SYNTHESIS OF ARCTIC RESEARCH (SOAR)

SCIENCE WORKSHOP REPORT

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Synthesis of Arctic Research (SOAR)
Science Workshop Report

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EXECUTIVE SUMMARY

The SOAR Science Workshop was held from 14-16 March 2012 at the Egan Center in Anchorage, Alaska. The SOAR Principal Investigators and Project Coordinator, all members of the Science Steering Committee, and 42 of the 43 invited SOAR Contributors attended the workshop (Appendix 1). Draft Science Themes and Questions developed by the SOAR Science Steering Committee (November 2011) were provided to participants in advance of the workshop, summarized as:

1. Ecosystem Response to Bottom-up and/or Top-down Forcing: *9 sample questions*
2. Marine Birds, Mammals, and Fish as Ecosystem Sentinels: *5 sample questions*
3. Acoustic Ecology: *5 sample questions*

The primary goals of the Science Workshop were to: (1) refine the Draft Science Themes and Questions, (2) form research teams to undertake analysis in support of development of peer-reviewed papers, and (3) develop short proposals to identify project milestones and financial support required to complete synthetic projects.

Day one of the workshop consisted of disciplinary talks in plenary session to provide all participants with the current state of knowledge in each area of study (Appendix 2). During day two of the workshop, science themes were revised to reflect group input. Participants divided into three theme-based breakout groups and began developing science questions to propose for SOAR. Day three of the workshop began with a plenary summary of the previous day's progress followed by breakout groups to write and submit one-page proposals for the projects requesting funding (see below). On the afternoon of the third day, an open-session was held to communicate workshop progress to BOEM scientists and managers, colleagues from the North Pacific Research Board and Alaska Ocean Observing System, industry representatives, and other interested parties .

List of 20 projects proposed at the workshop

On the last day of the SOAR Science Workshop, participants worked together to develop 1-page proposals describing 20 projects, which could lead to peer-reviewed papers during Phase 1 (2011-2013) of the SOAR project. The 20 projects, organized under three science themes, are as follows, with the project lead name [in brackets]:

Theme 1: HOTSPOT MECHANISMS AND TROPHIC DYNAMICS

1. Mechanisms for enhanced trophic productivity in Barrow Canyon, Chukchi Sea [Pickart]
2. Seasonal and spatial patterns in marine bird and mammal densities, distribution, and community structure in the Pacific Arctic [Kuletz]
3. Seasonal and spatial patterns of Alaska Native subsistence hunting for marine mammals in the northern Bering, Chukchi, and western Beaufort seas [Hepa/Metcalf]

4. Fish of the Beaufort and Chukchi seas: Community structure, human use, and mechanisms determining similarities and differences (aka A Tale of Two Shelves) [Napp]
5. Effects of prey dispersion, sea ice, and walrus foraging on viability of a critical migration corridor for avian benthivores [Lovvorn]
6. Factors maintaining bird and mammal benthic hotspots: A latitudinal analysis [Grebmeier]

Theme 2: YEAR IN THE LIFE OF SELECTED SEABIRDS AND MARINE MAMMALS

7. Why are the bowhead whale hotspots located where they are? [Quakenbush]
8. Influence of sea ice, oceanographic conditions, and prey availability on the timing of fall bowhead whale migration from the Canadian Arctic along the Beaufort Shelf to Barrow, and the subsequent whaling success in Beaufort coastal communities [Ashjian]
9. Variation in the migration path of bowhead whales across the Chukchi Sea during the fall migration [Citta]
10. What sound environments to bowhead whales encounter in the Chukchi and Beaufort seas? [Clark]
11. What is the acoustic environment for walrus as they move through the Chukchi Sea and how might walrus behavior, such as herding or mother-calf communication be impacted by sound? [Jay]
12. Relationship between beluga whales, Arctic cod, and oceanographic conditions in Barrow Canyon and at the shelf break of the western Beaufort Sea [Suydam]

Theme 3: RESPONSES TO STEP-CHANGE IN PHYSICAL DRIVERS OF THE MARINE ECOSYSTEM

13. Variability in annual persistence, breakup, and formation of sea ice cover in the Pacific Arctic Region [Frey]
14. Primary production in the Pacific sector of the Arctic Ocean [Arrigo]
15. Causes of drastic climate change for the Pacific Arctic [Overland]
16. Is Arctic sea ice retreat affecting the body condition of bowhead whales? [George]
17. Walrus shift to central-place foragers in the Chukchi Sea [Jay]
18. Consequences of loss of cryopelagic prey to marine birds and mammals [Divoky]
19. An ocean acidification sensitivity index for the Pacific Arctic Region [Mathis]
20. Scale matters: Higher trophic species integrate and reflect ecosystem change across a range of temporal and spatial scales [Harwood]

INTRODUCTION

The Synthesis of Arctic Research (SOAR) aims to bring together a multidisciplinary group of Arctic scientists and Alaskan coastal community representatives to explore and integrate information from completed and ongoing marine research in the Pacific Arctic Region. The goal of this project is to increase scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic prey species (forage fish and zooplankton), and marine mammal distribution and behavior in the Pacific Arctic, with particular emphasis on the Chukchi Sea Lease Sale Areas.

The SOAR project is supported by the Bureau of Ocean Energy Management (BOEM) via an Inter-Agency Agreement (IAA) with the National Oceanic and Atmospheric Administration (NOAA). The IAA to support the SOAR project was accepted by all parties in May 2011, with the 5-year period of performance agreed as 13 May 2011 to 12 May 2016. The SOAR Science Workshop was the key deliverable identified for the first quarter of calendar year 2012 and this report describes the activities undertaken from 14-16 March 2012 at the Egan Center in Anchorage, Alaska. Additional details about the Workshop and copies of plenary presentations (in pdf format) are available at the SOAR website: http://www.arctic.noaa.gov/soar/ and are referenced throughout this workshop report.

