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Institute
University of Alaska

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Submitted by:
Dr. Michael Castellini, Director
University of Alaska Coastal Marine Institute

To

U.S. Department of the Interior
Bureau of Ocean Energy Management
Alaska OCS Region
Anchorage, Alaska

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Contact information
email: CMI@alaska.edu
phone: 907.474.6782
fax: 907.474.7204

Coastal Marine Institute
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
P. O. Box 757220
Fairbanks, AK 99775-7220

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Introduction

The University of Alaska Coastal Marine Institute (CMI) is a cooperative agreement between the University of Alaska and the U. S. Department of the Interior Bureau of Ocean Energy Management (BOEM, formerly Minerals Management Service) to study coastal topics associated with the development of natural resources in Alaska's outer continental shelf. Under this cooperative program, BOEM supports highly qualified scientific expertise at the University of Alaska to conduct research used to inform management of oil, gas, and marine mineral resources. The initial agreement began in June 1993. CMI is pleased to present this 2011 Annual Report, our 18th annual report. We are currently working under BOEM Cooperative Agreement M08AX12644.

Under BOEM, the Environmental Studies Program (ESP) is formally directed to provide information in support of the decisions involved in the planning, leasing, and management of exploration, development, and production activities. The BOEM research agenda is driven by the identification of specific issues, concerns, or data gaps by federal decision makers and the state and local governments that participate in the process. Within that framework, the University of Alaska Coastal Marine Institute partners with BOEM and the State of Alaska to develop regional research goals and execute an annual request for proposals that initiates up to two million dollars of new research every year.

The proposal process is initiated each summer with a request for proposals to addressing one or more of the research goals. This request is publicized and sent to researchers at the University of Alaska, to various state agencies, and to relevant profit and non-profit corporations. The proposals are reviewed both externally and by BOEM internally. The CMI technical steering committee then decides which proposals should be recommended to BOEM for funding.

In 2011, CMI supported nine active research projects targeting research in the Chukchi Sea and Beaufort Sea region where BOEM has active lease sales. This includes three new projects funded in 2011:

Satellite-tracked Drifter Measurements in the Northeast Chukchi Sea
Investigator: Dr. Thomas Weingartner

Epifaunal Communities in the Beaufort Sea
Investigator: Dr. Brenda Konar

Population Assessment of Snow Crab, *Chionoecetes opilio*, in the Chukchi and Beaufort Seas including Oil and Gas Lease Areas
Investigators: Dr. Bodil Bluhm, Dr. Katrin Iken

2011 Administrative Accomplishments (under Cooperative Agreement M08AX12644)

- Staffing reorganization with significant reduction in administrative costs
- Revision of project final reporting process
- Publishing overdue final reports and bringing reporting current

- Publishing current final reports
- Facilitating annual award cycle
- Facilitating CMI Annual Research Review (public seminar)
- Project administrative support and oversight

Reports Published in 2011

Castellini, M.A. (Director). 2011. University of Alaska Coastal Marine Institute Annual Report No. 17. OCS Study BOEMRE 2011-29. University of Alaska Fairbanks and USDOI. BOEMRE, 79 p.

Hardy, S.M., K. Iken, K. Hundertmark and G.T. Albrecht. 2011. Population connectivity in Bering, Chukchi and Beaufort Sea snow crab populations: Estimating spatial scales of disturbance impacts. Final Report. OCS Study BOEM 2011-060, University of Alaska Fairbanks and USDOI, BOEM Alaska OCS Region, 26 p.

Naidu, A.S., J.J. Kelley, O.P. Smith, Z. Kowalik, W.J. Lee, M.C. Miller and T.M. Ravens. 2011. Assessment of the Direction and Rate of Alongshore Transport of Sand and Gravel in the Prudhoe Bay Region, North Arctic Alaska Final Report. OCS Study BOEM 2011-038, University of Alaska Fairbanks and USDOI, BOEM, Alaska OCS Region, 29p.

Naidu, A.S., J.J. Kelley, D. Misra, A. Blanchard and M.I. Venkatesan. 2011. Synthesis of Time-Interval Changes in Trace Metals and Hydrocarbons in Nearshore Sediments of the Alaska Beaufort Sea: A Statistical Analysis Final Report. OCS Study BOEM 2011-031, University of Alaska Fairbanks and USDOI, BOEM, Alaska OCS Region, 60 p.

Weingartner, T.J. and J. Kasper. 2011. Idealized Modeling of Circulation Under Landfast Ice.. Final Report. OCS Study BOEM 2011-056, University of Alaska Fairbanks and USDOI, BOEM Alaska OCS Region, 134 p.

Final Reports Pending

Recovery in a High Arctic Kelp Community
Cooperative Agreement: M08AC12645
PI: Brenda Konar
Status: Report draft is being reviewed by BOEM

Current and Historic Distribution and Ecology of Demersal Fishes in the Chukchi Sea Planning Area
Cooperative Agreement: M07AC13416
PI: Brenda L. Norcross
Status: Final revision for publishing is over-due from PI

Satellite-tracked drifter measurements in the Northeast Chukchi Sea

Dr. Thomas Weingartner

School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

Period of Performance: 03/08/2011 – 03/31/2013
Cooperative Agreement Number: M11AC00001

Project Overview

Circulation over the Northeast Chukchi Sea shelf is forced by a mean pressure gradient between the Pacific and Arctic Oceans and winds. The wind-influence is felt in two ways: 1) directly as a surface stress, which decays with depth and 2) through wind-driven convergences and divergences that alter the shelf pressure field. The wind-forced alterations to the shelf pressure field can be considered as fluctuations about the mean pressure field. Historical sub-surface velocity measurements indicate that the sub-surface flow is often opposite to the surface winds, indicating that the force on the motion exerted by the mean pressure field can be larger than the wind-forced contributions to the momentum balance. However, the early measurements did not capture the near-surface currents, where the effects of surface wind stress may be expected to dominate. The satellite-tracked drifters used in this experiment were drogued at 1 and 15 m depth. Hence the drifters respond to surface wind-stress as well as the sum of the mean and fluctuating components of the pressure field. The results are relevant to BOEM's mission, since the data will be useful in evaluating circulation and oil spill trajectory models for this shelf.

We established an informal partnership with the North Slope Borough (NSB) in our experiment. Under separate funding the NSB planned to deploy 24 similar drifters in the nearshore waters of the NE Chukchi shelf (within 10 miles of the coast). Our deployments occurred in the central Chukchi in the various areas leased to the oil industry. Consequently the experiment was envisioned to include both nearshore and offshore drifter trajectories.

2011 Accomplishments

The 48 drifters sued in this experiment were purchased from Technocean, Inc. (Coral Gables, FL) in spring 2011 and shipped to Seward Alaska in early June, where they were loaded onto the Westward Wind for transit and deployment to the Chukchi Sea. Several problems were identified early on in the project based on test strings of data that the manufacturer forwarded to us:

1. The sea surface temperature sampling did not appear to be working. At first we thought we were interpreting the data strings incorrectly, but after repeated requests for guidance in data decomposition from the manufacturer it was apparent that SST data were not in the data string due to a programming error on the part of the manufacturer. Thus we received no temperature data from any drifter. The manufacturer understands this and admitted that this was not tested prior to shipping.

2. We asked that the drifters be programmed as in previous experiments, which meant that they should collect GPS positions hourly throughout the day and then transmit these within two six-hour time blocks per day via the global network of ARGOS satellites. We had elected for this transmission schedule in order to save money on transmitting fees that are encumbered when passing data across the ARGOS satellite network. The manufacturer did not program the drifters according to this protocol. Instead the drifters were transmitting 24 hours/day, potentially increasing our satellite transfer fees. (Note that Technocean is the drifter manufacturer; but satellite fees are billed separately through a contract with CLS America). We worked with CLS America to transfer the data via telenet, which was adequate and cost-effective, but slower.

