks that warrant additional shipping regulation (e.g., designated shipping lanes, tug boat escorts)." This research priority could be addressed by evaluating vessel traffic information and the costs and benefits of alternative methods for regulating traffic.

The ninth priority was to "provide training/education for vessel operators and communities for risks involved in response to fuel/oil spills and downed vessels." Training and education could be offered to Aleutian communities for resident and vessel operators through workshops, lectures and training exercises.

The tenth priority was to "improve reporting and forecasting of sea conditions." NOAA's National Weather Service maintains a network of buoys, tidal stations and satellite measurements to forecast and report sea condition information. Research opportunities to address this priority could include studies to identify gaps in the existing network of buoys and tidal stations, studies to improve near- and long-term forecasts, and studies of the efficacy of different means of communicating information on current and anticipated conditions.

The eleventh research priority was to "regularly update bathymetric maps of the seafloor and currents models through the Aleutian Island passes to increase transportation safety." This priority would also help to address priority eight under the *Improving Ecosystem Health* theme. The National Ocean Service provides ocean bathymetric maps and an evaluation of needed updates to maps and current models could be conducted through this agency.

The twelfth priority was to "determine incentives to attract private investment in infrastructure needed for emergency response." This research priority would require evaluation of incentives and other ways to attract private investment.

The thirteenth research need was to "identify transportation routes that cross sensitive habitats." In order to overlap transportation routes with sensitive habitats, these habitat types should be mapped for distribution. This would overlap with research priorities in the *Improving Ecosystem Health* theme such as mapping kelp and macroalgal habitat. This research priority could support management objectives such as marine spatial planning in the Aleutian Islands.

The fourteenth priority was to "assess the risks and impacts of ballast water and small fuel discharges on the environment." The risk of ballast water was also included in the *Human Health* theme "Determine if ballast water discharges impact the safety of commercial and subsistence seafood." A common risk from ballast water is the release of invasive species. Risks from small fuel discharges include contaminants. Research could be conducted through monitoring ballast water and fuel discharges to determine impacts to the marine environment.

The fifteenth priority was to "determine how traffic related to anticipated Outer Continental Shelf [OCS] exploration and development will impact the Aleutian Islands. In 2010, President Obama issued a Memorandum that forestalled oil and gas development and exploration in Bristol Bay and the North Aleutian Basin through 2017. Thus, the North Aleutian Basin area is not likely to impact the Aleutian Islands in the near future. However, oil and gas exploration and development in the Beaufort and Chukchi Seas may affect the Aleutian Islands indirectly, and should be monitored as it occurs.

The sixteenth research priority was to "examine alternatives for managing environmental impacts of shipping (e.g., traffic lanes, no transit zones around critical habitat, speed limits)." This research priority could be addressed by evaluating available vessel traffic information and by distinguishing areas of environmental importance in vessel transit areas. This research could be supported by the information in research priority thirteen and other monitoring information of important habitat in the Aleutian Islands. This research priority could also support management objectives for marine spatial planning in the Aleutian Islands.

The seventeenth priority was to "How do disturbance impacts to marine life and habitat differ in areas of occasional versus steady marine traffic. Studies on marine mammals indicate that disturbances from boat traffic can change behavior and could negatively affect energy budgets (Tyack 2008, Williams et al. 2006, Henry and Hammill 2001). Studies specific to the Aleutian Islands could compare marine mammal behavior and abundance in controlled versus trafficked areas.

The eighteenth priority was to "assess marine shipping impacts with attention to anticipated effects of changes in lanes and routes." Because this research priority is within the category for minimizing negative environmental impacts, we can assume that it is related to environmental impacts. This research priority

would overlap with research priorities 13 and 16 with the addition of analyzing how effects may change with changes in lanes and routes in the future.

The nineteenth priority was to "map habitats and the effects of shipping, fishing and marine debris on those habitats." This research priority could be addressed in combination with other research priorities that would contribute toward a better understanding of habitats and impacts. This could include priorities in category C, such as 13, 16 and 18 that also address impacts to the marine environment from shipping.

The twentieth priority was to "estimate the frequency and causes of collisions with whales with increased shipping." Gathering accurate data related to the frequency and cause of whale ship strikes is difficult because the events may be undetected and may be underreported (Gabriele et al. 2007). The NMFS marine mammal stranding database records whale strike reports and a summary of available data for 1978 through 2006 in Alaskan waters suggests an increase in the frequency of reports (Gabriele et al. 2007). An updated whale strike summary for years after 2006, to evaluate trends with increased vessel traffic, would be useful for applications to the Aleutian Islands. This analysis could be combined with forecasts of increased shipping in the Aleutian Islands and forecasts of changes in whale populations to estimate changes in the potential for whale collisions.

Sensitivity Analysis

The sensitivity analysis did not uncover statistically significant differences between ranked priorities for all panel participants and ranked priorities when panel members affiliated with particular interest groups (i.e., agency, NGO, academic and fishing industry) were excluded. Nor were any statistically significant differences found between the rankings of different interest. Moreover there were no differences in rank order greater than two when comparing rank ordering from the entire panel and rank ordering when panel members affiliated with interest groups were excluded. This indicates a consensus about the ranked research priorities.

Discussion

The top four research and information needs were more than one standard deviation above the mean. This indicates the expert panel considered these research and information needs substantially higher than other research and information needs. The top four priorities were either in category A "improve response to marine vessel disasters and emergencies," or category D "assess the socioeconomic impacts of marine traffic" (Appendix C). Priorities five through nine were above the mean but less than one standard deviation above the mean. These priorities were also in categories A and D. Research priorities ten through 15 were below the mean, but above one standard deviation below the mean. These research priorities were in categories A, B "foster efficient and safe marine traffic to reduce risk of harm from marine vessel disasters and emergencies," and C "assess and minimize negative environmental impacts of marine traffic." Priorities 16 through 20 were more than one standard deviation below the mean, indicating a substantially lower preference for these research and information needs, particularly because there were a total of 20 research and information needs for this theme. These priorities were in category C, which suggests panelists considered environmental impacts already addressed by other measures or may not be feasible to research.

Because there is overlap between priorities, particularly those within categories, several research needs could be integrated to serve similar purposes. For example, research needs in category C could provide information related to marine spatial planning. Because reports related to the Aleutian Island risk assessment project have analyzed oil spill response plans in the Aleutian Islands, research needs in category A may need to be reassessed to avoid duplicating efforts.

III. The Ocean's Role in Climate

The ocean plays a vital role in regulating climate. As stated in the Intergovernmental Panel on Climate Change, "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007). Not much is known about how the Aleutian Islands will adapt to changes in climate, but studies in the region suggest the eastern and western regions of the archipelago may respond in different ways from one another (Hunt and Stabeno 2005, Rodionov et al. 2005). Winter surface air temperatures for the Aleutian Islands west of Samalga Pass show a declining trend in recent decades, while the eastern Aleutian Islands have shown a warming trend (Rodionov et al. 2005, Fig. 1). Samalga Pass represents as ecological division as seen species composition changes east and west of the Pass (Hunt and Stabeno 2005, Fig. 1).

Changes in species distribution in the Aleutian Islands may occur due to climate related effects. For example, fossil records on select Aleutian Islands indicate climatic and regime changes over the past three millennia have influenced the distribution and abundance of seabirds (Causey et al. 2005). The effects of ocean acidification, such as the shoaling of aragonite and calcite saturation horizons in the North Pacific, may have a substantial impact on calcium dependent organisms such as cold-water corals. Since the Aleutian Islands may harbor the highest diversity and abundance of cold-water corals in the world, it is important to understand how these habitats are changing (Heifetz et al 2005). Improved understanding of climate change in the Aleutian Islands will assist in preparing for changes in natural resource management and responses to climate related hazards such as sea level rise and changing weather patterns.

Stakeholder input on research and information needs related to the ocean's role in climate were organized into a hierarchy of categories, sub-categories and 65 research and information needs, with expert panel scores included in the hierarchy (Appendix D). The top twenty research and information needs are shown with mean and standard deviation lines (Table 3, Fig. 4). Lettered codes (Table 3, Fig. 4) represent the category (first letter), subcategory (second letter) and research and information need (third letter) as shown in the ocean's role in climate hierarchy (Appendix D).

Table 3 Top twenty research and information needs for the ocean's role in climate

Rank	Research/information need	Code
1	Identify spatial patterns of abundance to better understand connections between marine communities and ocean processes.	Dd
2	Determine how ocean acidification affects deep-sea corals, shellfish, etc.	Db
3	Research how ocean acidification impacts phytoplankton communities and if it is responsible for recent species composition shifts.	Da
4	Estimate if an increase in water temperature will influence coral distribution in the Aleutian Islands.	Dc
5	Research how ocean acidification affects the ocean's ability to produce oxygen.	Fa
6	Estimate how climate change will affect oceanic circulation patterns in the Aleutian Islands.	Fb
7	Research how changing ocean and atmospheric conditions influence the flow of heat, salt and nutrients into the Bering Sea through the Aleutian passes.	Fd
8	Assess impacts of climate change on volatility of natural hazards (e.g., increased storms).	Fe
9	Research if oceanic and atmospheric climate changes are similar north and south of Aleutian Islands.	Fc
10	Determine which species or populations of the Aleutian Islands are most sensitive to climate change and if these can serve as indicator species.	Be
11	Monitor distribution and movement patterns of sensitive "sentinel" species.	Bb
12	Determine which vital signs and other key physiological states of protected species can serve as indicators of ocean/atmospheric changes.	Bf
13	Determine if it is best to monitor all the Aleutian Islands or focus on certain areas and indicator species.	Bg
14	Estimate the impact of ocean warming and acidification on the terrestrial, nearshore and marine ecosystems of the Aleutian Islands.	Ebc
15	Use meta-analysis to develop multivariate (oceanographic/biological/economic) indicators and to characterize the dominant patterns of spatial/temporal variation in ocean conditions for a periodic "state of Alaska marine ecosystems" report.	Bh
16	Investigate if climate change might lead to invasions by non-native species.	Eba
17	Monitor changes in lower trophic level organisms coincident to sea ice loss.	Bc
18	Map kelp beds as an indicator of climate change affecting nearshore communities.	Ba
19	Research if warm water pathogens are becoming more common, their spatial and temporal distribution, if they are concentrated in shellfish, and if they cause disease in mammals that eat shellfish.	Ebb
20	Investigate indicators of climate variability stored in seabed cores, sediments in coastal lagoons and sockeye lakes.	Bd

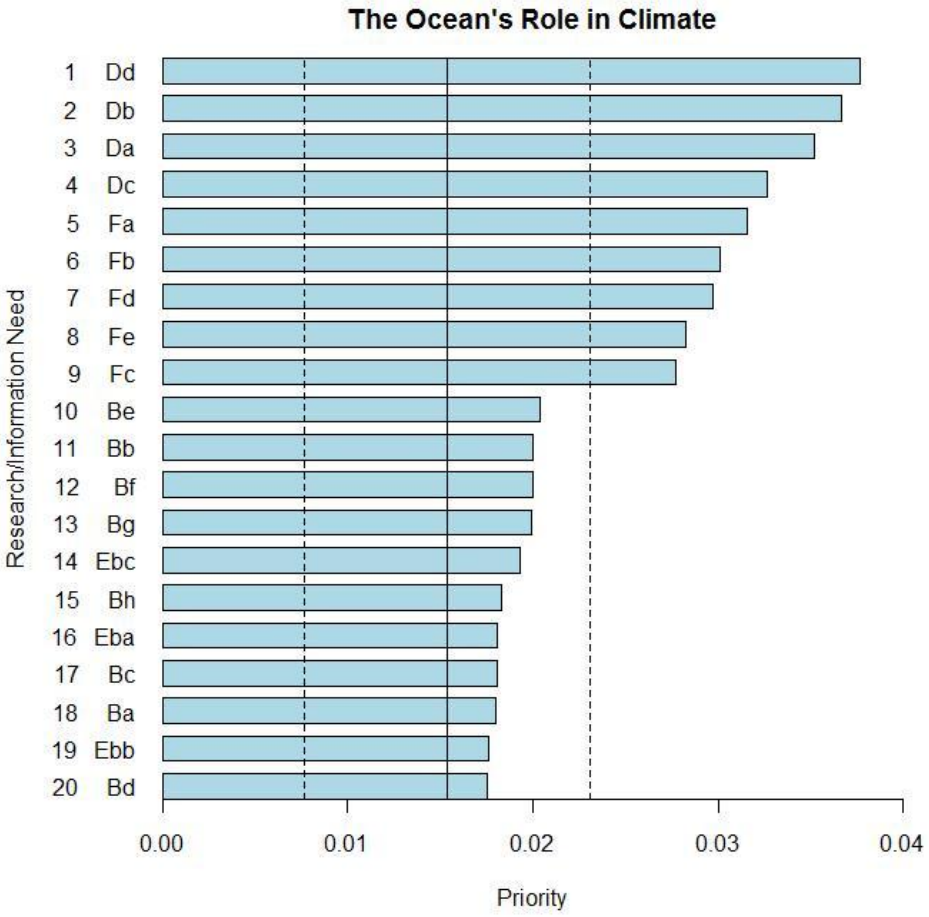

Figure 4 Top twenty research and information needs for ocean's role in climate with mean (solid) and standard deviation (dashed) lines

The first priority was to "identify spatial patterns of abundance to better understand connections between marine communities and ocean processes." The composition of marine communities change when moving west along the archipelago and a known ecological division occurs at Samalga Pass. This division is related to changes in physical and biological oceanography and other ecological divisions are hypothesized to occur further west on the archipelago (Hunt and Stabeno 2005, Logerwell et al. 2005). Because the distribution of species, such as a northward migration, is known to be a response to climate change, it is important to monitor species distribution in the Aleutian Islands. As noted in the Aleutian Island Fisheries Ecosystem Plan (NPFMC 2007), since the islands are oriented east/west as opposed to north/south species may have difficulty adapting to warming conditions by moving north. This research priority overlaps with the first priority in the *Improving Ecosystem Health* theme to "monitor species distribution and abundance indices." Research to address this need could include monitoring marine communities and oceanographic features in representative locations along the archipelago such as those conducted on interdisciplinary research cruises.

The second research priority was to "determine how ocean acidification affects deep-sea corals, shellfish, etc." The Aleutian Island Fisheries Ecosystem Plan (NPFMC 2007) conducted a risk assessment for ocean acidification and recommended ideal indicators for monitoring changes such as aragonite and calcite saturation horizon depths, pH and some measure of coral health. Further research could be conducted through laboratory studies that expose deep-sea corals and shellfish to various ocean

conditions. In 2012, NOAA's Deep Sea Coral Research and Technology Program is beginning a three year research plan for deep-sea corals and sponges in Alaska, where ocean acidification research to address this research priority may occur. Monitoring of ocean acidification indicators is necessary to gather a baseline for future comparison.

The third priority was to "research how ocean acidification impacts phytoplankton communities and if it is responsible for recent species composition shifts." Due the importance of phytoplankton in marine food webs, impacts to phytoplankton communities could substantially alter marine ecosystems (Fabry et al. 2008). In order to correlate changes in phytoplankton community to ocean acidification, monitoring of ocean acidification indicators, such as those identified in the second research priority, should occur. Once ocean acidification indicators are put in place, monitoring of various phytoplankton communities should occur in representative regions throughout the Aleutian archipelago.

The fourth priority was to "estimate if an increase in water temperature will influence coral distribution in the Aleutian Islands." This research need could be addressed through laboratory studies on deep-sea corals and field studies that monitor the distribution and abundance of deep-sea corals in the Aleutian Islands. Since there is a general lack of information on deep-sea corals in the Aleutian Islands, this research need would overlap with the first priority in the *Improving Ecosystem Health* theme to "monitor species distribution and abundance indices." Monitoring to address this research priority could be conducted in conjunction with monitoring ocean acidification indicators for the second research priority in this theme.

The fifth priority was to "research how ocean acidification affects the ocean's ability to produce oxygen." Increased carbon dioxide and lowered pH levels are expected to impact marine organisms in a variety of ways including calcification rates and nutrient availability (Royal Society 2005). Primary producers, such as phytoplankton and marine vascular plants, are important oxygen producers. Since ocean acidification may impact calcifying organisms such as phytoplankton and nutrient availability for marine plants, oxygen levels in the ocean may be affected. In order to better understand these impacts, laboratory studies should be conducted to measure ocean acidification tolerance levels of marine oxygen producing species. Locations in Aleutian Islands should be monitored for baseline information and changing conditions.

The sixth priority was to "estimate how climate change will affect oceanic circulation patterns in the Aleutian Islands." Two potential changes hypothesized for climate change in the Aleutian Islands include less severe, but more frequent, warmer and wetter storms, and a decrease in the volume flux of the Alaskan Stream into the Bering Sea along with an increase in volume from the Alaska Coastal Current (Schumacher and Kruse 2005). Research to address this need could include modeling of climate change scenarios under various conditions and monitoring changes in ocean circulation patterns.

The seventh research priority was to "research how changing ocean and atmospheric conditions influence the flow of heat, salt and nutrients into the Bering Sea through the Aleutian passes." Although limited knowledge exists regarding the impact of climate change on the Aleutian Islands, one of the hypothesized changes includes a decrease in the volume flux of the Alaskan Stream into the Bering Sea along with an increase in volume from the Alaska Coastal Current due to increases in coastal precipitation (Schumacher and Kruse 2005). The water composition of the Alaska Coastal Current is known to be less saline, warmer and nitrate poor compared to the Alaska Stream (Coyle 2005, Ladd et al. 2005). If the Alaska Coastal Current increases in volume, this could transport more of these water qualities to the Bering Sea and affect productivity. Sampling of oceanic conditions is necessary to monitor changes and could be conducted through oceanographic sampling cruises and modeling scenarios.

The eighth priority was to "assess impacts of climate change on volatility of natural hazards (e.g., increased storms)." As mentioned in priority six, more frequent but less severe storms could occur in the Aleutian Islands with changing climate (Schumacher and Kruse 2005). Research to address this priority

could include modeling of climate change scenarios and monitoring changes in natural hazards that occur in the Aleutian Islands.