BOEM Development of the SOAR Project

Background on the development of the SOAR project was provided by the BOEM COR, Heather Crowley (pdf: Crowley_Background). In preparation for possible oil and gas exploration in the Chukchi Sea, BOEM (formerly the Minerals Management Service) convened the Chukchi Offshore Monitoring in the Drilling Area (COMIDA) planning workshop November 1-3, 2006, in Anchorage. More than 100 scientists and stakeholders participated in the workshop to identify potential monitoring tasks for a COMIDA field effort to meet Agency needs. Identified topics included:

- Chemical and hydrocarbon monitoring
- Physical oceanography
- Potential impacts on benthic organisms, fish and birds
- Characterization of the ecosystem
- Distribution and abundance of marine mammals: Tagging, aerial surveys, acoustic assessments
- Impact assessment for subsistence hunting

More than $20,000,000 in MMS/BOEM funded research evolved directly from the COMIDA Workshop and it was recognized at that time that some effort to synthesize the information would be needed.

The idea for what became the SOAR project was first developed by BOEM scientists in 2009 (for the FY 2011 Studies Plan), in recognition of the fact that MMS/BOEM will have invested more than $50,000,000 in marine mammal and related physical, chemical and biological oceanography studies in the western Arctic between 2005 and 2015. Recently completed and ongoing studies include:

- Bowhead Whale Feeding Variability in the Western Alaskan Beaufort Sea: Satellite Tracking of Bowhead Whales and Oceanography and Feeding (BOWFEST)
- Ecosystem Observations in the Chukchi Sea: Passive Acoustic Detection and Monitoring of Endangered Whales in the Arctic and Biophysical Mooring and Climate Modeling (CHAOZ)
- Distribution and Relative Abundance of Marine Mammals in the Chukchi Sea and the Fall Migration of Bowhead Whales in the Beaufort Sea (BWASP and COMIDA aerial surveys)
- Walrus Habitat Use in the Potential Drilling Area
- Pinniped Movements and Foraging: Bearded Seals
- COMIDA CAB
- Hanna Shoal Ecosystem Study
- Arctic marine research studies supported through NOPP and many others

Information and data from all these studies, in addition to Arctic research supported by the NSF, NOPP and other entities, are sought in support of the SOAR project.

Goals of the SOAR Science Workshop

The primary goals of the SOAR Science Workshop were to: (1) refine the Science Themes and Questions drafted by the SOAR SSC in November 2011; (2) form research teams to undertake analysis in support of development of peer-reviewed papers; and (3) develop short proposals to identify project milestones and financial support required to complete synthetic projects (pdf: Moore_Introduction). A broad outline of activities was provided for each day of the workshop, with an emphasis that input on the direction and products of the SOAR project come from the workshop participants, including their role as representatives of their discipline. The Draft Science Themes and Science Questions developed by the SOAR SSC were provided in advance of the workshop (Appendix 3; on the web, at public meetings and in the materials sent to participants), and in brief were summarized as:

- Ecosystem Response to Bottom-up and/or Top-down Forcing: *9 sample questions*
- Marine Birds, Mammals, and Fish as Ecosystem Sentinels: *5 sample questions*
- Acoustic Ecology: *5 sample questions*

A simplified timeline for activities anticipated for the FY12-13 time frame included three steps: (1) the Science Workshop – where synthetic science themes would be agreed upon and analytical teams (AT) formed; (2) an Integration and Analysis step, including funding of proposals and tracking of progress in quarterly updates; and (3) the provision of Science Products as peer-reviewed papers, science presentations, and education and outreach materials (Fig. 1). Finally, it was emphasized that the SOAR project provide an opportunity to ***think*** about what can be learned about the Pacific Arctic marine ecosystem by ***synthesis*** of information across disciplines.