3. Initial instructions for decoding the incoming data stream were faulty. Once the proper position data instructions were supplied, test data sent from the drifter was additionally problematic insofar as the data stream did not allow us to associate each GPS position fix to a GPS time of fix. This was extremely crucial, because without the correct time of a location we cannot compute velocities accurately and this was a fundamental goal of our project. Mr. Seth Danielson (UAF), spent many hours making this point to Technocean and asking for assistance. None of their replies worked and it appeared to us that they did not (and still do not) understand this issue completely. Mr. Danielson's dedicated effort, combined with guesswork based on assembling selected fragments of Technocean's individual instruction sheets, eventually allowed him to decode the data correctly to match the GPS time and position. He spent about 1-2 weeks over the course of the month prior to deployments in fixing this problem.

Having successfully resolved some of the issues noted above, we concluded that we could go forward with the experiment. However, prior to the UAF deployments, the North Slope Borough informed us that they were having similar problems (which we could resolve for them) as well as others. In particular, many of the NSB drifters were failing shortly after deployment. The failure rate seemed abnormally high. For example, our previous success rate (considered to be a drifter that operates for more than 6 weeks after deployment) was about 98%. The NSB failure rate was exceeding 50%. We instructed them to turn all their remaining drifters on before further deployments. Many of those did not operate. Those that did were then deployed although many again failed shortly upon deployment. We forwarded this information to BOEM (and industry who provided match through the shipboard logistics). We informed them that the failure rate appeared excessive, but we could not be sure if our drifters would perform as poorly. We asked BOEM if we should suspend the experiment or proceed. We were advised to proceed, which we did.

We deployed all drifters that sent a valid position from the deck of the vessel, but did not deploy any drifters that were not functioning during the deck test. Many of our drifters passed the deck test, but failed shortly (hours to days) after deployment. In our opinion, this failure rate was due to failed seals in the pressure hull of the drifter, which led to flooding of the electronics by seawater. Figure 1 shows the duration of the drifters that were deployed. Several of the drifters did work throughout October, although some of these had sporadic GPS fixes causing us to rely on the less accurate position fixes obtained from the ARGOS satellite. However, our failure rate was ~80%.

The high failure rate and the other problems encountered with these drifters prevent us from performing many of the statistical analyses we intended to undertake as part of this project as limited data precludes statistical confidence in the results. Despite the large number of failures, we established a website, updated daily, which provided information (positions, trajectories, current speeds) for each functional drifter. Several of the drifters worked satisfactorily and yielded valuable information on the surface circulation and, although statistically weak, there were results of some interest and value.

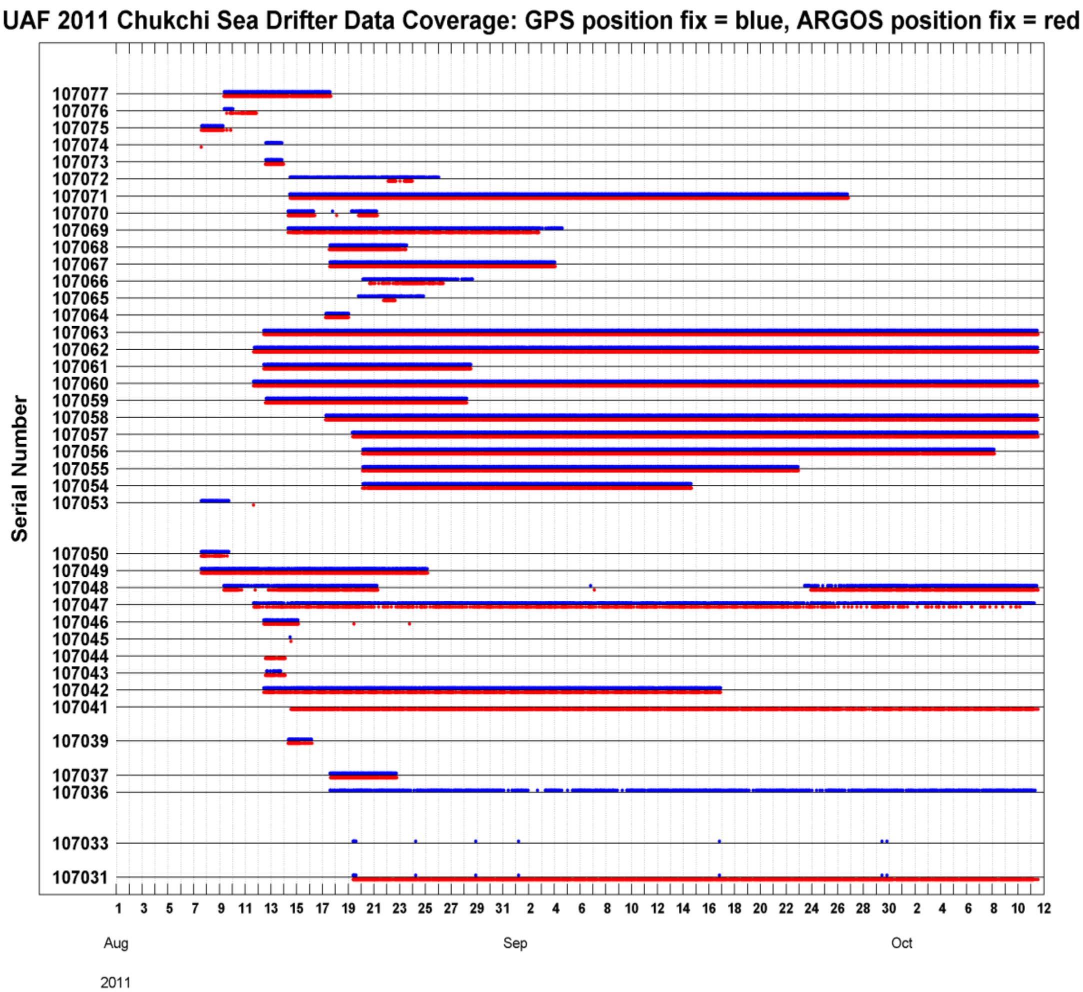

Figure 1. Time line of individual drifter durations in the Northeast Chukchi Sea, summer-fall 2011.

For example, Figure 2 shows the trajectories of 6 drifters deployed between 8/12 – 8/17, 2011 in the general vicinity of the dashed box shown in the middle panel of the bottom row. Each of these drifters moved eastward through early September at which point they entered the coastal current (between 71^{o} and 71.5^{o}N and 160^{o}W) near Barrow Canyon. During this time the mean winds were westward at ~3.5 m s^{-1}. Hence these drifters moved "upwind" in agreement with suggestions from the historical sub-surface current measurements made from oceanographic moorings at fixed locations. These results imply that there is a strong background geostrophic flow, largely associated with the mean pressure field. After entering the coastal current, most of the drifters moved northeastward in Barrow Canyon to the Chukchi shelf break. They then drifted westward along the shelf break under forcing by strong (westward) fall winds.