The ninth priority was to “research if oceanic and atmospheric climate changes are similar north and south of Aleutian Islands.” The net nutrient transport is north though the Aleutian passes and reduced stratification occurs away from passes that contributes to an increase in productivity (Mordy et al. 2005). Monitoring of atmospheric changes and oceanic sampling such as those conducted in research cruises would provide further insight into changes to the north and south of the Aleutian Islands.

The tenth priority was to “determine which species or populations of the Aleutian Islands are most sensitive to climate change and if these can serve as indicator species.” In general, shallow water species are affected by increases in surface air temperatures and impacts could include changes in physiological rates, distribution, or abundance. Species such as eelgrass, corals, invertebrate and various fish species could be studied in laboratory experiments to measure tolerance levels and monitored in the marine environment for changes in health or distribution.

The eleventh priority was to “monitor distribution and movement patterns of sensitive "sentinel" species.” This research priority could overlap with priority ten in similar studies. Research that includes worldwide monitoring of plankton species suggests these species serve as sentinel species for climate change (Hays et al. 2005). Other studies have suggested marine mammals serve as useful sentinel species because of their long lifespan and ability to accumulate toxins (Bossart 2006). Distribution and movement patterns should be evaluated after taking into consideration climate change indicators along with human influences through actions such as fishing.

The twelfth priority is to “determine which vital signs and other key physiological states of protected species can serve as indicators of ocean/atmospheric changes.” In order to address this research need, an evaluation of protected species in the Aleutian Islands should be conducted to determine which species would be most feasible to study. It is known that species have physiological thresholds for temperature and salinity that can influence distribution (Walther et al. 2002). Vital signs and physiological states could be studied in laboratories and through field observations.

The thirteenth priority was to “determine if it is best to monitor all the Aleutian Islands or focus on certain areas and indicator species.” Monitoring representative locations in the Aleutian Islands would save time and money due to the size and remoteness of the region. Addressing this research priority depends on the context of what is being monitored and for what purpose. Known ecological divisions occur to the east and west of Samalga Pass and other ecological divisions likely occur west of Samalga Pass (Hunt and Stabeno 2005, Logerwell et al. 2005). Understanding the presence of ecological divisions along the archipelago is important for choosing representative sites to monitor. Selecting indicator species for monitoring would overlap with the previous priorities ten and eleven.

The fourteenth priority was to “estimate the impact of ocean warming and acidification on the terrestrial, nearshore and marine ecosystems of the Aleutian Islands.” So far, no attempts have been made to quantify ocean warming and acidification impacts to the Aleutian Islands. The Aleutian Island Fisheries Ecosystem Plan (NPFMC 2007) conducted a risk assessment for changes in water temperature and ocean acidification on ecosystem processes and acknowledged that impacts are largely unpredictable. Climate change effects including regime changes and weather patterns, could impact various trophic levels and ecosystem structure. Increased acidification could impact ecosystem habitat and food webs. Monitoring of indicators such as water temperature, aragonite, calcite saturation horizons, pH and corals is necessary to evaluate changes.

The fifteenth priority was to “use meta-analysis to develop multivariate (oceanographic, biological, economic) indicators and to characterize the dominant patterns of spatial/temporal variation in ocean conditions for a periodic "state of Alaska marine ecosystems" report.” Since at the present time there is a lack of data on oceanographic, biological indicators in the Aleutian Islands, more research would be

necessary to conduct a meta-analysis. This research priority would be supported by information gathered from the other research priorities in this theme, such as monitoring ocean conditions related to climate change.

The sixteenth priority was to "investigate if climate change might lead to invasions by non-native species." Various factors such as rising ocean temperatures or ballast water exchanges could contribute toward non-native species invasions in the Aleutian Islands. Because the amount of vessel traffic is expected to increase through the Aleutian Islands, more frequent ballast water exchanges could lead to invasive species particularly if water temperature rises. Monitoring of the marine environment, particularly in areas of rising temperatures or ballast water exchanges would provide early indications of the presence of potentially invasive non-native species.

The seventeenth priority was to "monitor changes in lower trophic level organisms coincident to sea ice loss." Although sea ice does not exist within the scope of this project, loss of sea ice in areas such as the eastern Bering Sea would likely have indirect effects for the Aleutian Islands. The "Bering Sea Project" integrates the National Science Foundation's Bering Ecosystem Study and the North Pacific Research Board's Bering Sea Integrated Ecosystem Research Program. The goal of these research plans is to understand how climate change is affecting the Bering Sea ecosystem and the consequences of changes on lower trophic levels for marine species. Therefore, impact in the Bering Sea are likely addressed through this Program, however, indirect affects to the Aleutian Islands are not likely included in these studies. Since sea ice decline will open new habitat and if sea temperature increases a migration of species to the north may occur. Changes could be monitored through sampling marine community structure in the Aleutian Islands.

The eighteenth priority was to "map kelp beds as an indicator of climate change affecting nearshore communities." Kelp is unevenly distributed throughout the Aleutian Islands (NPFMC 2007), and is known to support productive marine ecosystems and buffer shorelines from erosion. Rises in ocean temperature can decrease algae abundance and distribution (Schiel et al. 2004). Few studies have estimated the impact of climate change on kelp in subarctic environments such as the Aleutian Islands. Mapping kelp bed distribution and changes over time would provide useful information that could be combined with other climate indicators to evaluate the effects of climate change on kelp. This research priority overlaps with priority fourteen in the *Improving Ecosystem Health* theme to map kelp distribution.

The nineteenth priority was to "research if warm water pathogens are becoming more common, their spatial and temporal distribution, if they are concentrated in shellfish, and if they cause disease in mammals that eat shellfish." Pathogens are a causative agent of disease and studies on pathogens around the world have found that pathogen outbursts are coincident with higher temperatures associated with events such as El Niño (Harvell et al. 1999, 2002). Since there is a lack of information related to pathogens in the Aleutian Islands, further field and laboratory studies are needed to better understand the risk of pathogens to this region. This research priority could contribute toward priority one in the *Enhancing Human Health and Safety* theme to research zoonotic disease in marine species.

The twentieth priority was to "investigate indicators of climate variability stored in seabed cores, sediments in coastal lagoons and sockeye lakes." Researching previous changes in climate will provide a better understanding of the region's history and assist to estimate future changes in climate. Observation of the Aleutian Island region climate have shown the eastern Aleutian Islands have experienced a warming climate since 1977 while the western Aleutian Islands have experienced a cooling trend since the 1950s (Rodionov et al. 2005) Therefore, sampling should occur in various regions of the Aleutian Islands to various climate variability changes.

Sensitivity Analysis

Differences between ranked priorities for all panel participants compared to ranked priorities for panel members affiliated with particular interest groups (i.e., Agency, NGO) were not statistically significant. Moreover, differences between the rank orderings of the interest groups were not statistically significant.

However, although not statistically significant, there were substantial differences in the rank ordering when agency input was excluded. Research priority 17 to "monitor changes in lower trophic level organisms coincident to sea ice loss," increased in rank order by seven places. Because the rank order increased when agency input was excluded, this indicates that agency panel members did not consider this research priority as important as the other panelists. One reason for this difference could be that agency panelists considered this research need outside of the project scope. For example, a comment by an agency panel member indicated that there was no sea ice in the Aleutian Islands. Although there could be indirect effects to the Aleutian Islands from loss of sea ice in the Bering Sea, agency affiliated panelists may consider this research need as being addressed in other research occurring in the Bering Sea. Since much of this research may not be published and available to the public, other interest groups may not be aware of this research and consider this research more of a priority. Similarly, research priority 13 to "determine if it is best to monitor all the Aleutian Islands or focus on certain areas and indicator species," decreased in rank order by seven places when agency input was excluded. Because the rank order decreased for this priority, this indicates that agency panel members considered this need a higher priority than other panelists. Since agencies are responsible for resource management in the Aleutian Islands, they are likely interested in designing a useful approach for monitoring. Since the Aleutian Island region is large and remote, agencies would likely consider targeting representative species and locations as a cost-effective approach.

Discussion

The first nine priorities were more than one standard deviation above the mean. This indicates the expert panel considered these research and information needs substantially more important than the others. The first four research priorities were all the research needs within category D "research how ocean processes affect marine communities" (Appendix D). The next five priorities were in category F "assess impacts of climate change on the ocean." Priorities 10 through 20 were above the mean, but less than one standard deviation above the mean. These priorities were in categories B "identify and monitor biological indicators of climate change" and E "assess impacts of the ocean and its role in climate change on marine populations," subcategory b "predict climate change impacts to marine populations."

IV. Enhancing Human Health and Safety

The marine environment includes abundant resources that produce a variety of known, and potentially undiscovered health benefits to humans. The marine environment can also be a source of risks to human health from environmental factors such as harmful algal blooms, seafood contamination, known and emerging disease-causing microbes, and poor water quality. Aleutian Island communities are heavily dependent on subsistence and commercial harvests of marine resources. Therefore, the health of marine organisms is essential for local traditions and economies in the Aleutian Islands.

Studies on mercury levels of subsistence foods in the Aleutian Islands indicate high levels occur in some fish and birds species that are consumed by local Unangan (Aleut) people (Burger et al. 2007). Risks from seafood, such as shellfish, are significant due to the prevalence of paralytic shellfish toxins (PSTs) and paralytic shellfish poisoning (PSP) in Alaska. Currently, commercially harvested areas are the main areas monitored by Alaska Department of Environmental Conservation for PSP or other forms of pollutants. A diverse set of PSTs in Aleutian Islands shellfish have been confirmed (Costa et al. 2009),

indicating the need for biotoxin monitoring programs in the region. Understanding the causes of health hazards and how they can be reduced will lead to fewer illnesses from marine resources.

Stakeholder input on human health and safety research and information needs was organized into a hierarchy of categories and 23 research and information needs (Appendix E). Scores that reflect expert panel ratings are shown in the hierarchy. The top twenty research and information need priorities are shown with mean and standard deviation lines (Table 4, Fig. 5). Lettered codes shown with each research and information need (Table 4, Fig. 5) represent the category (first letter) and research and information need (second letter) that are shown in the human health and safety hierarchy (Appendix E).

Table 4 Top twenty research and information needs for *Human Health and Safety*

Rank	Research/information need	Code
1	Determine what zoonotic diseases are active in foods such as shellfish, fish and marine mammals.	Bd
2	Implement a human disease surveillance program in the Aleutian Island region.	Ba
3	Determine if changing local diets affect disease incidence.	Bc
4	Determine the human health risks related to boats coming to port (i.e., disease).	Bb
5	Determine contaminant loads in commercial and subsistence resources harvested in the region.	Ac
6	Determine the sources and pathways of the major pollutants in the Aleutian Islands.	Ad
7	Design search and rescue programs to effectively respond to emergencies throughout Aleutian Area.	Ch
8	Develop personal, community, and regional emergency response preparedness plans.	Cf
9	Develop effective warning systems to alert community members to algal blooms, contaminant spills, and other health hazards.	Aa
10	Distribute information on safe consumption levels [of contaminants] for local and imported seafood.	Ab
11	Determine risks and impacts to human health of harmful algal blooms in the Aleutian Islands. What are the safest times of year to harvest bivalves.	Ae
12	Improve monitoring to warn the public or to certify specific shellfish harvest areas as safe.	Ah
13	Promote human health and safety in the Aleutian Island region through education and outreach.	Cb
14	Locate former US military dump sites and determine levels of toxic materials.	Af
15	Can the timing of fisheries could be optimized to minimize human casualties associated with fishing.	Ci
16	Determine the most serious immediate human health and safety needs in region.	Ca
17	Estimate the human health risks of increased shipping traffic.	Cj
18	Determine if ballast water discharges impact the safety of commercial and subsistence seafood.	Ai
19	Investigate conditions (natural or anthropogenic) that trigger harmful algal blooms.	Ag
20	Need to know how coastal zone development affects health.	Ce

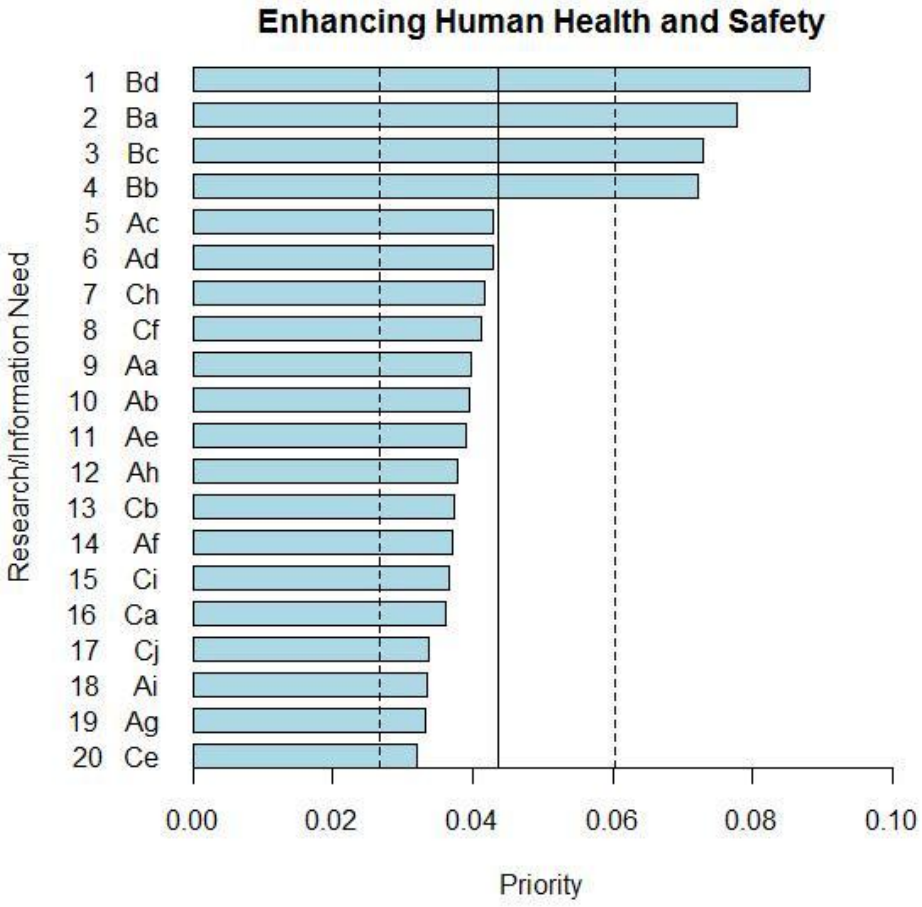

Figure 5 Top twenty research and information needs for human health and safety with mean (solid) and standard deviation (dashed) lines

The first priority was to "determine what zoonotic diseases are active in foods such as shellfish, fish and marine mammals." Research on marine birds and mammals in the Northwest Atlantic indicates the presence of zoonotic pathogens that have the potential to be transmitted to people (Bogomolni et al. 2008). Although zoonotic diseases have been studied in other regions of the world, zoonotic diseases in the Aleutian Islands have not been reported. If there is a low risk of zoonotic diseases in the Aleutian Islands, this information should be communicated with the public. This research need could be addressed by sampling representative marine species.

The second priority was to "implement a human disease surveillance program in the Aleutian Island region." The Eastern Aleutian tribes operate health clinics in communities such as Akutan, False Pass and Adak, and the Iliuliuk Family and Health Services operates a clinic in Unalaska. These clinics could integrate a human disease monitoring program to address this research priority.

The third priority was to "determine if changing local diets affect disease incidence." This research priority could be integrated with the second research priority by working with local clinics to monitor human diseases and concurrently survey patients for changes in diets. Interviewing Aleutian residents for local and traditional knowledge could contribute toward understanding diets have changed over time. This information could be compared to provide an indication if an increase in diseases occurred simultaneously with changes in diet.

The fourth priority was to "determine the human health risks related to boats coming to port (i.e., disease)." Human health risks could include diseases brought by humans or animal species, such as rats, that are commonly onboard vessels. This research need could be addressed through a risk analysis that assimilates known health risks from vessels coming to port and avoidance measures.

The fifth priority was to "determine contaminant loads in commercial and subsistence resources harvested in the region." Studies on subsistence species harvested in the Aleutian Islands, indicate unsafe levels of mercury (Burger et al. 2007). Similarly, fish collected from sites in the Aleutian Islands indicate higher levels of organochlorines such as polychlorinated biphenyls (PCBs) at sites formerly occupied by US military (Miles et al. 2009). Seabird studies indicate that organochlorines and mercury may be coming from distant sources influenced by atmospheric-oceanic processes and migration of seabirds (Anthony et al. 2007, Ricca et al. 2008). Because studies have shown that contaminants occur in marine resources in the Aleutian Islands, available information should be compiled and communicated to Aleutian residents to evaluate if a consistent monitoring program should be established.

The sixth priority was to "determine the sources and pathways of the major pollutants in the Aleutian Islands." Seabird studies indicate contaminants along with mercury may be coming from distant sources influenced by atmospheric-oceanic processes and migration of seabirds (Ricca et al. 2008). Studies on bald eagle eggs indicate higher concentrations of DDE (breakdown products of DDT), and mercury moving westward along the archipelago (Anthony et al. 2007). Contamination could occur through point source (near old military sites) or through global transport and atmospheric distillation and migratory seabirds (Anthony et al. 2007, Ricca et al. 2008). Further studies could investigate sources and pathways of pollutants in greater extent.

The seventh priority was to "design search and rescue programs to effectively respond to emergencies." The US Coast Guard is responsible for search and rescue in the region; however, the closest base with search and rescue capabilities is located in Kodiak. Therefore, it may be useful for Aleutian Island residents to receive training in search and rescue. This research priority may overlap with research priority nine in the *Marine Transportation and Safety* theme to "provide training/education for vessel operators and communities for risks involved in response to fuel/oil spills and downed vessels."

The eighth priority was to "develop personal, community, and regional emergency response preparedness plans." This research priority could be addressed through training and education for various types of emergencies that could occur in the Aleutian Islands. This research priority would overlap with the seventh priority described above.

