An Independent Review of USGS Circular 1370: "An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas, Alaska"

Prepared for the Pew Environment Group
and Ocean Conservancy

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Aug. 28, 2011

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I. Introduction

The Arctic Ocean, within the territorial waters of the United States, holds large quantities of fossil fuels that have contributed and can further contribute to domestic energy needs, and therefore there is intense pressure for their full exploration and development. Currently there are several offshore petroleum production facilities in the Beaufort Sea on gravel islands along Alaska's North Slope, and there are plans for continued exploration and development. More exploration is proposed for the summer of 2012. The Chukchi Sea to the west has experienced only limited exploratory drilling for petroleum, but extensive seismic surveying has been conducted. Several lease sales have been held in the Chukchi Sea, and further exploratory drilling could be imminent. Eight predominantly Alaska Native communities on the coastlines of the Beaufort and Chukchi seas utilize marine waters for subsistence and transport. There are former military bases along the Arctic coast and port facilities at Prudhoe Bay and Red Dog Mine. In addition, persistent organic pollutants are transported to the Arctic from lower latitudes and enter the food web. Overall, however, the U.S. Arctic Ocean is more pristine than almost any other ocean.

The same factors that have limited development—extreme cold, extensive ice, intense storms, and limited industrial infrastructure—make drilling and extraction of hydrocarbons more risky in these seas than in other offshore areas of the United States. These conditions also make response to and control of an oil spill or blowout more challenging than in other areas of the country. In the *Exxon Valdez* and *BP Deepwater Horizon* oil spills*,* both of which occurred in more favorable climates and conditions, only a relatively small fraction of spilled oil was recovered from the sea. According to the environmental impact statement for oil and gas Lease Sale 193 in the Chukchi Sea, the chance of a large oil spill (more than 1,000 barrels) is estimated at 40 percent for the lifetime of extraction of offshore resources under Department of the Interior (DOI) Alternative I.[1] There is thus strong incentive to reduce the risk of a spill and to increase the chance that spill impact might be limited.

The Arctic ecosystems are unique, complex, and not fully characterized. The Chukchi Sea, for example, has a rich benthic fauna and large numbers of seabirds, walrus, seals, and whales, yet we have a limited understanding of how this ecosystem responds to various physical and chemical factors. Arctic marine ecosystems are driven in large part by sea ice dynamics that are key to productivity. Ice also provides habitat for algae, invertebrates and much of the megafauna. Climate change is accelerating warming of the Arctic, and the extent, thickness, and duration of sea ice are shrinking. This accelerating change will cause widespread ecological responses even in the absence of further industrial development.

The ecological value of the Arctic seas to indigenous people and others, and its intrinsic value, has prompted a vigorous debate on the level of knowledge needed to proceed safely with development, and whether development should proceed at all. Although technology improvements and control of human error are key parts of the risk equation, our level of scientific understanding of the environment and the effects of seismic surveys, oils spills, and infrastructure development, all in the face of climate change, are central to questions of readiness. Therefore, responding to a directive from Interior Secretary Ken Salazar, the U.S. Geological Survey (USGS) conducted an extensive review of science needs for offshore development in the Arctic Ocean in Alaska. In late June 2011, the USGS presented its findings in the report "An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas, Alaska" (USGS Circular 1370).[2] The report consists of an introduction and chapters on geology; ecology and subsistence; climate change; oil spill risk, response and impact; marine mammals and anthropogenic noise; and cumulative impacts. Throughout the main body of the report, findings and recommendations on a series of issues are highlighted.

Why this review of a review? The Pew Environment Group and Ocean Conservancy have a keen interest in the conservation of the Chukchi and Beaufort seas. They initiated an evaluation of the USGS report findings and solicited recommendations on what next steps should be taken scientifically. They requested that the evaluation be independent of the DOI and contributed to by scientists who are mainly associated with universities, conservation organizations and consultancies. The requested evaluation was undertaken shortly after the release of the USGS report. Twelve scientists with expertise in a variety of marine science fields and extensive Arctic experience agreed to review Circular 1370 and provide comment. Here we present the findings of this independent review.

Our comments come under two headings: 1. The adequacy of the identified science needs in the Arctic relative to future development; and 2. Recommended actions to improve science management in the Arctic and better integrate science and policy.

II. Adequacy of the Report

1. Completeness

The USGS has identified the major gaps in scientific knowledge about the Arctic Ocean in the face of potential further industrial development, particularly offshore oil development. The agency has taken a thoughtful approach and dealt with the issues without bias. This effort is a significant advance toward reducing uncertainty about the impacts of outer continental shelf (OCS) development in the Arctic. The report is highly successful in putting a large amount of material into a structured and accessible format. Of particular value is the effort that went into reviewing and synthesizing findings from reports by industry and agencies that often are not as easily accessed as mainstream scientific literature. We therefore commend the effort of the USGS team in putting together this broad assessment. We offer specific constructive comments on the report in this evaluation.

2. What Is Missing?

a. Lacks Historical Context

Somewhere in this report, and certainly in future syntheses, there should be a summary of the major environmental studies conducted in the Beaufort and Chukchi seas beginning, at least, with the Outer Continental Shelf Environmental Assessment Program (OCSEAP) in the 1970s. Those efforts provided most of our current understanding of these regions and produced a wealth of data that are available for retrospective analyses, model verification, and comparison with future data. We should recognize the people and organizations that contributed, and provide a historical overview of these research efforts, their foci, geographic coverage, key goals, and results. Much of the data collected in these programs resides in government archives and is thus available for environmental and engineering design considerations. A similar comment could be made about research efforts underway or planned. These include a variety of efforts supported by the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the petroleum industry, the North Slope Borough, and the state of Alaska.

In addition, findings from the Project Chariot studies in the eastern Chukchi Sea from 1959 to 1961 could profitably have been reviewed, despite some less favorable aspects of the studies, to aid in understanding contemporary regional ecology and the nature of change. This large project included a broad range of disciplines, both marine and terrestrial, but is seldom mentioned in recent literature.

b. Dissemination Lags

Although the USGS report did in many instances dig deep into unpublished material, there is much more research occurring in the Chukchi and Beaufort seas than Circular 1370 indicates. This phenomenon is due in large part to the time it takes for research results to be published and disseminated to the wider scientific community. The lag was noticed particularly by our reviewers with active research programs in, for example, physical oceanography, biological oceanography, and marine mammal studies. While it may not have been appropriate to include unpublished research results, it would be relevant to note active research programs that are addressing identified gaps.

c. Lacks Priority Setting

The USGS report was quite thorough in identifying knowledge gaps and science needs for the Chukchi and Beaufort seas with respect to oil and gas development. Indeed, it was a veritable laundry list of nearly all things imaginable. However, it lacked a priority ranking by which gaps must be filled, e.g., high, medium, and low priority, which would serve to guide future research. Research to address all the gaps identified is beyond the current financial and logistical capability of U.S. marine science. This is not to say that there is one single thing that should be addressed first, but it should be explicitly recognized that some things are clearly more important than others.

d. Lacks Specific Recommendations for Some Larger Issues

If Arctic science is to improve, there must be progress on:

- Implementation of large-scale integrated monitoring.
- Agreed-upon methods for assessing cumulative impacts.
- Improved data management, comparability and exchange.
- More timely communication of results.
- Better integration of studies.

It is not enough to reiterate these problems; these are areas that require specific recommendations in order to progress. Having conducted this review, USGS would have been uniquely positioned to recommend how best to move forward.

3. Highlights from Comments on the Main Chapters of the USGS Report

The following comments on Chapters 2 to 7 are in most cases direct quotes from individual reviewers. Some editing was done for complete sentences, etc., but every effort was made to stay true to the reviewers' comments.

a. Comments on "Geological Context," Chapter 2

Chapter 2 does an excellent job of highlighting the uncertainties associated with various oil and gas resource distribution and economic assessments. The key question emerging from this chapter, and the report as a whole, is whether or what specific actions can be taken to reduce these uncertainties. Above all, it is projections of undiscovered resources and economic viability that drive a lot of activities in the early stages of resource exploration and production. Hence, better constraining these estimates may improve planning at the policy and management level and reduce the amount of effort expended by regulatory agencies, communities, and possibly industry.

An appropriate next step would be to specify the type of geological or geophysical (or other) information that could help reduce uncertainty in resource estimates at a range of scales. This should be followed by an evaluation of approaches that might lead to the release of well or seismic data without harm to economic or strategic interests. Possibly looking toward other countries, such as Canada or Norway, to identify innovative approaches for greater transparency on resource estimates may be of value. At the very least, a comparison of industry, agency, and (if available) academic estimates of resource potential may be feasible.

b. Comments on "Ecological and Subsistence Context," Chapter 3

i. Physical Factors

The discussion of physical oceanography is extremely thin and includes few details, which could easily have been gleaned from the publications cited or drawn from the peer-reviewed literature. There is a considerable body of data on aspects of the coastal meteorology. For example, the climate atlases assembled by Brower *et al.* (1977)[3] are exceptionally good and deserve to be noted. It is stated that the wind field is poorly understood. This comment was probably taken from a Minerals Management Service (MMS) workshop report from 2003 or 2004. The situation has changed substantially since then. For example:

- BOEMRE has funded a substantial data-mining and regional (high-resolution, state-of-the-art) meteorological monitoring program over the past few years.
- Industry has deployed several wave and meteorological buoys in the Chukchi Sea during the open-water season.
- There have been extensive studies on the marine atmospheric boundary layer under a variety of Arctic conditions. Such studies are almost certainly relevant to air pollutant dispersal issues likely to arise in any offshore development scenarios.

