Initiating an Arctic Marine Biodiversity Observing Network (AMBON)

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http://ambon-us.org

LONG-TERM GOALS

The goal of the Arctic Marine Biodiversity Observing Network (AMBON) project is to demonstrate and build an operational marine biodiversity observation network (MBON) for the US Chukchi Sea continental shelf as a prototype network for the nation. The importance of the Arctic Ocean to global climate and ecosystem processes, and the speed at which climate changes are already occurring in the Arctic, elevate the urgency for coordinated observations of Arctic marine biodiversity. In an end-to-end approach, from microbes to whales, AMBON science experts work with the Alaska Ocean Observing System (AOOS) to coordinate data streams from past and ongoing programs into one observation network for the US Arctic. Important collaborative links connect AMBON to other BON efforts in the nation and on the global scale. Effective data management, integration and dissemination will provide critical information on the status of Arctic ecosystem health and resilience to decision makers and local, regional and global communities.

OBJECTIVES

The objectives of this project are:

1. Apply end-to-end approach in biodiversity observations: microbes, phytoplankton, zooplankton, infauna, epifauna, fish, marine mammals and birds
2. Incorporate environmental data collections (chlorophyll, nutrients, water mass indicators, sediment characteristics)
3. Continue existing time series and close current gaps in taxonomy
4. Integrate and synthesize with past and ongoing research programs in the Chukchi Sea
5. Demonstrate practical metrics for a sustainable observing network for the Arctic and other regions

APPROACH AND WORK PLAN

1. *Proposed scientific and/or technical approach, including data quality requirements*

The AMBON project combines new and ongoing field sampling in the Chukchi Sea, with research cruises in 2015 and 2017. All samples are worked up and data quality-assessed following standard protocols. Data are stored in the Alaska Ocean Observing System (AOOS) workspace to be shared among investigators. Once data processing and QA/QC is completed, data with appropriate metadata are published through the AOOS Data Portal. Through data management at the AOOS database, AMBON also links to other (historical and ongoing) data steams on biodiversity in the Chukchi Sea. AMBON also links through AOOS to other national MBONs. Through the PIs of the project, we ensure that AMBON is also linked internationally with biodiversity efforts (e.g., Distributed Biological Observatory [DBO], Circumpolar Biodiversity Monitoring Program [CBMP], Ecosystem Studies of Subarctic and Arctic Seas [ESSAS], Group on Earth Observations Biodiversity Observation Network [GeoBON], etc).

2. *The key individuals participating in this work and their roles*

Katrin Iken: Overall project management, epifaunal community
Seth Danielson: Hydrography (CTD measurements, liaison to Chukchi Ecosystem Observatory long-term mooring)
Lee Cooper: Water column and sediment characteristic (chlorophyll a, nutrients, sediment grain size, total organic content, $\delta^{13}C$ and $\delta^{15}N$ values of sediment organic matter), liaison to DBO program
Eric Collins: Microbes (water column, sediment), meiofauna genetic analyses

Russ Hopcroft: macro/meso-zooplankton community
Jacqueline Grebmeier: macrofauna community, phytoplankton species composition, liaison to DBO program
Franz Mueter: fish community
Kathy Kuletz: seabird observations
Kate Stafford: marine mammal observations
Sue Moore: marine mammal observation coordination with other ongoing Arctic programs (e.g., DBO)
Bodil Bluhm: epifauna community, international (European Arctic) liaison (e.g., CBMP)
Rob Bochenek, Stacey Buckelew: Data management and coordination

3. Work plans for the upcoming year

In the upcoming year (October 1, 2016 to September 30, 2017) we will conduct a second field cruise in the AMBON region (4-28 August 2017 on the RV Norseman II) and collect samples across all disciplines to accomplish the end-to-end approach (i.e., microbes to whales). Remaining sample analyses from the 2015 cruise are continuing. Data analyses, including linkages to historical data, will be continued. Data will be managed through the AOOS Workspace and completed data will be made publicly available through the AOOS data portal after appropriate QA/QC and with the appropriate metadata. Through data sharing, and if applicable through shared field sampling, information will be shared with other Arctic programs. Outreach to the public will be through updates to the website, public engagement, and coordination of field work plans with Native communities.

WORK COMPLETED

Samples from the 2015 AMBON cruise were analyzed, resulting data analyzed, AMBON results presented at scientific conferences, and networking with other Arctic project and other national MBONs on common observing metrics continued. Most of the 2015 samples have been analyzed, although some more labor-intense samples are still in progress (macrofauna, zooplankton, phytoplankton, micobes). Data have been posted to the AOOS Workspace and metadata are being posted to the MBON Data Portal (https://mbon.ioos.us/) to inform the public about the types of data until the full data become available. Results of the project have been conveyed at a number of scientific conference venues. Collaborations with other field programs (especially the DBO and planning of the Arctic Shelf Growth, Advection, Respiration and Deposition Rate Experiments (ASGARD) project), and with other MBONs have included coordination of data management, outreach, genetic analyses, development of a national MBON implementation plan, international participation within GeoBON working group 5), and international organizations or coordination efforts (e.g., CBMP, Pacific Arctic Group) are ongoing.

RESULTS

We have begun using AMBON data from the 2015 cruise to assess relevant metrics for a sustainable biodiversity observing system, for example by identifying **indicator species and community groupings** in relation to environmental drivers. Because this is a demonstration project, it is necessary to explore and test **scales of variability** (e.g., temporal, spatial) to determine the components and design that comprise a practical long-term observing system. As a network, AMBON **links to other appropriate data sets** and provides integration between biodiversity measures and among ecosystem components. Here, we provide examples of such assessments that make use of and demonstrate the project's network character, where we combine AMBON cruise-derived data with historical or ongoing other data streams.

In addition, **data management** is a key element of the Observing Network and we provide an update of the data management strategy and progress.

Determining indicator species and community groupings

Analyses have begun to identify regional indicator species. One example provided here is for the fish community. In this case, the catch-per-unit-effort of all species was assembled and mapped (Table 1, Fig. 1). Catches were dominated by slender eelblenny (*Lumpenus fabricii*), Arctic staghorn sculpin (*Gymnocanthus tricuspis*), hamecon (*Artediellus scaber*), shorthorn sculpin (*Myoxocephalus scorpius*) and Arctic cod (*Boreogadus saida*) (Table 1). Demersal species richness was highly variable throughout the study area but decreased towards the northeast (Fig. 2). Midwater species richness was even more variable and was lowest on the two southern transects and at the offshore end of the northern transects (Fig. 2).

Table 1: Catch-per-unit-effort (CPUE) by weight ranks by numerical abundance for all major fish taxa collected by plumb staff beam trawl during 2015 AMBON cruise

	Name	***Common Name***	***CPUE (weight)***	***Rank (numeric)***
1	Lumpenus fabricii	slender eelblenny	55.897	1
2	Gymnocanthus tricuspis	Arctic staghorn sculpin	52.500	2
3	Artediellus scaber	hamecon	24.841	6
4	Myoxocephalus scorpius	shorthorn sculpin	21.561	4
5	Boreogadus saida	Arctic cod	17.379	5
6	Hippoglossoides robustus	Bering flounder	17.301	12
7	Liparis sp.	Liparis sp.	12.185	3
8	Lycodes sp.	eelpout	11.951	9
9	Anisarchus medius	stout eelblenny	10.775	8
10	Liparis gibbus	variegated snailfish	10.681	20
11	Liparis tunicatus	kelp snailfish	9.769	14
12	Stichaeus punctatus	Arctic shanny	9.341	13
13	Eleginus gracilis	saffron cod	6.655	7
14	Ammodytes hexapterus	sandlance	5.733	10
15	Gymnelus sp.	Gymnelus sp.	3.925	16
16	Icelus spatula	spatulate sculpin	2.912	17
17	Triglops pingelii	ribbed sculpin	2.758	21
18	Aspidophoroides olrikii	Arctic alligatorfish	2.019	15
19	Limanda sp.	Limanda sp.	1.876	11
20	Limanda aspera	yellowfin sole	1.536	23
21	Nautichthys pribilovius	eyeshade sculpin	0.628	18
22	Podothecus accipenserinus	sturgeon poacher	0.404	19
23	Trichocottus brashnikovi	hairhead sculpin	0.188	22
24	Aspidophoroides monopterygius	alligatorfish	0.023	24