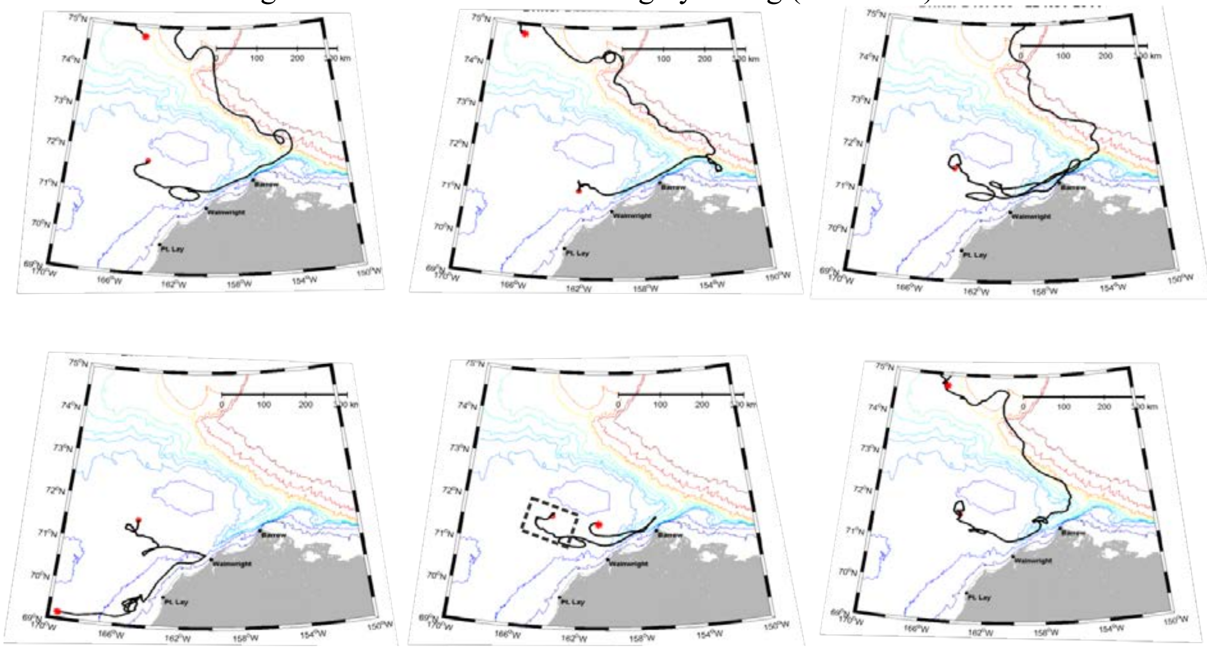

Figure 2. Trajectories of 6 satellite-tracked drifters released in the dashed box , August 12 to 17, 2011. The open circles denote the release position and the asterisks denote the position of last transmission.

Three other drifters released from this general area moved southwestward and then northward in the Central Channel (Figure 3). The initial southwestward displacement occurred under strong winds from the northeast, but their northward movement in the Central Channel is consistent with current meter measurements previously made there. It is not clear why these drifters initial movement was to the southwest given that those in Figure 2 moved eastward initially.

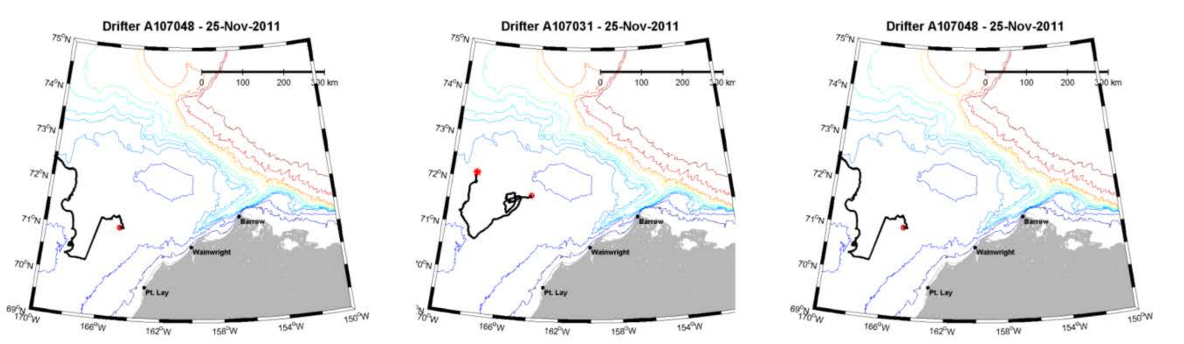

Figure 3. Trajectories of 3 satellite-tracked between August 12 to 17, 2011 that moved southwestward initially and then northward in the Central Channel between 168^{o} and 170^{o}W.

Figure 4 shows the trajectories of all drifters (regardless of their lifetime). What we find striking in this figure is that none of the drifters moved northward onto the shelf region between Barrow Canyon and Hanna Shoal. The only drifter that moved into this region had first exited Barrow Canyon and was then blown back onto the shelf toward Hanna Shoal. Given the few drifters that survived this experiment we cannot make definitive conclusions regarding the circulation here. However, the lack of drifters in this location is consistent with model results that indicate that the flow here is southward on average and part of the broader counterclockwise circulation around Hanna Shoal.

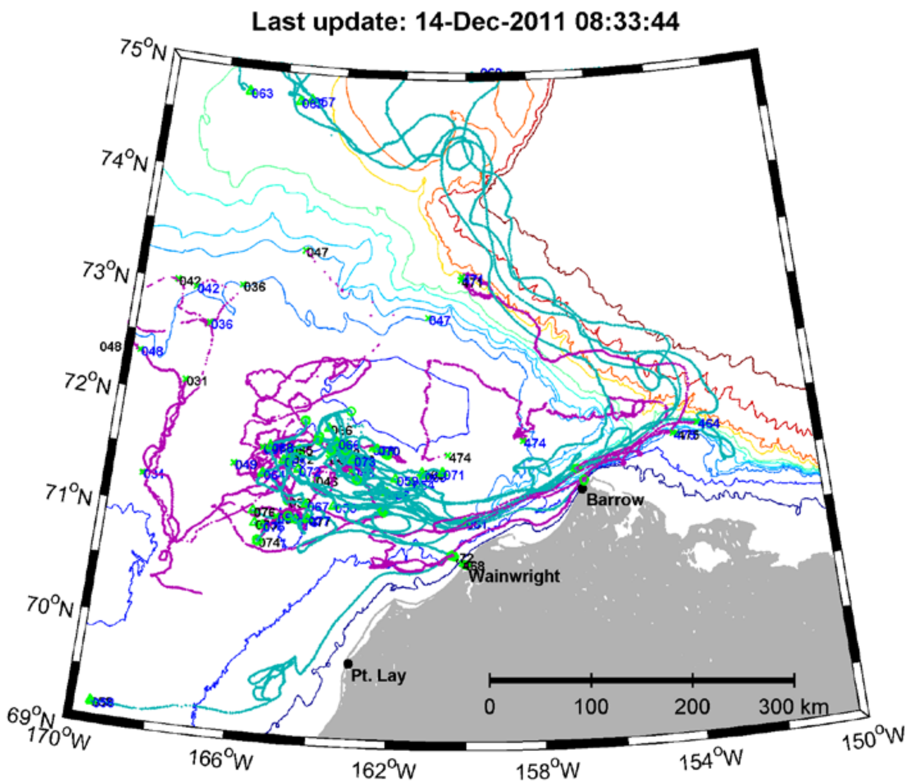

Figure 4. Trajectories of all satellite-tracked drifters released in the northeast Chukchi Sea in August, 2011.

Future work will examine more closely the wind-drifter relationship and compare the drifter velocities and trajectories with those obtained from a regional network of high-frequency radars.

Project Related Presentations/Publications

Weingartner, T., S. Danielson, Satellite-tracked drifter measurements in the Northeast Chukchi Sea, CMI Annual Review November 29, 2011, Fairbanks, AK

Thomas Weingartner, T., R. Potter, H. Statscewich, P. Winsor, and S. Danielson, Circulation in the Northeast Chukchi Sea Depicted by Oceanographic Moorings, Drifters, and HF Radar, Alaska Marine Science Symposium, January 17, 2012, Anchorage, Alaska.