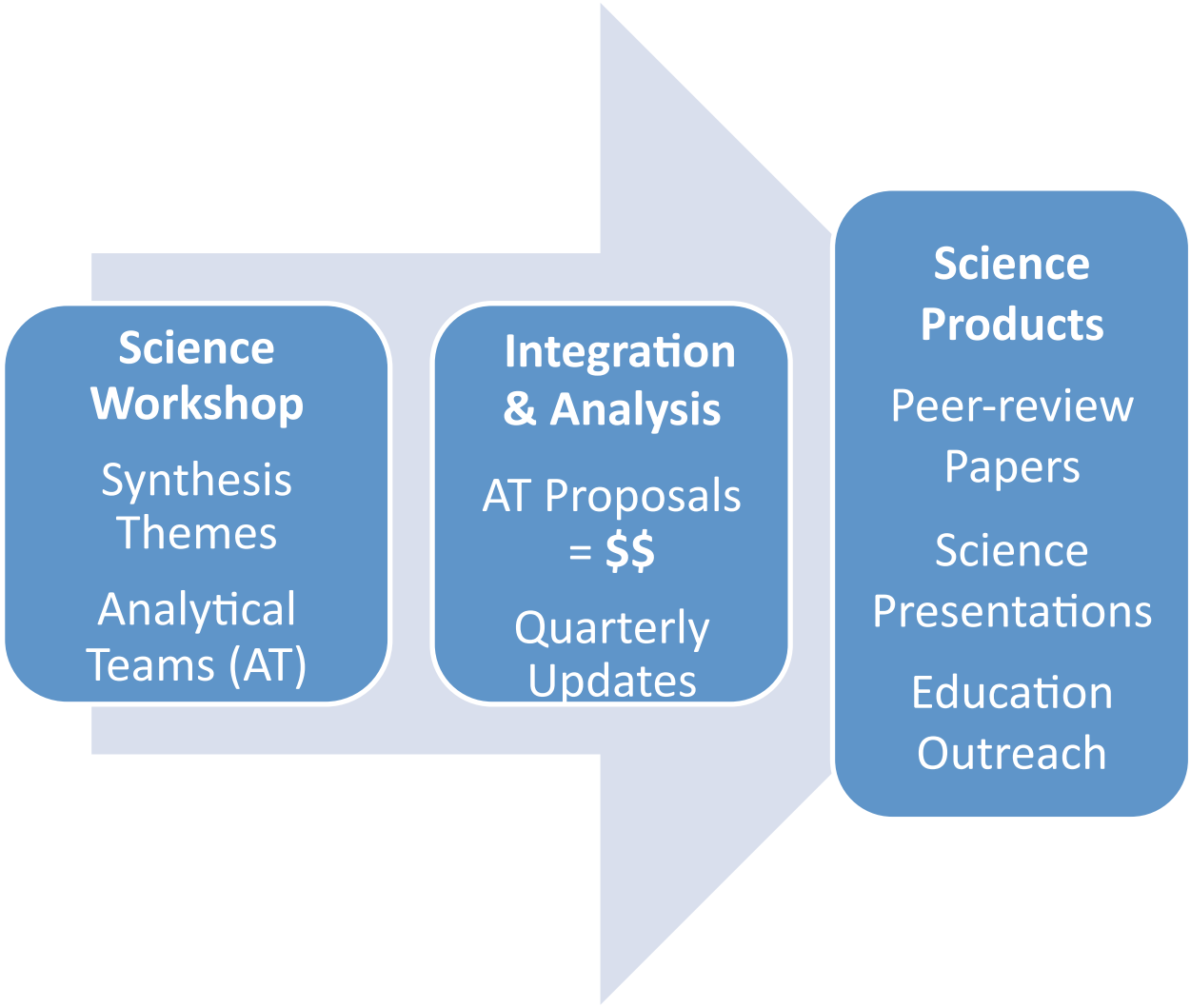

Figure 1. Simplified timeline of anticipated steps in the SOAR project for FY12-13.

PLENARY SESSION (Day 1): Disciplinary Overviews

Overarching science presentations were provided for six disciplines. Speakers were asked to address six points in their Disciplinary Overviews, including: (1) discipline history & state of knowledge; (2) key observations, datasets & time frame; (3) examples of change; (4) identify stressors; (5) capability to forecast and (6) example questions to initiate discussion at the SOAR workshop.

1. **Atmospherics & sea ice** (pdf: Overland)
   - The last 5 years (2007-2011) are a new regime
   - The Arctic is changing more rapidly than the Bering Sea
   - It would be difficult to return to the conditions we had a decade ago because of sea ice loss
2. **Physical & chemical oceanography** (pdf: Weingartner)
   - Bering Sea and Strait are key to many of the features of the Chukchi and Beaufort shelves – these ecosystems (Bering, Chukchi, Beaufort) are a continuum
   - Bathymetry is crucial to circulation, ice, and property distributions of Chukchi Sea; mesoscale variability also may be more important than previously thought
   - Beaufort Sea is influenced by the Pacific via the Chukchi, but this is sensitive to winds and ice; Arctic rivers and Mackenzie shelf are seasonally important
3. **Primary production/nutrients** (pdf: Frey)
   - General increases in Arctic primary production are predicted, but trends are varied
   - The central Arctic Ocean may see smaller increases in production than other Arctic shelf seas due to low nutrient concentrations
   - Areas newly outside the seasonal ice zone may see decreases in production due to increased stratification with overall warming
   - Inner coastal shelves may see little increase in production due to enhanced delivery of light-inhibiting river-derived material
4. **Lower Trophic Level** (LTL = zooplankton/benthos) (pdf: Grebmeier_and_Ashjian)
   - Zooplankton are advected from the Bering Sea into the Chukchi Sea
   - The Chukchi Sea is benthically dominated because zooplankton biomass cannot consume all of the primary production
   - Information on zooplankton skewed towards spring-early fall when region is accessible by ship
   - Benthic biomass is greatest at high latitudes
   - Strong benthic trophic links to terrestrial carbon sources in Arctic coastal and estuarine systems
   - Benthic infauna that produce calcium and aragonite are vulnerable to ocean acidification
   - Benthic primary production reflects overlying water transparency

5. **Upper Trophic Level** (UTL = marine fish, birds, mammals, and subsistence)
   5A: Western science (pdf: Suydam_and_Angliss)
   - Arctic upper trophic level species are responding to loss of sea ice in a wide variety of ways
   - Good data from marine mammal acoustics and sampling of harvested animals
   - Large changes in distribution of seabirds in PAR – system now dominated by planktivores rather than piscivores

   5B: Local knowledge (pdf: Metcalf; pdf: Hepa)
   - Changes in migratory patterns, seal haul out areas, accumulation of garbage/marine debris, diseased animals (seal UME)
   - Local hunters now travel 60-80 miles by boat to find ice suitable for hunting
   - Increased shipping traffic
   - Listen to locals, set hypotheses based on their observations and ideas; review research with community before publishing
6. **Acoustics** (pdf: Clark)
   - Large amounts of acoustic data have been collected and processing and management of those data has become challenging
   - It is important to know the natural variation in acoustic habitat
   - Sounds from human activities such as shipping can mask animal communication

BREAK-OUT SESSIONS (Day 2): Revised Science Themes and Questions

Three new Science Themes emerged on DAY 2 of the Workshop, based upon discussions that followed the disciplinary presentations. The three themes, example supporting questions, and identity of SSC members that participated in breakout groups are given in Table 1.