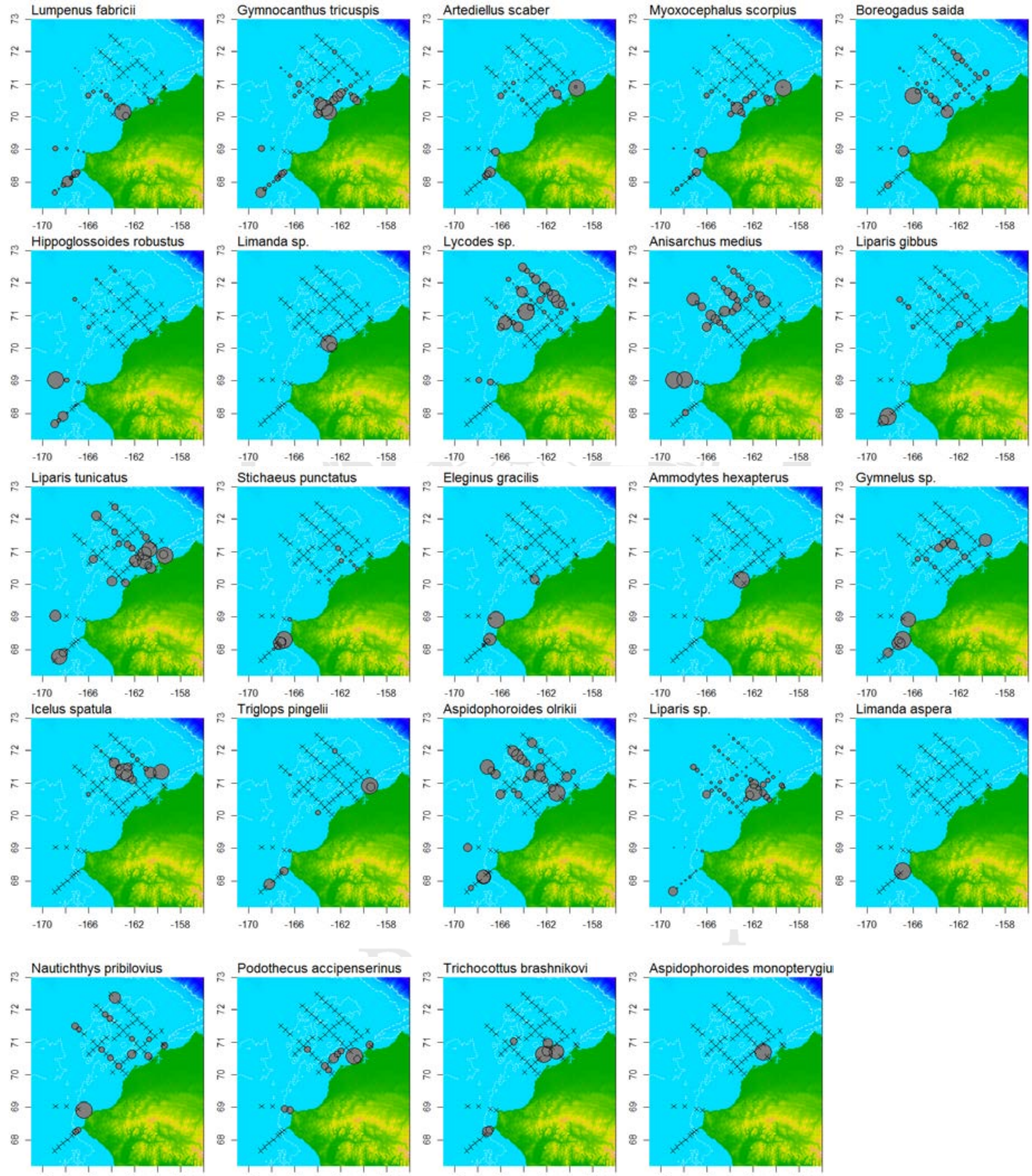

Figure 1: Relative Catch-per-unit-effort (kg km^{-2}, square-root transformed to highlight lower abundances, 'x' denotes zero catch) for all major fish taxa collected during 2015 AMBON cruise.

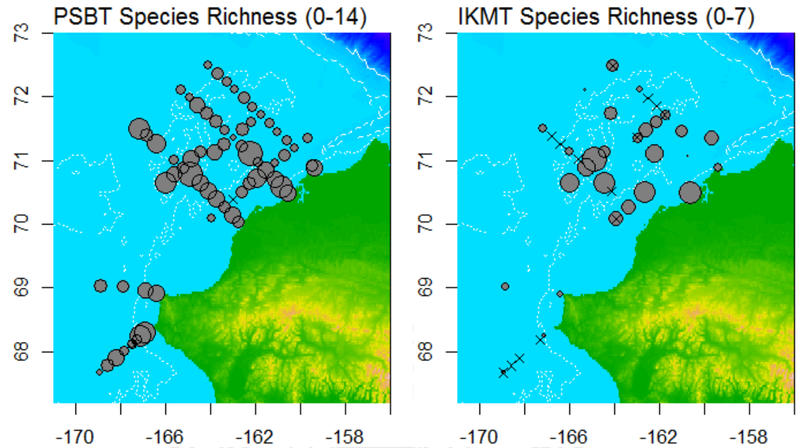

Figure 2: Pattern of species richness of demersal fish community sampled by plumb staff beam trawl (PSBT) and midwater community as sampled by Isaac-Kidds midwater trawl (IKMT) during AMBON 2015. Note that maximum species richness in PSBT samples was twice as high as richness in IKMT samples.

We have begun integrating datasets across components, including AMBON-collected physical and chemistry data (temperature, salinity, nutrients, sediments) and biological assemblages (zooplankton, epibenthos, fish and seabirds). The approach will be to relate variability in assemblage structure to environmental gradients and to quantify connections among different community assemblages, as recently used successfully by Sigler et al. (in press). For the fish community, strong north-south and onshore-offshore gradients are present (Fig. 3), likely reflecting the influence of different water masses on species composition (Sigler et al., in press). An Arctic group including stout eelblenny (*Anisarchus medius*) and Arctic cod (*Boreogadus saida*) was clearly separated from more southern and coastal groups, which are influenced by waters of Pacific origin, including Alaska Coastal Water and Bering Chukchi Summer Water (water mass designation *sensu* Danielson et al. in press).

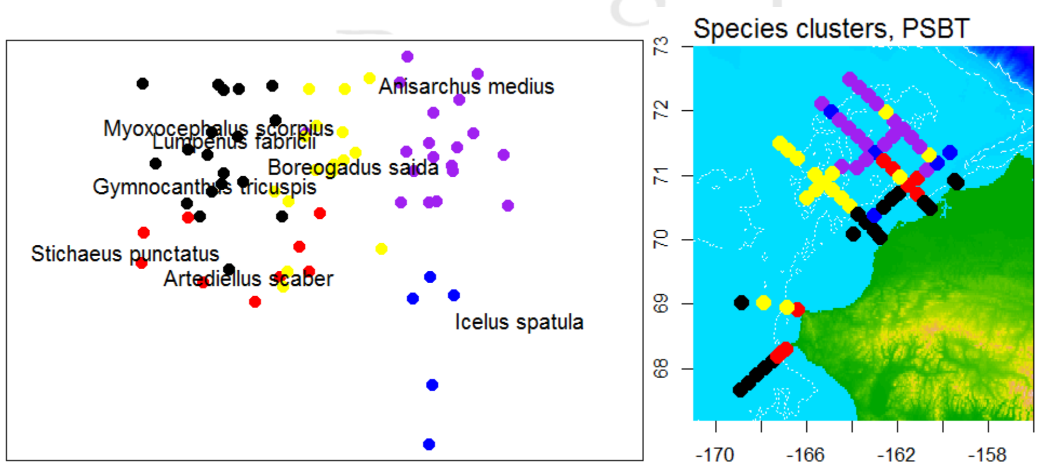

Figure 3: Ordination plot of the species composition of 24 fish species in 68 samples, denoting similarity in species composition among samples with five station groups identified through hierarchical cluster

analysis (highlighted in color) and corresponding indicator species that best separated station groups (left). The station groups show strong north-south and nearshore-offshore gradients (right).

Temporal scales: Comparing short-term (cruise-based) measurements against long-term (mooring) patters

The close vicinity and the programmatic overlap between the AMBON cruise sampling and the Chukchi Ecosystem Observatory (CEO) in the northern study region around Hanna Shoal provides the opportunity to place short-term measurements accomplished during a research cruise with long-term measurements by the mooring over a year. Here we present an example of this comparison based on a major storm event that occurred during the AMBON 2015 cruise (8 Aug – 5 Sept). A significant atmospheric low-pressure system on 25-29 Aug 2015 (Fig. 4) temporarily interrupted the AMBON ship-based sampling. This storm significantly reorganized the Chukchi water column and advected shelf waters laterally, altering the shelf's thermal conditions (Fig. 5).