Epibenthic community variability on the Alaskan Beaufort Sea Continental Shelf

Dr. Brenda Konar
Alexandra Ravelo (student)

School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

Period of Performance: 04/15/2011 – 09/30/2012
Cooperative Agreement Number: M11AC00002

Project Overview

The epibenthic community composition on the Alaskan Beaufort Continental Shelf is mostly unknown. Prior to the 2008 NOAA survey, which covered the western portion of the shelf, the only existing epibenthic data for this region are available in the form of maps of species distribution, and date from the 1970s (Carey, 1976). Arctic epibenthic communities can be highly variable in terms of abundance, biomass and species richness (Bluhm et al., 2009; Piepenburg, 2005). However, in some Arctic regions epibenthic biomass can constitute a large portion of the total benthic biomass and show an intermediate species richness only marginally lower than comparable Antarctic communities (Piepenburg, 2005). In general, Arctic epibenthic organisms have slow growth rates and some groups can have long life spans (Piepenburg, 2005). Many species constitute important prey items for many species of fish, birds and marine mammals (Bluhm and Gradinger, 2008). Taking into consideration these characteristics and the increasing interest in oil exploration of the Beaufort Shelf region, the potential for bioaccumulation and biomagnification of pollutants for this region should be a matter of great concern. Knowing the distribution of assemblages and the taxa present in each assemblage could aid in understanding the implications of anthropogenic disturbance to the region, and also detect areas of higher sensitivity to potential future changes to the ecosystem. The main objective of this study is to characterize the epibenthic community of the Alaskan Beaufort continental shelf and compare these data with similar data collected in the northeastern Chukchi Sea shelf.

2011 Update

The cruise onboard the R/V Norsman II extended from August 16th to September 3rd, 2011, starting at the most eastern stations of the Alaskan Beaufort Sea, from 70.45° N and 145.09° W and moving westward up to 71.66°N and 155.25°W. The study area was divided in eastern, central and western Beaufort. Epibenthic samples were collected at 72 sites (Table 1). At each site, one plum staff beam trawl (PSBT) was completed (Gunderson and Ellis, 1986). A modified version of the same trawl gear (PSBT-A) was used alternatively in areas of very soft sediments, the modification consisted in the addition of rollers on the bottom opening of the net to allow a more surficial swath. Five sites were revisited with the purpose of comparing gear types (labeled GC in Table 1) and seven sites were revisited to assess the variability in trawl performance using the same gear type (labeled R in Table 1). Station CB26 had an excessively full and torn cod-end. The sample collected from this trawl was very small and not representative of the entire catch so it was not included in any analysis.

Table 1. Sampling data from 2011 Beaufort Sea cruise (NS = no sample).

Station	Gear type/ Number	Date	Biomass (grams/m²)	Abundance (organisms/ 100 m²)	Standardized Number of taxa	Sediment sample
EB21	PSBT-4	8/17	83.23	2413	42	x
EB23	PSBT-1	8/17	15.12	1001	22	x
EB12	PSBT-8	8/18	8.69	1010	31	x
EB14	PSBT-6	8/18	13.75	140	30	x
EB16	PSBT-7	8/18	6.57	658	32	x
EB19	PSBT-A-2	8/18	9.70	400	23	x
EB04	PSBT-A-4	8/19	1.58	77	30	x
EB06	PSBT-A-5	8/19	27.11	400	26	x
EB08	PSBT-11	8/19	3.29	198	26	x
EB10	PSBT-10	8/19	32.69	537	35	x
CB11	PSBT-A-8	8/20	19.43	178	26	x
EB02	PSBT-A-7	8/20	1.34	168	23	x
EB32	PSBT-15	8/20	11.26	336	20	x
CB01	PSBT-16	8/21	12.27	122	27	x
CB02	PSBT-A-9	8/21	1.21	44	15	x
CB12	PSBT-A-11	8/21	6.59	414	31	x
CB22	PSBT-A-12	8/21	1.59	228	20	x
CB04	PSBT-A-16	8/22	0.28	31	15	x
CB13	PSBT-A-14	8/22	3.86	340	25	x
CB14	PSBT-A-17	8/22	1.47	89	19	x
CB23	PSBT-A-13	8/22	14.13	1525	26	x
CB24	PSBT-A-18	8/22	7.78	900	17	x
CB03	PSBT-A-15	8/23	3.15	94	27	x
CB05	PSBT-A-22	8/23	0.13	36	6	x
CB06	PSBT-A-23	8/23	4.68	30	10	x
CB15	PSBT-A-20	8/23	0.34	31	18	x
CB16	PSBT-A-28	8/23	1.62	50	20	x
CB25	PSBT-A-19	8/23	48.01	2657	24	x
CB07	PSBT-A-25	8/24	0.06	11	7	x
CB17	PSBT-A-26	8/24	0.48	38	12	x
CB27	PSBT-A-31	8/24	43.69	6483	15	x
CB28	PSBT-A-32	8/24	157.36	13352	12	x
CB29	PSBT-A-34	8/24	28.74	3430	26	x
CB08	PSBT-A-36	8/25	0.01	0.3	11	x
CB20	PSBT-A-35	8/25	0.10	46	11	x
CB09	PSBT-A-38	8/26	0.95	39	6	x
CB10	PSBT-A-39	8/26	0.54	14	4	x
CB31	PSBT-A-40	8/26	0.49	14	4	x
WB17	PSBT-A-42	8/26	0.30	40	12	x
WB19	PSBT-A-43	8/26	12.79	194	38	x
CB30	PSBT-A-44	8/27	58.95	13037	23	x
WB08	PSBT-A-46	8/27	21.03	1304	32	x
WB20	PSBT-A-45	8/27	130.38	14916	20	x
WB07	PSBT-A-47	8/28	111.48	5587	33	x
WB23	PSBT-A-51	8/28	1.79	141	29	x

Station	Gear type/ Number	Date	Biomass (grams/m²)	Abundance (organisms/ 100 m²)	Standardized Number of taxa	Sediment sample
WB24	PSBT-A-50	8/28	0.21	7	29	x
WB31	PSBT-A-48	8/28	115.40	7452	27	x
WB10	PSBT-A-56	8/29	28.01	882	38	x
WB12	PSBT-A-54	8/29	4.67	154	32	x
WB15	PSBT-A-53	8/29	36.99	1015	44	x
WB16	PSBT-A-52	8/29	20.31	1449	31	x
WB26	PSBT-A-55	8/29	8.69	273	26	x
WB04	PSBT-A-58	8/30	503.80	27559	41	x
WB05	PSBT-A-60	8/30	44.74	6687	27	NS
WB22	PSBT-A-61	8/30	2.37	196	32	x
WB27	PSBT-A-59	8/30	228.79	23843	31	NS
WB02	PSBT-A-63	8/31	43.40	1395	35	NS
WB13	PSBT-A-69	8/31	3.28	80	29	x
WB21	PSBT-A-65	8/31	23.66	786	30	x
WB28	PSBT-A-64	8/31	160.91	4854	31	x
WB30	PSBT-A-68	8/31	0.17	4	3	x
WB14	PSBT-20	9/1	0.93	90	26	x
WB25	PSBT-A-70	9/1	1.37	49	15	x
WB32	PSBT-A-74	9/1	15.36	963	34	x
WB34	PSBT-A-72	9/1	0.35	13	12	x
WB35	PSBT-A-71	9/1	1.15	47	15	x
CB32	PSBT-A-80	9/2	0.11	4	6	x
WB18	PSBT-A-79	9/2	15.76	882	27	x
WB36	PSBT-A-78	9/2	36.31	3346	30	x
CB33	PSBT-A-83	9/3	0.25	14	5	x
CB34	PSBT-A-87	9/3	130.40	15206	26	x
CB35	PSBT-A-88	9/3	231.74	8083	16	x
WB32-R	PSBT-A-49	8/28	21.00	2417	39	NS
WB21-GC	PSBT-17	8/31	23.19	769	26	NS
WB32-R2	PSBT-A-75	9/1	48.16	7088	33	NS
WB13-GC	PSBT-18	9/1	23.34	514	26	NS
WB14-GC	PSBT-20	9/1	25.21	1151	33	NS
WB31-R	PSBT-A-76	9/1	180.53	2986	28	NS
WB18-GC	PSBT-21	9/2	0.02	0.4	26	NS
WB07-R	PSBT-A-77	9/2	83.51	2663	33	NS
CB33-GC	PSBT-23	9/3	2.16	45	8	NS
CB33-R	PSBT-A-82	9/3	0.14	15	6	NS
CB34-R	PSBT-A-86	9/3	86.12	10933	13	NS
CB35-R	PSBT-A-89	9/3	221.68	19888	17	NS