Table 1. Revised Science Themes and questions

Theme 1: Hotspot Mechanisms & Trophic Dynamics SSC Members = Stabeno, Grebmeier, Ragen, Metcalf	
	What mechanisms drive and maintain marine mammal, bird, and benthic hotspot areas across latitudes? How have these mechanisms changed during the last five years?
	Why are some hotspots benthic, but not pelagic, and vice versa?
	How can chemical tracers help us understand hotspot dynamics?
	What offshore 'hotspot' prey fields are known? – Copepods, euphausiids, amphipods, mollusks, fishes
	What are the trophic dynamics ('lead' Top Predators) – sea duck, seabird and marine mammals use of hotspots – issues of temporal and spatial scale (fine scale sampling in Lease Areas vs. larger-scale sampling in Chukchi; temporal match & mismatch issues
	Coastal villages as hotspots = long term observations of changes in physical conditions
Theme 2: Year in the Life of Selected Seabirds and Marine Mammals SSC Members = Angliss, Ashjian, Clark, Suydam, Jay	
	Where do species go over the course of one year (observations, visual surveys, tracking and acoustics)?
	Why are the bowhead whale 'hot spots' located where they are?
	How does the oceanography and prey availability in the eastern Beaufort impact the timing of the bowhead whale migration and bowhead arrival in Barrow, Cross Island, and Kaktovik?
	What sound environments do bowheads encounter in the Chukchi and Beaufort Seas?
	Synthesis of marine mammal and seabird distributions based on: a) tags, b) aerial surveys, c) acoustic recorders, d) ship-based surveys, and e) traditional knowledge and are there common patterns?
	How have gray whale feeding areas in the NE Chukchi and western Beaufort changed over the last 30 years?
	What is the acoustic environment for walrus as they move through the Chukchi? How might walrus behavior, such as herding, or mother-calf communication be impacted by sound?
	Why do walrus use Hanna Shoal but not Herald Shoal?
	Why do belugas like the slope vs. the shelf?
	Why do benthic feeders (walrus, eiders) congregate at Point Lay?
	Where & what do they eat?
	What acoustic fields are they exposed to at daily resolution?

Theme 3: Responses to Step-change in Physical Drivers of the Marine Ecosystem SSC Members = Weingartner, George, Hepa, Moore	
	Comparison of 2007-11 to 2002-06 (& earlier periods) - Importance of spatial and temporal scale to responses at lower-trophic and higher-trophic levels.
	Whale and seal body conditions vs. ice variability (combine/continue existing work)?
	How have changes in sea ice cover & ocean conditions (storms) impacted ambient acoustic conditions?
	What are the anthropogenic noise sources/seasons – and the combined acoustic field over the course of a year?

SHORT SUMMARY OF BREAK-OUT GROUP DISCUSSIONS

Participants self-selected their primary Theme of interest and joined breakout groups for more intensive discussion, a short summary of which is provided here.

Theme 1: Hotspots & Trophic Dynamics

Participants: Lovvorn, Stabeno, Grebmeier, Bluhm, Kuletz, Metcalf, Noongwook, Koonooka, Logerwell, Parker-Stetter, Ferguson, Napp, Ragen, Pickart, Okkonen, Farley, Guy

Several members of Theme 1 team shared slides of relevant data on hotspots in the Pacific Arctic. General topics such as identification of known hotspots, a comparison of pelagic vs. benthic hotspots, and hotspots centered at village sites, were discussed. Some of the resources and data considered to address questions about hotspots were: 1) observations from Native villages and timing of the hunt; 2) passive acoustic data; 3) oceanographic moorings; 4) seabird and marine mammal survey data; and 5) satellite data. The mechanisms that create and maintain pelagic vs. benthic hotspots differ, so the group decided to further split to focus on the unique properties of each. The pelagic and benthic groups then independently narrowed down research questions that could be answered using available data within 18 months, and within the scope of the SOAR funding level. Although many pertinent topics related to hotspot dynamics were considered, the group settled on six accomplishable synthesis goals.

Theme 2: Year in the Life of Selected Seabirds and Marine Mammals

Participants: Ashjian, Norcross, Okkonen, Jay, Quakenbush, Clark, Blackwell, Berchok, Suydam, Citta, Koonooka, Angliss, and Boveng (Divoky participated initially but then relocated)

Group 2 participants initiated the discussion by asking Steve Okkonen to provide background to help focus the group discussion. Steve described his initial idea of focusing on the life history and spatial distributions of the different marine mammals and birds. For example, one could look at migration hotspots in sequence and determine the factors that make these locations hotspots. A lively discussion was had about bowheads after it was noted that bowhead whale migration past St. Lawrence Island has changed in recent years. We recognized that it was important to remember that numerical models can be useful. Some discussion of mapping

available data was initiated at this point in the discussion. These maps would be very useful to decision making so it would be desirable to derive single rather than multiple species maps.

Early on in the discussion it was decided that the group would not focus on marine birds since only a portion of their life history was spent in the Arctic.

The group associated each of the marine mammals with their primary feeding target – benthic, plankton, or fish. Although one species was identified that was thought to be most important for each group (walrus-benthic, bearded seals-fish, bowheads-plankton), the group did decide to review all of the species listed prior to eliminating those other species as primary target. Discussions focused on important questions, the type and amount of available data, identification of synthesis questions, and whether the data were sufficient to conduct these syntheses.