The ninth priority was to "develop effective warning systems to alert community members to algal blooms, contaminant spills, and other health hazards." In order to warn communities of health hazards, an ocean monitoring system would have to be put in place to address various health hazards. Many of the research or information need priorities in this theme could help to address this priority. For example, priorities ten and twelve address contaminants in seafood and safety related to shellfish harvest areas. Since most of the Aleutian communities are small, it is likely feasible to communicate this information to residents through contact webs.

The tenth priority was to "distribute information on safe consumption levels [of contaminants] for local and imported seafood." This research priority could be addressed through public outreach including educational seminars, information pamphlets and directing the public to appropriate websites. This priority overlaps with priority thirteen to "promote human health and safety through education and outreach."

The eleventh priority was to "determine risks and impacts to human health of harmful algal blooms in the Aleutian Islands - What are the safest times of year to harvest bivalves?" Because PSP incidences in the Alaska occur outside of the summer months and blooms may be colorless, the Alaska Division of Public Health and the Alaska Department of Environmental Conservation do not recommend any months

as a safe time to harvest bivalves (RaLonde 1996). In order for an area to be considered safe for bivalve harvest, a comprehensive phytoplankton and shellfish monitoring program is necessary (RaLonde 1996). Although there has been some monitoring of PSP in Aleutian Island shellfish (Costa et al. 2009), further monitoring on a more consistent basis could provide more information and determine if there are any safe times to harvest shellfish.

The twelfth priority was to "improve monitoring to warn the public or to certify specific shellfish harvest areas as safe." In 2008, the North Pacific Research Board (NPRB) funded a project that included a public outreach component to educate subsistence harvesters in Aleutian communities about PSP and training local coordinators to monitor occurrence and distribution of the toxin (Wright et al. 2008). In order for an area to be certified as safe, monitoring would need to occur on a consistent basis. Public education is important to stress the importance of reporting of PSP symptoms. This research priority overlaps with priorities ten and nine. A follow up study to the NPRB project would be useful for evaluating the success of the educational outreach in the Aleutian communities.

The thirteenth priority was to "promote human health and safety in the Aleutian Island region through education and outreach." Although this is a broad research priority, results from addressing many of the research and information needs in this theme would be useful information to communicate to Aleutian residents. For example, improved monitoring for subsistence harvest of marine resources such as contaminants and PSP, are important issues for human health and safety in the region. Improved communication with the public on these issues, though education, would promote human health and safety in the Aleutian Islands region.

The fourteenth priority was to "locate former US military dump sites and determine levels of toxic materials." Several former US military sites were identified around Aleutian Islands including Adak and Amchitka (Miles et al. 2009, Ricca et al. 2008). Monitoring in fish and birds indicate that military dump sites are likely point sources of PCBs and mercury (Miles et al. 2009, Ricca et al. 2008). Further monitoring of known sites and identification of additional sites should occur along with communicating available information to residents.

The fifteenth priority was "can the timing of fisheries could be optimized to minimize human casualties associated with fishing." Commercial and recreational fisheries have various timing for opening and closures and the winter-time is the most hazardous in terms of storm severity and frequency. Management programs, such as the individual vessel quota system utilized for Pacific halibut and sablefish, increases the fishing season length to eight months. This allows fishermen more flexibility in fishing times and increases safety. This research need could be addressed by evaluating the timing of other fisheries for potential adjustments to improve safety.

The sixteenth priority was to "determine the most serious immediate human health and safety needs in region." Because the research and information needs in this *Human Health and Safety* theme are prioritized based on level of importance, these priorities could be representative of the most "serious" human health and safety issues in the region. Therefore, addressing other research and information needs in this theme would address this priority.

The seventeenth research priority was to "estimate the human health risks of increased shipping traffic." Risks from increased shipping traffic could include oil and cargo spills or invasive species. These priority overlaps with priority four that relates to disease risk from boats and priority eighteen that relates to ballast water risks. Risks to human health from vessel traffic could be evaluated and prioritized by conducting a risk analysis.

The eighteenth priority was to "determine if ballast water discharges impact the safety of commercial and subsistence seafood." This research need could be addressed by monitoring water quality in the areas where ballast water discharges occur compared to ambient conditions. This research priority overlaps

with priority fourteen in the *Marine Transportation and Security* theme to "assess the risks and impacts of ballast water and small fuel discharges on the environment."

The nineteenth priority was to "investigate conditions (natural or anthropogenic) that trigger harmful algal blooms." Although studies have suggested environmental factors such as nutrient and climate fluctuation contribute to blooms (Zingone and Enevoldsen 2000), models to predict bloom events have not been very successful. Therefore, this research need may be best addressed by focusing on monitoring phytoplankton.

The twentieth priority was "need to know how coastal zone development affects health." Because coastal development often includes estuary disturbance, building roads, housing, etc., increased pollution may occur from run-off and sedimentation that can negatively affect marine species. Environmental Impact Statements and Environmental Assessments required through the National Environmental Policy Act are designed to analyze impacts of development projects including human health issues. Because the Aleutian Islands are not a heavily developed area it is not likely that coastal development will increase substantially in the near future. However, human health risks should be evaluated in conjunction with coastal zone development.

Sensitivity Analysis

Differences between ranked priorities for all panel participants and ranked priorities when panel members affiliated with particular interest groups (i.e., agency, NGO) were excluded were not statistically significant. Nor were differences between interest groups statistically significant. However, there were substantial differences in the ranking of the top twenty priorities when agency input was excluded. Research priority 17 to "estimate the human health risks of increased shipping traffic," increased in rank order by 11 places. This indicates that agency panelists considered this a lower priority compared to other panelists. Agency panelists could have considering this research priority too difficult to quantify or considered this priority a low risk to human health. Research priority 10 to "distribute information on safe consumption levels [of contaminants] for local and imported seafood," decreased by 8 places. Priority 12 to "improve monitoring to warn the public or to certify specific shellfish harvest areas as safe," decreased in rank order by five places. This indicates that the agency panelists considered these needs a higher priority than the other panelists. Both of these research priorities relate to warning the public about food safety; therefore, agency panelists would likely support an improvement in the public communication system. Since agency affiliated panelists may be more aware of the literature that indicates contaminant levels and PSP risks for marine resources, they may be more aware of the risks of not communicating this information.

Discussion

The top four research and information needs were more than one standard deviation above the mean, indicating a substantially higher preference compared to the other research and information needs. All four priorities were in category B "reduce risk from disease" (Appendix E). The remaining research and information need priorities were less than the mean, but more than one standard deviation below the mean. These priorities included all research needs in category A "reduce risk to people from contaminants" and most of the research needs in category C "increase community health and safety." Because there were only 23 research and information needs within this theme, most were included in the top 20 priorities.

V. Stewardship of Natural and Cultural Ocean Resources

According to the earliest archeological sites in the Aleutian Islands, the Unangan (Aleut) people have inhabited the Aleutian Islands for approximately 9,000 years (Veltre and Smith 2010). Cultural influences occurred with Russian occupation for fur trade purposes beginning in the mid-1700s and US military presence beginning in World War II. Currently, five communities in the Aleutian Islands are established and the local economies are heavily dependent on commercial and subsistence fisheries. Effective management of natural and cultural ocean resources requires accurate assessment of current conditions. Provided with this information, resource managers can responsibly select management options to promote ocean stewardship.

Stakeholder input on research and information needs for the stewardship of natural and cultural ocean resources was organized into a hierarchy of categories, sub-categories and 64 research and information needs (Appendix F). Scores that reflect expert panel ratings are shown in the hierarchy. The top twenty priorities ranked by the expert panel are shown with mean and standard deviation lines (Table 5, Fig. 6). Lettered codes shown with each research and information need (Table 5, Fig. 6) represent the category (first letter), subcategory (second letter) and research and information need (third letter) as shown in the hierarchy (Appendix F).

Table 5 Top twenty research and information needs for *Stewardship of Natural and Cultural Ocean Resources*

Rank	Research/information need	Code
1	Examine the major impacts on coastal communities facing diminishing commercial fisheries.	Cbc
2	Can coastal communities adapt to changes in resource use? How have communities adapted to past changes in resource availability?	Cba
3	Assess if subsistence harvests respond to variations in resource abundance and distribution.	Cbb
4	Explore economic opportunities for small scale value-added processing (e.g., smoked/ specialty products).	Baf
5	Develop place-based curriculum that incorporates marine resource issues to meet state education standards.	Dc
6	Identify, study, and protect archaeological and culturally sensitive sites.	Cae
7	Exchange information on the major threats to natural and cultural resources.	Dd
8	Determine ways to improve two-way communication between residents and agencies, and between agencies.	Dh
9	Explore the effects of economic development on traditional culture.	Caa
10	Organize fisheries resource marketing studies (e.g., Alaska Seafood Marketing Institute).	Bac
11	Explore markets for sustainable harvests of currently non-targeted species.	Bad
12	Expand marine resource outreach to more communities in the Aleutian Islands.	Da
13	Conduct surveys of harvested species abundance, diversity and distribution in the Aleutian Islands (e.g., maintain the NMFS stock assessment surveys).	Aba
14	Determine the effects of commercial fisheries on subsistence activities.	Cab
15	Advance college level education opportunities in the marine sciences in Alaska.	De
16	Need community outreach on laws regarding subsistence use (e.g., sea otter and sea lions).	Dg
17	Disseminate stock abundance and target/non-target catch data to local residents.	Df
18	Examine how to balance federally managed land use with local human activities (e.g., roads).	Bbi
19	Involve Alaska natives, local citizens, and youth in the research, management, and stewardship of the environment and subsistence resources.	Db
20	Determine if crab stock enhancement is biologically and economically feasible.	Bae

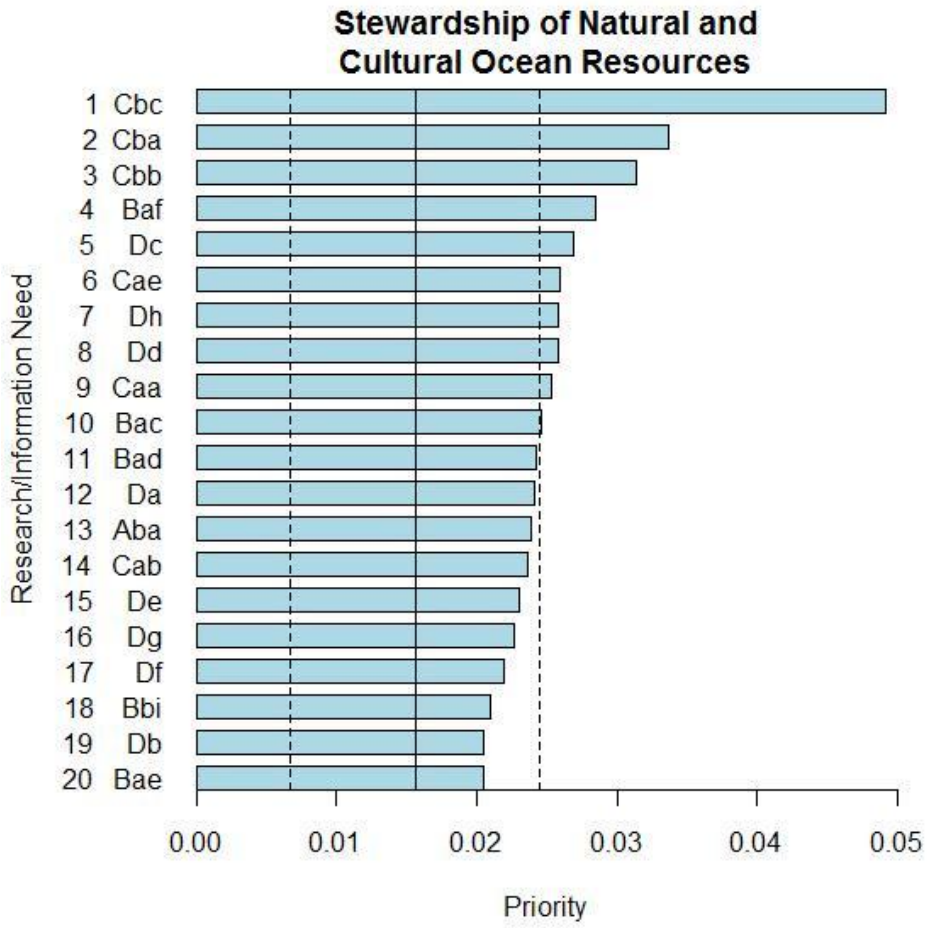

Figure 6 Top twenty research and information needs for stewardship of natural and cultural ocean resources with mean (solid) and standard deviation (dashed) lines

The top priority was to "examine the major impacts on coastal communities facing diminishing commercial fisheries." Although the groundfish fisheries of the Aleutian Islands and the Bering Sea are among the largest landings in the world, declines in fisheries from events such as climate change or fishery collapses should be assessed in terms of community impacts. Communities in the Aleutian Islands, such as Unalaska, are heavily dependent on commercial fisheries to sustain the local economy. The Aleutian Island Fisheries Ecosystem Plan (NPFMC 2007) conducted a socioeconomic risk analysis that assessed how "changes in fishery activities impact the stability of Aleutian Island communities." Since residents are likely to leave a community where they cannot sustain their livelihood, one identified indictor for monitoring changes in fisheries was changes in community populations. This research need could be addressed by building off of the previous socioeconomic risk analysis (NPFMC 2007) and through economic analysis for communities in the region. The community profiles for North Pacific fisheries in Alaska (Sepez et al. 2005) would provide a useful foundation for evaluating communities and risks from diminishing commercial fisheries.

The second research priority was "can coastal communities adapt to changes in resource use? How have communities adapted to past changes in resource availability?" Due to the fluctuations in marine species population levels, the Aleutian communities have adapted to changes in resource use in the past. For example, population crashes of economically valuable species such as Pacific Ocean perch and red king crab required a switch in targeted species for commercial fishing (Schumacher and Kruse 2005,

NPFMC 2007). This research priority could be addressed through a risk analysis, where the dependence of coastal communities on particular marine resources is identified along with risks (e.g., environmental and overharvest) to these resources. In addition, there is need for research to address the extent to which Community Development Quotas and individual quotas and sector allocations affect the viability of switching strategies in commercial and subsistence fisheries.

The third priority was to "assess if subsistence harvests respond to variations in resource abundance and distribution." This priority could be addressed by comparing subsistence harvest data to biological information related to resource abundance and distribution. Changes in time could be evaluated for correlations. Because there may be a lack of data for subsistence harvests in the Aleutian Islands, additional information could be gathered through interviews for traditional and local knowledge.

The fourth priority was to "explore economic opportunities for small scale value-added processing (e.g., smoked/ specialty products)." Studies to address this research priority could be conducted through an analysis of markets and viable options for new products. The University of Alaska Fairbanks Kodiak Seafood and Marine Science Center may be an appropriate place for this research since their mission is to "increase the value of Alaska's fishing industry and marine resources through research, technological development, education and service." This research priority could be explored through a directed graduate study or through workshops and short courses.

The fifth priority was to "develop place-based curriculum that incorporates marine resource issues to meet state education standards." This research need could be addressed by incorporating a marine resource educational component into school curriculum for Aleutian Island communities. Alaska Sea Grant and its extension arm, the Marine Advisory Program, were designed to develop and support marine education. Since there is an Alaska Sea Grant Marine Advisory Program located in Dutch Harbor, this office would be an appropriate resource for addressing this research priority.

The sixth priority was to "identify, study, and protect archaeological and culturally sensitive sites." Studies on early human sites in the Aleutian Islands have provided insights into how long humans have inhabited the region along with changes in marine bird distribution and abundance that relate to climate and environmental variability (Causey et al. 2005, Veltre and Smith 2010). Therefore, these sites are important to protect for their intrinsic value and for their potential research value. If additional sites are identified, they should also be protected and studied. Several locations in the Aleutian Islands are listed on the National Register of Historic Places that is administered by the National Park Service. In addition, the Alaska Historic Preservation Act protects historic, prehistoric or archaeological resources on state lands.

The seventh priority was to "exchange information on the major threats to natural and cultural resources." Since threats to these resources include damage from oil spills, pollution, or natural disasters, these threats should be communicated and researched in collaboration with priorities in the other themes such as *Marine Transportation and Security*, and *Increasing Resilience to Natural Hazards*.

The eighth priority was to "determine ways to improve two-way communication between residents and agencies, and between agencies." Communication between various interest groups is important for collaboration and sharing information. For example, many of the priorities that were ranked differently for the various themes in this report may be a result of lack of communication. Effective ways to promote communication could be explored through various methods including seminars, informal meetings and email listservs. The results from this report may interest both residents and agencies and should be made available to both groups.

The ninth priority was to "explore the effects of economic development on traditional culture." Various economic changes have likely influenced traditional culture in the Aleutian Islands. For example, the 1971 Alaska Native Claims Settlement Act created for-profit Native Corporations that led to the Aleut Corporations in the Aleutian Islands. In 1992, the Community Development Quota Program began

allocating a portion of Bering Sea and Aleutian Island harvests to communities in the Aleutian Islands. This priority could be addressed by conducting local interviews to gather information related to changes in traditional culture that occurred after these economic changes occurred in the Aleutian Islands.

The tenth priority was to "organize fisheries resource marketing studies (e.g., Alaska Seafood Marketing Institute)." The Alaska Seafood Marketing Institute (ASMI) is a non-profit organization whose mission is to increase the economic value of Alaska seafood. Fisheries marketing options, such as the Responsible Fisheries Management Certification provided by ASMI to Alaska commercial fisheries, should be explored through marketing studies to address this priority.

The eleventh priority was to "explore markets for sustainable harvests of currently non-targeted species." This research priority could be combined with the tenth priority in a similar study that investigates markets and species appropriate for harvest. In order for a species to be sustainable harvested, sufficient data on the biology of the species is necessary. Therefore, information available from the North Pacific Fisheries Management Council should be taken into consideration if new species are going to be harvested commercially. Researchers at the University of Alaska Fairbanks Kodiak Seafood and Marine Science Center may be an appropriate place for researching new markets for non-targeted species.

The twelfth priority was to "expand marine resource outreach to more communities in the Aleutian Islands." This research priority could be combined with the fifth priority to "develop place-based curriculum …" and could be addressed by offering marine resource classes to Aleutian communities. The Marine Advisory Program, located in Dutch Harbor, could assist in achieving this research priority.