In summary, our knowledge of the regional wind field is much better than it was five years ago, and this should allow updating of the circulation and spill-trajectory models.

With regard to Hanna Shoal, an area important biologically and also a prime region for industrial exploration: both industry and BOEMRE are, or will shortly be, supporting efforts to examine the water circulation around the shoal. These studies include physical and marine ecological studies ranging across several trophic levels. BOEMRE is currently sponsoring state-of-the-art modeling efforts in the Chukchi and Beaufort seas relevant to offshore development activities. Evaluation of these models will include comparison with historical data and the large amounts of data now being collected. The modeling effort builds on a variety of historical sea ice and circulation modeling efforts, none of which was mentioned in this section.

The sea ice dynamics discussion is similarly thin. The authors note land-fast ice and pack ice, but nothing is said about the circulation differences in these regions or why these different forms of ice are present. The box on Page 43 is about circulation interactions between land-fast and pack ice, but nothing in the text serves as a context for this issue.

Nothing is said in the sea ice section about ice grounding and scour, the stamukhi zone, ridging intensity, ice thickness distribution, or the seasonal variability in many of these parameters. These issues are pertinent to any development scenario and certainly are important ecological phenomena. There has been work (in some cases, a considerable body) on several of these topics, but they are not addressed here. While the report refers to the complicated hydrography of the Hanna Shoal and Chukchi shelf break regions in the vicinity of the Chukchi lease areas, there is a broader, possibly urgent need to improve understanding of this region because ice conditions are quite complicated as well. Thus, ice grounds on Hanna Shoal in about 66 feet (just over 20 meters) of water depth every year, with ice trapped over that location into the summer, most likely as a result of the local circulation. Local ice features may present hazards to operations early in the season, but at the same time lingering ice may be of value to walrus and other marine mammals as the ice edge recedes farther north each year. While not a high priority, some kind of synthesis of available information on this region and its potential significance in the context of development may be in order.

ii. Biology and Ecology

The summary and superficial nature of many sections of Chapter 3 might suggest we know relatively little, when in fact we know major patterns and properties. Some of the recommendations (basically from Hopcroft *et al.* 2008)[4] are no longer concerns because of recent or ongoing research. It is notable that with the exception of some sections on the birds and mammals, there is no new synthesis here or in other chapters.

(1) Primary and Secondary Production

The primary production, microbial, and protist sections are accurate; however, significant progress has been made in understanding the relative importance of some gelatinous nekton groups since the text was written, although more remains to be learned. There is agreement with Sidebar 3.03—industry has made major contributions in this area, as well as most recently NOAA, with concepts such as the Distributed Biological Observatory (DBO) and the Circumpolar Biodiversity Monitoring Program (CBMP) holding promise.

In addition to the findings and recommendations stated, more focus should have been placed on the impact of shorter ice seasons and longer open-water seasons on primary production. Alterations of upwelling dynamics are just one way biological (primary) productivity may be affected. An attempt to model the expected changes in primary productivity based on longer open-water seasons should be established as a baseline. How will inorganic nutrient dynamics mitigate primary production despite a longer growing season?

To further develop the issue of rapid coastal erosion affecting biological processes, primary production needs to be a specific target of future research. Alterations of forcing factors on primary production can cause ecosystem-wide impacts. To what extent will sediment be transported through coastal waters, and where will the sediment ultimately be deposited? How will water clarity changes affect the attenuation of photosynthetically active radiation in the water column and benthos? How will increased suspended sediment load change the clarity of sea ice and affect sea ice algal photosynthesis? These questions also apply to any sedimentation events that occur from drilling activities.

The relative contributions by phytoplankton, ice algae, and benthic microalgae to total primary production and to the support of higher trophic levels are poorly understood. Further efforts using multiple tracers (e.g., bulk and compound-specific stable isotopes, biomarkers) should be emphasized in future studies to better understand which primary producers provide carbon subsidies to which consumers. A NASA program, “Impacts of Climate change on the Eco-Systems and Chemistry of the Arctic Pacific Environment” (ICESCAPE), in the Chukchi Sea is just finishing its last year of fieldwork, and the focus of the program has been primary production by phytoplankton.

(2) Benthos and Epibenthos

There is very little discussion of the benthic substrates in this chapter despite the fact that they are a key determinant of the variability of benthic communities that are particularly important for higher trophic level organisms in the Chukchi Sea. Chapter 3 reviews Arctic ecology, including fishes, but does not cite a significant and important research report: NOAA's Alaska Fisheries Science Center's survey of the Beaufort Sea in 2008. This important survey, funded by MMS (now BOEMRE), used standard bottom trawl survey techniques, as are used in the Bering Sea and Gulf of Alaska, to survey fishes and invertebrates at stations offshore and northeast of Barrow. This was the first survey of Beaufort fishes since Frost and Lowry's surveys in the mid-1980s and was conducted along specific transects. This survey found many species of fish and invertebrates, and some species range extensions.

(3) Fish

This section is much better than the section on marine mammals. Diadromous fishes in the Beaufort are a very good example of how, during OCSEAP, science needs were assessed, research was done to address those needs, and mitigation was put in place based on the science. The report's authors might make good use of this example. In contrast, it's very discouraging to see that for marine fishes there has been relatively little increase in knowledge since needs were identified in OCSEAP research and workshops in the late 1970s. Much more has been learned about other animal groups than about fish.

There is no mention of recent syntheses of fish inventory data by the Census of Marine Life. Shell Oil Co. is one of three industry members co-sponsoring new research in the Chukchi on fish, although it acts alone in the Beaufort. Another fish study is starting soon sponsored by BOEMRE.

The overview section highlights consequences of spills much more than other sections, but not climate change, which is probably of greater consequence and certainty and is discussed in the following chapter. Sidebar 3.07 seems much more specific here than in other sections, although that is probably true of the Hopcroft *et al.* report from which much of this is extracted. Similar to previous sections, notable progress has been made on these research needs through recent funding by industry, NOAA and BOEMRE.

(4) Seabirds

This section does not credit the sources of information on which it relies. In terms of information needs, it does not include the most recent (and extensive) industry surveys. It credits Shell for BOEMRE's Chukchi Offshore Monitoring in Drilling Area (COMIDA) program but wrongly credits the joint Shell/Statoil/ConocoPhillips Chukchi Sea Environmental Assessment Program (CSEAP) that is trying to make linkages between birds and their prey. Otherwise, Sidebar 3.06 (marine birds) seems reasonable.

(5) Marine Mammals

The U.S. Arctic is not the most diverse region in terms of absolute species numbers, but all of the many species there are well represented by many individuals. For Sidebar 3.05 (marine mammals), previous figures show we are now learning much more about movements of animals by tagging, plus population structure through genetics, but enumeration remains problematic for the more cryptic ice-associated seals. More extensive real-time data could result in a greater harvest by local hunters. Industry has been making significant efforts to identify threshold levels of noise, and this does not appear to be reflected in the report (this topic is handled extensively in Chapter 6 but with similar problems).

The marine mammal section is not very useful for establishing risk. The thumbnail descriptions of the focal marine mammal species are very brief and nearly without citations (about six for the seven NMFS species and eight for the two U.S. Fish and Wildlife species). The findings and recommendations could be paraphrased as "We need to learn more about just about everything." In contrast, the background, findings, and recommendations on marine mammals in Chapter 6 (sound impacts) are quite well written and focused. In fact, a number of the recommendations in Chapter 6 (e.g., 6.09 (bowhead whales and anthropogenic noise), 6.12 to 6.15 (critical habitat for beluga whales, gray whales, and ice seals; noise in marine systems), and 6.19 (walrus habitat)) should be in this section. Although they do pertain to data needed to assess sound impacts, the same information is needed to consider physical impacts on habitats, plan for response scenarios, assess cumulative effects, etc.

This section could be improved by starting with identifying the research questions. Although many approaches might be used, a simple order might be:

- What are the important places and habitats used by each species?
- Why are those places and habitats important?
- How might OCS activities affect use of those habitats?

Then one looks at the data available, and if the questions can all be answered sufficiently there are no science needs. If not, then the needs should be described. It should be possible to do this, especially given the recent status reviews for several key species. Obviously the conclusions will vary by species. For the first question, data are probably sufficient for polar bears and bowhead whales. For the other species the data are insufficient and additional satellite telemetry studies and/or aerial or ship surveys are needed. Passive acoustics might be helpful for beluga and gray whales. The second question is difficult, and data might be considered sufficient only for polar bears. One often assumes that seals and whales spend their time in places where they feed, but that can be verified using advanced telemetry devices. Seals and belugas may also concentrate in places for birthing and molting, and that can be investigated by direct observations—aerial, shipboard, or land. Migration routes can be determined by satellite tagging. The third question requires the sort of sound sensitivity/response information discussed in Chapter 6 as well as information on prey distribution and behavior, and modeling.