Walrus: The group discussed the new haul-out location near Point Lay relative to their preferred feeding location on Hanna Shoal and what the long distance between the two locations might mean to feeding success. The group also discussed the potential impact of the large numbers of walrus inhabiting a critical habitat for eiders and the interactions between the two species. The group also thought that identifying the differences between Hanna Shoal (used by walrus) and Herald Shoal (not used by walrus) would be useful. Another discussion focused on how long Hanna Shoal might be a good feeding area. Later in the session the group revisited walrus and thought that an effort focusing on the acoustic environment for walrus in the Chukchi would be worthwhile. Chad Jay is already looking at the energetic consequences of hauling out on ice vs. at Point Lay.

Bearded Seals: The discussion of bearded seals was rather short. Limited data are available on bearded seals from aerial surveys, acoustic detections, and stomach data. The group decided that there may not be sufficient information on bearded seals to conduct a productive synthesis.

Gray Whales: There exist a number of data sets useful to gray whale syntheses including benthic data, acoustic data, physical oceanographic data, and aerial survey data. Most questions focused on why gray whale feeding areas have changed and why gray whales are so often found near shore. A potential synthesis effort focusing on 30 years of benthic, aerial, and oceanographic data and local knowledge was identified.

Beluga Whales: The primary driving question from the beluga whale discussion focused on why beluga whales like the slope, with the assumption that it is because their fish prey are found there. There is a good amount of available data from acoustics, aerial surveys, satellite tagging, visual surveys, stomach contents, and fish data from both Barrow Canyon and the eastern Beaufort.

Ringed Seals: It was noted that there was some tagging and three years of acoustic data collected from near Barrow. The ringed seal discussion was quite short as the group quickly decided that there wasn't sufficient data to permit a synthesis with ringed seals.

Bowhead Whales: The group immediately identified four potential syntheses/papers focusing on bowheads. There was some discussion regarding the availability of data on when seismic ships were operating and when air guns were operating, on using modeling to identify krill trajectories, on spring feeding by bowheads that particularly seems to be benthically targeted (muddy bowheads), and the scarcity of actual data from the Chukotka Coast.

Polar Bears: The polar bear discussion was quite short and focused mainly on polar bears returning to St. Lawrence Island this year.

Eiders: The group identified tagging data on eiders and questioned why the region near Point Lay is so important for the birds. The group also discussed the potential of developing a map of habitat utilization for all of the species by deriving kernel densities such as was done for the bowhead tagging effort of Quakenbush and Citta. However, deriving kernel densities would take much longer than the time available in these projects and also such analysis could be difficult for some species and might be misleading. It was noted also that Oceana, an international ocean conservation organization, has taken abundance and traditional knowledge data to map concentration areas by species, although there was some skepticism regarding this effort. The Barbara Block paper focusing on top predators in the Pacific was brought up as an example of a useful and interesting analysis that might be helpful for the Western Arctic. It was also suggested that simply developing maps of all of the acoustic data, all of the aerial survey data, etc. on one map each, rather than developing kernels, would be insightful. An overview paper on data availability and the distributions of marine mammals and birds was identified.

Theme 3: Responses to Step-change in Physical Drivers of the Marine Ecosystem

Participants: Blackwell, Arrigo, Weingartner, Burns, Farley, Cooper, Maslowski, Mathis, Hannay, Jones, Woodgate, Harwood, Moore, Frey, Dunton, George, Overland, Drukenmiller, Rexford, Divoky, Hopcroft

The Theme 3 group focused on recent changes seen in the Pacific Arctic, especially in the last five years. Types of changes discussed were dramatic seasonal loss of sea ice, body condition of marine mammals and Arctic char, changes in water components and freshwater content. There has been a 33% reduction in sea ice thickness during the 2000s. There has been an increase in primary production due to the longer open-water season. The role of heat in the Chukchi Sea and how it is advected and lost (to the atmosphere or melting of ice) is an important topic, especially with regard to an increase in storms north of Bering Strait and the impact this has on coastal communities without sea ice to buffer the storm surge. There has been a change in the prey of piscivorous Black Guillemots from Arctic cod to sculpin and other prey items since 2006 as the ice edge has moved out of foraging range of these birds during the nesting season. Walruses have been hauling out by the 1000s along the NW Alaskan coast since 2007, essentially arriving after the last remnants of sea ice melt in the NE Chukchi Sea.

PLENARY SESSION (Day 3): List of Draft Projects and Project Leads

Development of 1-page project summaries

Workshop participants spent the morning of Day 3 developing 1-page proposals for projects suggested as the core of Phase I of the SOAR synthesis. Proposals were not submitted for those synthesis projects that did not request funding. The projects were:

HOTSPOT MECHANISMS AND TROPHIC DYNAMICS

1. Mechanisms for enhanced trophic productivity in Barrow Canyon, Chukchi Sea [Pickart]
2. Seasonal and spatial patterns in marine bird and mammal densities, distribution, and community structure in the Pacific Arctic [Kuletz]
3. Seasonal and spatial patterns of Alaska Native subsistence hunting for marine mammals in the northern Bering, Chukchi, and western Beaufort seas [Hepa/Metcalf]
4. Fish of the Beaufort and Chukchi seas: Community structure, human use, and mechanisms determining similarities and differences (aka A Tale of Two Shelves) [Napp]
5. Effects of prey dispersion, sea ice, and walrus foraging on viability of a critical migration corridor for avian benthivores [Lovvorn]
6. Factors maintaining bird and mammal benthic hotspots: A latitudinal analysis [Grebmeier]