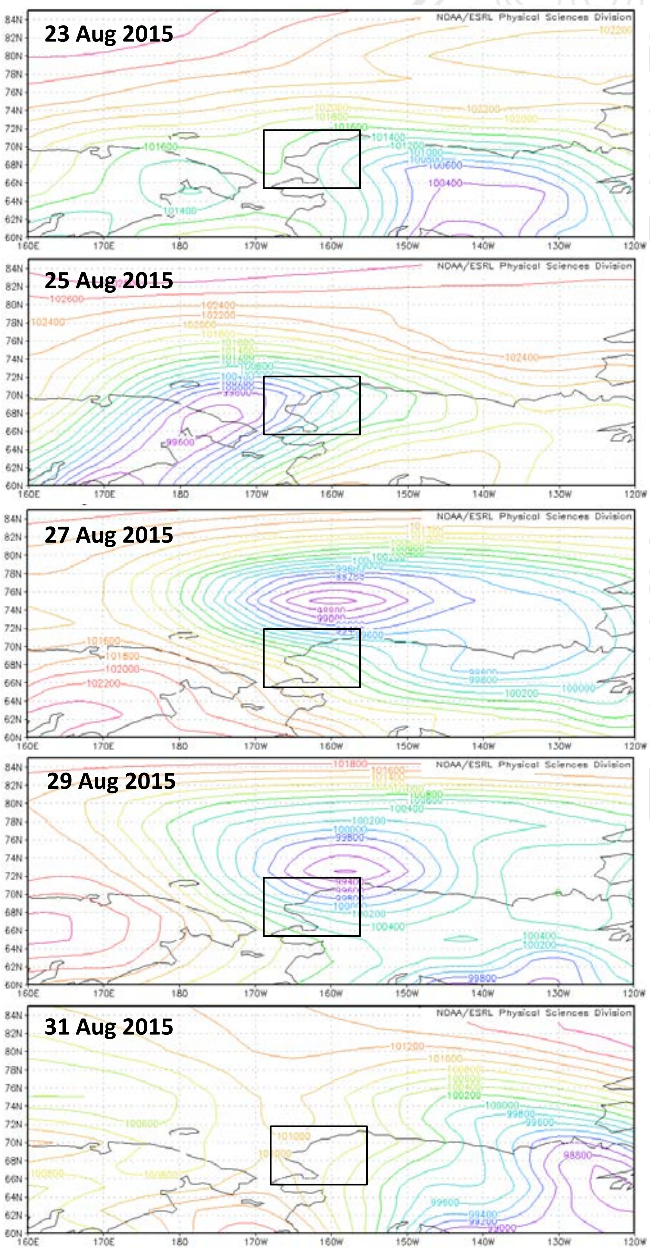

Figure 4: Daily mean sea level pressure (SLP) during the storm event, showing the passage of a low pressure system into and over the AMBON study area (box). Images show SLP hindcasts from the NCEP-NCAR Reanalysis, provided by Physical Sciences Division, Earth System Research Laboratory, NOAA, Boulder, Colorado, at http://www.esrl.noaa.gov/psd/.

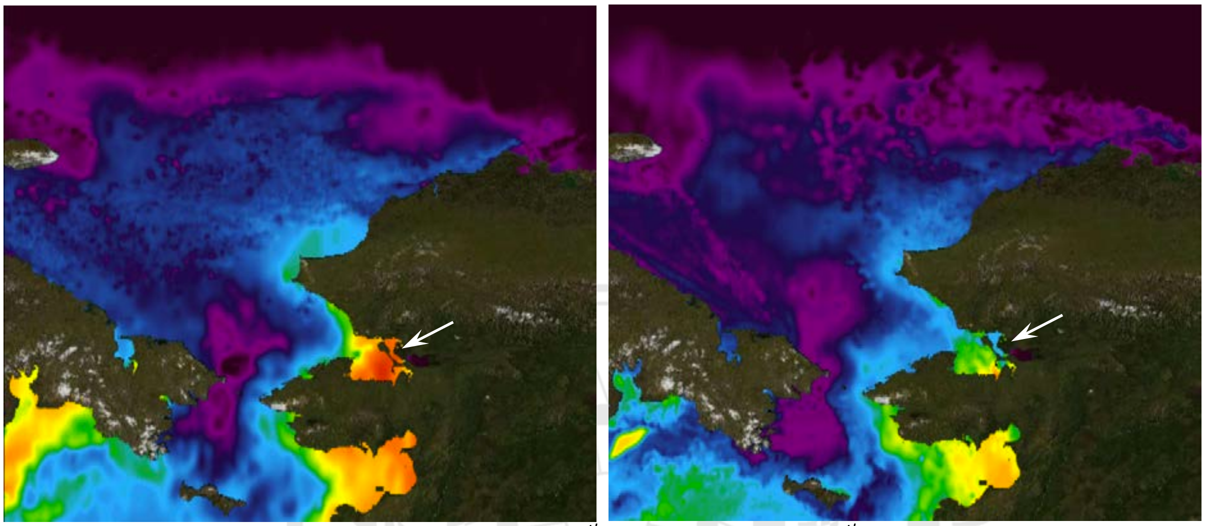

Figure 5: Sea surface temperature on August 20th (left) and August 30th (right) 2015. Colors vary from 0 °C (black) to 15 °C (red). Images downloaded from NASA Worldview using the G1SST dataset (https://worldview.earthdata.nasa.gov/) from the multi-mission GHRSST Global Hi-Resolution Sea Surface Temperature compilation. Kotzebue Sound (mentioned in text) is marked by the arrow.

Satellite imagery (Fig. 5) shows that between August 20th and August 30th the extent of relatively warm coastal waters decreased across the study region (including all major embayments such as Kotzebue Sound) and that the distribution of cooler waters expanded southwestward from the NE Chukchi Sea. Cooler waters also were found along the Siberian Coast and in the Bering Strait region after the storm.

The AMBON ship sampling occupied station ML4.8 twice, before and after the storm event. This station is located about 16 km north of the CEO moorings and the first shipboard occupation occurred on August 21st at 05:00 UTC. The second occupation of ML4.8 occurred on August 30th at 04:30 UTC. The CEO moorings, deployed on 20 August just prior to the storm, recorded a detailed time history of the storm. The water column profiles at the ML4.8 and CEO locations (Fig. 6) show that the surface mixed layer deepened during the storm from about 10 to 20 m. While the total water column heat content showed little change from before (21 Aug) to after (30 Aug) the storm, the mean water column salinity increased. Hence, vertical mixing cannot alone account for the change in water column properties and lateral advection must also have played a role. Beam transmittance (water clarity) remained above 80% in the upper 20 m of the water column before and after the storm, but the transmittance decreased from ~60% to below 20% following the storm, presumably due to particulate resuspension from the seafloor, although changes in water column chlorophyll may also have played a role. The CTD fluorometer showed that the chlorophyll a maximum evolved from a narrow feature (~10 m wide centered on 30 m depth) with higher peak values (~6-9 ug/L) before the storm into a broader feature (~20 m wide centered on 30 m depth) peak with smaller chlorophyll a values (~ 3-5 ug/L). The filtered chlorophyll *a* measurements made shipboard from bottle samples agreed well with the CTD fluorometer readings prior to the storm but higher peak concentrations (~10 ug/L) were observed in bottle samples following the storm relative to the fluorometer mounted on the CTD. Nutrient concentrations varied somewhat differently depending on constituent: Ammonium increased near the seafloor, probably due to re-suspension while total inorganic nitrate and nitrite decreased after the storm. Silicate remained about the same below the mixed layer depth but increased above it.

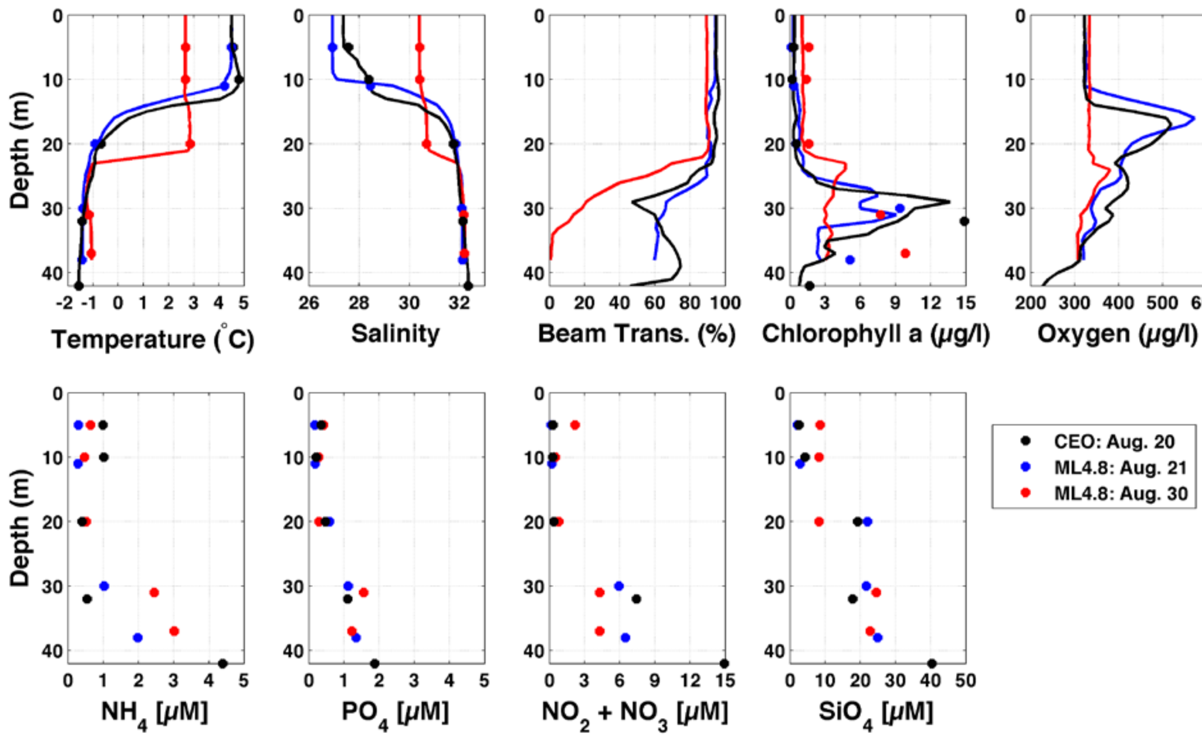

Figure 6: Vertical profiles from the CTD (lines) and discrete bottle samples (circles) showing the water column evolution from before the storm (August 20/21) to after the storm (August 30) at station ML4.8 and the nearby CEO mooring site (pre-storm only). Upper row, from left to right, shows temperature, salinity, beam transmittance, chlorophyll a and dissolved oxygen. Lower row, from left to right, shows ammonium, phosphate, nitrite plus nitrate, and silicic acid.