If the purpose of this report is only to inform where and when development should occur, then some of the recommendations are not needed. Examples include enumeration of population abundance, wintering distribution and habitats if they are not in lease areas, and population dynamics. Obviously these are good things to know, and they become very important when assessing the potential impacts of development, cumulative effects, and damages if they occur. Also, considering that most species are listed or close to being listed under the Endangered Species Act (ESA), studying and monitoring of population abundance and vital parameters are very important in the big picture. Monitoring is barely mentioned in this section and should have been given a fuller treatment. The authors should consult a recent report[5] from a workshop on this subject.

iii. Subsistence

Subsistence Patterns, Variability and Trends

Many studies have examined various aspects of subsistence production by North Slope residents and communities. In most cases, the documentation of use areas and harvest levels has been done at intervals too great to assess interannual variability, the causes thereof, and possible trends over time. Such studies are, however, time-consuming and often intrusive for North Slope residents, and require their full involvement in design, implementation, and analysis. A collaborative effort should be made with the North Slope Borough and North Slope tribes to identify a subsistence monitoring program to gather pertinent data on use areas, effort and travel, harvest levels, and distribution and sharing.

iv. Traditional Knowledge

(1) Retrospective Studies

Several studies have documented traditional knowledge of North Slope residents on various ecological topics, including beluga and bowhead whales, polar bears, walrus, and sea ice. Many more topics could be covered and are likely to be identified in relation to other ongoing studies and topics of scientific and management significance. North Slope residents, tribes, and organizations often call for greater recognition of traditional knowledge and expertise, indicating strong local support for such work. At the same time, such studies are often time-consuming and can be seen as intrusive for North Slope residents, so some degree of coordination may be desirable to avoid excessive numbers of requests or too many within a given period of time. A collaborative effort should be undertaken with the North Slope Borough and North Slope tribes to determine whether and how they would like traditional knowledge studies to be coordinated.

(2) Prospective Studies

North Slope hunters and fishermen spend considerable time on the land and sea throughout the year. They are careful observers of their surroundings, watching both the animals they pursue and the physical conditions that determine safety and access. Relatively little has been done to tap into this potential observing network, but a number of methods and tools exist to do so, from GPS-equipped data recorders to photo journals to post-trip interviews. Such efforts are time-consuming and may be seen as intrusive, so careful planning in collaboration with the North Slope Borough and North Slope tribes is essential when designing, carrying out, and storing and analyzing data from such a program. Nonetheless, the engagement of even a modest number of hunters in a continuing data-gathering exercise would contribute both to the body of available information and to the sense of involvement that can in turn lead to greater collaboration and mutual understanding of the Arctic environment among scientists, managers, and local residents.

The Indigenous People's Council for Marine Mammals[6] "is a coalition of tribal marine mammal commissions, councils and other Native organizations formed for the purpose of identifying and addressing marine mammal issues of common concern." Included among the member organizations are the Alaska Eskimo Whaling Commission, Eskimo Walrus Commission, Alaska Nanuuq Commission, Ice Seal Committee, Alaska Beluga Whale Committee, and others. These organizations are possible partners for collaborative research and monitoring.

(3) Data Management

The information generated from traditional knowledge studies is often qualitative and may come in a variety of media, from interview notes to audio and video recordings to maps, photos, artwork, songs, and so on. Organizing these data, providing appropriate protection from misuse, and allowing legitimate users to discover and access data where permitted, are all essential aspects of data management. At present, no such system exists for traditional knowledge from the North Slope (or anywhere else in Alaska). Some organizations, such as the Exchange for Local Observations and Knowledge in the Arctic,[7] are developing tools for traditional knowledge data management and can provide advice and assistance where needed. A system of data management that places information under the control of appropriate bodies (e.g., tribes, co-management organizations, etc.) but facilitates data discovery will help increase the use of traditional knowledge, better store the work that has been done, and reduce redundant studies.

c. Comments on "Climate Change Considerations," Chapter 4

As pointed out in the report, the "primary source of information about future climate conditions in the Arctic is the suite of projections provided by fully coupled atmosphere-ocean global climate models (AOGCMs)"; "secondary sources include downscaled AOGCM projections, physical understanding of the processes governing regional climate processes, and recently observed climate changes." With the recognized uncertainties in interpolating climate model output to the regional level (which the report mentions explicitly), this raises an important question that is left open in the report: What can be done to provide a better range of plausible future climatic conditions (ocean, ice, atmosphere) at the regional or local level in the context of permitting and planning? Could paleoclimatic or historic data contribute to such assessments, along with local and traditional knowledge and other approaches such as complex system models? This question needs to be evaluated with a comparatively high degree of urgency. The key goal is to provide a more realistic (though possibly wider) set of bounds on the future climate regimes that will govern operations and decisions in the region. In this context, quantitative assessments of predictability (vs. actual predictions without specification of error bounds) may be just as valuable in assessing the potential impacts of climate change.

The gaps in knowledge of the effects of ocean acidification on the Arctic Ocean and neighboring shallow seas are apparent. What is the expected pH change? To what depth will the pH change permeate? How fast will the change occur? To what extent will the calcium carbonate compensation depth (the depth below which calcium carbonate is dissolved faster than it is accreted) shoal (become shallower)? Both NSF and NOAA have ocean acidification programs, and an explicit focus on the Chukchi and Beaufort shelf and slope regions should be included.

More should be said, in the main text and in the findings/recommendations, about potential climate change impacts on beluga whales. Both of the beluga populations of concern concentrate every summer in traditional coastal/estuarine areas (the Kasegaluk Lagoon area for the Chukchi population and the Mackenzie Delta for the Beaufort population). These areas have particular physiographic and oceanographic conditions that are very likely to change with climate warming. Unfortunately, there is no clear understanding of why whales select these particular areas. If studies were done to describe the features that make these places special for the whales, projections of what will change with warming (increases in sea level, changes in freshwater and sediment flows, etc.) could allow some prediction of what climate change impacts might be on belugas. Belugas are not as high-profile as bowheads and polar bears, but they are a very important subsistence resource in towns adjacent to lease areas, such as Point Hope, Point Lay, and Wainwright.

d. Comments on "Marine Mammals and Anthropogenic Noise," Chapter 6

The USGS did a thorough review of Arctic marine mammals and noise, but did not mention that efforts are underway by industry to determine thresholds for disturbance. There are also some minor comments in the appendix on this chapter.

e. Comments on "Cumulative Impacts," Chapter 7

This chapter provides a general overview of the status of cumulative effects analysis (CEA) in the Arctic and the broad issues associated with cumulative impacts, and makes some general recommendations. Among the most critical recommendations are synthesizing available information; establishing baseline data; standardizing the approach and methodology for CEA; and accounting for uncertainty, future actions, and climate change (including ocean acidification) in the evaluation of cumulative impacts. This chapter also identifies many of the basic problems (independent/uncoordinated agency assessments of cumulative impacts, project-specific focus vs. regional analysis), and presents some general solutions. However, the report misses an important opportunity to provide specific recommendations of next steps for improving CEA. In particular, it does not outline a process for setting scientific priorities or next steps to support regulatory and management decisions by federal agencies responsible for energy development in the OCS. There are numerous references to the 2003 National Research Council report on cumulative impacts, which also was fairly generic and did not describe a clear path forward for the implementation of broad system-level recommendations. Likewise, this report makes observations on the current status of the CEA process in the Arctic, and identifies several important problems with that process, without recommending specific solutions.

The chapter also recommends implementation of ecosystem management and marine spatial planning without providing a logical linkage to CEA, addressing how these concepts might benefit management decisions, or recommending specific science needs related to those concepts. For instance, Recommendation 7.05 states: "A methodology for comprehensive, quantitative cumulative impact analysis that is transparent, externally vetted, and adopted consistently across at least the Bureaus of the DOI and other key agencies should be developed. … A common language and a common set of metrics should be developed." So, what should the "language" include? What units can be used to quantify cumulative impacts and assess interactions between impacts to different resource types? How do we start to resolve this problem? Approaches to synthesis in applied ecological studies have been developed by the North Slope Borough in its requirements for monitoring industrial development in the Prudhoe Bay region. These models should be considered. One could consult with Dr. John Kelley at the University of Alaska Fairbanks (UAF), who chaired a North Slope Borough committee responsible for advising the borough on its large-scale synthesis and monitoring program for the Endicott Development.

CEA will become much more useful when information from different research programs can be integrated coherently. The idea of standardized assumptions—such as agreement on reasonably foreseeable future actions (RFFAs), metrics and analytic techniques for CEA—is crucial. Standardized metrics are needed so that interactions between impacts on different resource types from different projects can be estimated objectively. Given the number of lease sales and resource development projects awaiting approval, the number of regulatory agencies involved, and federal budget implications, recommendations are needed on immediate, practical next steps to improve CEA, in addition to bigger-picture recommendations.