YEAR IN THE LIFE OF SELECTED SEABIRDS AND MARINE MAMMALS

7. Why are the bowhead whale hotspots located where they are? [Quakenbush]
8. Influence of sea ice, oceanographic conditions, and prey availability on the timing of fall bowhead whale migration from the Canadian Arctic along the Beaufort Shelf to Barrow and the subsequent whaling success in Beaufort coastal communities [Ashjian]
9. Variation in the migration path of bowhead whales across the Chukchi Sea during the fall migration [Citta]
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12. Relationship between beluga whales, Arctic cod, and oceanographic conditions in Barrow Canyon and at the shelf break of the western Beaufort Sea [Suydam]

RESPONSES TO STEP-CHANGE IN PHYSICAL DRIVERS OF THE MARINE ECOSYSTEM

13. Variability in annual persistence, breakup, and formation of sea ice cover in the Pacific Arctic Region [Frey]
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15. Causes of drastic climate change for the Pacific Arctic [Overland]
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20. Scale matters: Higher trophic species integrate and reflect ecosystem change across a range of temporal and spatial scales [Harwood]

Open Session

An Open Session was convened after lunch to provide a snapshot of Workshop activities to interested parties from the Anchorage area. Eleven people representing 7 agencies and organizations attended (Appendix 5). Moore provided an abbreviated overview, drawing on the presentation given on the first day of the workshop (pdf: Moore_Introduction), followed by information on the revised Science Themes and Questions that the participants were working into short proposals and a timeline for next steps in the SOAR process. Participants were then encouraged to ask questions and discuss the progress and revised goals of the project. Formal discussion ensued for roughly half an hour, followed by nearly one hour of informal interaction among workshop participants and those that joined the meeting during the open session.

WORKSHOP PRODUCTS AND NEXT STEPS

Products from the SOAR Science Workshop included: (1) six disciplinary overview presentations, (2) revised SOAR Science Themes and Questions, (3) sixteen 1-page proposal summaries, and (4) this workshop report.

Of the 20 proposals, 16 requested funding from SOAR. These 16 proposal summaries were subsequently combined into a pdf packet for review by the SOAR SSC, which convened by teleconference on 6 April 2012. Prior to the teleconference, the SOAR SSC categorized the proposals as ‘green’ if they could be combined (n=2), ‘yellow’ if they needed substantial revision (n=3), and ‘red’ if they had been dropped from consideration (n=1). Those not coded were considered adequate to proceed to the next step of providing a Statement of Work, Milestones Timeline, Budget and Sole Source Justification for submission to NOAA/PMEL. The period of performance was set at 1 June 2012 – 31 December 2013, to provide a framework for funding that includes both FY12 and FY13. Submission of these documents is anticipated by the end of April, with funding to follow within two months.

SOAR GOALS AND NEXT PHASE

The SOAR project was designed to proceed in two Phases. During Phase 1, the Principal Investigators, Project Coordinator, and Science Steering Committee will work closely with synthesis teams to track progress on synthesis projects, all of which have a period of performance of 1 June 2012 – 31 December 2013, through regular contact with project leads. Each project includes periodic milestone-based deliverables to aid in assessing progress. Milestones include deliverables such as paper outlines, summary of required data, analysis methods, team meeting/workshop reports, and completion of a draft manuscript suitable for submission to a peer-reviewed journal. Progress made by synthesis teams will be detailed in BOEM Quarterly Reports. SOAR PIs will select a journal to host the SOAR special issue/theme section and begin submitting draft papers for review as they become available. In 2014 SOAR will begin Phase 2 of the project in which selected Phase 1 projects may be augmented with additional funding for smaller, newly identified projects. Synthesis findings will be communicated to local Arctic residents, resource managers, science societies and the general public via presentations, community-based outreach products, the SOAR website, and the media when appropriate. Completion of these two phases and the associated publications and communication of synthesis findings will meet the SOAR goal to increase scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic prey species (forage fish and zooplankton), and marine mammal distribution and behavior in the Pacific Arctic, with particular emphasis on the Chukchi Sea Lease Sale Areas.

APPENDIX 1 – PARTICIPANT LIST

Science Steering Committee	Affiliation	Location
Robyn Angliss	NOAA/NMML	Seattle, WA
Carin Ashjian	WHOI	Woods Hole, MA
Christopher Clark	Cornell	Ithaca, NY
Jacqueline Grebmeier	UMCES	Solomons, MD
Craig George	NSB	Barrow, AK
Taqulik Hepa	NSB	Barrow, AK
Vera Metcalf	EWC/Kawerak	Nome, AK
Chad Jay	USGS	Anchorage, AK
Tim Ragan	MMC	Washington, DC
Robert Suydam	NSB	Barrow, AK
Tom Weingartner	UAF/SFOS	Fairbanks, AK
Science Contributors	**Affiliation**	**Location**
Kevin Arrigo	Stanford	Stanford,CA
Catherine Berchok	NOAA/NMML	Seattle, WA
Susanna Blackwell	Greeneridge Sciences, INC	Santa Barbara, CA
Bodil Bluhm	UAF/SFOS	Fairbanks, AK
Peter Boveng	NOAA/NMML	Seattle, WA
Eugene Brower	Barrow Whaling Captains Assn	Barrow, AK
John Burns	ADF&G (ret.), Living Resources Inc.	Fairbanks, AK
Robert Campbell	URI	Newport, RI
John Citta	ADFG	Fairbanks, AK
Lee Cooper	UM/Chesapeake Bio. Lab	Solomons, MD
Robert Day	ABR, Inc	Fairbanks, AK
George Divoky	Friends of Cooper Island	Seattle, WA
Matthew Druckenmiller	UAF/CIRES	Fairbanks, AK
Ken Dunton	U of Texas	Austin, TX
Ed Farley	NOAA/AFSC	Juneau, AK
Megan Ferguson	NOAA/NMML	Seattle, WA
Karen Frey	Clark University	Worcester, MA
David Hannay	Jasco Research	Victoria, BC, CAN
Lois Harwood	Fisheries and Oceans	Yellowknive, NT, CAN
Russ Hopcroft	UAF/SFOS	Fairbanks, AK
Josh Jones	Scripps	San Diego, CA
Merlin Koonooka	Native Village of Gambell	Gambell, AK
Kathy Kuletz	USFWS/MBM	Anchorage, AK