The thirteenth priority was to "conduct surveys of harvested species abundance, diversity and distribution in the Aleutian Islands (e.g., maintain the NMFS stock assessment surveys)." NMFS stock assessment surveys are conducted on a biannual basis and provide important species information for this region. Additional harvest information could be gathered for subsistence harvests in the Aleutian Islands. This could provide information to assist in addressing the third priority to understand changes in subsistence harvest in the Aleutian Islands.

The fourteenth priority was to "determine the effects of commercial fisheries on subsistence activities." This research priority would be better addressed if more subsistence information was collected on a regular basis. The Aleutian Island Fisheries Ecosystem Plan (NPFMC 2007) conducted a risk assessment for the potential competition between commercial fishery and subsistence uses. Communities in the Aleutian Islands are heavily dependent on subsistence; however, the Aleutian communities are small not likely competing with the demands of commercial fisheries. Indicators identified to assess changes in fisheries and subsistence include monitoring the commercial and recreational fisheries for major changes and making a regional economic model for subsistence fishing (NPFMC 2007). This research priority could be addressed by monitoring the recommended indicators for the recommendations of the risk assessment previously conducted and evaluating monitoring information.

The fifteenth priority was to "advance college level education opportunities in the marine sciences in Alaska." This research need could be addressed by providing grants/scholarships to people from the Aleutian Islands who want to attend college. The Alaska Sea Grant may be an appropriate organization to address this research priority.

The sixteenth priority was "need community outreach on laws regarding subsistence use (e.g., sea otter and sea lions)." Under the Marine Mammal Protection Act, Alaska Natives living along the North Pacific or Arctic may harvest Steller sea lions for subsistence use. Similarly, sea otters may be harvested for subsistence and are regulated by the US Fish and Wildlife Service. Regulations for the sale of products derived from sea lions and sea otters require significant alteration from raw or tanned skin form and also restrict export. Regulations such as these should be communicated to residents through educational pamphlets or other outreach information.

The seventeenth priority was to "disseminate stock abundance and target/non-target catch data to local residents." Presenting this information to local residents could take various forms including directing residents to appropriate websites or through educational seminars in communities. This priority could be addressed in collaboration with priority eight to promote communication between agencies and residents.

The eighteenth priority was to "examine how to balance federally-managed land use with local human activities (e.g., roads)." The majority of the Aleutian Islands are part of the National Wilderness Preservation System. Since the Roadless Area Conservation Rule prevents the building of roads in wilderness areas, regulations that conflict with human activities in the Aleutian Islands may need to be evaluated for balanced solutions.

The nineteenth priority was to "involve Alaska natives, local citizens, and youth in the research, management, and stewardship of the environment and subsistence resources." A successful example of this type project occurred for involving Aleuts in the research and monitoring of radionucleotide levels in marine subsistence species around Amchitka Island (Burger et al. 2009). This priority overlaps with priority eight and the other research priorities that involve outreach for marine resource education. This priority could be addressed by including the public in marine research projects that occur in the Aleutian Islands similar to those that have been successful (Burger et al. 2009).

The twentieth priority was to "determine if crab stock enhancement is biologically and economically feasible." Several laboratory studies have tested various techniques for most effective cultivation of crabs for potential hatcheries (Daly et al. 2009, Stevens et al. 2008). An economic analysis may be necessary to assess if crab stock enhancement should occur in the Aleutian Islands.

Sensitivity Analysis

Sensitivity analyses were not conducted on these results because several expert panel members deferred rating to other panelists that had more expertise in this theme, thus there was not enough input from various interest groups was available to compare ranking of priorities.

Discussion

The first ten research and information need priorities were more than one standard deviation above the mean, indicating the expert panel considered these priorities substantially higher than the other research and information needs. The top three research priorities were all within category C "foster resilient communities through greater understanding of factors that impact human culture and human activities" and subcategory b "community adaptability" (Appendix F). The next seven research and information need priorities were in a mixture of category B "foster vital communities through greater understanding of factors that impact socioeconomics," category C "foster resilient communities through greater understanding of factors that impact human culture and human activities" and category D "promote communication between agencies and communities." All research and information needs under category D were in the top twenty priorities. This indicates a need for improved communication in the Aleutian Islands. Priorities 11 through 20 were above the mean but less than one standard deviation above the mean. These priorities were in the same categories as the higher ranked priorities with the addition of category B "foster vital communities through greater understanding of factors that impact socioeconomics."

VI. Increasing Resilience to Natural Hazards

Natural hazards can impact communities, cultural resources, and ecosystems. The Aleutian Islands form the northern boundary for the Pacific ring of fire, known for large numbers of earthquakes and volcanic activity. Volcanic eruptions, tsunamis and earthquakes, can be significant natural disturbances on ecosystems and recoveries vary depending on frequency and magnitude of each event (Del Moral and Grishin 1999). Long-term studies that monitor an area after a natural disturbance, such as the Kasatochi Island Volcano eruption in the Aleutian Islands, provide important insights for ecosystem reassembly (Del Moral 2010).

Many of the Aleutian Island communities are within close proximity to active volcanoes. Twenty-seven historically active volcanoes occur in the Aleutian Islands and nine have had at least one major eruptive event since 1990 (Schaefer et al. 2009). Seismic activity is common in the region, and due to the exposed nature of the Islands, communities are also vulnerable to tsunamis and storm events. Impacts to communities from natural disasters can be reduced with an increased understanding of physical processes and planning response efforts.

Stakeholders suggested twenty-seven research and information needs related to resilience to natural hazards. These were organized into a hierarchy of categories of related topics with scores reflecting expert panel ratings (Appendix G). The top twenty research and information priorities are shown with mean and standard deviation lines (Table 6, Fig. 7). Lettered codes shown with each research and information need (Table 6, Fig. 7) represent the category (first letter) and research and information need (second letter) that are shown in the hierarchy (Appendix G).

Table 6 Top twenty research and information needs for increasing *Resilience to Natural Hazards*

Rank	Research/information need	Code
1	Consider how communities will fund rebuilding after natural disasters.	Ca
2	Determine the economic viability of reconstructing or relocating communities in high-risk locations damaged by natural disasters.	Cc
3	Determine how communities can adapt to reduce damage from natural disasters and if adaptation is more effective than engineering solutions.	Cd
4	Research historical native responses and adaptations to natural hazards.	Cb
5	Research how increases in storm intensity (due to reduced ice and longer open water seasons) impact coastal zones, communities and marine life.	Da
6	Determine if damage to community infrastructure (e.g., bulk fuel leaks, waste-water spills) due to natural hazards poses direct threats to ecosystems.	Df
7	Research how changes in shoreline integrity threaten terrestrial species.	Dd
8	Determine how long it takes for marine communities to recover from large natural disasters, such as earthquakes, volcanoes, tsunamis, and storms.	Db
9	Develop models to assess risk of natural hazards for marine species.	Dc
10	Determine the impact of underwater landslides and tsunamis on nearshore environments.	De
11	Map shorelines, seafloor structure, geology, water quality and the distribution of marine species for environmental monitoring, disaster planning and mitigation.	Bf
12	Develop a natural disaster warning system for the Aleutian Islands region.	Bd
13	Determine how infrastructure can be designed (e.g., by amending local zoning plans and building codes) to be resilient to natural hazards.	Be
14	Consider what is needed to safeguard air transport facilities and routes against natural hazards.	Bh
15	Assess channels, shipping corridors, and docks to identify alternate transport routes in case current routes are compromised by natural disasters.	Bg
16	Consider habitat damages when planning for and mitigating damage from natural hazards.	Bb
17	Develop better predictive models of storm erosion.	Ae
18	Develop metrics to identify areas at high risk for damage from natural disasters and determine if communities are located in high-risk areas.	Ah
19	Deploy a comprehensive ocean observing system.	Af
20	Establish an emergency planning protocol and conduct emergency response workshops for natural disasters that threaten the Aleutian Islands region.	Bc

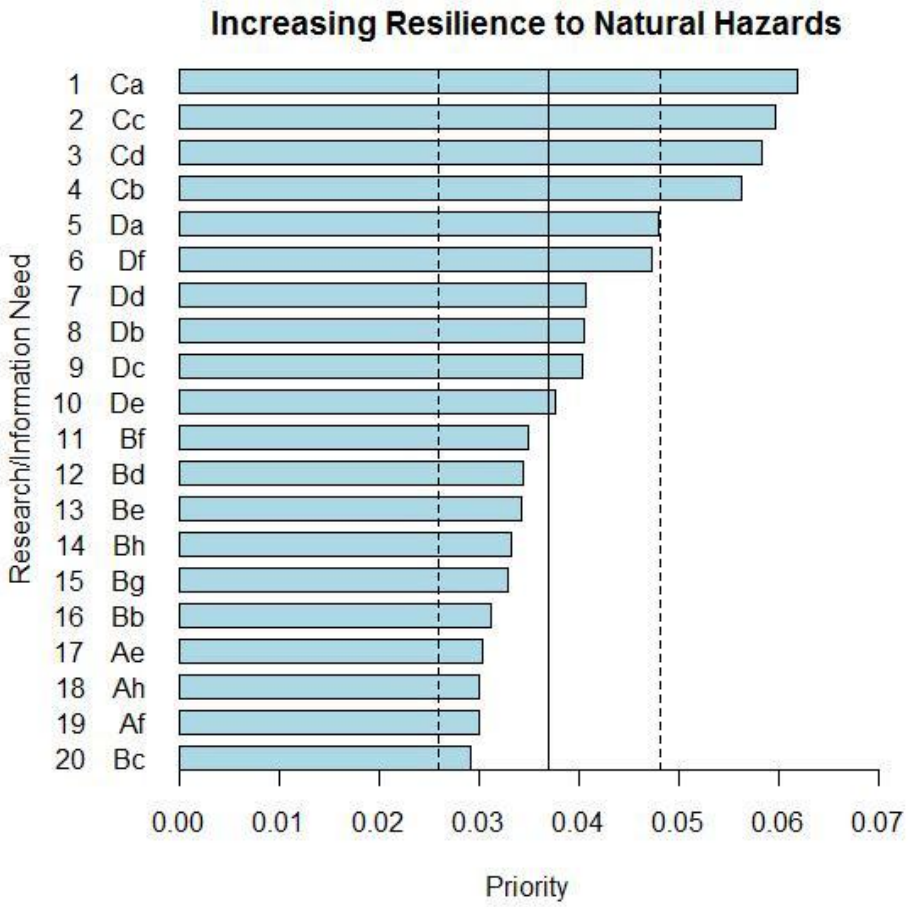

Figure 7 Top twenty research and information needs for resilience to natural hazards with mean (solid) and standard deviation (dashed) lines.

The first research priority was to "consider how communities will fund rebuilding after natural disasters." Since volcanic eruptions and earthquakes commonly occur in the Aleutian Islands, the communities established in this region are accustomed to small scale natural disturbances such as storms. A risk analysis could address this research priority by evaluating which communities are at risk for natural disasters, types of risks involved, and organizations with potential monetary resources available for rebuilding. In addition, prevention measures could be addressed to avoid these risks.

The second priority was to "determine the economic viability of reconstructing or relocating communities in high-risk locations damaged by natural disasters." This research priority could be combined with the first research priority. If there are communities at high risk for natural disasters for which there are no funds available for rebuilding, options for relocation could be evaluated. However, relocation options should take into consideration how the local economy could be supported in a new location.

The third priority was to "determine how communities can adapt to reduce damage from natural disasters and if adaptation is more effective than engineering solutions." Adaptation could take various forms and should be catered to the risk that each community faces. For example, would expanding growth of a community to higher ground be more effective than building seawalls within communities if erosion

or tsunamis are likely. This research priority would be most effective when combined with research priorities one through four.

The fourth priority is to "research historical native responses and adaptations to natural hazards." Since the native Aleut people have inhabited the Aleutian Islands for thousands of years, responses and adaptions to natural hazards have developed. Research to address this priority could include interviews with Native Alaskans of the Aleutian Islands for traditional knowledge related to responses and adaptations. In addition, information from archeological sites may provide insights for adaptation to natural hazards.

The fifth priority was to "research how increases in storm intensity (due to reduced ice and longer open water seasons) impact coastal zones, communities and marine life." In order to address impacts from these events, predictions should be made for changes that are likely to occur in the region. This priority overlaps with priority eight in the ocean's role in climate theme. This research priority could be addressed through a risk assessment similar to those conducted in the Aleutian Island Fisheries Ecosystem Plan (NPFMC 2007), including alternatives for addressing these risks.

The sixth priority was to "determine if damage to community infrastructure (e.g., bulk fuel leaks, waste-water spills) due to natural hazards poses direct threats to ecosystems." Since natural hazards are common in the Aleutian Islands, infrastructure should be evaluated to avoid risks and prevent damage from natural hazards. This could include safety inspections and evaluating predictions for increases in storms in the region.

The seventh priority was to "research how changes in shoreline integrity threaten terrestrial species." Loss of terrestrial habitat near shorelines, such as seabird nesting areas, could occur from shoreline erosion. The Coastal and Marine Geology Program of the US Geological Survey is conducting an analysis of historical shoreline changes of the US that includes parts of Alaska. Although the Aleutian Islands have not been evaluated, this would be an appropriate agency to address this research priority and to estimate projected loss of terrestrial species habitat.

The eighth priority was to "determine how long it takes for marine communities to recover from large natural disasters, such as earthquakes, volcanoes, tsunamis, and storms." Some potential impacts to marine species from natural disasters such as volcanic eruptions include ash distribution in the marine environment and loss of habitat for species such as marine birds and mammals. In 2008, a volcanic eruption occurred on Kasatochi Island in the central Aleutian Islands and the US Geological Survey and US Fish and Wildlife Service conducted monitoring of marine birds, mammals and nearshore processes (Drew et al. 2010, Jewett et al. 2010, Williams et al. 2010). Monitoring studies for sites after other natural disasters such as earthquakes, tsunamis and storms, could provide insights into ecosystem dynamics by demonstrating how long marine communities take to recover from these events.

The ninth priority was to "develop models to assess risk of natural hazards for marine species." Monitoring sites where natural disasters occur provide useful information that can be used to predict recovery time for marine species. A conceptual model could be developed to address risks to marine species from natural hazards, similar to one that was designed to demonstrate ecosystem recovery after the Kasatochi Volcano eruption (Degange et al. 2010).

The tenth priority was to "determine the impact of underwater landslides and tsunamis on nearshore environments." In order to quantify the impacts from these events to nearshore environments, sufficient baseline information is necessary. Therefore, areas in high-risk locations should be monitored before events occur so that sufficient information could be available for comparison. Monitoring of nearshore environments could overlap with priority eleven, described below and priority eight in the improving ecosystem health theme that address seafloor mapping.

The eleventh priority was to "map shorelines, seafloor structure, geology, water quality and the distribution of marine species for environmental monitoring, disaster planning and mitigation." Because

some of this information may be available for some locations, a review of studies that address this research need should be conducted to ensure efforts are not duplicated. This research need could be conducted in collaboration with priority eight in the improving ecosystem health theme that also addresses seafloor mapping. Because the Aleutian Islands region is large and remote, prioritizing high risk sites would be the most efficient way to use resources.

The twelfth priority was to "develop a natural disaster warning system for the Aleutian Islands region." Currently, there are systems in place to provide warnings for tsunamis in the region. The Alaska Volcano Observatory is a joint program that includes US Geological Survey, the Geophysical Institute of the University of Alaska Fairbanks, and the State of Alaska Division of Geological and Geophysical Surveys. The program is designed to monitor volcanic activity in Alaska, including the Aleutian Islands, and provide information related to volcanic hazards. Communities likely have natural disaster warning systems in place; however, an evaluation of warning systems could be conducted to consider improvements.

The thirteenth priority was to "determine how infrastructure can be designed (e.g., by amending local zoning plans and building codes) to be resilient to natural hazards." This research priority would best be addressed in combination with research priorities one through six. These research priorities could address improvements that communities could make to local infrastructure.

The fourteenth priority was to "consider what is needed to safeguard air transport facilities and routes against natural hazards." Natural hazards have the ability to impact air transport. For example, volcanic activity could require diversion of transcontinental aviation. An evaluation of safety needs could be conducted for air transport facilities that include natural hazard risks in the region.

The fifteenth priority was to "assess channels, shipping corridors, and docks to identify alternate transport routes in case current routes are compromised by natural disasters." This research priority could be addressed through a risk analysis where various natural disaster scenarios are evaluated with alternate transportation routes.

The sixteenth priority was to "consider habitat damages when planning for and mitigating damage from natural hazards." Damage to habitat from natural disasters such as essential fish habitat and habitat areas of particular concern could affect marine populations due to the high ecological value of this habitat. In order to mitigate damage adequate baseline information should be gathered for establishing restoration success goals. This research priority could be addressed with habitat mapping research priorities such as priority eleven.

The seventeenth priority was to "develop better predictive models of storm erosion." Since storm events will likely increase with climate change, monitoring and predicting erosion is important to prepare for and mitigate impacts. The USGS would likely be the appropriate agency to monitor erosion since they have conducted similar studies in other areas of Alaska. This priority could be addressed in combination with priority seven.

The eighteenth priority was to "develop metrics to identify areas at high risk for damage from natural disasters and determine if communities are located in high-risk areas." This priority could be addressed by evaluating various metrics including the frequency and magnitude of natural disasters that have impacted communities in the past, and proximity of communities to natural hazards (i.e., volcanos). This research priority would provide some of the necessary information for priority two that addresses relocation of communities in high risk areas.

The nineteenth priority was to "deploy a comprehensive ocean observing system." The Alaska Ocean Observing System (AOOS) was developed as part of the national Integrated Ocean Observation System. The AOOS provides ocean and coastal observation data and includes a Bering Sea/Aleutian Island regional observing network. This research priority could be accomplished by working with AOOS to identify and address data gaps for additional ocean monitoring in the Aleutian Islands.