Chapter 7 does not recognize impacts of past development, a key component of National Environmental Policy Act (NEPA) CEA, nor the roles of commercial whaling, Cold War military facilities, scientific research, or oil and gas development (abandoned sites, spread of infrastructure), in cumulative effects. This shortcoming is exemplified in a statement that "the Arctic has seen little development, and today's conditions could represent a baseline." The cumulative effects from the spread of oil and gas infrastructure along the Beaufort Sea coast, especially roads, pipelines, and gravel pads, have long been a stakeholder concern. Solutions to this concern are difficult to impose at the individual project or applicant level and may require regional solutions, such as private-public partnerships to finance and operate common facilities.

Chapter 7 only touches on one of the important agency tools for assessing and mitigating cumulative impacts: adaptive management and associated monitoring and mitigation requirements. This is another broad concept that has been challenging to implement under NEPA. Specific recommendations on how adaptive management should focus on areas of uncertainty, missing information, mitigation measures, monitoring, and reassessing results would be helpful. Also needed is to run some scenarios of negative ecosystem effects to determine whether the regulatory machinery in place can alter already-approved activities. In other words, can true adaptive management occur under the current circumstances in response to research and ecosystem monitoring results?

Note: For consistency and brevity in the main body of this report, some additional comments and recommendations from Chapters 3, 6 and 7 have been placed in Appendix 1.

III. Overarching Issues and Recommendations

Here we discuss several issues and make recommendations for improving Arctic marine science and its application to management and conservation. Topics discussed in this section include data management, synthesis, coordination, the need for long-term monitoring, setting research priorities, adaptive management, and identification of areas of special significance. Many of these topics and our recommendations are interrelated. For example, as recognized by the USGS report, there is a serious lack of synthesis of the data we have in the Arctic. The first step in improving synthesis is to make as much data as possible available to scientists working in the Arctic. Optimistically, data integration might lead to improved coordination among parties carrying out research, which in turn would provide a basis for crafting a long-term, broad-scale monitoring program that is needed for almost all of the identified issues revolving around energy development impacts.

1. Data Management

The single most important and urgent issue emerging from the USGS report, in terms of what is missing and essential next steps, concerns data management. There is a lack of concerted, cutting-edge effort to integrate the mostly disparate data sets and data streams of environmental variables into a single, unified context that allows derivation of data and information products at spatial-temporal scales and in formats relevant to decision makers, operators and the public. Industry may have made the most progress in this regard, but unfortunately there is comparatively little discussion of industry data, most likely because such data are not always easily accessible. In general, a conclusion that is implicit in the different sections of the report, but never made explicit with the degree of urgency it deserves, is that despite increasing coverage and volume of environmental, and to a lesser extent biological, data collected in the Arctic, there is no easy way to access different data streams in a unified, coherent setting that enables integration and derivation of usable data products. Rather, as illustrated by Figure 5-3 in the report, it would involve a significant effort even to assemble all the relevant data sets shown in the Alaska Ocean Observing System's (AOOS) Arctic Assets Application, let alone consolidate these into a single computing environment. Yet, such an environment would facilitate decisions that consider all the relevant information. For retrospective data analysis that is so relevant to permitting or leasing decisions, these challenges may be surmountable for small subregions involving a limited number of data sets. For operational settings, however, or in the context of spill response tactics where rapid access is needed to information directly related to the task at hand, the great potential of existing data is not fully realized. To be sure, industry is likely to have systems in place that perform some of these functions, but given the amount of observing system assets in place, a broader, more integrated effort to consolidate these data streams is needed.

The most appropriate next step to address this issue is to intensify and concentrate efforts to catalog existing and planned observing efforts, similar to AOOS' Arctic Research Assets Map. This would not require meetings, but rather more effective outreach and incentives or support to allow the relevant assets to be captured. Because a number of parallel activities are underway that offer such information nationally and internationally, these groups may have to agree on a joint strategy and division of tasks and responsibilities. In the long run, only a single entity that is robust, relevant and accessible is likely to be able to attract a large pool of (self-reporting) data acquisition and reporting systems.

The next step would be to use existing agreements and frameworks (such as the Arctic Observing Network supported by NSF, the Arctic Research Commission, or BOEMRE programs such as COMIDA or the Arctic Nearshore Impact Monitoring in the Development Area program, and industry efforts) to move from mutual information about observing asset deployment to coordination, development of common formats and standards, and eventually a more integrated observing system that can address the information needs highlighted in the USGS report. Thus, the subsequent logical step in scientific management would be improved program coordination.

2. Syntheses of Existing Information

Large-scale synthesis of existing data sets is underway at UAF for fish (Norcross, Mecklenburg), benthos (Blanchard, Bluhm), zooplankton (Hopcroft), and sea-ice communities (Gradinger). Industry is working to do the same for seabirds (through Alaska Biological Research) as well as some aspects of marine mammals. A multidisciplinary regional synthesis is needed after that. Industry is sponsoring an overall synthesis of its work in the Chukchi Sea over the past three years this fall. BOEMRE has funded a large synthesis of Arctic research by NOAA. A synthesis effort is underway by the Pacific Arctic Group (PAG) that will result in a 13-chapter book in 2012 (J. Grebmeier, ed.). A report on the Bering Strait summarizes a wide consensus of science status and needs in the region (Cooper *et al.* 2011).[8]

It will be informative to see the results of the UAF synthesis on Arctic fishes. Much of the work conducted over the past decades on fish was very limited spatially, and rarely, if ever, replicated, and investigators used a wide variety of sampling equipment, so results are not always comparable. We need more work like that completed by Logerwell *et al.* in 2008[9] in the western Beaufort. In addition, most of the historic and recent marine fisheries studies completed in the Chukchi and Beaufort seas are reviewed in the 2009 North Pacific Fishery Management Council Arctic Fishery Management Plan’s accompanying Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis.

The assessment of cumulative impacts can be seen as another form of synthesis, especially in regard to cumulative effects from many stressors (as opposed to the cumulative impacts of noise from a single stressor, such as many ships or drill rigs). What are the relative contributions of different activities, locations, times, and stressors to impacts on benthos, fish, birds, marine mammals, and subsistence? Are there priority targets for mitigation? For further study?

3. Research and Monitoring Coordination

The USGS report's identification of areas that would benefit from further scientific research is a first step for improved management of Arctic science. Although the recommended further research would undoubtedly advance our knowledge base and allow for better decisions, there is in reality little likelihood that all of it can be funded given the current situation with government budgets. In addition, there are greatly overlapping goals and potential inefficiencies in having so many separate participants in Arctic science. Many state and federal agencies and universities across the United States are developing Arctic programs and projects. Consortiums of groups are being formed to coordinate and cooperate in Arctic scientific studies. Do we really need all of these groups working independently, each within its particular but overlapping area of interest?

We already have BOEMRE, the NAS Polar Research Board, NSF's Office of Polar Programs, AOOS, PAG, North Pacific Research Board (NPRB), North Pacific Marine Science Organization (PICES), Pacific Science Center, Scott Polar Research Institute, the Army's Cold Regions Research and Engineering Laboratory, Arctic Council, Russian-American Long-term Census of the Arctic, National Snow and Ice Data Center, International Arctic Science Committee/Marine Working Group, Arctic Research Consortium, Barrow Arctic Science Consortium, Smithsonian's Arctic Science Center, and many NOAA programs and groups, to name a few. Industry also has sponsored research efforts.

There are many valid interests, regulatory needs and mandates, and other reasons for so many entities, but are all of these groups essential, given pressing needs and tight budgets? What is a possible "solution" to the existence of so many entities initiating programs in the Arctic? Could greater efficiencies be achieved by bringing all of the major scientific efforts under one umbrella management structure, or at least a substantially smaller number of management structures? We believe that this single act, challenging as it might be to accomplish, is one of the best things that could be done for Arctic science. This probably would have to be done in steps and with powerful (monetary) incentives, but the benefits would be enormous: more could be learned over a wider area for the long-term; greater efficiencies in vessel usage could be achieved; duplicate work could be avoided; data management and sharing could be improved; synthesis efforts could be sponsored more easily; common approaches could be applied to evaluating cumulative development effects across the Arctic.

We have already alluded to coordinated data management as a first step toward greater integration and coordination. It may take a federal interagency effort to streamline some of the many entities mentioned above.

Another mechanism for greater communication and integration is geographically specific scientific meetings. At present, the Alaska Marine Science Symposium (AMSS) is a good forum for exchanging scientific findings well in advance of publication. Marine scientists exchange ideas, compare research approaches and discuss opportunities for coordinated research at this meeting. However, the session devoted to the Arctic Ocean has been limited to one day. This could profitably be expanded. Additionally, some organizations, such as the Exxon Valdez Oil Spill Trustee Council (EVOSTC) have made funding contingent on presenting study results at the AMSS. If all of the funding organizations made such a requirement, greater coordination of research activities at the level of principal investigators would result. Support is also needed for scientists to attend larger national and international forums to allow broader evaluation of science in the Arctic relative to other global regions. The EVOSTC was successful in coordinating large, multidisciplinary ecosystem studies in the northern Gulf of Alaska for about a dozen years, involving state and federal government agencies, private consultants, and universities. Studies were proposed, peer reviewed with the objective of achieving ecosystem restoration goals, and adaptively managed. The advantage of the EVOSTC process was that there was one pot of money to start with, and that provided a powerful incentive for coordination by participating institutions. Another model with a somewhat similar structure is the NPRB.