Science Contributors	Affiliation	Location
Libby Logerwell	NOAA/AFSC	Seattle, WA
Jim Lovvorn	Southern Illinois U	Carbondale
Wieslaw Maslowski	Naval Postgraduate School	Monterey, CA
Jeremy Mathis	UAF/SFOS	Fairbanks, AK
Jeff Napp	NOAA/AFSC	Seattle, WA
George Noongwook	Native Village of Savoonga	Savoonga, AK
Brenda Norcross	UAF/SFOS	Fairbanks, AK
Stephen Okkonen	UAF/SFOS	Fairbanks, AK
Jim Overland	NOAA/PMEL	Seattle, WA
Sandy Parker-Stetter	UW	Seattle, WA
Robert Pickart	WHOI	Woods Hole, MA
Lori Quakenbush	ADFG	Fairbanks, AK
Scott Raborn	LGL	College Station, TX
Fenton Rexford	Native Village of Kaktovik	Kaktovik, AK
Kate Stafford	UW	Seattle, WA
John Trefry	FL Institute of Technology	Melbourne, FL
Rebecca Woodgate	UW/APL	Seattle, WA
BOEM Participants	**Affiliation**	**Location**
Heather Crowley	BOEM	Anchorage, AK
Warren Horowitz	BOEM	Anchorage, AK

APPENDIX 2 – Workshop Agenda

14 March 2012 (9AM-5PM)

DAY 1 GOAL: Disciplinary overview talks in plenary sessions to give all participants a common background regarding the state of knowledge in each field, with late afternoon break-out groups by discipline to further explore specialties.

9-9:30 – Welcome & SOAR Introduction: Science Themes, Questions & Goals
(Crowley, Moore & Stabeno)

9:30-10:30 - Disciplinary Overview Talks:

- Atmospherics & Sea Ice (Jim Overland)
- Physical & Chemical Oceanography (Tom Weingartner)

10:30-11:00 - BREAK

11:00–Noon - Disciplinary Overview Talks:

- Primary Production & Nutrients (Karen Frey)
- Lower Trophic Levels: Zooplankton & Benthos (Jackie Grebmeier & Carin Ashjian)

Noon –1:30 – LUNCH

1:30-3:00 - Disciplinary Overview Talks

- Upper Trophic Levels = marine fish, birds & mammals (Robert Suydam – western science)
- Upper Trophic Levels = marine fish, birds & mammals (Vera Metcalf & Taqulik Hepa – community & subsistence observations)
- Acoustic Ecology (Christopher Clark)

3-3:30 - BREAK

3:30-5:00 - Disciplinary Break-out groups – discuss state of knowledge and make adjustments to Draft Science Themes & Questions from discipline standpoint

5:00 - ADJOURN – Self-organized group dinner(s)

15 March 2012 (9AM-5PM)

DAY 2 GOAL: Create Analytical Teams to address and revise questions within each science theme, break-out into inter-disciplinary teams to begin drafting proposals

9-9:30 – Brief review of disciplinary discussions from Day 1

9:30-10:30 - Identify Analytical Teams, team leads & initiate discussion of potential projects

Ecosystem: Meet as one Team (Stabeno leads discussion)

Marine Mammals as Sentinels: Meet as one Team (Moore leads discussion)

Acoustic Ecology: Meet as one Team (Berchok leads discussion)

10:30-11 - BREAK

11:00 – 12:30 – Analytical Teams begin discussion 3-5 Projects/Theme – Identify inter-disciplinary questions, relevant datasets, observations & local knowledge, discuss analytical approach, who could undertake analyses and where the work would be done

12:30-1:30 - LUNCH

1:30 – 3:30 - Continue development of Projects/Theme -- including initiation of ~5 page proposals to include Project Objective, Key Contributors, Timeline, Milestones & Estimated Cost

3:30-4:00 - BREAK

4-5:00 - Report out on progress of Analytical Team project development

5:00 – ADJOURN – Self-organized group dinners

16 March 2012 (8:30-4:30PM)

DAY 3 GOAL: Presentation of proposed projects in plenary sessions, followed by public open session to present workshop results

8:30-9:00 – Overview of progress & discussion of any questions arising from Day 2

9-10:30 - Short presentations of projects by Analytical Team Leads, with discussion by full group

10:30-11 - BREAK

11-12:30 - Analytical Team Leads continue project presentations, with group discussions

12:30-2:00 - LUNCH

2-4:30 - Workshop Outcome = OPEN SESSION for Industry Science Program Managers, AOOS, NPRB, etc.