Compared with the ship-based water column profile data, the mooring data show a somewhat different picture of the storm and its effects. Note that most measurements made by the moored observatory are from the top float package, which sits about 34 m below the surface. The CEO mooring is in slightly deeper water than station ML4.8 and while the ship-based CTD profiles did not show any change in temperature of the near-bottom waters (see Fig. 6), the mooring recorded a nearly 3 °C increase from August 27 to August 31 (Fig. 7). The mid-depth salinity signal from the mooring is somewhat more complex, increasing temporarily on 26 August, decreasing on 27 August, and then remaining steady over August 28-31. Lack of measured light following August 27th was likely due to increased turbidity in the bottom boundary layer (see CTD vertical profile of transmittance) rather than decreasing sunlight due to cloud cover. Over 26-27 August, the nitrate concentrations measured autonomously on the mooring decreased from ~ 15 to 7 µM (a similar decrease was observed from the discrete bottle samples collected shipboard) while the water column dissolved oxygen content increased appreciably (not consistent with the CEO profile). These decreases in nutrient concentrations coincided with a peak in the fluorometer voltage on the mooring, which suggests as much as a doubling of chlorophyll in one 24-hour period on August 26-27 (Fig. 7).

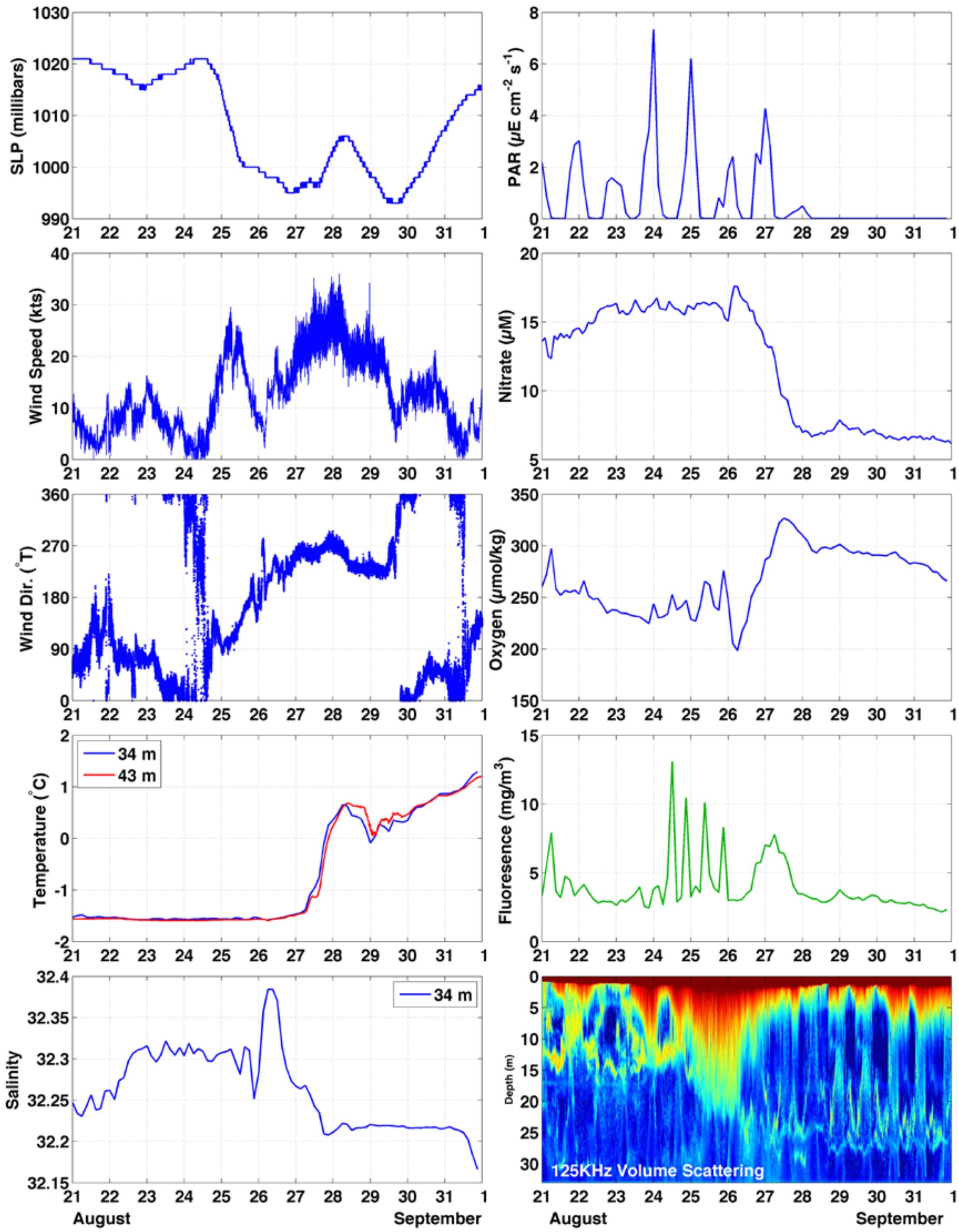

Figure 7: Left column, top to bottom: Shipboard measurements of atmospheric pressure, wind speed, wind direction along with CEO mooring measurements of ocean temperature at 34 and 43 m depth and salinity at 34 m depth. Right column, top to bottom: CEO moored measurements of PAR, nitrate, oxygen, chlorophyll a fluorescence, and Scattering Volume of the Acoustic Zooplankton Fish Profiler at 125 kHz.

The active acoustics from the Acoustic Zooplankton Fish Profiler (Fig. 7) provided another window into the ecosystem changes during this storm. High-intensity scattering signals during the high wind events that emanate downward from the surface are interpreted here to reflect the increased significant wave height and the injection of bubbles downward from the surface. The backscatter below the surface noise reveals the deepening of a dense scattering layer from about 15 to 25 m during the storm, suggesting that many scatterers (e.g., macrozooplankton and Arctic Cod) often remain just a few meters below the surface mixed layer. In addition, the acoustic data suggest that the cohort of diurnal vertically migrating organisms decreases during the storm.

In summary, we find that the mooring and ship-based measurements show complementary but different aspects of the water column response to the passage of a major late summer storm. Neither dataset is complete in itself yet the combination of the two is able to effectively leverage our understanding of the mechanistic drivers of short-term variability, production, and its fate. This example shows how integrating the AMBON and CEO efforts – and their datasets – provides considerable added value from combination of these two core programs.

Spatial scales: Building the basis for larger-scale (regional to pan-Arctic) comparisons

Here we present examples on how AMBON data are being integrated into larger-scale comparisons. This is demonstrated on two ecosystem components: microbes and seabirds.

Microbes (single-celled organisms from bacteria to phytoplankton) make up 90% of the living biomass in the world oceans, including in the Arctic Ocean, where they are responsible for 100% of the primary production that feeds higher trophic levels. Changes in microbial community composition due to global warming or other ecosystem disturbances could have lasting impacts on the function and efficiency of the microbial loop, which in turn could lead to significant changes in food sources available to higher trophic levels. Because these changes are expected to be pan-Arctic, it is crucial that we work with international partners to monitor changes in microbial biodiversity across the Arctic. A forthcoming report from the Circumpolar Biodiversity Monitoring Program (CBMP) will highlight the lack of organized monitoring for microbes and other plankton in the Arctic. As a contribution to this ongoing effort, AMBON has partnered with the Norwegian Institute of Marine Research to expand our monitoring of microbial communities in the Arctic. Like AMBON, TIBIA ("Trophic interactions in the Barents Sea - steps towards an Integrated Ecosystem Assessment"), brings together a team of researchers spanning multiple trophic levels to understand the marine environment from a holistic perspective. During the 2015 summer field season, AMBON and TIBIA each sampled stations in the Chukchi Sea and Barents Sea, respectively, for many of the same parameters, including temperature, salinity, nutrients, chlorophyll *a*, phytoplankton and zooplankton diversity, and microbial community composition. A graduate student master's thesis is currently being supported through AMBON and TIBIA that is working to compare the communities in these two water gateways to the Arctic Ocean, which will then be compared with the resident diversity based on samples collected during 2015 and 2016 research cruises. Together these data will present the first synoptic, large-scale, baseline picture of microbial diversity in the Arctic marine system. The continuation of monitoring efforts will eventually enable a model of 'diversity flux' within the Arctic, in which we will be able to quantify the inflowing and outflowing diversity through Arctic gateways in order to detect changes in ecosystem stability as a function of environmental parameters. Results to date indicate that this methodology enables detection of over 10,000 molecular species of microbes (as operational taxonomic units, OTUs).