Another intermediate state, or possible evolutionary step, toward a fully integrated scientific research and monitoring effort would be large ecosystem-based studies with participation of multiple funding institutions. The Sound Ecosystem Assessment and the Nearshore Vertebrate Predator studies conducted under the EVOSTC umbrella are two examples that brought together investigators from state and federal governments, universities, and private organizations in integrated research programs. Other notable focused, highly productive studies in the Bering and Chukchi seas were Processes and Resources of the Bering Sea Shelf (PROBES), Inner Shelf Transfer and Recycling (ISHTAR), Western Arctic Shelf-Basin Interactions' (SBI) global change program, and the Bering Sea Integrated Ecosystem Research Project (BSIERP), which serve as excellent models for the organization of tractable scientific programs within a comprehensive management structure.

One way to conceptualize the evolution of greater integration among institutions doing Arctic research and monitoring is presented in Figure 1. The early steps in this evolution would involve joint data management: getting institutions to find ways to share and derive benefit from a common pool of Arctic data, and solve the myriad problems of common formats, data exchange mechanisms, and data preservation. This could naturally develop into identifying syntheses of benefit to all, with the possibility of joint funding, to the benefit once again of all institutions. With input from an expanded Arctic forum such as the AMSS, it is not difficult to imagine a progression to joint research programs. A similar progression in designing a large monitoring program, using existing ongoing measurements and new ones, would be another step in aggregating functions common to the needs of participating institutions. This is a very preliminary sketch of how further integration might take place and would need further consideration and refinement. However, it offers the prospect of progress toward greater integration and efficiency without immediate reorganization.

We are not practitioners in institutional architecture, but we do know that the best environmental science is done in a coordinated way, has access to all relevant data, is ecosystem-based, has explicit conceptual models and hypotheses, and is peer-reviewed, cross-disciplinary and adaptively managed. It may be too difficult to implement an umbrella governance structure in the short run because of differing mandates, data needs, and funding sources, but some aggregation surely is possible. Beginning with small steps would be better than what exists now.

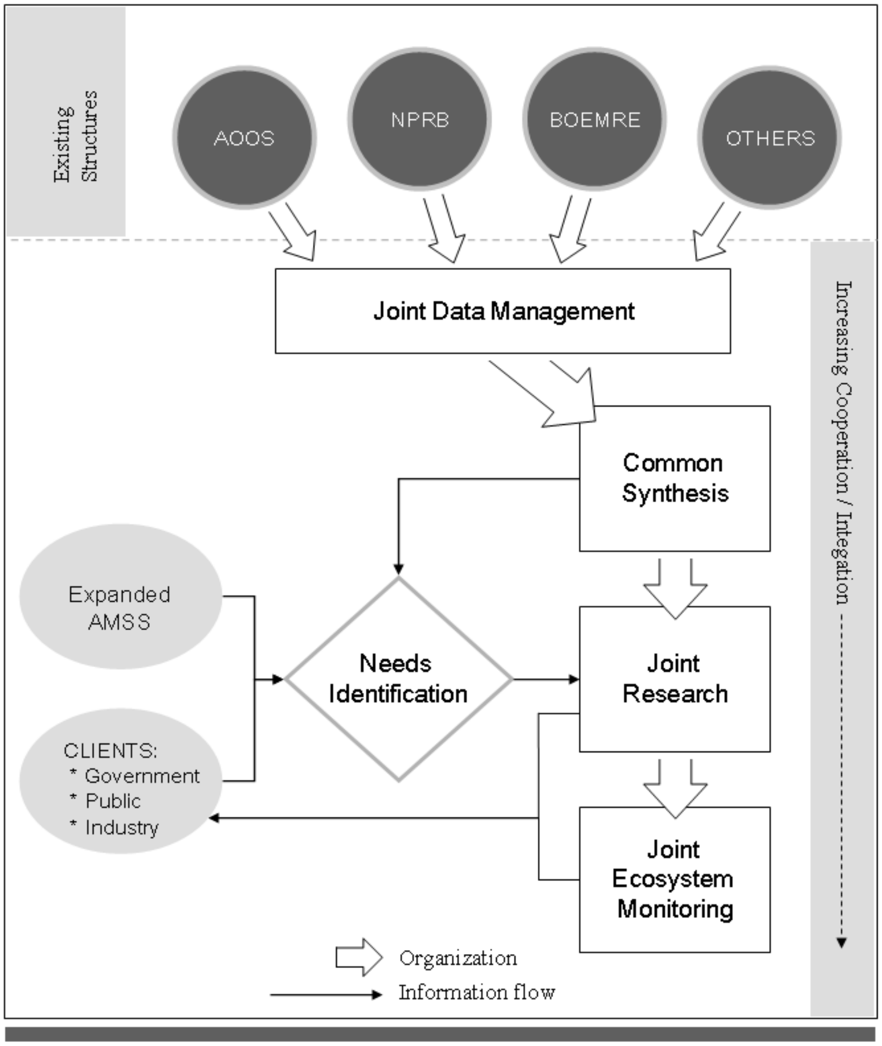

Figure 1. Suggested framework for enhanced cooperation and integration among institutions carrying out Arctic marine ecosystem research. This proposes a step-by-step evolution of integration.

4. Long-Term Monitoring

Almost every marine scientist now appreciates the absolute necessity of long-term monitoring for understanding ecosystem change and for gathering the necessary information for ecosystem-based management. The problem is finding sufficient and stable financial resources to support a program of basic measures at all levels of the ecosystem that will last for decades, including time scales on which ecosystems fluctuate in response to climate and other pressures. Again, political support and institutional strength are likely to improve if there is a concerted and coordinated structure for science management. Our reviewers recommend the following next steps:

- Develop a series of monitoring stations at which physical, chemical, and biological data are collected repeatedly, over the long-term.
- Develop a list of core physical, chemical, and biological measurements for monitoring that will be measured at the time-series stations. Other stations and measurements can be tailored to specific needs at sites of prospective development or where key ecological processes with broad importance occur, e.g., Barrow Canyon or Hanna Shoal.
- Link monitoring to the outcomes of a comprehensive, issue-driven, integrated ecosystem-based research program; consider the DBO concept and NPRB's BSIERP. Findings 3.03 (long-term plankton monitoring), 3.04 (monitoring hot spots of biological activity), 5.24 (use of the DBO), and 5.25 (using existing study frameworks for Arctic science) are high priority items.

5. Setting Research Priorities

One of the most important next steps in setting the agenda for Arctic marine science in the Beaufort and Chukchi seas is a process for prioritizing research and monitoring needs. There are two approaches to identifying research priorities: applied risk assessment and basic ecosystem research. Both are needed. The USGS report includes a recommended methodology, "Structured Decision Making" (SDM) (Appendix C), for improving the way decisions are made in the OCS and thereby helping to determine what information is needed to make them. Key components of this SDM are risk and uncertainty. The USGS report has: 1) described a large number of unknowns such that if we had nearly inexhaustible resources to research those unknowns we could reduce uncertainty, and 2) provided a recommended process for making decisions using existing and new information to describe risk. What is missing is a way to link these two and a process for prioritizing the science that needs to be done with finite resources. The missing process involves some way of assessing risk from OCS activities, identifying the important unknowns (or asking the appropriate questions, or, more formally, stating the important hypotheses).

Risk assessment, even with its known weaknesses, is an appropriate process for identifying the "known unknowns." It is a structured process that needs to be strengthened to more closely and explicitly link policy decisions to scientific findings. The weakness of risk assessment, as we have recently seen in the nuclear plant disasters in Japan, is that some elements of risk are not identified and that risk assessment often provides a level of confidence in decisions that is unwarranted. So we need to continue to do basic research on Arctic ecosystems and the ways in which anthropogenic effects are manifest in these systems, to identify the "unknown unknowns" as much as possible.

If the management of risk is truly carried out in an adaptive mode, then the risk assessment will be an iterative process that is continually refined by research into ecosystems, informed by ecosystem monitoring and then linked to real control of development. An increased ecosystem understanding will also help inform the design of long-term monitoring efforts needed for risk assessment, identifying cumulative effects of OCS activities and providing the information needed for adaptive management of policy—by which we mean the ability to change established policies if they are ineffective.

One of the most fruitful approaches to understanding changes in Arctic ecosystems, and one that would help greatly in understanding cumulative change, designing new monitoring efforts, and identifying areas of priority research, would be to repeat some of the studies carried out in the 1970s and ’80s in OCSEAP. An assessment of OCSEAP results should be made to identify which studies and measurements should be repeated and why they would be relevant to current decisions.

Four areas that should be considered among the top priorities for basic biological research on Arctic ecosystems are:

- Population dynamics of key pinnipeds, cetaceans, marine birds, forage fishes, and commercial fishes. Programs are underway and have been for many years for some species. For others, there still is no reliable estimate of abundance, much less trend in abundance. Rationale: Population size and trend are the ultimate indicators of the biological status of a species.
- Habitat use by cetaceans, pinnipeds, and marine birds, including breeding locations and foraging and movement/migration patterns. Rationale: With respect to resource development, conflicts between habitat needs of wildlife and the desires of industry (and consequences of accidents such as oil spills) must be understood and resolved.
- Pelagic and benthic food web structure, including particularly diets of key species of marine fishes, birds, and mammals. Traditional and novel methods such as the use of molecular biomarkers should be employed. Rationale: Knowledge of trophic dependencies of species is key to understanding their natural histories, and changes in diet are important indicators of change in populations of forage species and community structure.
- Phytoplankton, zooplankton, and benthic community structure and productivity. This would again include traditional approaches as well as novel methods. Rationale: Primary and secondary production set the upper limit of biomass yield in ecosystems, and there is concern over possible alterations in Arctic production budgets due to climate change and the loss of sea ice.