As each trawl was brought on board the ship, catches were cleaned of mud and organisms were sorted to the lowest practical taxonomic level (in most cases to genus). All groups were individually counted and their damp biomass determined. Voucher specimens were fixed in 10% buffered formalin for further taxonomic identification. At each station two surface sediment samples were collected from Van Veen grabs and immediately frozen for latter chlorophyll a and total organic carbon analysis.

Preliminary analyses have shown variation in number of taxa present, biomass, and abundance among stations (Figure 1-3).

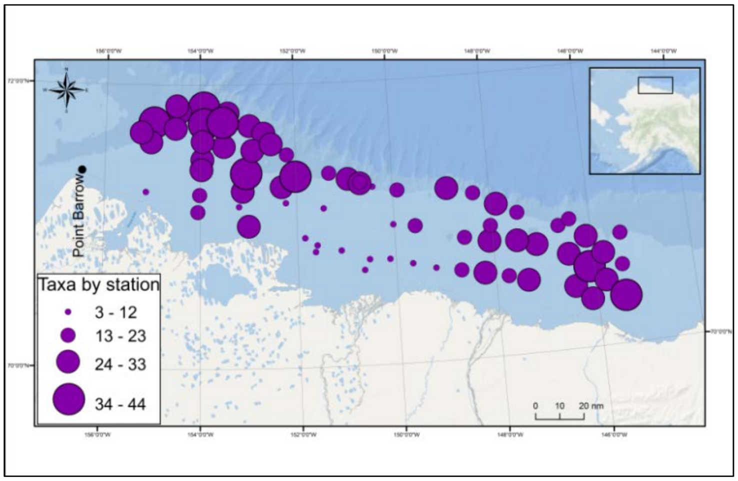

Figure 1: Number of taxa present at each station. The sizes of the circles represent the standardized number of taxa for each station.

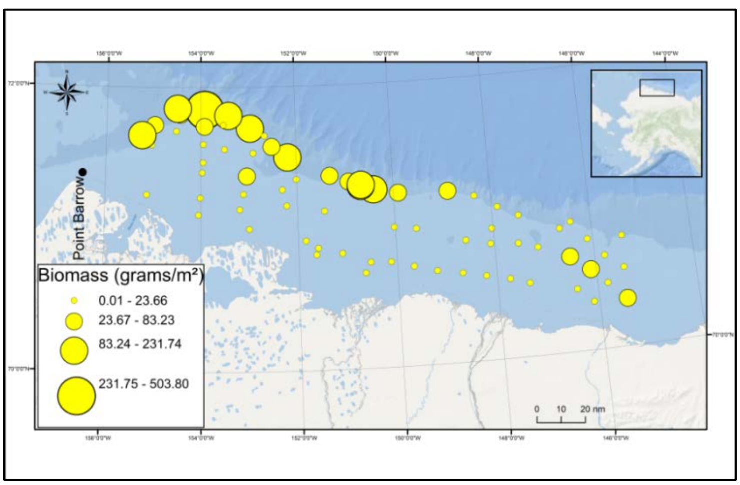

Figure 2: Epibenthic biomass at each station. The sizes of the circles represent the standardized biomass for each station.

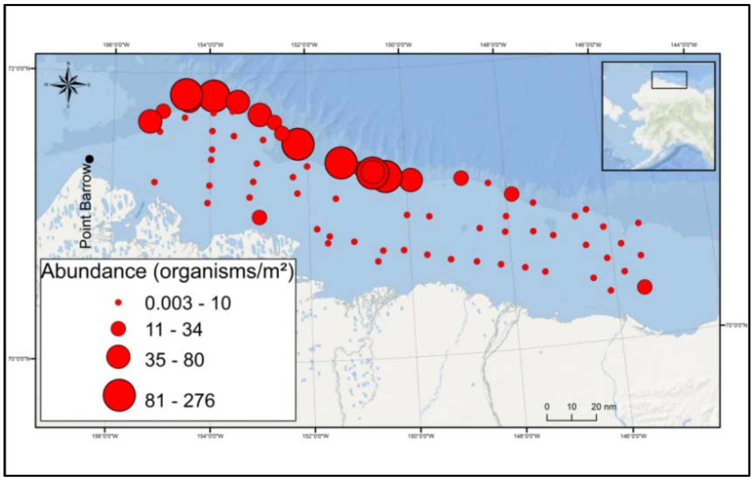

Figure 3: Epibenthic abundance at each station. The sizes of the circles represent the standardized biomass for each station.

To determine the existence of assemblages within the study area, stations were divided into three depth categories (Table 2). An ANOSIM test using the statistical software PRIMER v.6 (Clarke and Gorley, 2006) showed significant difference between these depth categories (p=0.1). A BEST analysis (PRIMER v. 6) was performed which identified taxa that would best represent each depth at specific correlation values (Table 2).

Table 2: Depth categories and taxa selected as the best representatives for each depth assemblage at the specified correlation value.

Depth Category (m)		Correlation Value	Taxa Selected
Shallow Stations	0 - 20	0.958	amphipods, *Saduria entomon*, *Saduria sabini*, shrimp
Mid-Depth Stations	21 - 100	0.8	*Hyas* spp., shrimp, *Leptasterias* spp., *Urasterias* spp., *Psolus* spp., *Ophiura sarsi*, *Ophiocten* spp.
Deep Stations	101 - 220	0.955	*Ctenodiscus* spp., *Gorgonocephalus* spp., *Strongylocentrotus* spp., *Ophiacantha* spp., *Ophiura sarsai*, *Ophiocten* spp.

Our next step is to examine what environmental variables could be affecting the epibenthic community. Data on corresponding environmental variables were collected on the same cruise as the epibenthic data, by the Norcross lab and epibenthic sampling team. This data consists of sediment grain size, seafloor characteristics, bottom water characteristics (temperature, salinity, dissolved Oxygen), sediment chlorophyll a and sediment organic matter. A list of taxa present in the study area could aid potential future research in the area. Also, an objective of this project is to compare the results of this research with similar epibenthic community data from the Chukchi Sea.