The twentieth priority was to "establish an emergency planning protocol and conduct emergency response workshops for natural disasters that threaten the Aleutian Island region." This research priority could be addressed by working with communities to determine the most effective methods to respond to natural disasters. This research priority would overlap with the twelfth priority to develop a natural disaster warning system.

Sensitivity Analysis

The sensitivity analysis did not reveal any statistically significant differences between ranked priorities for all panel participants and ranked priorities when panel members affiliated with particular interest groups (i.e., agency, NGO) were excluded. Similarly, there were no statistically significant differences between interest groups.

However, there were substantial differences in the ranking of the top twenty priorities when input from panelists affiliated with agencies was excluded. Research priority 11, to "map shorelines, seafloor structure, geology, water quality and the distribution of marine species for environmental monitoring, disaster planning and mitigation," decreased in rank order by five places. Since agencies are commonly involved in environmental assessments, where quantifying damage is necessary for mitigation processes, agency panelists could consider this research priority necessary for baseline information. Priority 14 to "consider what is needed to safeguard air transport facilities and routes against natural hazards," decreased by 5 places when agency input was excluded. Since the Aleutian Islands are remote and difficult to access, agencies panelists could consider this need important for community safety. Agency panelist may consider this priority in need of review, while other panelists may have considered this priority already addressed. The research need to "determine the frequency of natural hazards" that was not in the top twenty priorities increased 9 places and into the top twenty priorities when agency input was excluded. Priority number 17 to "develop better predictive models of storm erosion," increased in rank order by 6 places. Because both of these priorities relate to monitoring natural hazards, agency panelists may be aware of studies or research that adequately address these needs. Other panelist may not be aware of this information that may demonstrate a lack of communication between interest groups.

Discussion

The top four research and information need priorities were more than one standard deviation above the mean, indicating a substantially higher preference for these research and information needs. All four of these priorities were in category C "enhance recovery and adaptation to reduce lasting damage to communities following natural disasters" (Appendix G). Priorities five through ten were above the mean, but less than one standard deviation above the mean. These priorities were all in category D "improve understanding of effects of natural disasters on the ecosystem and its recovery time." Priorities 11 through 20 were less than the mean, but more than one standard deviation below the mean. Research and information need priorities 11 through 16 and priority 20 were in category B "better prepare communities to mitigate impacts from natural disasters through education and planning." Research priorities 17 through 19 were in category A "predict and assess risk of damage to communities through monitoring and modeling." Because there were only 27 research and information needs for the increasing resilience to natural hazards, most were included in the top twenty priorities. Since the first four priorities were substantially above the mean, preference should be given to these needs when addressing research and information needs within this theme.

Discussion

The final recommendations of the Interagency Ocean Policy Task Force (CEQ 2010) identified ecosystem-based management as a priority for ocean management in the US. In order to develop an

ecosystem-based management plan, objectives for management along with indicators to monitor thresholds are necessary. A science framework is essential to support management decisions and the Aleutian Island regional marine research plan is intended to assist in moving toward improved understanding and management of the Aleutian Islands.

Knowledge of the Aleutian Island marine environment improved with research published in the 2005 special issue of *Fisheries Oceanography* related to Steller sea lion declines. In addition, the Aleutian Island Fisheries Ecosystem Plan (NPFMC 2007) assimilated available information on the Aleutian Islands, conducted a risk analysis for various topics, and provided a management tool to specifically address the region separate from the Bering Sea. Although knowledge of the region has improved in the last decade, managers and scientists acknowledge that not enough is known to properly understand the marine environment and to effectively manage the living marine resources of the Aleutian Islands.

Development of the Aleutian Island regional marine research plan provided a unique opportunity for sampling a broad range of stakeholders for management critical needs that address interdisciplinary marine topics. Research priorities developed through the Aleutian Islands regional marine research plan could be used to complement existing research plans or facilitate new opportunities for research and ecosystem-based management.

Conclusion

Results from exclusion tests showed that preferences for the top twenty research and information need priorities were consistent between interest groups. This increases confidence in the top twenty priorities presented under each ocean societal theme and indicates that priorities were robust to the set of individuals on the expert panel. However, there were differences in ranked priorities when interest groups were excluded and this most frequently occurred when agency affiliated panelists were excluded. There are a variety of reasons for why this occurred including a general agency perspective on the cost or feasibility of a specific research or information need, or the general difference in knowledge between the interest groups. For example, agencies could be more aware of technical reports and grey literature that is part of their jobs and; therefore, could consider some research priorities already addressed. Panelists affiliated with other interest groups could be unaware of studies that have addressed these research needs, indicating a communication lapse between agencies and other interest groups. Alternatively, other interest groups could feel that previous research did not ask the right questions or approach questions from the right angle and would like to see additional research to address the priority. Comments made by panelists in surveys provide some indication of why research and information needs were rated in a particular way. However, comments were not made for every research need; therefore, it is difficult to interpret all the reasons why a panelist rated a particular research or information need higher or lower than another.

Results from the Aleutian Islands regional marine research plan should be made available through Alaska Sea Grant's website. This will inform potential funding sources and groups that may be interested in these priorities such as the North Pacific Research Board, North Pacific Fisheries Management Council, and National Sea Grant. Coordination with other Sea Grant regional plans that have been developed around the US will continue to occur.

Further studies are currently underway to compare the expert panel research and information need priorities to those from a broader group of stakeholders. Results will provide an indication of the extent to which the expert panel represented a broader group of stakeholders. These stakeholders had an opportunity to suggest additional research and information needs not shown in the surveys. If the Aleutian Island regional marine research plan is made available online as a live document, additional research and information need priorities suggested by a broader stakeholder group could be included in this document.

References

Anthony R.G., A.K. Miles, M.A. Ricca, J.A. Estes. 2007. Sources of environmental contaminants in nesting bald eagles, Aleutian Archipelago, Alaska. *Journal of Environmental Toxicology and Chemistry* 26:1843-1855.

Bogomolni A.L., R.J. Gast, J.C. Ellis, M. Dennett, K.R. Pugliares, B.J. Lentell, M.J. Moore. 2008. Victims or vectors: a survey of vertebrate zoonoses from coastal waters of the Northwest Atlantic. *Diseases of Aquatic Organisms* 81:13-38.

Bossart, G.D. 2006. Marine mammals as sentinel species for oceans and human health. *Oceanography* 19:44–47.

Braham, H.W., R.D. Everitt, D.J. Rugh. 1980. Northern sea lion decline in the Eastern Aleutian Islands. *Journal of Wildlife Management* 44:25-33.

Burger J, M. Gochfeld, C. Jeitner, S. Burke, T. Stamm, D. Snigaroff, R. Patrick, J. Weston. 2007. Mercury levels and potential risk from subsistence foods from the Aleutians. *Science of the Total Environment* 384:93-105.

Burger J., M. Gochfeld, K. Pletnikoff. 2009. Collaboration versus communication: the Department of Energy's Amchitka Island and the Aleut Community. *Environmental Research* 109: 503–510.

Causey, D., D.G. Corbett, C. Lefevre, D.L. West, A.B. Savinetsky, N.K. Kiseleva, B.F. Khassanov. 2005. The paleoenvironment of humans and marine birds of the Aleutian Islands: three millennia of change. *Fisheries Oceanography* 14(Suppl. 1):292-306.

Cooper, D., S. McDermott. 2011. Seasonal, small-scale distribution of Atka mackerel in the Aleutian Islands, Alaska, with respect to reproduction. *Marine and Coastal Fisheries* 3:10-20.

Costa, P.R, K.A. Baugh, B. Wright, R. RaLonde, N. Tatarenkova, S.M. Etheridge, K.A. Lefebvre. 2009. Comparative determination of paralytic shellfish toxins (PSTs) using five different toxin detection methods in shellfish species collected in the Aleutian Islands, Alaska. *Toxicon* 54:313-320.

Coyle, K.O. 2005. Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes. *Fisheries Oceanography* 14(Suppl. 1):1477-1492.

Daly, B., J.S. Swingle, G.L. Eckert. 2009. Effects of diet, stocking density, and substrate on survival and growth of hatchery-reared red king crab (*Paralithodes camtschaticus*) juveniles in Alaska, USA. *Aquaculture* 293:68-73.

DeGange, A.R., G.V. Byrd, L.R. Walker, C.F. Waythomas. 2010. Introduction—the impacts of the 2008 eruption of Kasatochi Volcano on terrestrial and marine ecosystems in the Aleutian Islands, Alaska. *Arctic, Antarctic, and Alpine Research* 42:245-249.

del Moral, R. 2010. The importance of long-term studies of ecosystem reassembly after the eruption of the Kasatochi Island Volcano. *Arctic, Antarctic, and Alpine Research* 42:335-341.

del Moral, R., S.Y. Grishin. 1999. The consequences of volcanic eruptions. Chapter 5 *in* L.R. Walker (ed.), *Ecosystems of Disturbed Ground*. Elsevier Science, Amsterdam.

Det Norske Veritas (DNV) and ERM-West, Inc. (2011a). Aleutian Islands Risk Assessment Project Phase A Summary Report. Prepared for National Fish and Wildlife Foundation, United States Coast Guard, Alaska Department of Environmental Conservation.

Det Norske Veritas (DNV) and ERM-West, Inc. (2011b). Aleutian Islands Risk Assessment Phase A – Preliminary Risk Assessment. Task 3-4 Draft Consequence Analysis Report. Prepared for National Fish and Wildlife Foundation, United States Coast Guard, Alaska Department of Environmental Conservation. http://www.aleutiansriskassessment.com/documents/2011_7_7_AIRAPhaseACAReportFINALwCovLtr.pdf

Doroff, A.M., J.A. Estes, T.T. Tinker, D.M. Burn, T.J. Evans. 2003. Sea otter population declines in the Aleutian archipelago. *Journal of Mammalogy* 84:55–64.

Douglas W.V., M.A. Smith. 2010. Historical overview of archaeological research in the Aleut Region of Alaska. *Human Biology* 82:487-506.

Drew, G.S., D.E. Dragoo, M. Renner, J.F. Piatt. 2010. At-sea observations of marine birds and their habitats before and after the 2008 Eruption of Kasatochi Volcano, Alaska. *Arctic, Antarctic, and Alpine Research* 42:325-334.

Fabry, V.J., B.A. Seibel, R.A. Feely, J.C. Orr. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science* 65: 414–432.

Gabriele, C.M, A.S. Jensen, J.L. Neilson, J.M. Straley. 2007. Preliminary Summary of Reported Whale-Vessel Collisions in Alaskan Waters: 1978-2006.

Harvell, C.D., C.E. Mitchell, J.R. Ward, S. Altizer, A.P. Dobson, R.S. Ostfeld, M.D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. *Science* 296:2158-2162.

Harvell, C.D., K. Kim, J. Burkholder, R.R. Coldwell, P.R. Epstein, D.J. Grimes, E.E. Hoffman, E.K. Lipp, A.D.M.E. Osterhaus, R.M. Overstreet, J. Porter, G.W. Smith, G.R. Vasta. 1999. Emerging marine diseases: climate links and anthropogenic factors. *Science* 285:1505–1510.

Hays, G.C., R.J. Anthony, C. Robinson. 2005. Climate change and marine plankton. *Trends in Ecology and Evolution* 20:6.

Heifetz, J., B.L. Wing, R.P. Stone, P.W. Malecha, D.L. Courtney. 2005. Corals of the Aleutian Islands. *Fisheries Oceanography* 14(Suppl. 1):131–138.

Henry E, M.O. Hammill. 2001. Impact of small boats on the haulout activity of harbour seals (*Phoca vitulina*) in Metis Bay, Saint Lawrence Estuary, Quebec, Canada. *Aquatic Mammalogy* 27:140-148.

Hunt, G.L. Jr., and P.J. Stabeno. 2005. Oceanography and ecology of the Aleutian Archipelago: spatial and temporal variation. *Fisheries Oceanography* 14(Suppl. 1):259-276.

Interagency Ocean Policy Task Force. 2010. Final recommendations of the interagency ocean policy task force. (Accessed August 2011: http://www.whitehouse.gov/files/documents/OPTF_FinalRecs.pdf)

Intergovernmental Panel on Climate Change (IPCC). 2007. Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jensen, A.S., G.K. Silber. 2003. Large whale ship strike database. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-OPR- , 37 pp.

Jewett, S.C., J.L. Bodkin, H. Chenelot, G.G. Esslinger, M.K. Hoberg. 2010. The nearshore benthic community of Kasatochi Island, one year after the 2008 volcanic eruption. *Arctic, Antarctic, and Alpine Research* 42:315-324.

Kawai, T.H., T. Hanyda, M. Lindeberg, S.C. Lindstrom. 2008. Morphology and molecular phylogeny of *Aureophycus aleuticus* Gen. Et Sp. Nov. (*Laminariales, Phaeophyceae*) from the Aleutian Islands. *Journal of Phycology* 44:1013–1021.

Ladd, C., G.L. Hunt Jr., C.W. Mordy, S.A. Salo, P.J. Stabeno. 2005. Marine environment of the eastern and central Aleutian Islands. *Fisheries Oceanography* 14(suppl 1): 22-38.

Livovenko, L.A. 1964. Distribution of the larvae of rockfish (*Sebastodes alutus* Gilbert) in the Gulf of Alaska. Pages 217-225 *in* P.A. Moiseev, editor, *Soviet Fisheries Investigations in the Northeastern Pacific*, Part III.

Logerwell, E.A., K. Aydin, S. Barbeauz, E. Brown, M.E. Conners, S. Lowe, J.W. Orr, I. Ortiz, Reuter, P. Spencer. 2005. Geographic patterns in the demersal ichthyofauna of the Aleutian Islands. *Fisheries Oceanography* 14(Suppl. 1) 93–112.

Mardle, S., S. Pascoe. 1999. A review of applications of multiple-criteria decision-making techniques to fisheries. *Marine Resource Economics* 14:41-63.

McCraney, W.T., C.M. Kondzela, J. Murphy, J.R. Guyon. 2010. Genetic stock identification of chum salmon from the 2006 and 2007 Bering-Aleutian Salmon International Survey. North Pacific Anadromous Fish Commission, Doc. 1288, 11 p. Vancouver, BC, Canada.

McCraney, W.T., E.V. Farley, C.M. Kondzela, S.V. Naydenko, A.N. Starovoytov, J.R. Guyon. 2011. Genetic stock identification of overwintering chum salmon in the North Pacific Ocean. *Environmental Biology of Fishes* DOI:10.1007-S10641-011-9972-2.

Merritt, M.F., K.R. Criddle. 1993. Evaluation of the analytic hierarchy process for aiding management decisions in recreational fisheries: a case study of the Chinook salmon fishery in the Kenai River, Alaska. In: G. Kruse, D.M. Eggers, R.J. Marasco, C. Pautzke, and T.J. Quinn II (eds.), *Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations*, Alaska Sea Grant Program, Fairbanks.

Merritt, M.F., T.F. Quinn II. 2000. Using perceptions of data accuracy and empirical weighting of information: assessment of a recreational fish population. *Canadian Journal of Fisheries and Aquatic Science* 57:1459–1469.

Miles**,** AK, Ricca MA, Anthony RG, Estes JA. 2009. Organochlorine contaminants in fishes from coastal waters west of Amukta Pass, Aleutian Islands, Alaska. *Journal of Environmental Toxicology and Chemistry* 28:1643-1654.

Mordy, C.W., P.J. Stabeno, C. Ladd, S. Zeeman, D.P. Wisegarver, G.L. Hunt. 2005. Nutrients and primary production along the eastern Aleutian Island Archipelago. *Fisheries Oceanography* 14(Suppl 1):55–76.

National Marine Fisheries Service (NMFS). 2010. Endangered Species Act - Section 7 Consultation Biological Opinion for the Bering Sea and Aleutian Islands Groundfish Fisheries. NMFS Alaska Region Juneau AK.

National Ocean and Atmospheric Administration (NOAA). 2005. Appendix F.2 Essential Fish Habitat Assessment Report for the Groundfish Resources of the Bering Sea and Aleutian Islands Regions. NMFS Alaska Region Juneau AK.

National Research Council. 2000. *Bridging Boundaries Through Regional Marine Research*. National Academy Press, Washington, D.C.

National Science and Technology Council's Joint Subcommittee on Science and Technology (JSOST). 2007. Charting a course for ocean science in the United States for the next decade: an ocean research priorities plan and implementation strategy. Available: http://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc-orppis.pdf. (February 2011).

North Pacific Fishery Management Council (NPFMC). 1990. Fishery Management Plan for the Salmon Fisheries in the EEZ off the Coast of Alaska. Anchorage, Alaska.

North Pacific Fishery Management Council (NPFMC). 2007a. Aleutian Islands Fishery Ecosystem Plan. North Pacific Fishery Management Council, Anchorage, Alaska.

North Pacific Fishery Management Council (NPFMC). 2007b. Draft Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis for Amendments to the Fishery Management Plan (FMP) for Groundfish of the Bering Sea and Aleutian Islands Management Area (BSAI) (Amendment 88), BSAI Crab FMP (Amendment 23), Scallop FMP (Amendment 12) and the Salmon FMP (Amendment 9) and Regulatory Amendments to revise the Aleutian Islands Habitat Conservation Area. Anchorage, Alaska.

North Pacific Fishery Management Council (NPFMC). 2008. Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs. Anchorage, Alaska.

North Pacific Fishery Management Council (NPFMC). 2009. Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area. Anchorage, Alaska.

Nuka Research and Planning Group LLC and Cape International. 2006. Vessel traffic in the Aleutians subarea. Report for Alaska Department of Environmental Conservation. 51 p.

Orr, J.C., V.J., Fabry, O. Aumont, , L. Bopp, S.C. Doney, R.A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R.M. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R.G. Najjar, G.-K. Plattner, K.B. Rodgers, C.L. Sabine, , J.L. Sarmiento, R. Schlitzer, R.D. Slater, I.J. Totterdell, M.-F. Weirig, Y. Yamanaka, A. Yool. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437:681-686.

RaLonde R. (ed.). 1996. Paralytic Shellfish Poisoning: The Alaska Problem. Alaska's Marine Resources. Marine Advisory Program 8:2.