National Oceanographic Partnership Program

To conduct microbial community monitoring, targeted amplicon sequences from both 16S (Bacteria and Archaea) and 18S (Eukarya) ribosomal RNA genes were obtained from nearly 300 samples on an Illumina MiSeq to a mean depth of 20,000 sequences per sample. From these samples we identified 2918 eukaryotic OTUs, 6942 bacterial OTUs, and 219 archaeal OTUs. Amongst the Bacteria and Archaea, many of the same taxonomic groups were prominent in both the Chukchi and Barents Seas, for example *Pelagibacter* (SAR11 Clade Alphaproteobacteria), SAR86 Clade Gammaproteobacteria, *Nitrosopumilus* (Marine Group I Thaumarchaeota), and Marine Group II Euryarchaeota. However, some differences were observed between the seas: at large taxonomic scales, Gammaproteobacteria of the Oceanospirillales were more prevalent in the Barents Sea while Bacteroidetes of the Flavobacteriia were more common in the Chukchi Sea. The Eukaryotic protist communities showed larger differences, with the Barents Sea sequences dominated by *Thalassiosira* and *Chaetoceros* (both diatoms), whereas abundant sequences in the Chukchi Sea included *Chrysochromulina* (a haptophyte) and *Didinium* (a ciliate), in addition to *Chaetoceros*. In future work, we will quantify the effect of abiotic factors on microbial community structure, in addition to analyses of community members (e.g. algal groups) as structural drivers themselves. This analysis of the diversity and distribution of Arctic marine microbes will lay the groundwork for understanding the effects of a changing climate on these biogeochemically central components of the marine ecosystem.

Besides microbes, our sampling techniques also enable us to identify extracellular DNA ("eDNA") from marine animals ranging from worms to whales. Because metazoans are not our primary targets, and because molecular marker databases are incomplete, the molecular resolution we obtain is lower than it is for microbes. However, as these research approaches mature, the techniques could easily be adapted to include additional markers, such as the 12S ribosomal RNA gene and cytochrome oxidase I gene that are targeted for monitoring by the other MBONs. Table 2 below lists the Phylum and Class of the metazoan OTUs we detected in our sampling efforts in the Chukchi Sea during the AMBON 2015 cruise, along with the number of OTUs that were detected in each case.

Table 2: Phylum and class of metazoan DNA detected in environmental samples in the Chukchi Sea in 2015.

Taxonomic group	OTUs
Annelida	43
Eunicida	6
Haplotaxida	24
Parergodrilidae	7
Questidae	2
Rhynchobdellida	3
Terebellida	1
Arthropoda	88
Acari	1
Araneae	3
Coleoptera	7
Diptera	13
Eucarida	6
Maxillopoda	51
Opiliones	2
Orthoptera	4
Pleurostigmophora	1
Brachiopoda	33
Lingulida	10
Rhynchonellida	10
Terebratulida	13
Cnidaria	65
Actiniaria	22
Alcyonacea	6
Antipatharia	15
Ceriantharia	1
Corallimorpharia	14
Scleractinia	3
Zoantharia	4

Taxonomic group	OTUs
Echinodermata	25
Asteroidea	7
Echinoidea	7
Ophiuroidea	11
Entoprocta	3
Barentsiidae	3
Mollusca	55
Heterobranchia	10
Mytiloida	18
Pectinoida	11
Solemyoida	5
Veneroida	11
Nematoda	12
Ascaridida	2
Chromadorida	1
Rhabditida	9
Nematomorpha	5
Gordea	5
Platyhelminthes	8
Continenticola	2
Dalyellioida	3
Neodalyellida	2
Stenostomidae	1
Tunicata	10
Enterogona	1
Stolidobranchia	9
Vertebrata	9
Mammalia	4
Semionotiformes	1
Squalimorphii	4
Grand Total	356

Seabird survey data analysis was conducted with an emphasis on comparing seabird species richness, composition, and abundance in the AMBON study area (including two DBO transects) to the greater Chukchi region and adjacent seas. Our preliminary results from the 2015 cruise suggest that the AMBON survey captured roughly two-thirds of the species present in the offshore Chukchi Sea waters, and reflects the relative abundance and distribution of numerically dominant species (primarily short-tailed shearwater, black-legged kittiwake, crested auklet, least auklet, common murre, and thick-billed murre).

As part of the network functionality of AMBON, in 2016 the USFWS (funded by BOEM and NPRB) conducted seabird studies from three research vessels that worked primarily in the Chukchi Sea. In brief, the survey transects that overlapped with the AMBON area showed similar diversity and abundances as was found in 2015. North of the AMBON area, however, seabird abundance and diversity in the Chukchi Borderlands region were extremely low, consisting primarily of surface-feeding larids that are piscivorous or scavengers (glaucous gulls, black-legged kittiwakes, one ivory gull, and jaegers). This was in sharp contrast to the high density of predominately planktivorous diving birds (as well as piscivorous species) in the AMBON area.

Using seabird data collected throughout the Bering Sea and Arctic waters by USFWS (2007-2015), we found that species richness (and density calculations) increased with km surveyed (as expected), which for these regions reached an asymptote of ~45 species after ~7,000 km surveyed (Fig. 8). The Chukchi Sea has relatively higher species richness (and density) than the Arctic Basin and Beaufort Sea, but lower than the northern Bering Sea. Although the Chukchi Sea has approximately half of the survey effort as the southern Bering Sea, species richness is equivalent (Fig. 8), indicative of the importance of the region to seabirds in late summer and fall.

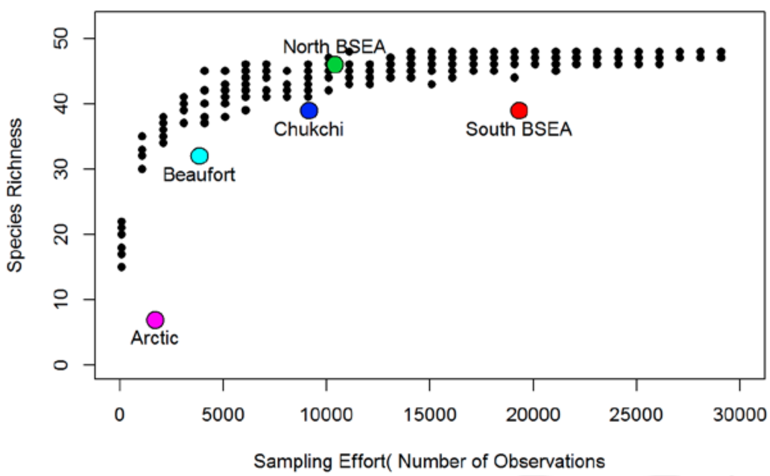

Figure 8: Species richness and sampling effort (number of 3-km transect segments) based on seabird surveys (2007-2015) for five marine regions (colored circles) and the predicted curve based on randomized selection of 3-km segments from throughout all regions (black dots). BSEA = Bering Sea

The AMBON sampling grit includes several DBO lines, specifically DBO3 (Hope Basin), DBO4 (between Wainwright and south Hanna Shoal); the DBO5 (upper Barrow Canyon) is just north of the AMBON area. Of these, DBO3 had the highest species richness, although all three sites were within the predicted values based on survey effort (Fig. 9). As suggested in our 2015 report, these results indicate that future analyses focus on the six abundant seabird species relative to environmental and prey data.

Two other approaches are currently underway in our seabird analysis, with a goal of presentation in two two peer-reviewed publications: (1) Latitudinal and longitudinal distribution of seabirds within the DBOs compared to the greater Northern Bering, Chukchi, and Beaufort seas (Kuletz et al.); and (2) Physical and biological influences on seabird distribution in the northern Chukchi Sea, focusing on cross-shelf seasonal and inter-annual patterns, 2010-2015 (Gall et al.).

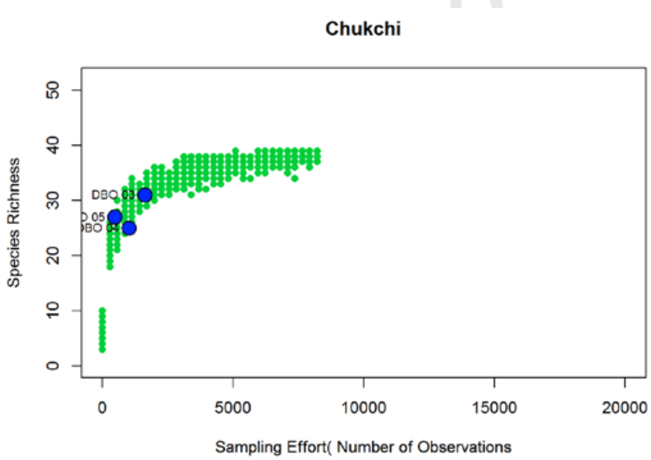

Figure 9: Species richness relative to sampling effort (number of 3-km transect segments) for the three DBO sites in or near the AMBON study area (blue dots). The predicted species richness for the entire Chukchi Sea (green dots) was derived from a randomized selection of 3-km segments from surveys in 2007-2015 (Kuletz, unpublished data).