List of Analytical Teams: Leads & Projects

Discussion of Project Tracking – need for SSC attention & possible intervention if problems encountered

Plans for coordination & outreach to communities, other projects & synthesis efforts

4:30 - ADJOURN

APPENDIX 3 – PRE-WORKSHOP DRAFT SCIENCE THEMES AND QUESTIONS

1. Ecosystem Response to Bottom-up and/or Top-down Forcing

- How are spatial (regional and local) and temporal (seasonal and inter-annual) variations in sea ice linked to primary production?
- How do primary production hotspots correspond to zooplankton, benthic, forage fish, and marine bird and mammal hotspots?
- What is the importance of advection, upwelling and eddies to lower trophic level (e.g. nutrients, primary production, zooplankton) and to pelagic predators (e.g. seabirds, bowheads, beluga, ringed seals)?
- How do benthic production hotspots correspond to benthic predators (e.g., eiders, walruses, bearded seals & gray whales) and can these benthic hotspots provide a framework to assess ecosystem heterogeneity and change?
- What is the importance of Arctic and saffron cod, and other forage fishes, in the system?
- How does pressure by top marine predators affect historic benthic hotspots?
- How can marine bird and mammal bioenergetics help inform population and ecosystem models and what data sets are required?
- How are stressors such as ocean acidification, contaminants, anthropogenic activity (transportation, oil and gas, commercial fishing, etc.), and habitat alteration (loss of sea ice, weather patterns, temperature, erosion) affecting the biological components of the marine ecosystem?
- How are changes in the marine ecosystem affecting subsistence resources and access to them?

2. Marine Birds, Mammals, and Fish as Ecosystem Sentinels

- How can combined track maps from satellite-tagged marine birds and mammals be used to identify hotspots and evaluate habitat partitioning among species?
- What can marine bird and mammal diet, body condition, health status, and abundance inform us about environmental change and variability?
- How do vital rates of marine birds and mammals change (age at first reproduction, growth rates, etc.) relative to environmental conditions?
- How can marine mammal distribution and relative abundance be used as a tool to identify and assess variability in benthic, pelagic, and subsistence hotspots?
- How can we link variability in relative abundance, distribution, species composition, and growth of fish to environmental conditions?

3. Acoustic Ecology

- What are the relative contributions of natural and anthropogenic sound sources to the cumulative sound field?
- How are sound fields changing with loss of sea ice, change in weather patterns, and extension of the open-water season?
- What are the temporal and spatial relationships between the distribution, behavior, and abundance of marine mammals and seismic surveys, drilling operations, and ship transits?
- What are the sampling capabilities and limitations from the existing grid of long-term recorders for describing and tracking change in the acoustic environment?
- What are the effects of shipping, drilling operations, and seismic activity on marine mammal and bird prey and the availability of subsistence resources to local communities?

APPENDIX 4 – DRAFT SCIENCE THEMES AND QUESTIONS AS REVISED AT THE WORKSHOP

HOTSPOT MECHANISMS AND TROPHIC DYNAMICS

1. Mechanisms for enhanced trophic productivity in Barrow Canyon, Chukchi Sea [Pickart]
2. Seasonal and spatial patterns in marine bird and mammal densities, distribution, and community structure in the Pacific Arctic [Kuletz]
3. Seasonal and spatial patterns of Alaska Native subsistence hunting for marine mammals in the northern Bering, Chukchi, and western Beaufort seas [Hepa/Ragen]
4. Fish of the Beaufort and Chukchi seas: Community structure, human use, and mechanisms determining similarities and differences (aka A Tale of Two Shelves) [Napp]
5. Effects of prey dispersion, sea ice, and walrus foraging on viability of a critical migration corridor for avian benthivores [Lovvorn]
6. Factors maintaining bird and mammal benthic hotspots: A latitudinal analysis [Grebmeier]

YEAR IN THE LIFE OF SELECTED SEABIRDS AND MARINE MAMMALS

7. Why are the bowhead whale hotspots located where they are? [Quakenbush]
8. Influence of sea ice, oceanographic conditions, and prey availability on the timing of fall bowhead whale migration from the Canadian Arctic along the Beaufort Shelf to Barrow and the subsequent whaling success in Beaufort coastal communities [Ashjian]
9. Variation in the migration path of bowhead whales across the Chukchi Sea during the fall migration [Citta]
10. What sound environments to bowhead whales encounter in the Chukchi and Beaufort seas? [Clark]
11. What is the acoustic environment for walrus as they move through the Chukchi Sea? How might walrus behavior, such as herding or mother-calf communication be impacted by sound? [Jay]
12. Relationship between beluga whales, Arctic cod, and oceanographic conditions in Barrow Canyon and at the shelf break of the western Beaufort Sea. [Suydam]

RESPONSES TO STEP-CHANGE IN PHYSICAL DRIVERS OF THE MARINE ECOSYSTEM

13. Variability in annual persistence, breakup, and formation of sea ice cover in the Pacific Arctic Region [Frey]
14. Primary production in the Pacific sector of the Arctic Ocean [Arrigo]
15. Causes of drastic climate change for the Pacific Arctic [Overland]
16. Is Arctic sea ice retreat affecting the body condition of bowhead whales? [George]
17. Walrus shift to central-place foragers in the Chukchi Sea. [Jay]
18. Consequences of loss of cryopelagic prey to marine birds and mammals. [Divoky]
19. An ocean acidification sensitivity index for the Pacific Arctic Region. [Mathis]
20. Scale matters: Higher trophic species integrate and reflect ecosystem change across a range of temporal and spatial scales. [Harwood]

APPENDIX 5 – OPEN-SESSION PARTICIPANT LIST

Name	Affiliation
Chris Campbell	BOEM
Danielle Dickson	NPRB
Darcy Dugan	AOOS
Amy Holman	NOAA
Jim Kendall	BOEM
Michael Macrander	Shell
Molly McCammon	AOOS
Caryn Rea	Conoco Phillips
Cheryl Rosa	USARC
Cynthia Suchman	NPRB
Dee Williams	BOEM