Rand, K.M.. S.A. Lowe. 2011. Defining Essential Fish Habitat for Atka mackerel with respect to feeding within and adjacent to Aleutian Islands Trawl Exclusion Zones. *Marine and Coastal Fisheries* 3:21-31.

Ricca M.A., A.K. Miles, R.G. Anthony. 2008. Sources of organochlorine contaminants and mercury in seabirds from the Aleutian Archipelago of Alaska: inferences from spatial and trophic variation. *Science of the Total Environment* 406:308-323.

Rodionov, S., J.E. Overland, N.A. Bond. 2005. Spatial and temporal variability of the Aleutian climate. *Fisheries Oceanography* 14(Suppl. 1):3-21.

Rooper, C.N., J.L. Boldt. 2005. Distribution of Pacific Ocean Perch *Sebastes alutus* in the Aleutian Islands in relation to benthic habitat. *Alaska Fisheries Research Bulletin* 11:102-112.

Royal Society. 2005. Ocean acidification due to increasing atmospheric carbon dioxide. Policy document Royal Society, London. The Clyvedon Press Ltd, Cardiff.

Schaefer, J.R., C.E. Cameron, C.J. Nye. 2009. Historically active volcanoes of Alaska. Alaska Department of Natural Resources, Division of Geological & Geophysical Surveys, Miscellaneous Report MP 133. 1 pp. Anchorage, AK.

Schiel, D.R., J.R. Steinbeck, M.S. Foster. 2004. Ten years of induced ocean warming causes comprehensive changes in marine benthic communities. *Ecology* 85:1833–1839.

Schmoldt, D.L., J. Kangas, G.A. Mendoza, M. Pesonen (eds.). 2001. *The Analytical Hierarchy Process in Natural Resource and Environmental Decision Making*. Kluwer Academic Publishers, Dordrecht, Netherlands.

Schumacher, J.D., G.H. Kruse. 2005. Toward sustainable ecosystem services from the Aleutian Archipelago. *Fisheries Oceanography* 14(Suppl. 1):277-291.

Sepez, J.A., B.D. Tilt, C.L. Package, H.M. Lazrus, I. Vaccaro. 2005. Community profiles for North Pacific fisheries - Alaska. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-160, 552 p. Seattle, WA.

Shelden, K.E.W., S.E. Moore, J.M. Waite, P.R. Wade, D.J. Rugh. 2005. Historic and current habitat use by North Pacific right whales *Eubalaena japonica* in the Bering Sea and Gulf of Alaska. *Mammal Review* 35:129–155.

Stevens, B.G., S. Persselin, J. Matweyou. 2008. Survival of blue king crab *Paralithodes platypus Brandt*, 1850, larvae in cultivation: effects of diet, temperature and rearing density. *Aquaculture Research* 39: 390-397.

Tollit, D.J., A D. Schulze, A.W. Trites, P.F. Olesiuk, S.J. Crockford, T.S. Gelatt, R.R. Ream, K.M. Miller. 2009. Development and application of DNA techniques for validating and improving pinniped diet estimates. *Ecological Applications* 19:889-905.

Transportation Research Board. 2008. Risk of vessel accidents and spills in the Aleutian Islands: Designing a Comprehensive Risk Assessment. Special Report 293. http://www.aleutianriskassessment.com/documents/sr293.pdf.

Tyack, P.L. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. *Journal of Mammalogy* 89:549-558.

United States Fish and Wildlife Service (USFWS). 2000. Beringian seabird colony catalog. US Fish and Wildlife Service, Anchorage, Alaska.

Veltre, D.W., M.A. Smith. 2010. Historical overview of archaeological research in the Aleut region of Alaska. *Human Biology* 82: 5-6, Article 2. Available at: http://digitalcommons.wayne.edu/humbiol/vol82/iss5/2

Von Szalay, P.G., C.N. Rooper, N.W. Raring, M.H. Martin. 2011. Data report: 2010 Aleutian Islands bottom trawl survey, 153 p. NTIS No. PB2011-108304.

Walther, G.R., E. Post, P. Convery, A. Menzel, C. Parmesan, et al. 2002. Ecological responses to recent climate change. *Nature* 416:389–95.

White House Council on Environmental Quality (CEQ). 2010. Final recommendations of the Interagency Ocean Policy Task Force. Washington, DC: White House.

Williams, J.C., B.A. Drummond, R.T. Buxton. 2010. Initial effects of the August 2008 volcanic eruption on breeding birds and marine mammals at Kasatochi Island, Alaska. *Arctic, Antarctic, and Alpine Research* 42:306-314.

Williams, R., D. Lusseau, P.S. Hammond. 2006. Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). *Biological Conservation* 133:301–311.

Wooster, W.S. 1992. King crab dethroned. Pages 14-30 *in* M.H. Glanz (ed) *Climate, Variability, Climate Change and Fisheries*. New York: Cambridge University Press.

Wright, B.A., R. RaLonde, V.S. Gofman, M. Harmon, K. Khanna. 2008. Response and intervention system for climate change induced paralytic shellfish poisoning (PSP) in Aleut communities, PSP monitoring and outreach, NPRB Project 644 Final Report. Anchorage, AK.

Zingone, A., H.O. Enevoldsen. 2000. The diversity of harmful algal blooms: a challenge for science and management. *Ocean and Coastal Management* 43:725-748.

Regional Research and Information Themes for the Aleutian Island Region

Answer this survey and qualify for a prize drawing for $200 in Alaska Sea Grant publications, videos, and posters!

Welcome to the survey on regional research priorities for the Aleutian Island Region. For this project, research needs are those that require the discovery of new knowledge about the coast and/or ocean. Information needs are those that require the synthesis or translation of existing knowledge. We are focusing on needs that will contribute to management of coastal and oceanic natural resources and the communities that depend on them.

Over the next several pages, we will ask you to provide input on research and information needs associated with six topical themes. You will also have an opportunity to provide input on needs that cut across topical areas or are not included within the areas we have listed.

Stewardship of resources
Resilience to natural hazards
Marine transportation/security
The ocean's role in climate
Ecosystem health
Human health & safety
Cross-cutting and other priorities

You may take this survey as often as you like, but we ask that if you do so, please identify yourself each time so that we can accurately track the number of individuals who have responded.

Theme #1: Stewardship of Natural and Cultural Ocean Resources

To sustain a high quality of life for those who enjoy and rely on coastal and ocean resources, we need better ways to define and measure the social and economic vitality of coastal communities and a better understanding of factors that contribute to this vitality. For example,

- What is the value of Marine Stewardship Council (MSC) certification and what are the implications of growing international interest in the carbon footprint of fisheries and food miles?
- What are the characteristics of the major undersea habitats near the Aleutians, and how critical are they to commercial and non-commercial species? What invasive species have been introduced in the past 5 years, and what are the paths of introduction?

Please list up to 5 research and information priorities for this theme area. For each priority, indicate if it is a near-term (1–3 years) or long-term (4 or more years) research priority and please rate its importance. When you are done entering priorities under this theme, please select “Next” at the bottom of the page.

Stewardship research priority #1

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Stewardship priority #1	◯	◯	◯	◯	◯	◯	◯	◯	◯

Stewardship research priority #2

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Stewardship priority #2	◯	◯	◯	◯	◯	◯	◯	◯	◯

Stewardship research priority #3

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Stewardship priority #3	◯	◯	◯	◯	◯	◯	◯	◯	◯

Stewardship research priority #4

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Stewardship priority #4	◯	◯	◯	◯	◯	◯	◯	◯	◯

Stewardship research priority #5

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Stewardship priority #5	◯	◯	◯	◯	◯	◯	◯	◯	◯

Theme 2: Resilience to Natural Hazards

Coastal storms and tsunamis have demonstrated that natural hazards can affect our economy, environment, public health, and safety. Flooding, tsunamis, earthquakes, landslides, volcanic eruptions, severe storms, and other natural hazards cannot be eliminated. However, with well targeted research and information we can improve management and predictions to reduce impacts to coastal communities and natural resources. For example,

- How can we bring together engineering knowledge of shoreline reinforcement, administration of federal reinforcement projects, natural erosion processes, etc., to make best management decisions for communities?
- What areas are at particular risk for damage from natural hazards?
- How do natural hazards affect fish and marine mammals?

Please list up to 5 research and information priorities for this theme area. For each priority, indicate if it is a near-term (1–3 years) or long-term (4 or more years) research priority and please rate its importance. When you are done entering priorities under this theme, please select “Next” at the bottom of the page.

Resilience research priority #1

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Resilience priority #1	◯	◯	◯	◯	◯	◯	◯	◯	◯

Resilience research priority #2

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Resilience priority #2	◯	◯	◯	◯	◯	◯	◯	◯	◯

Resilience research priority #3

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Resilience priority #3	◯	◯	◯	◯	◯	◯	◯	◯	◯

Resilience research priority #4

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Resilience priority #4	◯	◯	◯	◯	◯	◯	◯	◯	◯

Resilience research priority #5

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Resilience priority #5	◯	◯	◯	◯	◯	◯	◯	◯	◯

Theme 3: Marine Transportation and Security

Our ports, both small and large, are essential to healthy coastal economies. Ports and maritime transportation also present security risks and environmental hazards. A better understanding of the impacts of our marine transportation system can help managers meet the challenge of maintaining safe and secure ports and preventing groundings while reducing the negative environmental impacts. For example,

- What are optimal strategies for stationing response vessels in the Aleutian Islands region? How should these strategies evolve in response to changes in shipping routes and the intensity of traffic as arctic shipping routes open?
- How critical are the linkages between the maintenance of port services and the presence of shore-based processing capacity?
- How do port operations and marine transport affect management of living marine resources, including northern right whales?

Please list up to 5 research and information priorities for this theme area. For each priority, indicate if it is a near-term (1–3 years) or long-term (4 or more years) research priority and please rate its importance. When you are done entering priorities under this theme, please select “Next” at the bottom of the page.

Marine transport research priority #1

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Marine transport priority #1	◯	◯	◯	◯	◯	◯	◯	◯	◯

Marine transport research priority #2

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Marine transport priority #2	◯	◯	◯	◯	◯	◯	◯	◯	◯

Marine transport research priority #3

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Marine transport priority #3	◯	◯	◯	◯	◯	◯	◯	◯	◯

Marine transport research priority #4

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Marine transport priority #4	◯	◯	◯	◯	◯	◯	◯	◯	◯

Marine transport research priority #5

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Marine transport priority #5	◯	◯	◯	◯	◯	◯	◯	◯	◯

Theme 4: The Ocean's Role in Climate

Our ability to better predict climate changes on both seasonal and decadal scales depends on our knowledge of the interrelationships between the ocean and the atmosphere. Better projections of climate will help society respond to climate-related hazards and adapt to climate change and variations such as sea level rise and changing weather patterns. For example,

- What satellite data tools can be developed to track changing ocean conditions?
- What are the links between physical oceanographic systems and living marine resources? Which species provide early indications of climate-related changes and sensitivities? How do we monitor those species and use the information for management decisions?
- What are the links between the spatial distribution of species, their carrying capacity, and climate-driven changes in the ocean and atmosphere?

Please list up to 5 research and information priorities for this theme area. For each priority, indicate if it is a near-term (1–3 years) or long-term (4 or more years) research priority and please rate its importance. When you are done entering priorities under this theme, please select "Next" at the bottom of the page.

Ocean and climate research priority #1

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ocean-climate priority #1	◯	◯	◯	◯	◯	◯	◯	◯	◯

Ocean and climate research priority #2

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ocean-climate priority #2	◯	◯	◯	◯	◯	◯	◯	◯	◯

Ocean and climate research priority #3

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ocean-climate priority #3	◯	◯	◯	◯	◯	◯	◯	◯	◯

Ocean and climate research priority #4

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ocean-climate priority #4	◯	◯	◯	◯	◯	◯	◯	◯	◯

Ocean and climate research priority #5

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ocean-climate priority #5	◯	◯	◯	◯	◯	◯	◯	◯	◯

Theme 5: Ecosystem Health

Open ocean, coastal, and estuarine ecosystems host an abundance of natural resources and provide numerous benefits to society. For managers to be more effective in achieving sustainable use, as well as protecting and restoring ecosystem health, we need to gain a better understanding of how these complex ecosystems work. For example,

- What are the movement patterns associated with nearshore fish species?
- Are predator/prey relationships hindering the recovery of depleted species?
- What factors trigger regime shifts in the ecosystem? How do regime shifts affect the feasibility of current management objectives and the stability of fisheries and fishery-dependent communities?

Please list up to 5 research and information priorities for this theme area. For each priority, indicate if it is a near-term (1–3 years) or long-term (4 or more years) research priority and please rate its importance. When you are done entering priorities under this theme, please select “Next” at the bottom of the page.

Ecosystem health research priority #1

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ecosystem priority #1	◯	◯	◯	◯	◯	◯	◯	◯	◯

Ecosystem health research priority #2

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ecosystem priority #2	◯	◯	◯	◯	◯	◯	◯	◯	◯

Ecosystem health research priority #3

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ecosystem priority #3	◯	◯	◯	◯	◯	◯	◯	◯	◯

Ecosystem health research priority #4

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ecosystem priority #4	◯	◯	◯	◯	◯	◯	◯	◯	◯

Ecosystem health research priority #5

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Ecosystem priority #5	◯	◯	◯	◯	◯	◯	◯	◯	◯

Theme 6: Human Health and Safety

The coastal and ocean environment can be a source of risks and benefits for human health. Research and information are needed to reduce human health risks from things like harmful algal blooms, seafood contamination, and poor water quality. Research and information is also needed to identify and sustainably derive health benefits from bio-products, safe seafood consumption, and other yet-to-be-imagined ocean commodities. For example,

- Which environmental signs can help predict the beginning and/or end of harmful algal bloom events?
- How do changes in the management of fisheries, changes in the geographic distribution of fish populations, and changes in shipping traffic affect the best positioning of emergency response resources?
- Do changes in the mix of lower-trophic species affect the nutritional value of seafoods?

Please list up to 5 research and information priorities for this theme area. For each priority, indicate if it is a near-term (1–3 years) or long-term (4 or more years) research priority and please rate its importance. When you are done entering priorities under this theme, please select “Next” at the bottom of the page.

Human health/safety research priority #1

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Health-safety priority #1	◯	◯	◯	◯	◯	◯	◯	◯	◯

Human health/safety research priority #2

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Health-safety priority #2	◯	◯	◯	◯	◯	◯	◯	◯	◯

Human health/safety research priority #3

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Health-safety priority #3	◯	◯	◯	◯	◯	◯	◯	◯	◯

Human health/safety research priority #4

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Health-safety priority #4	◯	◯	◯	◯	◯	◯	◯	◯	◯

Human health/safety research priority #5

a. Is this a near-term or long-term priority?

◯ Near-term (1–3 years)
◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Health-safety priority #5	◯	◯	◯	◯	◯	◯	◯	◯	◯

Theme 7: Cross-Cutting Themes and Other Research Priorities

Please do not let the previous six themes limit your responses. If you would like to provide input on research and information needs not covered by those themes, please do so. For example,

- What are the effects of marine debris—including garbage discarded under MARPOL V, river-borne garbage, and derelict fishing gear—on living marine resources, including marine mammals, seabirds, and living marine substrate?
- What are links between physical, biological, and social systems in the Aleutian Islands region?

Please list up to 5 research and information priorities for this theme area. For each priority, indicate if it is a near-term (1–3 years) or long-term (4 or more years) research priority and please rate its importance. When you are done entering priorities under this theme, please select “Next” at the bottom of the page.

Cross-cutting research priority #1

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Cross-cutting priority #1	◯	◯	◯	◯	◯	◯	◯	◯	◯

Cross-cutting research priority #2

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Cross-cutting priority #2	◯	◯	◯	◯	◯	◯	◯	◯	◯

Cross-cutting research priority #3

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Cross-cutting priority #3	◯	◯	◯	◯	◯	◯	◯	◯	◯

Cross-cutting research priority #4

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Cross-cutting priority #4	◯	◯	◯	◯	◯	◯	◯	◯	◯

Cross-cutting priority #5

a. Is this a near-term or long-term priority?

- ◯ Near-term (1–3 years)
- ◯ Long-term (4 or more years)

b. Please rate the importance of this research or information priority.

	Low		Moderate		High		Very High		Highest
Cross-cutting priority #5	◯	◯	◯	◯	◯	◯	◯	◯	◯

Background Information

Please provide us with some background information to help us determine whether this survey represents a diverse group of people.

Where do you live?

Country

State

City

County or borough

Please check all answers that characterize your relationship to the coast and ocean.

- [ ] Beach or ocean enthusiast
- [ ] Coastal and ocean advocacy is part or all of my job
- [ ] Coastal and ocean education is part or all of my job
- [ ] Coastal and ocean management is part or all of my job
- [ ] Coastal and ocean research is part or all of my job
- [ ] Coastal resident
- [ ] Subsistence harvester
- [ ] Sport fisherman
- [ ] Marine tourism or charter industry owner, operator, or employee

Other (please specify)

Gender

- ◯ Female
- ◯ Male

Age range

- ◯ Younger than 16
- ◯ 16 to 19
- ◯ 20–29
- ◯ 30–39
- ◯ 40–49
- ◯ 50–59
- ◯ 60–69
- ◯ 70 or older

Ethnicity

Optional Contact Information

Would you like to:

- [ ] Stay informed about this project. You can expect a maximum of one email or postal mailing per month.
- [ ] Be entered in the drawing for $200 in Alaska Sea Grant publications, videos, and posters.

Mailings may include the progress of this project, additional opportunities to participate, draft reports, and final reports. Your contact information will not be shared.

To qualify for the survey prize drawing, we will need your name and email address or phone number.

Contact information

First name

Last name

Organization or affiliation (if any)

If you prefer to be contacted by email please enter your email address below.

If you prefer to be contacted via post, please provide your mailing address.

Address

City

State

Zip

Country

Phone number

Would you like to be recognized for your contribution? If you choose to be recognized, your name and/or organization will be listed in an appendix of the final report. Your specific comments will not be connected with your name and/or organization. Alaska Sea Grant will clearly state that not all views represent all people who provided input.