6. True Adaptive Management

True adaptive management that is protective of resources must seamlessly integrate monitoring with ongoing risk assessment and be able to adjust the scope of anthropogenic activities. Adaptive management must receive a serious commitment for implementation and the funds necessary to support it. Such a system does not exist on a large scale today in the Arctic Ocean of the United States. The report does mention adaptive management, but only superficially. Given the myriad guiding legislative and decision-making processes, additional review is needed to determine whether, to what extent, and how adaptive management can be applied in the Arctic. Without the flexibility to respond in a timely and adaptive way to what is learned by research and monitoring, which is at the heart of adaptive management, there is less incentive to study the outcomes of policy decisions and the cumulative impacts of development in the Arctic.

7. Identification of Areas of Special Significance for Protection

There is a need to continue undertaking workshops and syntheses of information on biological hot spots, building upon results of similar recent exercises to avoid duplicating efforts.

An overview synthesis of Ecologically and Biologically Significant Areas (EBSAs) in the Arctic was completed by the International Union for Conservation of Nature (IUCN) and the Natural Resources Defense Council (NRDC) in April 2011 following a "Workshop to Identify Areas of Ecological and Biological Significance or Vulnerability in the Arctic Marine Environment" in La Jolla, Calif., in November 2010. "The purpose of the La Jolla workshop was to advance the process of identifying EBSAs in the Arctic marine environment. In addition, the workshop served as a venue to bring together and build on the work of several parallel projects, including those undertaken under the auspices of the Arctic Council, the World Heritage Arctic marine site identification process, and mapping efforts by non-governmental organizations including the World Wildlife Fund, Oceana, and the National Audubon Society."[10]

A second synthesis of information on Arctic ecosystems, "Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Research," was produced in 2008 by the Institute of Marine Science at UAF and funded by NPRB. "The goal of this effort was directed at summarizing the current state of knowledge and then identifying: (1) the most crucial information gaps, (2) 'pulse points' in the biological/physical environment that require monitoring, and (3) how climate change might impact biota through its influence on: sea ice extent/characteristics, shelf currents and transport through Bering Strait, coastal currents along Alaska's north coast and their relationship to various biological processes and life histories."

These syntheses are both broad treatments that identify particular locations and systems of ecological and cultural importance in need of study and protection. With respect to the findings of these reports and the USGS report's Recommendation 3.07, "Biological hotspots for long-term research and monitoring," syntheses of available information on some or all of the individual sites should be undertaken.

This has been done at some level for regions from the northern Bering Sea to Barrow Canyon.[11, 12]

Among the hot spots listed in Recommendation 3.07, Ledyard Bay has been identified as a Super EBSA in the IUCN/NRDC report and as an Important Bird Area (IBA) of global significance by the National Audubon Society. Ledyard Bay includes the embayment between Cape Lisburne (itself an IBA of global significance) and Point Lay, the lagoons, and nearshore waters. Although much remains to be done scientifically in Ledyard Bay to properly characterize it physically and biologically, and to understand the processes that cause it to be of such ecological importance, considerable work has been done there and enough information has been gleaned about it to warrant synthesis. Some has been published, but much has not. Of note with respect to Recommendation 3.07, "Capes Lisburne and Thompson (seabird colony and fishery oceanography dynamics)," a beginning foundation of understanding was established from the 1970s to the 1990s on forage fish variability as revealed through studies of seabird diets, the supporting marine food webs, and responses of forage fishes to climate change operating through those food webs. Recent studies related to Lease Sale Area 193 have added additional information. Inasmuch as Ledyard Bay is adjacent to Area 193, and despite the special recognition it was afforded under the ESA (Ledyard Bay Critical Habitat Unit), it is deserving of extra attention beginning with a synthesis of all available information.

A second location of considerable ecological and cultural importance is Kasegaluk Lagoon, also within an IUCN/NRDC Super EBSA and an Audubon IBA of global significance. As with Ledyard Bay, much remains to be learned about the ecological processes that cause it to be of such significance and about its sensitivity to disturbance. However, at Kasegaluk Lagoon there already has been enough work done scientifically, as well as through traditional ecological knowledge (TEK), that a synthesis of available information is warranted.

Although the Bering Strait region has been a focus of attention for decades, and syntheses of information on various components have been undertaken, including ecological processes and anthropological significance, none has fully integrated the multitude of features of this ecoregion in a suitably holistic way. In lieu of a synthesis *per se*, which would indeed be a monograph, an annotated bibliography of scientific studies, syntheses, and TEK would be an important first step to acquaint the modern world with the historical knowledge available for the region. It could be organized in a synthetic way—that is, it would follow logical and connected pathways to arrive at a description and understanding of this ecoregion, if and how it has changed in recent decades, and how and why it might be altered by resource development and climate change in the future.

IV. Conclusions and Recommendations

The USGS did a creditable job of summarizing the numerous gaps in our knowledge of Arctic marine ecosystems and the effects of OCS activities and climate change. Some parts of the report, such as aspects of the physical oceanography are incomplete. The report calls attention to the large body of scientific information that has been gathered about this environment, but much of this information has not been synthesized and therefore not accessible in a form that benefits the scientific community and even less so for policy decision makers and the public. In addition, the report calls attention to the many critical gaps in existing information, but does not give a sense of priority to guide the allocation of limited funding to address those gaps. The USGS report is a good starting point for further discussion, work, and integration, but the question of how much and what science is needed to support informed decisions about oil and gas activity in the Arctic remains unresolved. The DOI, having commissioned the report, should follow up on this first step along with other federal agencies in making science more relevant in the Arctic.

Following are our specific conclusions and recommendations:

1. Setting research priorities: The USGS report does not indicate which of the many science gaps are most important to fill. RECOMMENDATION: The DOI and other agencies need to set research priorities as there are not enough resources to study all of the topics suggested in the report. The SDM process outlined in Appendix C of the USGS report, as well as a more formal risk assessment process, should be used to identify immediate research needs.

2. Supporting basic ecosystem research: RECOMMENDATION: In addition to filling specific science gaps, the DOI and the federal government must continue to support a fully integrated scientific research and monitoring effort.

3. Identifying the next steps: The report lacks specific recommended next steps for study of some problematic areas, such as determining the cumulative effects of development and how to integrate the many monitoring activities across the Arctic. RECOMMENDATION: Specific next steps need to be identified as part of an overall strategy of integrated and relevant research and monitoring.

4. Assessing cumulative effects: Properly assessing cumulative effects is essential to informed decision making about oil and gas activities in the Arctic. For example, there is a considerable body of information about the impacts of noise on movements of bowhead whales, but very little is known about the cumulative impacts of multiple simultaneous or sequential noise events. RECOMMENDATION: The DOI and other federal agencies should undertake an assessment of cumulative

impacts, beginning with the development of a range of scenarios for industrial activities over the next few decades.

5. Improving timely dissemination of information: There is a significant lag in the communication of study results so that some of the areas suggested by USGS for research are being addressed already. For example, the USGS summary of nutrient chemistry and biology of non-vertebrates differs little from that reported by Hopcroft *et al.* (2008), although significant progress has been made since then in initiating new research on these topics.

6. Improving information exchange: A broader, more integrated effort at consolidating, coordinating, and sharing data streams is needed. RECOMMENDATION: The DOI and all participating institutions should develop better and more timely ways to share results among Arctic scientists and managers at a broadly based scientific forum such as the AMSS, the National Marine Fisheries Open Water Meeting, the Arctic Research Commission process, or the North Slope Science Initiative.

7. Implementing better monitoring: It is likely that climate change will overwhelm other sources of ecosystem forcing, and it is important to account for this probability in the design of monitoring. RECOMMENDATION: It is imperative that the DOI integrate existing and new monitoring into data systems that can then be used to answer pressing questions about ecosystem response to climate change and the accumulative effects of OCS development across the Arctic over many decades. This requires annual monitoring supported by stable long-term funding and enhanced planning and coordination.

8. Improving data management: RECOMMENDATION: The DOI and other institutions engaged in Arctic research need to do a better job of data management. Accessing various data streams for synthetic purposes is an urgent emerging issue requiring concrete next steps, including and surpassing those identified in the USGS report.

9. Improving research and monitoring coordination: RECOMMENDATION: Further integration of research and monitoring activities is needed. Greater efficiencies could be achieved by bringing all of the major scientific efforts under one umbrella management structure, or at least a substantially smaller number of management structures. We suggest that this start with coordinated data management and eventually aggregate research and monitoring functions via a smaller number of managing entities. The Interagency Working Group on Arctic Resource Development established by President Obama should provide incentives for further integration of what is now a piecemeal approach to the management of Arctic resources.