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Project Related Presentations/Publications

Preliminary results were presented at the CMI review meeting in December of 2011 in Fairbanks Alaska and at the Alaska Marine Science Symposium in an oral presentation, which took place in Anchorage Alaska in January of 2012

Population assessment of snow crab, *Chionoecetes opilio*, in the Chukchi and Beaufort Seas including oil and gas lease areas

Dr. Bodil A. Bluhm
Dr. Katrin Iken

School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

Period of Performance: 06/01/2011 – 11/30/2014
Cooperative Agreement Number: M11AC00003

Project Overview

The snow crab, *Chionoecetes opilio*, is a widely distributed and abundant epibenthic species on the Bering and Chukchi Sea shelves, and at least into the western Beaufort Sea. While the Bering Sea stock is regularly surveyed and the stock characteristics and biology reasonably well known, knowledge about the crab stock structure in the Chukchi and Beaufort Seas is limited to abundance and biomass estimates for parts of the region and some aspects of the reproductive biology (Jewett 1981, Paul et al. 1997). The recent northward contraction of the species in the Bering Sea (Orensanz et al. 2004), the assumed biomass increase in the Chukchi Sea (Bluhm et al. 2009), and the increased interest in the Chukchi Sea for oil and gas-related exploration activities motivated this study.
Our specific objectives are (1) to estimate abundance and biomass and assess distribution of snow crab in the Chukchi Sea and Beaufort Sea lease sale areas and adjacent regions in relation to environmental variables, (2) to determine stock structure and reproductive potential, (3) to identify diet and trophic position, and (4) to compare our findings to the few available earlier studies in the study area. The material for this study was/will be collected during four cruises to the Chukchi Sea (2009, two in 2010, 2012), and two cruises to the Beaufort Sea (2008, 2011).

2011 Update

Field activities
We spent the summer preparing for and participating in the BeauFish 2011 cruise. Just before the cruise, Bluhm visited the ADF&G office in Kodiak to get training from snow and tanner crab biologist, Laura Slater, and research coordinator for the westward region, Doug Pengilly. During the BeauFish cruise (16 August - 3 September 2011) a total of 79 stations were sampled onboard the Norseman II in the Alaskan Beaufort Sea between 70.22-71.85°N and 145.09-155.85°W (Figure 1). The following types of samples were collected (gear in parentheses): snow crab (otter and beam trawls), water samples for C and N isotopic signatures of the particulate organic matter to determined trophic level of crabs (CTD rosette Seabird model 33), sediment samples for C and N stable isotope signatures (double van Veen grab). Details on gear deployment are in Norcross' reports and details on numbers of certain samples types collected are in the cruise report.

Lab processing
In total, n=312 crabs from the Beaufort Sea (from 2008 and 2011 cruises) were processed for their body size, chela height (males), body wet weight, shell condition, sex, egg flap shape (as indicator of maturity stage for females), and clutch fullness. Stomachs of all crabs were dissected

and preserved for future stomach content analysis. Also in progress is the stable isotope work for snow crab muscle tissue and particulate organic matter from the 2011 cruise, which involves extraction of carbonates and lipids, re-drying and weighing tissue or folding filters for analysis. We obtained size, weight and sex data of an additional 86 crabs from the 2008 survey from K. Rand and L. Logerwell at AFSC/Seattle.

Results

Preliminary analysis of the combined 2008 and 2011 crab data show that *Chionoecetes opilio* is distributed across the western Beaufort Sea on the shelf and slope between about 40-470 m (Figure 1; 2008 data from Rand and Logerwell 2010). No *C. opilio* were found at shallow (< 40 m) stations. The central and eastern Beaufort Sea was only surveyed in 2011 and we found *C. opilio* exclusively on the slope (180-220 m) of the central Beaufort Sea. No *C. opilio* were found east of 147°30’ W. It is unclear if we detected an actual distribution barrier or if the observed pattern was related to the overall very low catches in the central and eastern regions. It is likely, however, that snow crabs are – if present – at least not very abundant on the central and eastern shelf. A total of five blue king crab specimens were found at a total of four deep locations (>180 m) during the 2008 and 2011 surveys combined (Figure 1). These are the first records for the area to our knowledge.

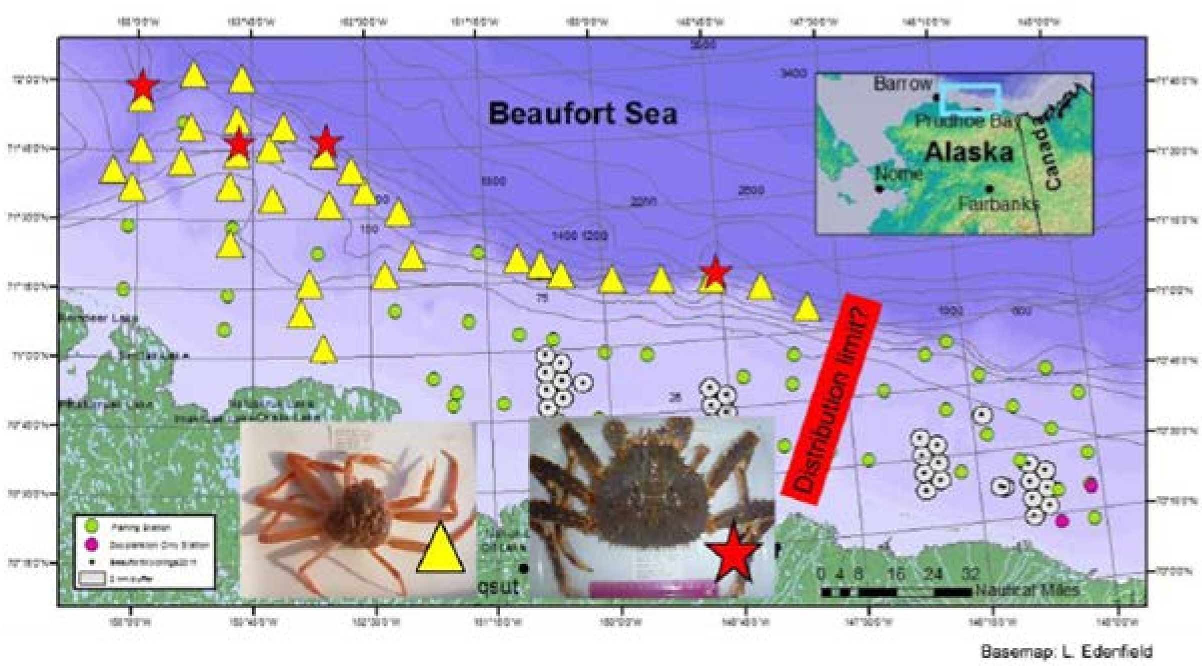

Figure 1. Stations sampled in 2008 and 2011 (green circles) with triangles marking *C. opilio* and stars marking blue king crab (details for 2008 in Rand and Logerwell 2010)

The combined 2008 and 2011 data reveal insights into the spatial segregation of male and female crabs as well as immature and mature crabs (Figure 2). Large males (>80 mm CW) only occurred at deeper than ~180 m. Mature females were only found deeper than 160 m (with one exception). Immature females and smaller crabs (to about 50 mm CW) were primarily found shallower than 200 m. The combined size-frequency-distribution of the 2008 and 2011 crabs

(Figure 3) shows that a large range of crab sizes occurs in the Beaufort Sea with about a third of the crabs larger than reported previously from the Chukchi Sea (~80 mm CW) (Paul et al. 1997).