- ◯ Yes, I would like both my name and organization listed in the report as a voluntary participant
- ◯ I would only like my name and not my organization listed
- ◯ I would only like my organization and not my name listed
- ◯ No, please do not list my name or organization

If you would like to receive other information from Alaska Sea Grant, please indicate your choices below.

	Email	U.S. Postal Service (please be sure to provide mailing address)
Publication announcements	◯	◯
Fishlines, a free monthly newsletter	◯	◯
2008 bookstore catalog	◯	◯

Thank you!

We appreciate your input! It is our goal to complete a plan that reflects the needs of people who live near the coast and who depend on the coast and ocean for their livelihood and recreation.

If you would like to be entered in the prize drawing, don't forget to provide us with your name and email address or phone number, so we can contact you if you win.

If you are filling out the paper version of this survey, please return it to:

Kurt Byers
Alaska Sea Grant
University of Alaska Fairbanks
PO Box 755040
Fairbanks, AK 99775-5040
(907) 474-6702

Appendix B. Research and information needs for improving ecosystem health are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

CATEGORY		SUB-CATEGORY		RESEARCH OR INFORMATION NEED
0.1980	A. Catalog organisms and identify habitats	0.1015	a. Map abundance and distribution	0.0260 Aaa. Monitor species distribution and abundance indices.
				0.0173 Aab. Identify which species west of 160 have connections to North America and which are more closely connected to Asia.
				0.0190 Aac. Improve identification and classification of invertebrates caught in trawl surveys.
				0.0202 Aad. Study the temporal and spatial distribution and abundance of pollock in Steller sea lion critical habitat.
				0.0189 Aae. Determine the winter distribution of seabirds in the Aleutians.
		0.0965	b. Map habitat	0.0238 Aba. Identify and map the foraging, spawning and nursery habitats of marine species.
				0.0195 Abb. Develop high resolution maps of seafloor geology, morphology and habitat.
				0.0175 Abc. Identify and map the distribution of kelp and other macroalgae.
				0.0177 Abd. Identify Pacific Ocean perch spawning sites.
				0.0180 Abe. Identify Essential Fish Habitat (feeding and spawning habitat) for Atka mackerel.
0.2105	B. Identify indicators, monitor trends & predict changes	0.0693	a. Investigate approaches for monitoring trends	0.0102 Baa. Develop new techniques and technology to interpret ecosystem change.
				0.0098 Bab. Groundtruth satellite and remote sensing data with observations on ecosystem function.
				0.0102 Bac. Evaluate if the use of satellite-based remote sensing can be used with sufficient detail in the Aleutians to be useful.
				0.0101 Bad. Link ecosystem-scale research programs and small scale process studies.
				0.0090 Bae. Determine criteria for establishing research control areas.
				0.0100 Baf. Develop a regional habitat conservation plan that includes monitoring of habitat quality.
				0.0101 Bag. Develop spatial design for long term ecological research stations (where to put them?)
		0.0770	b. Identify indicators	0.0097 Bba. Create an ecosystem report card for oceanographic / biological /economic indicators.
				0.0132 Bbb. Monitor indicators of ecosystem change.
				0.0127 Bbc. Identify and catalogue species in decline and monitor their population shifts.
				0.0113 Bbd. Monitor representative intertidal and nearshore subtidal ecosystems.
				0.0114 Bbe. Use seabird populations as indicators of ecosystem health.
				0.0111 Bbf. Monitor the health and size of eel grass beds.
				0.0076 Bbg. Monitor human health as a measure of ecosystem health.
		0.0642	c. Use local expertise to examine historical evidence of change	0.0089 Bca. Interview elders for local traditional knowledge of ecosystem health and changes over time.
				0.0087 Bcb. Use anthropological and archeological record to characterize environmental history.
				0.0100 Bcc. Study how the relative abundance of species has varied over a long time scale
				0.0088 Bcd. Involve residents in science that goes beyond data collection.
				0.0101 Bce. Determine how ocean carrying capacity has changed / is changing over time.

Appendix B. Research and information needs for improving ecosystem health are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

CATEGORY		SUB-CATEGORY		RESEARCH OR INFORMATION NEED
			0.0081	Bcf. Increase coastal monitoring with an emphasis on stakeholder interests.
			0.0095	Bcg. Increase cooperative with international Arctic researchers and managers.
0.2054	C. Determine the function and inter-relationships of organisms in the ecosystem (life history, food webs, etc.)	0.0504	a. Biological characteristics	0.0061 Caa. Examine the physiological tolerances of species, especially for reproduction.
				0.0064 Cab. Study life history patterns and how they vary in exploited populations.
				0.0071 Cac. Study diets and reproductivity rates of endangered species.
				0.0072 Cad. Determine how apex predator condition varies over time and location.
				0.0065 Cae. Research how surface and subsurface primary production influence salmon run strength.
				0.0060 Caf. Research life cycles of rockfish in nearshore ecosystems.
				0.0061 Cag. Study the early life history information for king crab.
				0.0049 Cah. Gain a better understanding of brown king crab physiology.
		0.0514	b. Movement and distribution	0.0137 Cba. Determine the best scale for evaluating movements of fish and other marine life.
				0.0119 Cbb. Research the movement patterns of nearshore fishes.
				0.0127 Cbc. Study the early life history habitat requirements for king crab.
				0.0131 Cbd. Identify critical habitat for endangered species (e.g., Northern Right Whale).
		0.0523	c. Ecological roles	0.0060 Cca. Study the ecological role of habitats created by cold water sponges and coral.
				0.0068 Ccb. Investigate linkages between marine habitats and resource productivity.
				0.0068 Ccc. Examine the role of marine habitat in fisheries production and ecosystem health.
				0.0058 Ccd. Research the ecological role of rockfish in nearshore ecosystems.
				0.0051 Cce. Determine the winter ecology of nearshore birds, eagles and ravens.
				0.0061 Ccf. Determine the role of benthic macroinvertebrates in the ecosystem.
				0.0065 Ccg. Examine the relationships between target stocks and other species (e.g., seabirds).
				0.0044 Cch. Determine the role of foxes in the coastal terrestrial ecosystem.
				0.0047 Cci. Determine the resource competition between pollock and Pacific ocean perch.
		0.0513	d. Population dynamics	0.0059 Cda. Determine physical and biological factors that drive recruitment variability (including species with episodic recruitment).
				0.0060 Cdb. Determine how to maintain sustainable fisheries with species that have episodic recruitment.
				0.0058 Cdc. Determine why crab, shrimp, and scallop populations have changed.
				0.0053 Cdd. Determine factors that regulate seabird populations.
				0.0061 Cde. Identify causes of large fluctuations in marine mammal populations (e.g. Steller sea lion).
				0.0061 Cdf. Identify causative factors behind decline in sea lions and sea otters.

Appendix B. Research and information needs for improving ecosystem health are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

CATEGORY		SUB-CATEGORY		RESEARCH OR INFORMATION NEED
			0.0058	Cdg. Determine the impact of sea otter decline on nearshore habitat.
			0.0052	Cdh. Need more research on the decline of pollock in the Aleutians.
			0.0052	Cdi. Need more research on the decline of red king crab in the Aleutians.
0.1948	D. Understand factors that influence & control ecosystem dynamics	0.0959	0.0119	Daa. Examine interactions between trophic levels of the Aleutian ecosystem.
		a. Energy flow: nutrient cycling, trophic/food chain dynamics	0.0109	Dab. Study the importance of salmon as prey for other fish (e.g., pollock and cod).
			0.0102	Dac. Study the importance of salmon as prey for Steller sea lions and fur seals.
			0.0129	Dad. Determine the trophic effects of depleting a target species.
			0.0122	Dae. Determine if predator/prey relationships hinder the recovery of depleted species.
			0.0124	Daf. Determine the importance of forage fish, including capelin, to upper trophic production in the Aleutians.
			0.0133	Dag. Examine the functional roles of commercial species in marine food webs.
			0.0120	Dah. Study the seasonal variation in food web dynamics.
		0.0989	0.0198	Dba. Examine the relationship between deep ocean ecosystems of the Western Aleutian Islands and shallower Bering Sea
		b. Ecosystem linkages	0.0213	Dbb. Study the role of deep passes in limiting the distribution of species.
			0.0179	Dbc. Determine if the Aleutian Islands are a separate ecosystem.
			0.0200	Dbd. Study the linkages between the nearshore habitat and pelagic ecosystems.
			0.0200	Dbe. Examine the links between fish and invertebrate populations in the Aleutians to the open ocean ecosystem and to the Bering Sea and Gulf of Alaska.
		0.0372	0.0056	Eaa. Research the transport vectors for Asian-origin contaminants.
		a. Contaminant sources, paths, and fates	0.0057	Eab. Identify toxic waste and debris in the region including origin and magnitude.
			0.0052	Eac. Determine the background level of hydrocarbon contamination.
			0.0058	Ead. Monitor the sea water pollutant levels and water quality.
			0.0047	Eae. Determine if pollution linked to urbanization affects nearshore ecosystems.
			0.0049	Eaf. Determine the contribution of inland garbage to marine pollution.
			0.0053	Eag. Determine the ecological fate of different contaminants.
		0.0392	0.0045	Eba. Determine if contaminant levels in marine biota are increasing or decreasing.
		b. Contaminant impacts on the ecosystem	0.0045	Ebb. Determine the effects of pollutants on the ocean ecosystem.
			0.0042	Ebc. Determine how littoral ecosystems are affected by marine contamination (e.g., marine debris and other forms).
			0.0047	Ebd. Determine how oil spill size, location and frequency impact the ecosystem.
			0.0040	Ebe. Study the impacts of harmful algal blooms on wildlife populations.
			0.0041	Ebf. Determine the environmental effects of fish processing waste discharges.

Appendix B. Research and information needs for improving ecosystem health are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

CATEGORY		SUB-CATEGORY		RESEARCH OR INFORMATION NEED
			0.0039	Ebg. Determine if onshore and offshore fish processors have different impacts on ecosystem health
			0.0044	Ebh. Study the impacts of toxins and disease on marine mammals.
			0.0048	Ebi. Identify invasive species, establish a monitoring program and assess impacts.
0.1914	E. Understand the significance of injurious agents, human activities and other perturbations on the ecosystem and mitigate impacts	0.0420	0.0039	Eca. Conduct research in unfished habitats to discern influence of fishing.
			0.0039	Ecb. Develop a better understanding of species dynamics in the absence of fishing.
			0.0042	Ecc. Determine the effects (e.g., ecosystem structure) between areas that are and are not (e.g., marine reserve and trawl exclusion zones) open to fishing.
			0.0040	Ecd. Determine ecosystem impact of fisheries and if effects spill over between regions.
			0.0036	Ece. Determine if catch shares in fisheries for some species have increased pressure on fish stocks not included in a catch share program.
		c. Fishing	0.0039	Ecf. Determine if fishing changes characteristics (size, age distribution) of fish stocks.
			0.0042	Ecg. Determine the long term ecosystem effects of bycatch.
			0.0041	Ech. Estimate the mortality rates of bycatch and adverse sub-lethal effects.
			0.0029	Eci. Determine the ecological effects of fishing vessel operation and maintenance.
			0.0038	Ecj. Research the habitat impacts of bottom-contacting fisheries (e.g., long lined crab pots).
			0.0034	Eck. Look at historical changes in fishing in local waters.
		0.0366	0.0056	Eda. Estimate the likelihood of occurance of various anthropogenic disasters.
			0.0054	Edb. Study the impacts of fish farming and hatchery operations on wild stocks.
			0.0034	Edc. Predict the risks to the Aleutians from increases in world population.
		d. Other human (non-traffic) impacts	0.0044	Edd. Determine the effect of military activities on marine mammals in the Aleutians.
			0.0060	Ede. Estimate the effects of oil and gas development on the marine environment.
			0.0051	Edf. Assess the impacts of port activities and construction on the ecosystem
			0.0068	Edg. Determine if natural variability in ecosystems can be distinguished from anthropogenic impacts
		0.0364	0.0046	Eea. Find the best way to prevent garbage in inland villages from reaching the sea.
			0.0054	Eeb. Find how nonnative species can be removed and enhance recovery of native species.
			0.0051	Eec. Examine if laws concerning waste disposal, discharge and water use are effective.
		e. Treatment and remediation options	0.0049	Eed. Identify successful international efforts to finance clean up of non-local debris.
			0.0055	Eee. Determine if impacts to the ecosystem from Outer Continental Shelf petroleum development can be mitigated
			0.0060	Eef. Establish criteria for Marine Protected Areas.
			0.0050	Eeg. Examine the effects of habitat restoration on ecosystem health.

Appendix C. Research and information needs for marine transportation and security are organized into categories of related topics, scores reflect expert panel rating.

	CATEGORY		RESEARCH OR INFORMATION NEED
0.263	A. Improve response to marine vessel disasters and emergencies	0.047	Aa. Determine incentives to attract private investment in infrastructure needed for emergency response.
		0.065	Ab. Develop shipping traffic maps for anticipated changes in shipping and fishing activity.
		0.072	Ac. Determine if current infrastructure (tugs, booms, refueling, marine services, etc.) is sufficient to respond to shipping accidents and oil spills.
		0.079	Ad. Develop a regional oil spill response plan.
0.259	B. Foster efficient and safe marine traffic to reduce risk of harm from marine vessel disasters and emergencies	0.055	Ba. Examine methods to control shipping (e.g., require VMS or emergency transponders and sailing plans on all transiting vessels).
		0.054	Bb. Determine if island passes are bottlenecks that warrant additional shipping regulation (e.g., designated shipping lanes, tug boat escorts).
		0.049	Bc. Regularly update bathymetric maps of the seafloor and currents models through the Aleutian passes to increase transportation safety.
		0.050	Bd. Improve reporting and forecasting of sea conditions.
		0.052	Be. Provide training/education for vessel operators and communities for risks involved in response to fuel/oil spills and downed vessels.
0.272	C. Assess and minimize negative environmental impacts of marine traffic	0.030	Ca. Estimate the frequency and causes of collisions with whales with increased shipping.
		0.032	Cb. Assess marine shipping impacts with attention to anticipated effects of changes in lanes and routes.
		0.036	Cc. Determine how traffic related to anticipated Outer Continental Shelf exploration and development will impact the Aleutian Islands
		0.038	Cd. Identify transportation routes that cross sensitive habitats.
		0.033	Ce. Determine disturbance impacts to marine life and habitat in areas of occasional vs. steady marine traffic.
		0.034	Cf. Examine alternatives for managing environmental impacts of shipping (e.g., traffic lanes, no transit zones around critical habitat, speed limits).
		0.038	Cg. Assess the risks and impacts of ballast water and small fuel discharges on the environment.
		0.031	Ch. Map habitats and the effects of shipping, fishing and marine debris on those habitats.
0.206	D. Assess the socioeconomic impacts of marine traffic	0.070	Da. Determine if changes in mandatory landing locations for fisheries in the region will reduce transportation costs.
		0.070	Db. Determine if an inter-island marine transportation system is feasible and will facilitate the transportation of goods and people.
		0.065	Dc. Determine the socioeconomic impacts of increased transit shipping.

Appendix D. Research and information needs for the ocean's role in climate are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

	CATEGORY		SUB-CATEGORY		RESEARCH OR INFORMATION NEED
0.1464	A. Collect baseline information on ocean conditions and monitor atmospheric forcing variables	0.0670	a. Explore new methods and expand current technologies to monitor ocean conditions	0.0117	Aaa. Find the best instruments to track ocean conditions.
				0.0110	Aab. Install oceanographic buoys and deep sea sensing arrays throughout the Aleutian Islands to collect long term data on temperature, salinity, dissolved oxygen, currents, tidal movement and other variables.
				0.0099	Aac. Expand network of weather buoys in the Aleutian Islands with real-time monitoring equipment including audio and video streams.
				0.0123	Aad. Use ships of opportunity to collect environmental data.
				0.0115	Aae. Fully implement the Alaska Ocean Observing System.
				0.0107	Aaf. Determine if there are adequate satellite services in place to track changing ocean conditions (e.g., predominant wave heights and directions).
		0.0793	b. Collect baseline information and develop monitoring plans	0.0141	Aba. Baseline data including temperature, currents, ocean pH and prevailing winds are needed.
				0.0136	Abb. Map ocean climate, including temperatures, acidity, and contamination.
				0.0137	Abc. Monitor climate forcing variables, determine where changes are occurring, their magnitude, and potential impact to the ocean environment and species.
				0.0133	Abd. Determine if we have gathered sufficient information (e.g., temperature) so that we can critically evaluate future changes.
				0.0116	Abe. Develop coastal monitoring program to monitor remote areas of the Aleutians.
				0.0130	Abf. Establish long term monitoring sites (LTER) in the Aleutians.
0.1523	B. Identify and monitor biological indicators of climate change			0.0180	Ba. Map kelp beds as an indicator of climate change affecting nearshore communities.
				0.0200	Bb. Monitor distribution and movement patterns of sensitive "sentinel" species.
				0.0181	Bc. Monitor changes in lower trophic level organisms coincident to sea ice loss.
				0.0175	Bd. Investigate indicators of climate variability stored in seabed cores, sediments in coastal lagoons and sockeye lakes.
				0.0204	Be. Determine which species or populations of the Aleutians are most sensitive to climate change and if these can serve as indicator species.
				0.0200	Bf. Determine which vital signs and other key physiological states of protected species can serve as indicators of ocean/atmospheric changes.
				0.0199	Bg. Determine if it is best to monitor all the Aleutian Islands or focus on certain areas and indicator species.
				0.0183	Bh. Use meta-analysis to develop multivariate (oceanographic/biological/economic) indicators and to characterize the dominant patterns of spatial/temporal variation in ocean conditions for a periodic "state of Alaska marine ecosystems" report.
		0.0697	a. Research how ocean processes/conditions affect marine populations	0.0145	Caa. Review data collections for evidence of changes in species distribution and abundance in light of known ocean conditions and cycles.
				0.0115	Cab. Use deepwater monitors to explore ties between temperature and stock abundance.
				0.0138	Cac. Research how species distribution and abundance vary as a function of episodic (e.g., ENSO, PDO) and directional climate change.
				0.0145	Cad. Consider how regime shifts affect threatened/endangered populations.
				0.0154	Cae. Determine if there currently are measurable (not estimated) effects of climate change on fisheries resources in the Aieutian Islands.