10. Implementing true adaptive management: RECOMMENDATION: To conserve Arctic resources, true adaptive management must be in place. The DOI should be able to revisit its policies and decisions on an ongoing basis, and change them in response to

research and monitoring findings. We recommend an additional independent examination of decision-making processes to determine whether this can be accomplished under existing laws, regulations and procedures, and what can be done in these areas to ensure that invaluable Arctic ecosystems can be protected.

11. Synthesizing existing knowledge: RECOMMENDATION: Syntheses—as well as new data—are needed for a number of priority topics. There are a number of biological syntheses underway at present. When these are completed the DOI in cooperation with other federal agencies should complete a regional ecological synthesis. Such a synthesis would help address basic questions about oil and gas activity, such as whether, where and when to allow such activities, and would also help identify geographic areas requiring enhanced protection and aid design of new monitoring programs.

12. Interpreting data and results: It is important that existing information about the Arctic marine environment are synthesized and interpreted for the benefit of decision makers and the public. If the goal is to inform policy decisions on oil and gas activities in the Arctic, the necessary information must be made available in timely and accessible ways. RECOMMENDATION: The DOI should develop an interpretation program to make results of scientific activity more broadly accessible to and understandable by nonscientists. The data used in OCS decision making should also be publically available for independent analysis.

13. Increasing assessment and incorporation of local and traditional ecological knowledge: RECOMMENDATION: The DOI needs to make greater efforts to incorporate local and traditional knowledge into Arctic research and resource management, as these sources can provide insight on environmental trends and relationships that might not be available from other sources. Doing this in partnership with Alaska Native tribes and organizations will ensure that it is done in ways that the holders of local and traditional knowledge approve and find suitable.

14. Identification of areas for enhanced protection: RECOMMENDATION: The DOI and other appropriate government agencies, e.g., NOAA, should make a concerted effort to protect areas of special biological and ecological importance based on available information and to give such areas priority in research and monitoring programs to better understand the underlying features and processes that make them important. Examples of important areas are Hanna Shoal, Ledyard Bay and Barrow Canyon, and unique habitats such as the Boulder Patch in the Beaufort Sea

V. Appendices

Appendix 1: Additional Reviewer Comments on Chapters 3, 6 and 7

a. Additional Comments on Chapter 3, “Ecological and Subsistence Context”

Physical factors: Caution should be exercised in using the Figure 3.1 cartoon because it obscures the many details known about the circulation. There was no discussion on the wind field over the Chukchi Sea and how this influences ice and water movements. There was a brief remark on the winds in the Beaufort Sea. There are seasonal wind variations that are well understood. There has been work on storm surges and some work on waves, but none of this work is mentioned in the text. Nothing was stated about how the discharge from North Slope rivers or the Mackenzie River affects the circulation characteristics of the Beaufort shelf and slope. Moreover, there was no clear connection between this presentation and the items highlighted in the recommendations box on Page 43. How did the authors decide on the recommendations in Box 3.01 given the discussion presented?

In the box on Page 43, Beaufort Sea: What is meant by the large-scale circulation of the Beaufort Sea and its thermohaline structure? Is this meant to be about the whole Beaufort Sea, the shelf (including the Mackenzie component), the slope or the adjacent basin? What are the crucial issues that connect interannual variability in ice and winds to the circulation and thermohaline fields? This recommendation is extremely vague.

There is far more detail presented on Page 83 regarding model analysis methodologies with respect to future climate scenarios than on the physical oceanography and sea ice sections. (In general, the sections in Chapter 4 [Pages 83 to 90] are far more illuminating and detailed than Pages 42 to 47.) Better balance, at the very least, is needed on these topics. The reviewer did not notice any mention of likely changes in the river discharge cycles. These will occur and result in increases in discharge and, perhaps more importantly, changes in the onset, duration, and persistence of runoff events and the seasonal cycle.

b. Additional Comments on Chapter 6, “Marine Mammals and Noise”

We note that the same topics are brought up in multiple chapters, but they don't necessarily refer to the same information. As an example, when ocean acidification is first mentioned, one is expecting to read about how this could impact calcium carbonate users such as bivalves and how this in turn could affect walrus foraging (on top of the issues walrus will have with reduced sea ice cover). Although this information was identified in the report, it’s scattered. Another example is the reference to the AOOS website with all the oceanographic mooring information—this isn't referenced at all in the acoustics chapter although more than 100 acoustic recording packages are shown on this site. These points are very minor but noticeable, possibly because the rest of the report was so nicely done.

Only four stocks of bowhead whales are recognized currently; the Davis and Baffin stocks have been merged.

There is no assessment of how many harbor porpoises there are in the Arctic seasonally. Therefore, one can't say "low abundance," because we don't know how many there are.

Gray whales are regular summer-long visitors to the Beaufort Sea and have been seen as far east as Canada. They generally appear to continue bottom feeding but some have been seen skim feeding on euphausiids. There has been no comprehensive assessment of gray whales in the Beaufort Sea.

Beluga whales are important subsistence species for coastal villages (especially at Point Lay) in northwestern Alaska. Finding 6.12 concerns spatial and habitat needs of beluga whales. Given their distribution over vast areas of ice-covered water, scientists need an improved survey methodology for this species in the Chukchi and Beaufort seas.

What this report highlighted was that we who work in the Arctic are not getting information out in a timely enough manner and that there is not enough coordination among researchers. It's not clear how to make this happen, although a workshop might be useful to connect people, possibly during the AMSS meeting or at the International Polar Year meeting in Montreal in 2012.

We also note the following specific errors:

- There are a couple of errors in the literature cited.
- Table 6-2 should be Delphinapterus, not Delphinus.
- Harbor porpoise = high frequency cetacean.

c. <u>Additional Comments and recommendations on Chapter 7, "Cumulative Impacts"</u>

Specific recommendations made in Chapter 7 that will improve cumulative impact assessment include the following:

- A single methodology could be consistently applied to different areas, account for regional variables, and allow for a comparison of results; there should be a single DOI approach.

- What seems to be missing from many of the cumulative impact analyses is consideration of future actions; there should be a consistent approach to "reasonably foreseeable" actions, and trans-boundary impacts need to be addressed.
- Monitoring is an important part of the iterative nature of cumulative impact analysis, to assess the accuracy of predictions of effects and to evaluate the success of mitigation.
- To develop a new cumulative impacts assessment methodology will require evaluating best practices across all agencies, domestic and international, and taking advantage of new analytical approaches emerging in fields outside of environmental sciences.
- Efforts to develop such a methodology should consider how best to incorporate more than single projects. The methodology and resultant analysis should include a plan for the number and types of projects in the region and be able to account for positive and negative trade-offs.
- Development and implementation of cumulative impact analysis must include the various stakeholders in the Arctic.
- A thorough synthesis of the existing Arctic literature is needed to develop a body of knowledge about cumulative impacts from which to develop the cumulative impact assessment.
- Cumulative impact assessment could benefit from applications of sophisticated geospatial techniques and regular synthesis of environmental data information.

Specific recommendations made in Chapter 7 that are problematic include the following:

- Consider using cost/benefit analysis to sort out the potential adverse/beneficial socioeconomic effects. This would be very difficult to do, and agreement among stakeholders on methodology would be difficult to attain.
- Cumulative impact assessment could benefit from applications of ecological forecasts and multidimensional evaluations of human developments. This concept needs more thought and specific suggestions in order to be helpful.
- Marine spatial planning is currently a controversial topic in Alaska. Issues associated with intent, jurisdiction, implementation, and stakeholder participation will need to be sorted out before there is broad acceptance of the concept.

While recommending an integrated DOI cumulative impact assessment, Chapter 7 was not able to address challenges associated with different agencies conducting individual cumulative impact assessments, including:

- Uneven treatment of Valued Ecosystem Components (VECs)/elements of the Arctic environment.
- No commonality on past, present, and reasonably foreseeable future activities.
- Different direct/indirect effects evaluated for cumulative impacts, and differences in addressing most probable vs. worst-case impacts.
- Determining significance thresholds for cumulative impacts is often difficult and problematic.
- Uneven use of modeling and predictive impact systems.
- Differences in reaching conclusions on significance of cumulative effects vs. the contribution of the proposed action and alternatives to cumulative effects.
- Different temporal and spatial frames of analysis.
- Different approaches in addressing uncertainty and missing information.
- Assessment of cumulative impacts at different stages in project development (lease sales vs. specific project development).
- Differences in the extent that cumulative impact assessment modifies alternatives and drives mitigation.
- Different philosophies on implementing mitigation:
    - Permit requirements.
    - Preventative measures—conflict avoidance agreements.
    - Compensatory mitigation—local requirements for impact mitigation funds; oil spill mitigation bonds.
- Different agency mandates, interests, budgets, and research needs.

Detailed Additional Recommendations for Cumulative Effects Analysis

Additional recommendations for CEA are presented on two major areas of discussion: the NEPA cumulative impact assessment process, and research needs associated with cumulative impact assessment.