Spatial scales: Determining spatial scales in biodiversity

The spatial scales that are appropriate sampling units to capture the biodiversity and distribution of specific ecosystem components vary by the distribution patterns of these components. Hence, a spatial sampling design that is "one size fits all" may not be appropriate. Epibenthic communities contribute high biomass, abundance, diversity, and ecological function to the Chukchi Sea shelf ecosystem. Despite this, epibenthic communities are not consistently included in some existing long-term observing programs that are designed to illuminate the processes that are driving key system variables and how these might change in light of climatic and anthropogenic pressures. Spatial overlap exists for the DBO line 3 in the southeastern Chukchi Sea and the DBO line 4 in the northeastern Chukchi Sea. These DBO transect lines are less spatially extensive than the sampling being undertaken as part of the AMBON. The difference in spatial coverage and how it represents biodiversity patterns of an ecosystem component is an important aspect of designing an appropriately scaled MBON. The sampling program in 2015 provided the opportunity to compare patterns in epibenthic biomass across the different spatial scales and environmental conditions covered by the two DBO lines and by AMBON. This effort combined data collected collaboratively within AMBON on epifauna as well as environmental data on chlorophyll *a*, sediment grain size, temperature and salinity. Epibenthic community composition correlated well with some physical characteristics, such as bottom temperature and the silt-clay sediment fraction, over the large (AMBON) and smaller (DBO) spatial coverages. In contrast, the strong primary productivity gradient along the DBO3 line from the seasonally high offshore values to low values near the Alaskan coast did only influence epibenthic community patterns within the DBO coverage, but not on the larger AMBON scale. The larger spatial clustering of epibenthic community structure (from AMBON) was well captured by the DBO-3 line, but several community similarity cluster groups in the northern study region were not adequately captured in the northern DBO-4 sampling scheme (Fig. 10). Adequately monitoring epibenthic community structure to fully represent the epibenthic community attributes that were apparent from the larger AMBON coverage would need to include sampling father offshore and closer to shore along the current DBO-4 line trajectory. Also, an extensive community cluster of a more south-central grouping within the northern study region (orange cluster in Fig. 10) would require additional sampling along the AMBON ML1 line.

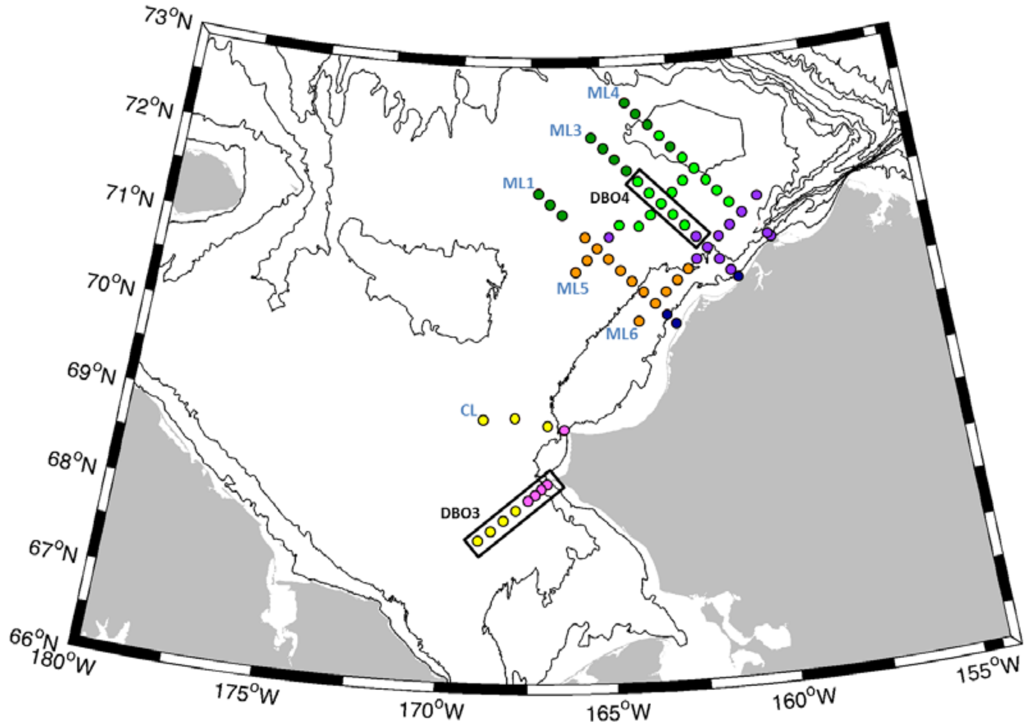

Figure 10: Spatial distribution of epibenthic community groupings based on cluster analysis. The station groups show strong north-south and nearshore-offshore gradients. Boxes indicate the DBO coverage and show that epibenthic community clusters in the southern study region were well captured with sampling along the DBO-3 line but not with sampling solely along the DBO-4 line in the northern study region. Within the northern study region, the northern-offshore (dark green), northern-coastal (purple), and southern-central (orange) community groups were not well represented.

Links to other data streams: Continuation of long-term records

The AMBON sampling stations cover the region of some previous sampling programs so that AMBON extends time-series sampling records for some stations and regions. One example of this time series continuation are stations in the Chukchi Sea Ecosystem Studies Program (CSESP), which was previously funded by oil industry support from 2008-2014.

For **<u>zooplankton</u>**, the 2015 AMBON cruise represented the 8th consecutive year of sampling in the northeastern Chukchi Sea that was begun under the CSESP program. Overall biodiversity remained similar to previous years, with ~60 species observed, half of which were copepods. Smaller shelf-associated taxa (i.e., *Pseudocalanus, Oithona*) were at typical abundances (Fig. 11), whereas the larger-bodied *Calanus glacialis* was at somewhat lower abundance than in recent years. Larvaceans (both *Fritillaria* and *Oikopleura*) were prominent, but not atypical in their abundance. Pacific species during AMBON 2015 were more common on the southern transect, but also present in typically low numbers in the northeast. Arctic Basin species were extremely rare, but were detected northwest of Hanna Shoal and at the head of Barrow Canyon where they have also been observed in previous surveys. Ice-associated species were also present in very low numbers at several stations. Meroplankton dominated the assemblages at the coastal stations in the northeast study area.

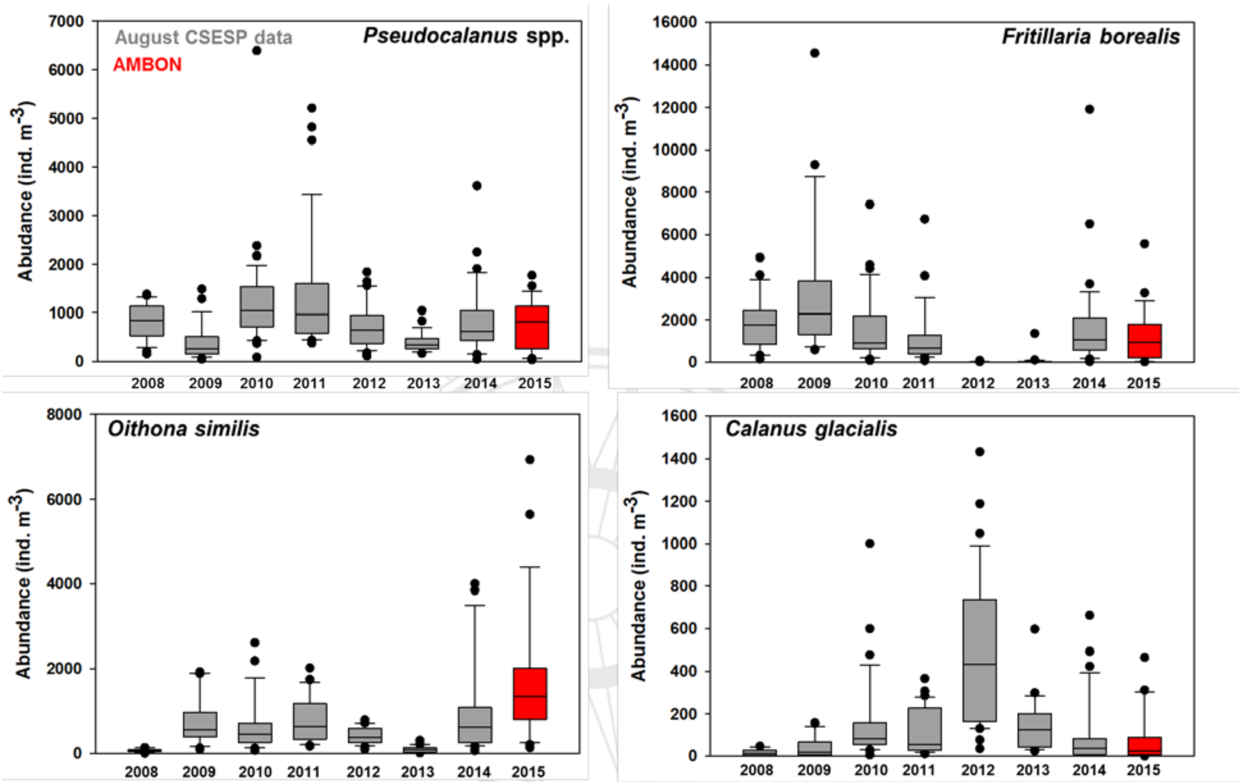

Figure 11: Abundance of select zooplankton species in the northern part of the AMBON study region. 2008-2014 data are from the CSESP program (August data only) and 2015 data are from AMBON cruise.