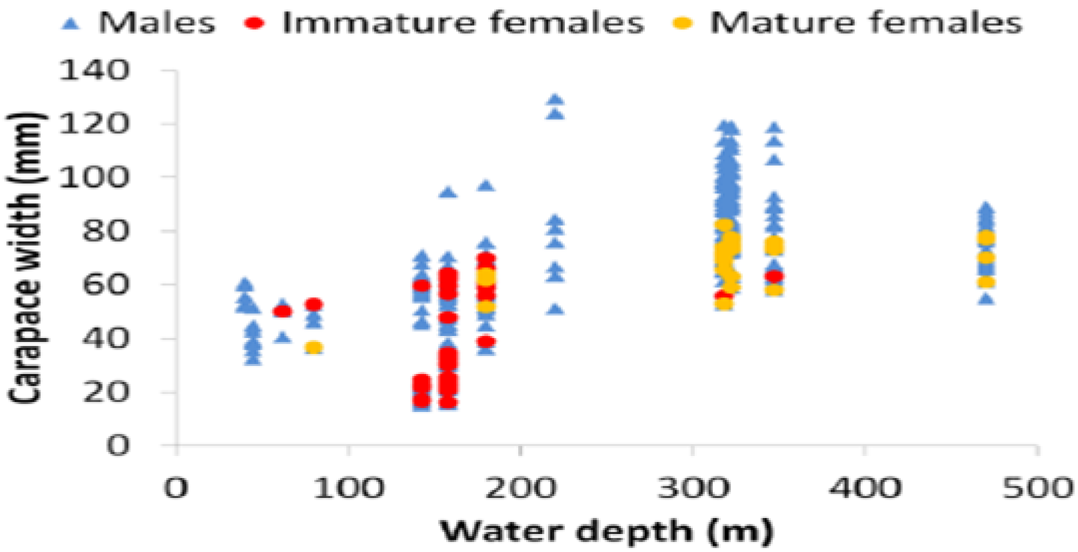

Figure 2. Distribution of *C. opilio* collected in the Beaufort Sea in 2008 and 2011 by water depth.

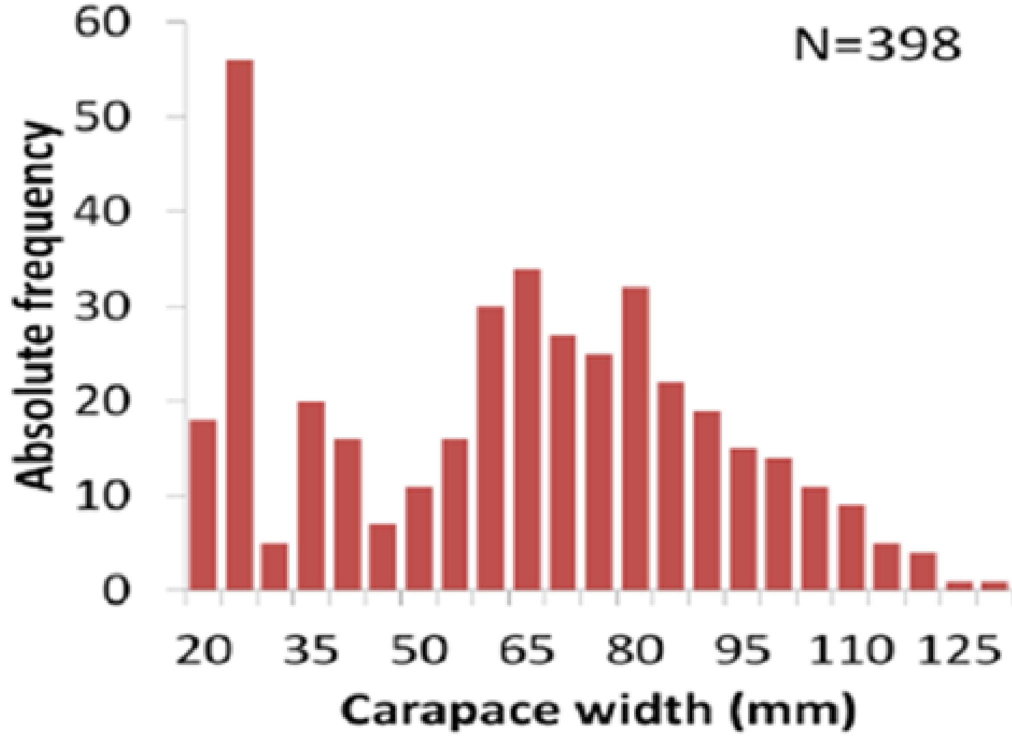

Figure 3. Size-frequency-distribution of Beaufort Sea *C. opilio* collected in 2008 and 2011.

The sex ratio in our sample of 398 crabs was skewed towards males with 80% males, 7% mature females and 13% immature females (Table 1). Part of that unequal sex ratio might be explained by gear selectivity and selective avoidance behavior during the rather slow trawling speed, or perhaps we did not sample areas that females prefer. Although the numbers of mature female *C. opilio* caught was overall low, their occurrence and the large size range of crab present in the region suggest that reproduction occurs in the region. Before the finding of large male and mature female crabs, it was assumed that Beaufort Sea crabs might be a 'dead end' of advected larvae from the Bering or Chukchi Seas.

Table 1 Minimum and maximum carapace width (CW) of n=398 *C. opilio* from the Beaufort Sea and proportions of males, mature and immature females caught.

	Males	Mat. F	Im. F
Min. CW (mm)	15	37	16
Max. CW (mm)	130	82	70
Total N	318	27	53
% of total N	80	7	13

Project team
Bluhm and Iken participated in the BeauFish cruise and performed all onboard tasks. They also conducted the data analysis of the 2008 and 2011 crabs, wrote reports and presented at the Alaska Marine Science Symposium and CMI Annual Review. During the fall semester, University of Alaska Fairbanks undergraduate Fisheries student Colton Lipka conducted size and weight measurements, dissected stomachs, egg flaps and spermatecae of preserved snow crab collected in the Beaufort Sea in 2008. University of Alaska Fairbanks Graduate Marine Biology student Lauren Divine processed the stable isotope samples collected from snow crab and particulate organic matter (POM) during BeauFish 2011.

Overall progress and troubleshooting
So far, the project is on schedule per the timeline in the proposal. The sample size reached for the Beaufort Sea is smaller than we had hoped for, which is probably related to low abundances in the region and (during the 2011 survey) short haul durations with relatively small gear, shallow maximum sampling depth relative to snow crab distribution, and slow trawl speed possibly resulting in avoidance behavior. As the results show, however, the data set is large enough to gain valuable insights on the population structure in the region. Also, the Beaufort Sea data set will be placed into the larger regional context once the Chukchi Sea crabs have been processed. In the next months, we will conduct the fecundity and trophic work for Beaufort Sea crabs, and begin to measure and dissect the Chukchi Sea crabs before collecting more materials during the RUSALCA cruise to the Chukchi Sea in Aug/Sept 2012.

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Project Related Presentations/Publications

Bluhm BA, Iken K. Population assessment of snow crab, *Chionoecetes opilio*, in the Beaufort Sea: preliminary findings. Alaska Marine Science Symposium, Anchorage, 16-20 January 2012 (poster)

Bluhm BA, Iken K. Population assessment of snow crab, *Chionoecetes opilio*, in the Chukchi and Beaufort Seas including oil and gas lease areas: First results. CMI Annual Review oral presentation, 29 Nov 2011

Divine LM, Iken K, Bluhm BA. Fitting snow crabs into benthic food webs in the central Alaskan Beaufort Sea. Alaska Marine Science Symposium, Anchorage, 16-20 January 2012 (poster)

Bluhm BA, Iken K. Population assessment of snow crab, *Chionoecetes opilio*, in the Chukchi and Beaufort Seas including oil and gas lease areas. Quarterly Reports Jul-Sept 2011, Oct-Dec 2011.

Bluhm BA, Iken K. BeauFish 2011 - Population assessment of snow crab, *Chionoecetes opilio*, in the Beaufort Sea. Cruise Report, Oct 2011

Bluhm BA, Iken K. Population assessment of snow crab, *Chionoecetes opilio*, in the Chukchi and Beaufort Seas including oil and gas lease areas. CD with over 20 digital images showing field work, lab processing, morphological characteristics of snow crab. Dec 2011, distributed to project officer Catherine Coon.