Appendix D. Research and information needs for the ocean's role in climate are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

CATEGORY		SUB-CATEGORY		RESEARCH OR INFORMATION NEED
0.1431	C. Assess impacts of the ocean and its role in climate change on marine populations	0.0734	b. Predict climate change related impacts to marine populations	0.0091 Cba. Estimate changes in commercial and subsistence fisheries within 10 and 50 years.
				0.0097 Cbb. Estimate what might happen if ocean warming changes the forage fish diet of seabirds.
				0.0085 Cbc. Estimate if increased beach erosion might affect nesting sites for seabirds and waterfowl.
				0.0098 Cbd. Research how marine bird and mammal populations will respond to climate change.
				0.0100 Cbe. Estimate how climate variability might affect productivity and relative abundance of fish and invertebrates in the Aieutian Islands.
				0.0070 Cbf. Estimate how rising temperatures and sea levels might affect the very short salmon streams in the Aleutians.
				0.0101 Cbg. Estimate how climate change might affect the timing of fish, shellfish, and marine mammal migrations
				0.0091 Cbh. Monitor the effects of warmer ocean temperature on the health of farmed shellfish.
0.1422	D. Research how ocean processes affect marine communities			0.0352 Da. Research how ocean acidification impacts phytoplankton communities and if it is responsible for recent species composition shifts.
				0.0367 Db. Determine how ocean acidification affects deep-sea corals, shellfish, etc.
				0.0327 Dc. Estimate if an increase in water temperature will influence coral distribution in the Aleutian Islands.
				0.0377 Dd. Identify spatial patterns of abundance to better understand connections between marine communities and ocean processes.
0.1428	E. Assess impacts of the ocean and its role in climate change on the marine ecosystem	0.0709	a. Investigate how ocean processes/conditions affect marine ecosystems	0.0085 Eaa. Determine the role of ocean circulation in maintaining the ecosystem.
				0.0102 Eab. Research changes in primary productivity in Gulf of Alaska, Aleutians and Bering Sea.
				0.0092 Eac. Identify the role of ocean currents and estuaries in ecosystem productivity.
				0.0088 Ead. Determine how changes in thermoclines and density gradients affect food chain dynamics.
				0.0076 Eae. Conduct lab studies of the effects of temperature, pH, and salinity on species dominance in mixed plankton cultures.
				0.0091 Eaf. Determine factors that trigger regime shifts in the ecosystem.
				0.0085 Eag. Identify exogenous forcing factors that determine health of the ecosystem.
				0.0090 Eah. Determine the impacts of freshwater inputs on marine ecosystems.
		0.0719	b. Predict climate change related to the marine ecosystem.	0.0181 Eba. Investigate if climate change might lead to invasions by non-native species.
				0.0176 Ebb. Research if warm water pathogens are becoming more common, their spatial and temporal distribution, if they are concentrated in shellfish, and if they cause disease in mammals that eat shellfish.
				0.0193 Ebc. Estimate the impact of ocean warming & acidification on the terrestrial, nearshore and marine ecosystems of the Aleutian Islands.
				0.0169 Ebd. Estimate how changes to the Arctic environment will affect the ecosystem.

Appendix D. Research and information needs for the ocean's role in climate are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

CATEGORY		SUB-CATEGORY	RESEARCH OR INFORMATION NEED	
0.1475	F. Assess impacts of climate change on the ocean		0.0316	Fa. Research how ocean acidification affects the ocean's ability to produce oxygen.
			0.0301	Fb. Estimate how climate change will affect oceanic circulation patterns in the Aleutians.
			0.0277	Fc. Research if oceanic and atmospheric climate changes are similar north and south of Aleutian Islands.
			0.0297	Fd. Research how changing ocean and atmospheric conditions influence the flow of heat, salt and nutrients into the Bering Sea through the Aleutian passes.
			0.0283	Fe. Assess impacts of climate change on volatility of natural hazards, e.g. increased storms.
0.1258	G. Predict and assess impacts of climate change to Aleutian communities and better prepare them to mitigate impacts through education and planning.		0.0121	Ga. Determine if sea level rise will require relocation of communities.
			0.0106	Gb. Consider how increased beach erosion might affect coastal infrastructure.
			0.0098	Gc. Synthesize archaeological and paleo-environmental data to understand how the Aleutian ecosystem has responded to past climate change.
			0.0102	Gd. Compile local and traditional knowledge of the effects of climate change in the region.
			0.0110	Ge. Examine if current fisheries and fishery-dependent communities are resilient to regime shift.
			0.0121	Gf. Estimate how environmental change will affect the availability of subsistence foods.
			0.0111	Gg. Provide education and outreach on the implications of climate change for Unangan (Aleut) culture.
			0.0114	Gh. Involve youth in climate change research; they have a big stake in the outcome.
			0.0127	Gi. Consider how living resources should be managed in a changing ecosystem - are current management strategies resilient to change?
			0.0125	Gj. Consider how protected areas in the Aleutians can be shifted or expanded to accommodate changes in ocean conditions.
			0.0124	Gk. Develop emergency response plans that account for anticipated changes in storm frequency and intensity.

Appendix E. Research and information needs for human health and safety are organized into categories of related topics and shown with scores that reflect expert panel rating.

	CATEGORY		RESEARCH OR INFORMATION NEED
0.3455	A. Reduce risk to people from contaminants	0.0397	Aa. Develop effective warning systems to alert community members to algal blooms, contaminant spills, and other health hazards.
		0.0395	Ab. Distribute information on safe consumption levels [of contaminants] for local and imported seafoods.
		0.0429	Ac. Determine contaminant loads in commercial and subsistence resources harvested in the region.
		0.0428	Ad. Determine the sources and pathways of the major pollutants in the Aleutians.
		0.0390	Ae. Determine risks and impacts to human health of harmful algal blooms in Aleutians. What are the safest times of year to harvest bivalves.
		0.0372	Af. Locate former U.S. military dump sites and determine levels of toxic materials.
		0.0333	Ag. Investigate conditions (natural or anthropogenic) that trigger harmful algal blooms.
		0.0378	Ah. Improve monitoring to warn the public or to certify specific shellfish harvest areas as safe.
		0.0334	Ai. Determine if ballast water discharges impact the safety of commercial and subsistence seafoods.
0.3112	B. Reduce risk from disease	0.0778	Ba. Implement a human disease surveillance program in the Aleutian Island Region.
		0.0722	Bb. Determine the human health risks related to boats coming to port (i.e., disease).
		0.0730	Bc. Determine if changing local diets affect disease incidence.
		0.0882	Bd. Determine what zoonotic diseases are active in foods such as shellfish, fish and marine mammals
0.3433	C. Increase community health and safety	0.0362	Ca. Determine the most serious immediate human health and safety needs in region.
		0.0373	Cb. Promote human health and safety in the Aleutian Island region through education and outreach.
		0.0258	Cc. Develop a protocol for stress-related mental health issues aboard vessels.
		0.0274	Cd. Need to know the nutritional value of fish and shellfish and if it changes over time.
		0.0321	Ce. Need to know how coastal zone development affects health.
		0.0412	Cf. Develop personal, community, and regional emergency response preparedness plans.
		0.0312	Cg. Develop protocols to increase operation safety for government, commerce and military.
		0.0417	Ch. Design search and rescue programs to effectively respond to emergencies throughout Aleutian Area.
		0.0365	Ci. Need to know if the timing of fisheries could be optimized to minimize human casualties associated with fishing.
		0.0337	Cj. Estimate the human health risks of increased shipping traffic.

Appendix F. Research and information needs for stewardship of natural and cultural ocean resources are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

CATEGORY		SUB-CATEGORY		RESEARCH OR INFORMATION NEED	
0.3342	A. Ensure accurate assessment and sustAleutiansnable use of marine resources through an examination of alternative management paradigms.	0.0850	a. Stock assessment methods (e.g., improve abundance estimates)	0.0130	Aaa. Collect spatially explicit data for managing localized stocks (e.g., rockfish) in the Aleutians.
				0.0144	Aab. Collect life history information for harvested species and better integrate into stock assessment models.
				0.0120	Aac. Determine if there are genetically distinct groundfish stocks in the Aleutian region.
				0.0156	Aad. Develop effective survey techniques for the Aleutians.
				0.0140	Aae. Develop better survey design to improve abundance estimates of Atka mackerel, rockfish and crab.
				0.0156	Aaf. Improve abundance and stock structure estimates of currently harvested species.
		0.0978	b. Stock status and population trends	0.0239	Aba. Conduct surveys of harvested species abundance, diversity and distribution in the Aleutians (e.g., maintain the NMFS stock assessment surveys).
				0.0200	Abb. Determine the status and population trends of apex predators.
				0.0186	Abc. Better determine the status and population trends of eastern and western stocks of brown king crab and Aleutian red king crab.
				0.0195	Abd. Determine the status of salmon populations in Aleutians (e.g., Reece Bay near Unalaska).
				0.0148	Abe. Determine why Andreonof cod are larger than Bering Sea cod - is it food or genetics?
		0.0735	c. Harvest and use	0.0074	Aca. Explore appropriate harvest rate strategies for red and brown king crab stocks.
				0.0077	Acb. Collect subsistence harvest information.
				0.0064	Acc. Determine a safe harvest rate for Pacific ocean perch in Aleutians west of 169.
				0.0061	Acd. Determine criteria to use in balancing local subsistence and commercial harvests with industrial-scale commercial harvests.
				0.0078	Ace. Eliminate or reduce bycatch.
				0.0061	Acf. Determine how to utilize fishery bycatch.
				0.0039	Acg. Determine if Aleutian Islands fisheries are fully utilized.
				0.0074	Ach. Determine if trawl exclusion zones protected Atka mackerel nesting habitat.
				0.0052	Aci. Expand on Alverson's study to Identify historic fishing grounds, including trends of fishing effort by gear type.
				0.0085	Acj. Assess tradeoffs between fisheries harvest and ecosystem function on local and regional spatial scales.
				0.0065	Ack. Determine if additional resources around Aleutian Island communities can support commercially viable fisheries.

Appendix F. Research and information needs for stewardship of natural and cultural ocean resources are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

CATEGORY		SUB-CATEGORY		RESEARCH OR INFORMATION NEED	
		0.0779	d. Management paradigms	0.0080	Ada. Continue to develop and implement the Fishery Ecosystem Plan.
				0.0042	Adb. Determine if higher exploitation rates are appropriate for short lived species (e.g., pollock).
				0.0054	Adc. Determine criteria that should be used to allocate TAC among gear groups.
				0.0069	Add. Consider if local area management is a viable option for fisheries and other Aleutian resources.
				0.0074	Ade. Explore alternative thresholds for sustainable exploitation of harvested populations.
				0.0069	Adf. Evaluate the relevance of integrating physical oceanographic data into management of exploited species.
				0.0072	Adg. Determine if single species management strategies are appropriate for ecosystems with combinations of long-lived and short-lived species.
				0.0074	Adh. Determine if information on trophic relationships can be used to restructure fisheries management and reduce competition with apex predators.
				0.0065	Adi. Define ecologically sustainable yields for Aleutian fisheries
				0.0069	Adj. Determine if ecosystem management is a viable and affordable management paradigm
				0.0095	Adk. Incorporate local ecological knowledge into natural resource and ocean resource stewardship.
0.2672	B. Foster vital communities through greater understanding of factors that impact socioeconomics	0.1300	a. Economic growth opportunities	0.0123	Baa. Determine the economic feasibility of direct marketing for local fishermen.
				0.0193	Bab. Determine the economic feasibility of shellfish/finfish aquaculture in the Aleutians.
				0.0246	Bac. Organize fisheries resource marketing studies (e.g., Alaska Seafood Marketing Institute).
				0.0242	Bad. Explore markets for sustainable harvests of currently non-targeted species.
				0.0205	Bae. Determine if crab stock enhancement is biologically and economically feasible.
				0.0285	Baf. Explore economic opportunities for small scale value-added processing (e.g., smoked/ specialty products).
		0.1372	b. Economic analysis	0.0142	Bba. Determine how fishing contributes to viable regional economies, and how infrastructure investments contribute to viable fisheries.
				0.0168	Bbb. Economic analysis of local community and individual dependency on commercial, subsistence/ personal and recreational use of natural resources.
				0.0122	Bbc. Develop linked bioeconomic models.
				0.0191	Bbd. Examine the impact of consolidation and privatization on fisheries (e.g., AFA).
				0.0083	Bbe. Compare the regional impacts of commercial activities versus recreational activities.
				0.0126	Bbf. Determine the likely value of non-renewable resources development.
				0.0142	Bbg. Examine how community stability is linked to harvest seasonality.
				0.0163	Bbh. Assess the economic value of habitat restoration and protection for Aleutian Islands.
				0.0209	Bbi. Examine how to balance federally managed land use with local human activities (e.g., roads)

Appendix F. Research and information needs for stewardship of natural and cultural ocean resources are organized into categories and sub-categories of related topics. Scores reflect expert panel rating.

CATEGORY		SUB-CATEGORY		RESEARCH OR INFORMATION NEED	
0.2058	C. Foster resilient communities through greater understanding of factors that impact human culture and human activities	0.0981	a. Culture	0.0253	Caa. Explore the effects of economic development on traditional culture.
				0.0236	Cab. Determine the effects of commercial fisheries on subsistence activities.
				0.0174	Cac. Map natural and cultural resources at scales relevant to users.
				0.0083	Cad. Identify World War II and Cold War sunken cultural resources and assess their condition.
				0.0259	Cae. Identify, study, and protect archaeological and culturally sensitive sites.
		0.1077	b. Community adaptability	0.0337	Cba. Can coastal communities can adapt to changes in resource use? How have communities adapted to past changes in resource availability?
				0.0314	Cbb. Assess if subsistence harvests respond to variations in resource adundance and distribution.
				0.0491	Cbc. Examine the major impacts on coastal communities facing diminishing commercial fisheries.
0.1928	D. Promote communication between agencies and communities			0.0241	Da. Expand marine resource outreach to more communities in the Aleutians.
				0.0205	Db. Involve Alaska natives, local citizens, and youth in the research, management, and stewardship of the environment and subsistence resources.
				0.0269	Dc. Develop place-based curriculum that incorporates marine resource issues to meet state education standards.
				0.0258	Dd. Exchanage information on the major threats to natural and cultural resouces.
				0.0230	De. Advance college level education opportunities in the marine sciences in Alaska.
				0.0219	Df. Disseminate stock abundance and target/non-target catch data to local residents.
				0.0227	Dg. Need community outreach on laws regarding subsistence use (e.g., sea otter and sea lions).
				0.0258	Dh. Determine ways to improve two-way communication between residents and agenciesand between agencies.

Appendix G. Research and information needs for resilience to natural hazards are organized into categories of related topics and shown with scores that reflect expert panel rating.

	CATEGORY		RESEARCH OR INFORMATION NEED
0.2543	A. Predict and assess risk of damage to communities through monitoring & modeling	0.0283	Aa. Estimate the potential losses of human life and property due to natural disasters.
		0.0286	Ab. Determine the frequency of natural hazards.
		0.0286	Ac. Develop models of tsunami influx for Unimak, Akutan and Unalga Pass.
		0.0244	Ad. Determine if seismic and volcanic activity are increasing in the Pacific Rim.
		0.0304	Ae. Develop better predictive models of storm erosion.
		0.0301	Af. Deploy a comprehensive ocean observing system.
		0.0280	Ag. Expand volcano research and monitoring throughout the region and continue to fund research on underwater volcanoes, earthquakes, and slides.
		0.0301	Ah. Develop metrics to identify areas at high risk for damage from natural disasters and determine if communities are located in high-risk areas.
		0.0257	Ai. Predict impacts of permafrost melt and how it will affect communities.
0.2551	B. Better prepare communities to mitigate impacts from natural disasters through education and planning	0.0249	Ba. Alaska Volcano Observatory needs to disseminate more public information, and conduct outreach and education.
		0.0312	Bb. Consider habitat damages when planning for and mitigating damage from natural hazards.
		0.0292	Bc. Establish an emergency planning protocol and conduct emergency response workshops for natural disasters that threaten the Aleutian Island region.
		0.0345	Bd. Develop a natural disaster warning system for the Aleutian Island region.
		0.0343	Be. Determine how infrastructure can be designed (e.g., by amending local zoning plans and building codes) to be resilient to natural hazards.
		0.0349	Bf. Map shorelines, seafloor structure, geology, water quality and the distribution of marine species for environmental monitoring, disaster planning and mitigation.
		0.0329	Bg. Assess channels, shipping corridors, and docks to identify alternate transport routes in case current routes are compromised by natural disasters.
		0.0332	Bh. Consider what is needed to safeguard air transport facilities and routes against natural hazards.
0.2360	C. Enhance recovery and adaptation to reduce lasting damage to communities following natural disasters	0.0618	Ca. Consider how communities will fund rebuilding after natural disasters.
		0.0563	Cb. Research historical native responses and adaptations to natural hazards.
		0.0596	Cc. Determine the economical viability of reconstructing or relocating communities in high-risk locations damaged by natural disasters.
		0.0583	Cd. Determine how communities can adapt to reduce damage from natural disasters and if adaptation is more effective than engineering solutions.
0.2545	D. Improve understanding of the effects of natural disasters on the ecosystem and its recovery time	0.0480	Da. Research how increases in storm intensity (due to reduced ice and longer open water seasons) impact coastal zones, communities and marine life.
		0.0406	Db. Determine how long it takes for marine communities to recover from large natural disasters, such as earthquakes, volcanoes, tsunamis, and storms.
		0.0403	Dc. Develop models to assess risk of natural hazards for marine species.
		0.0407	Dd. Research how changes in shoreline integrity threaten terrestrial species.
		0.0377	De. Determine the impact of underwater landslides and tsunamis on nearshore environments.
		0.0473	Df. Determine if damage to community infrastructure (e.g., bulk fuel leaks, waste-water spills) due to natural hazards poses direct threats to ecosystems.