Marine mammal sightings during the 2015 AMBON cruise were also compared with data collected from 2008-2014 during the prior CSESP program (available on AOOS). Regions of highest density for walrus from 2008-2014 were located between the two northernmost transects from the AMBON 2015 cruise (ML3 and ML4) but overall, most of the walrus sightings during AMBON were in regions with previously reported high walrus densities (Fig. 12). In contrast, relatively few large whales were seen during the AMBON 2015 cruise even in regions where the previous observational data indicated relatively high densities (Fig. 13). However, sea state conditions were often very high during the AMBON 2015 cruise and likely impeded sightings of all marine mammals.

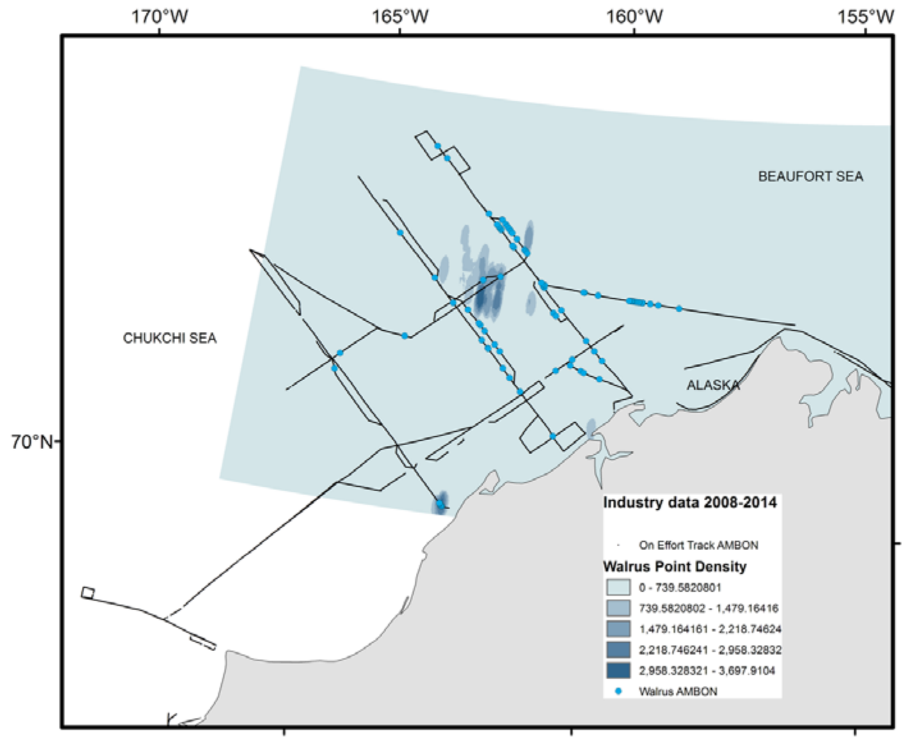

Figure 12: AMBON 2015 cruise walrus sightings (blue dots) and walrus high density areas based on CSESP data from 2008-2014. Black lines are on effort cruise tracks during AMBON 2015

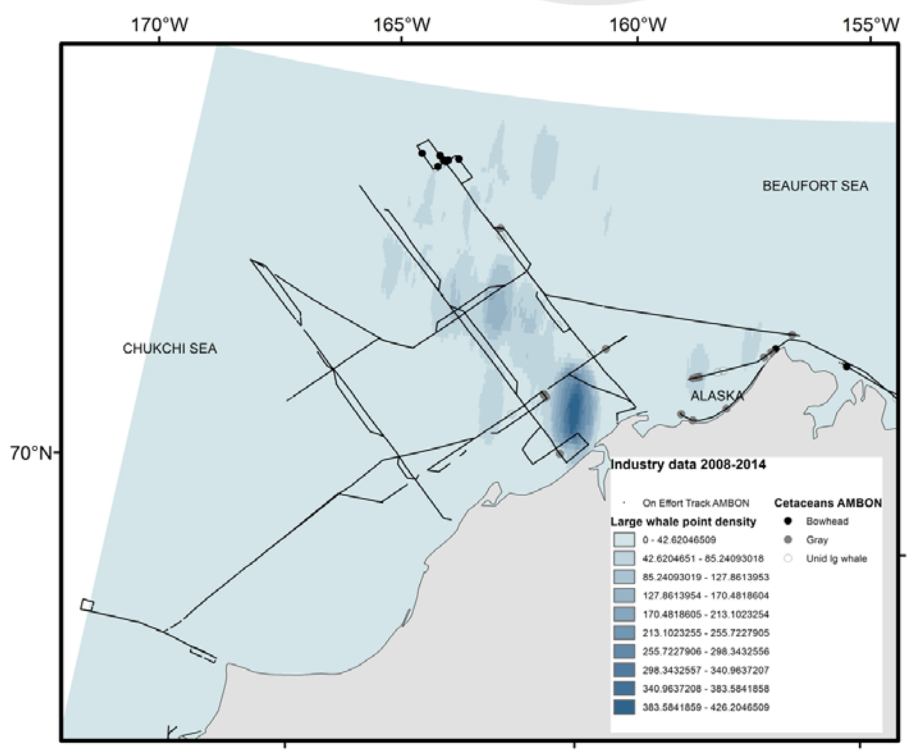

Figure13: AMBON 2015 cruise large whale sightings (black, gray and white dots) and large whale high density areas based on Industry data from 2008-2014. Black lines are on effort cruise tracks.

Data management

Core data management services for the AMBON program, provided by Axiom Data Science, focus on the integration and long-term preservation of scientific data collected by this program. The Ocean Workspace within AOOS is a web-based scientific collaboration and data management platform used by AMBON researchers to secure and centralize project information, share data, and generate metadata. Once finalized, data files from the Workspace are published openly on the public MBON data portal and other national data repositories. The Axiom data coordinator regularly tracks submission and metadata progress and provides technical assistance for the Workspace, as needed.

In this reporting period, the Axiom team has been developing enhancements to the data management capabilities that will allow for automated submission of AMBON data from the Workspace to the DataONE and NOAA-National Center for Environmental Information (NCEI) data centers. This enhanced feature will become operational in 2017 to facilitate the preservation and permanent access to AMBON data through national repositories. Additionally, the metadata editor native to the Ocean Workspace has been improved throughout 2016 to enable the export of xml metadata records in the ISO 19115-2/19110 standards. This new metadata editor will be released in 2017 (with the enabled publication pathways), along with other updates to the user-interface and functionality of the Workspace.

An important aspect of the Observing Network is the coordination of data-related activities across the three MBON programs. Progress in this regard has been made through participation by the Axiom data coordinator in the regular MBON Data Management and Communications (DMAC) meetings, including a June 2016 DMAC workshop specifically focused on cross-program data coordination. To meet the objectives identified by this group, AMBON has applied a common template to their data management plan (in concert with Sanctuaries and Santa Barbara Channel MBONs) and developed a local inventory of anticipated datasets to be produced by the program PIs. These documents are shared within the MBON Workspace, where they are accessible by all MBON collaborators. Further, the IOOS data catalog (developed by Axiom) and the Axiom-produced data visualization maps were two of the four mechanisms identified for MBON data delivery. To meet these data service objectives, metadata for 13 AMBON datasets have been aggregated and updated within the MBON Data Portal (https://mbon.ioos.us/). The intent is to inform user audiences and stakeholders about the AMBON data that have been collected and will be made fully available through these web services in the future.

References cited in Result Section

Danielson, S.L., Eisner, L., Ladd, C., Mordy, C., de Sousa, L., Weingartner, T.J. (in press). A comparison between late summer 2012 and 2013 water masses, macronutrients, and phytoplankton standing crops in the northern Bering and Chukchi Seas. Deep Sea Research II. http://doi.org/10.1016/j.dsr2.2016.05.024

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IMPACT AND APPLICATIONS

1. **National Security**
   Providing a platform for the annual turn-around of the CEO mooring array through the AMBON program enables gathering data and studies that promote National Security and Homeland Defense. For example, the CEO provides data on sea ice, waves, and water column stratification that can be used to improve ice forecast models that impact navigation and impacts of potential ship traffic

2. **Economic Development**
   Economic development in the study region is mostly related to potential fisheries and oil and gas extraction activities. Given the sensitivity of the Arctic ecosystem, careful and knowledge-based ecosystem monitoring is necessary. AMBON is providing a structure for continued observations of biodiversity as a measure of ocean health, which can be used to identify natural ranges of variability (spatial and temporal) of the system and as a benchmark to measure any potential impacts. Therefore, AMBON facilitates the development of sustainable economic practices.