Through a recent executive order, the president has established an Interagency Working Group on Coordination of Domestic Energy Development and Permitting in Alaska, which presents a tremendous opportunity to address improvements to assessing and recommending research on cumulative impacts. With regard to cumulative impacts, a recommendation would be for this working group to set up a subcommittee to address cumulative impacts, supported by scientific and stakeholder advisory groups. This is a similar model used by NMFS for its Arctic Open Water Meetings and Beluga Whale Recovery Plan. The advisory groups should include representatives of: federal, state, and local government; the oil and gas industry; Alaska Native organizations; NGOs; and scientific research organizations such as universities and independent research institutes. The working group should address procedural improvements to assessment of cumulative impacts under NEPA and research priorities that assist with NEPA compliance and other decision making.

Recommendations for consideration by the working group and participants in a cumulative impact assessment subcommittee include the following:

Working Group Procedural Guideline Recommendations:

- Recognize pressures of available funding, presidential/congressional interest in sound Arctic resource development.
- Agree on priorities for immediate action in cumulative impact assessment and research.
- Be constructive, flexible and solution-oriented.
- Agree on general principles that need to be included in all CEA.
- Explore avenues for a common regional cumulative impact baseline assessment, focusing an analysis of past, present, and reasonably foreseeable future activities, particularly climate change. Such a study could then be used for tiering individual agency NEPA compliance efforts from a common point of reference.

Specific Working Group NEPA Cumulative Impact Assessment Recommendations:

- Focus on the resource/elements/VECs of greatest concern for susceptibility to cumulative impacts; these can be short-term areas of emphasis for impact assessment and research.
- Develop a common understanding of key past and present contributors to cumulative impacts and trends, cause and effect.
- Develop a common understanding of RFFAs and how to update them.
- Reinforce Council on Environmental Quality guidance on speculative RFFAs.
- Evaluate causality and common assumptions.
- Reach consensus on key resources/elements/VECs for the focus of cumulative impact assessment.
- Focus on the mechanisms/events likely to cause cumulative impacts (noise, persistent contaminants, climate change).
- Focus on the sources of those mechanisms/events (air and vessel traffic, spills).
- Climate change is a big driver of past, present and future cumulative impacts; a common approach and analysis are needed that can be used by all agencies, perhaps driven by NOAA.
- Investigate use of modeling and predictive impact systems.
- Focus on thresholds and yardsticks of determining cumulative effects' significance (for example, potential biological removal).
- Develop a common vision of priorities for baseline studies.
- What geographic areas (sensitive and control areas).

- Institute a “look back” review on impact projections—what happened, what didn’t.
- Focus on mitigation and regional solutions:
  - What are best management practices that should be commonly used to reduce cumulative impacts? What worked, what didn’t?
  - Focus on what potential mitigation is within the purview and jurisdiction of individual agencies and where it can be implemented.
- Focus on the requirements and responsibilities for meaningful monitoring programs.
- Implement a comprehensive, documented approach to adaptive management:
  - Stakeholder involvement.
  - Prescribed milestones for monitoring reassessment permit stipulations.
  - Revisiting required mitigation.
- Evaluate how a regional approach can be used to develop efficient common infrastructure and avoid the spread of potential duplicative facilities—for example, public-private partnerships.

Specific Working Group Research Recommendations:

- Identify who is conducting/managing/coordinating research programs on the Arctic:
  - NSF.
  - Federal/state/local agencies.
  - Industry.
  - NGOs.
  - Universities.
  - North Slope Science Initiative.
- Inventory the research/programs that should be synthesized and integrated.
- Identify research priorities:
  - VECs.
  - Geographic areas sensitive to cumulative impacts and control areas for baseline research.
  - Long-term monitoring for fish and wildlife population levels and trends.
  - Long-term monitoring for subsistence harvest levels and trends.
- Best management practices—what is working to incrementally reduce cumulative effects?
- Focus research on the mechanisms/events likely to cause cumulative impacts (noise, persistent contaminants, climate change) and standardized metrics for quantifying interactions among mechanisms/events.
- Assess use of modeling and predictive impact systems.
- Provide a consistent funding stream and monitoring research.
- Focus on involvement of Alaska Natives and incorporation of TEK.
- Require mandatory annual presentations on research results and progress, and information sharing

Appendix 2: Acronyms

ABA	Arctic Biodiversity Assessment
AMSS	Alaska Marine Science Symposium
AOGCM	Atmosphere-Ocean Global Climate Models
AOOS	Alaska Ocean Observing System
ArcOD	Arctic Ocean Diversity
ARMS	Arctic Register of Marine Species
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BSIERP	Bering Sea Integrated Ecosystem Research Program
CBMP	Circumpolar Biodiversity Monitoring Program
CEA	Cumulative Effects Analysis
COMIDA	Chukchi Offshore Monitoring in Drilling Area
CSEAP	Chukchi Sea Environmental Assessment Program
DBO	Distributed Biological Observatory
DOI	U.S. Department of the Interior
EBSA	Ecologically and Biologically Significant Areas
ESA	Endangered Species Act
EVOSTC	Exxon Valdez Oil Spill Trustee Council
IBA	Important Bird Area
ICESCAPE	Impacts of Climate change on the Eco-Systems and Chemistry of the Arctic Pacific Environment
ISHTAR	Inner Shelf Transfer and Recycling (Program)
IUCN	International Union for Conservation of Nature
MMS	Minerals Management Service
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPRB	North Pacific Research Board
NRDC	Natural Resources Defense Council
NSF	National Science Foundation
OCS	Outer Continental Shelf
OCSEAP	Outer Continental Shelf Environmental Assessment Program
PAG	Pacific Arctic Group
PICES	North Pacific Marine Science Organization
PROBES	Processes and Resources of the Bering Sea Shelf
SDM	Structured Decision Making
TEK	Traditional Ecological Knowledge
UAF	University of Alaska Fairbanks
USGS	U.S. Geological Survey
VEC	Valued Ecosystem Components

Appendix 3: Useful Links

a. Arctic Ocean Diversity (ArcOD). www.arcodiv.org. This contains data sets, some sections being a bit dated but all are served through Ocean Biogeographic Information System (OBIS). www.iobis.org.

b. Arctic Register of Marine Species (ARMS). www.marinespecies.org/arms.

c. Arctic Biodiversity Assessment (ABA). http://www.caff.is/aba

d. Circumpolar Biodiversity Monitoring Program (CBMP). http://cbmp.arcticportal.org. Includes background and implementation plan.

e. Pacific Arctic Group (PAG). http://pag.arcticportal.org.

f. University of Maryland Arctic Studies Group. http://arctic.cbl.umces.edu.

VI. Endnotes

[1] Minerals Management Service, Alaska OCS Region. 2007. Chukchi Sea Planning Area, Oil and Gas Lease Sale 193 and Seismic Surveying Activities in the Chukchi Sea. Final Environmental Impact Statement. OCS EIS/EA MMS 2007-026. Vol. I. www.alaska.boemre.gov/ref/EIS%20EA/Chukchi_FEIS_193/LS%20193%20FEIS%20Vol%20I.pdf.

[2] U.S. Department of the Interior and the U.S. Geological Survey. 2011. An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas, Alaska. Circular 1370. http://pubs.usgs.gov/circ/1370/pdf/circ1370.pdf.

[3] Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska. Arctic Environmental Information and Data Center, University of Alaska Anchorage. http://gcmd.nasa.gov/KeywordSearch/Metadata.do?Portal=GCMD&KeywordPath=&NumericId=26208&MetadataView=Full&MetadataType=0&lbnode=mdlb3.

[4] Hopcroft, R., *et al.* 2008. Arctic Ocean Synthesis: Analysis of climate change impacts in the Chukchi and Beaufort Sea with strategies for future research. www.arcdiv.org/news/NPRB_report2_final.pdf.

[5] Simpkins, M., *et al.* 2007. A Framework for Monitoring Arctic Marine Mammals: Findings of a Workshop Sponsored by the U.S. Marine Mammal Commission and U.S. Fish and Wildlife Service, Valencia. CAFF International Secretariat, CAFF CBMP Report No. 16. www.mmc.gov/reports/workshop/pdf/valencia_report.pdf.

[6] Indigenous People's Council for Marine Mammals. www.ipcommalaska.org.

[7] Exchange for Local Observations and Knowledge of the Arctic. www.eloka-arctic.org.

[8] Available at http://arctic.cbl.umces.edu under the DBO link.

[9] *Polar Biology,* in press.

[10] Speer, L., and T.L. Laughlin. 2010. IUCN/NRDC Workshop to Identify Areas of Ecological and Biological Significance or Vulnerability in the Arctic Marine Environment. Workshop Report. http://data.iucn.org/dbtw-wpd/edocs/Rep-2011-001.pdf

[11] For example, Grebmeier, J.M., *et al.* 2006. "Ecosystem Dynamics of the Pacific-Influenced Northern Bering and Chukchi Seas." *Progress in Oceanography* 71:331-361. www.sciencedirect.com/science/article/pii/S0079661106001303. And Grebmeier, J.M., *et al.* 2010. "Biological Response to Recent Pacific Arctic Sea Ice Retreats" *Eos* 91(18):161-162. http://wordpress.clarku.edu/kfrey/files/2011/01/Grebmeier_Eos2010.pdf.

[12] Publication products of the NSF Shelf-Basin Interactions program. http://arctic.cbl.umces.edu/sbi/web-content/index.html.