3. **Quality of Life**
   The Arctic Chukchi Sea ecosystem relates to public well-being on a local, regional and global level. Locally, Alaska Native communities use marine resources through subsistence food gathering activities. Biodiversity observations that assess ocean health are a crucial part of maintaining quality of life and local subsistence economies. Regionally and nationally, the Arctic is of economic importance as a potential source for oil and gas resources and fisheries, as well as for the development of new shipping routes. AMBON data assist with developing appropriate ecosystem-based management strategies for the United States. On a global basis, the Arctic in general, and the Chukchi Sea in particular, are responding to climatic changes. These are not only physical impacts, such as reduced sea ice cover and surface water warming, but also extensive changes appearing in the biological components such as productivity and biodiversity. The Arctic is a critical global climate driver, and observing the existing and changing conditions in the Chukchi Sea contributes to an "early warning system". The Chukchi Sea also is an inflow shelf, so changes occurring in the North Pacific are directly transmitted into the Arctic Ocean through the Chukchi Sea.

4. **Science Education and Communication**
   AMBON contributes to science education and communication by providing graduate education opportunities in Arctic science and observing systems. Students are engaged in field work, sample processing, data analysis and management, publication of results, and outreach activities. Students also are engaged in learning communicating science strategies, such as through K-12 classroom outreach and lesson plan developments. AMBON PIs are engaged in a number of regular outreach activities, through public presentations, K-12 interactions, and through exchange of information made available on the AMBON website (www.ambon-us.org), Project goals and field activities are also being communicated with Alaska Native communities along the Chukchi Sea to make sure that they are informed and to avoid any conflicts with subsistence hunting activities.

TRANSMISSIONS

1. **National Security**
   All data from the AMBON project that may be relevant for National Security (e.g., data for forecast models) are publicly accessible through the AOOS website.

2. **Economic Development**
   Data obtained through the AMBON project are directly available to resource managers so they can be used in the development of ecosystem-based management strategies for the sustainable use of fisheries and energy resources in the region. We are also engaged in the development of a national strategic plan for the development of a national MBON.

3. **Quality of Life**
   Data obtained through the AMBON project are directly available to resource managers so they can be used in the development of ecosystem-based management strategies for the sustainable use of fisheries and energy resources in the region.

4. **Science Education and Communication**
   Results from the AMBON project are disseminated through presentations at scientific conferences, through peer-reviewed publications, as publicly accessible data from the AOOS Data Portal, and also public presentations and lesson plans.

   Presentations given during the reporting period:

AMBON – Arctic Marine Biodiversity Observing Network. <u>Iken K</u>, Danielson S, Cooper L, Grebmeier J, Hopcroft R, Kuletz K, Stafford K, Mueter F, Collins RE, Bluhm BA, Moore S, Bochenek R. **Oral** presentation at the Alaska Marine Science Symposium, Anchorage AK, 25-28 Jan 2016.

New estimates of growth, size-at-maturity, mortality and biomass of snow crab. *Chionoecetes opilio*, in the Arctic Ocean off Alaska. <u>Divine LM</u>, Mueter FJ, Kruse GH, Bluhm BA, Iken K. **Poster** presentation at the Alaska Marine Science Symposium, Anchorage AK, 25-28 Jan 2016 (included AMBON data).

Contribution of microbially-derived carbon sources to Chukchi Sea benthic food webs. <u>Zinkann AC</u>, Iken K. **Poster** presentation at the Alaska Marine Science Symposium, Anchorage AK, 25-28 Jan 2016 (included AMBON data).

A demonstration Marine Biodiversity Observing Network (MBON): Understanding marine life and its role in maintaining ecosystem services. <u>Mueller-Karger FE</u>, Iken K, Miller RJ, Duffy JE, Chavez F, Montes E. **Poster** presentation at Ocean Sciences Meeting, New Orleans LA, 21-26 Feb 2016

AMBON – Arctic Marine Biodiversity Observing Network. <u>Iken K</u>, Danielson S, Cooper L, Grebmeier J, Hopcroft R, Kuletz K, Stafford K, Mueter F, Collins RE, Bluhm BA, Moore S, Bochenek R. **Poster** presentation at Ocean Sciences Meeting, New Orleans LA, 21-26 Feb 2016

AMBON – Arctic Marine Biodiversity Observing Network. <u>Cooper LW</u>, Grebmeier JM, Danielson S, Hopcroft R, Iken K, Kuletz K, Stafford K, Mueter F, Collins RE, Bluhm BA, Moore SE, Bochenek R. **Oral** presentation at the Marine Biodiversity Observing Network (MBON) All Hands meeting, Silver Spring, MD, 3 May 2016

Late summer and fall migration of seabirds from the Bering Sea to the Chukchi Sea. Kuletz K, Gall A, Osnas E, Morgan T, Labunski E, Renner M. **Oral** presentation at the Pacific Seabird Group, Turtle Bay, Oahu, Hawaii, Feb 2016

North to the Arctic: Late summer migration of seabirds from the Bering Sea to the Chukchi Sea. Kuletz K. **Oral** presentation at the Alaska Public Lands Information Center, Summer Lecture Series, June 2016

North to the Arctic: Late summer migration of seabirds from the Bering Sea to the Chukchi Sea. Kuletz K. **Oral** presentation at the Hawaii Pacific University, Graduate Seminar, Waimanalo, HI, September 2016

RELATED PROJECTS

One program that the AMBON is especially closely linked with is the **Distributed Biodiversity Observatory** (DBO). The linkages between AMBON and DBO exist through sampling (two of the AMBON transects are also DBO lines), collection of ecosystem components that are not currently sampled on the DBO lines (e.g., epibenthos, fish, microbes), and data sharing through the AOOS Workspace and Data Portal. The AMBON is included in the 10-year Implementation Plan (IP) for the Distributed Biological Observatory (DBO), as developed by the DBO Collaboration Team of the Interagency Arctic Research Policy Committee (IARPC); a pdf of the DBO IP is available here: http://www.iarpccollaborations.org/teams/Distributed-Biological-Observatory

The **Chukchi Ecosystem Observatory** (CEO; http://mather.sfos.uaf.edu/~seth/CEO/) is a long-term moored observatory that records physical, biogeochemical, plankton, fisheries, and marine mammal datasets year-round near Hanna Shoal. The observatory moorings are serviced from the AMBON research cruise. The AMBON project provides nearby in situ sampling that helps place the observatory into a broader biological and spatial context. In turn, the CEO data help place the AMBON measurements within a broader temporal framework. The CEO is supported through a consortium that includes the North Pacific Research Board (NPRB), the Alaska Ocean Observing System (AOOS), the University of Alaska Fairbanks (UAF), the University of Washington, and Université Laval. Because the CEO program does not have the resources for a dedicated annual mooring turn-around cruise the support provided by the AMBON program provides continuity for these measurements.

The North Pacific Research Board (NPRB) is funding a new 5-year **Arctic Integrated Ecosystem Research Project** (AIERP; http://www.nprb.org/arctic-program/). With late spring and late summer research cruises to the northern Bering and Chukchi seas over 2017-2019 the AIERP seeks to better understand how reductions in Arctic sea ice and the associated changes in the physical environment will influence energy flow (carbon, trophic couplings) through the ecosystem. Some AIERP stations (e.g., DBO stations) will overlap with AMBON sampling sites. The data collections provided by AIERP and AMBON cruises in the same year will provide information about the ecosystem seasonality that we presently lack.

The AMBON PI group is actively engaged in **cross-program Marine Biodiversity Observing Networks (xMBON)** collaborations with the other two funded MBONs and the Smithsonian Institution's Tennenbaum Marine Observatories Network. This collaboration is determining essential biodiversity variables and protocols and best practices for data management and eDNA analyses. We participate in regular teleconferences and provide information on progress for appropriate meetings where the MBON research strategies are developed. We are part of the GEO BON Working Group 5 and participate in conference calls pertinent to those efforts. These efforts have led most recently to the development of a national strategic plan for MBONs and the beginning of an international implementation plan.

On the international level, AMBON links closely with the marine part of the **Circumpolar Biodiversity Monitoring Program** (**CBMP**, which is an Arctic Council program (http://www.caff.is/marine). AMBON PIs contributed to the original Marine Monitoring Plan of the CBMP, many elements of which have been implemented in the design of AMBON. Data and knowledge collected during the AMBON 2015 cruise have now contributed to the Status of the Arctic Marine Biodiversity Report (SAMBR), which is in the final editorial stages before publication in early 2017.