Biogeochemical Assessment of the North Aleutian Basin Ecosystem: Current Status and Vulnerability to Climate Change

Dr. Jeremy Mathis

School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

Period of Performance: 07/01/2008 – 12/31/2013
Cooperative Agreement Number: M08AX12760

Project Overview

Ocean acidification driven by absorption of anthropogenic carbon dioxide (CO_2) from the atmosphere is now recognized as a systemic, global process that could threaten diverse marine ecosystems and a number of commercially important species. The suppression of calcium carbonate ($CaCO_3$) mineral saturation states (Ω) brought on by the reduction of seawater pH could have potentially negative consequences from benthic and pelagic calcifying organisms and entire marine ecosystems. $CaCO_3$ suppression is most pronounced in high latitude regions, where mixing processes and colder temperatures naturally precondition the water column to have lower pH and Ω values compared to more temperate ocean environments. Of the greatest concern is the rate at which OA and $CaCO_3$ Ω suppression is progressing.

Our observations from the North Aleutian Basin Ecosystem (NABE) have already revealed areas of seasonal $CaCO_3$ mineral suppression and we have now expanded this study into the eastern Chukchi Sea. Aragonite undersaturation has been observed throughout the water column, while models project widening areas of aragonite undersaturation in the region during the next several decades. Potential negative effects on the abundant fisheries of the region could have negative consequences for the regional and national economy as well as subsistence communities in Alaska that rely on these fisheries as their primary source of protein.

2011 Update

In 2011, the synthesis effort continued, mostly lead by PhD student Jessica Cross who is making excellent progress towards here degree. She should defend her PhD and graduate sometime in 2013. A CMI funded post doc, Wiley Evans joined the group in 2011 and began working on this project. 450 new field samples were taken as part of the Fairweather cruises in the Chukchi Sea and this effort will continue during the summer of 2012. These new samples will allow us to expand our data synthesis into the potential oil and gas exploration regions and will be critical to our long-term understanding of the ecosystem. The project ran smoothly throughout 2011 and should continue that way into 2012.

Results

The biogeochemical assessment of the NABE and the Chukchi Sea has included repeat observations of the carbonate system of the Southeastern Bering Sea shelf northward to the Chukchi Sea shelf break, including seasonal observations of CO_2 gas fluxes, pH, and $CaCO_3$ Ω

as well as quantification of annual net community production (NCP). We have found a number of factors that naturally influence the carbonate system. Most control is annually exerted by NCP via the Phytoplankton-Carbonate Saturation State (PhyCaSS) Interaction, although the species composition of these blooms, the annual formation and melt of sea ice, the seasonal discharge of river waters, the penetration of basin waters onto the shelf, and seasonally cycling sea surface temperatures have also been shown to modify the carbonate system. We have also shown that none of these natural controls or any observed combination thereof would produce seasonal undersaturations of carbonate minerals without the influence of anthropogenic CO_2. Each of these natural controls, as well as OA is discussed further below, and summarized in Figure 1.

1. NCP and the PhyCaSS Interaction. On the Eastern Bering Sea Shelf, a biologically-driven seasonal divergence in pH and Ω is observed between surface and subsurface waters. During the spring phytoplankton bloom, high rates of NCP remove ~30 – 200 μmol CO_2 kg^{-1} from the surface waters, which increases pH and Ω values by ~0.1 and ~1, respectively. However, the vertical export of organic matter and its subsequent remineralization in bottom waters induces a significant build-up of CO_2 in bottom waters at depth, which suppresses both Ω and pH. This process has also been observed in other high-latitude seas, and is likely typical of highly productive polar and sub-polar continental shelves. The PhyCaSS interaction is most obvious through the Central Front, where NCP and bottom water Ω suppression is highest (40-50 mmol C m^{-2} d^{-1} and -0.35, respectively). Here, unique fluid flows mix bioavailable iron and nutrients to the surface and trap phytoplankton populations in an idealized production regime. In other areas of the shelf, limited macronutrient supply (inshore of the central front) and micronutrient supply (seaward of the central front) limit production. We also expect that during cold years, when export production is greater relative to warm years, the PhyCaSS interaction will be more active.

2. Species Composition of Phytoplankton Blooms. While normal phytoplankton production is dominated by diatoms for most of the production season, satellite imagery as well as widespread depletion of Total Alkalinity (TA) relative to salinity between summer and fall indicated a coccolithophore bloom over the Bering Sea Shelf. Coccolithophores form a hard skeletal exterior from calcium carbonate—which reduces the availability of this mineral in the water column and leads to surface layer suppression of $CaCO_3$ Ω. We estimate that the removal of ~80 umol TA kg^{-1} due to marine calcification processes could cause a 150 atm increase in the partial pressure of carbon dioxide (pCO_2) and a 0.5 to 1 decrease in $CaCO_3$ Ω. However, the concurrence of CO_2 consumption via primary production also increased saturation states at the surface layer, and no surface layer undersaturations were observed.

3. Sea Ice. The ~1700 km advance and retreat of sea ice over the Bering Sea Shelf is the largest of any of the Arctic or Sub-arctic regions, making it a significant source and sink for freshwater over the shelf. In addition to impacting hydrographic structure (i.e., formation of the cold pool), sea ice also impacts the carbonate system. Ice cores collected in 2009 exhibited both calcite and aragonite undersaturations, indicating that the melting of these waters will also produce carbonate mineral suppression at the surface layer. Like coccolithophore production, however, the simultaneous activity of ice-edge blooms prevents the occurrence of net suppression.

4. River Discharge. Freshwater discharges from the Yukon and Kuskokwim rivers naturally have a particularly low Ω for two different reasons. When river discharge rates are relatively low

CO_2 concentrations are highest and the shelf is covered with sea ice. This prevents outgassing at the air-sea interface, maintains supersaturation, and suppresses pH and Ω. When river discharge rates are highest, the naturally low TA of these river waters effectively causes the greatest dilution of shelf TA, which suppresses pH and Ω. Seasonally, these effects are seen particularly at the nearshore. Depending on the total volume of discharge and other hydrographic variables, this suppression can be confined to the very nearshore, as was observed with normal discharge volume in 2008; in 2009, high discharge caused the plume to expand and mix with a greater volume of shelf waters, and the influence of river water was more dilute, although it impacted a greater area; also in 2009, we observed an isolated pocket of river waters over the midshelf, indicating export of these river waters by another physical process, such as winds. When most concentrated, we have observed that Ω values are suppressed by approximately 0.1.

5. Penetration of deep basin water. Periodic upwelling events driven both by winds and by shoaling topography both occur over the Bering Sea Shelf near the shelf break, allowing deep basin waters rich in CO_2 concentrations to penetrate onto the shelf. The influx of these waters, which are naturally preconditioned to have particularly low Ω, reduce the Ω of shelf waters. These effects are the most noticeable in bottom waters near the shelf break and outer shelf, where proximity to basin waters is highest.

6. Temperature. Increased temperatures raise the partial pressure of carbon dioxide (pCO_2), promoting outgassing of dissolved CO_2 into the atmosphere, which in turn increases saturation states at the surface layer. These effects are particularly dominant over the southern region of the shelf, which may contribute to particularly high increases in surface layer saturation states observed in this region. Even in these southern regions, however, temperature induced outgassing event that cause saturation states to increase are certainly secondary to the increase in saturation states caused by the biogenic uptake of dissolved CO_2 in the surface layer. Temperature effects are only obvious in small, isolated areas around the Pribiloff Islands and in the extreme south.

7. Ocean Acidification. While these natural environmental processes play an important role in seasonal suppression of saturation states, without the anthropogenic CO_2 absorbed from the atmosphere, no undersaturation over the shelf would occur. We estimate based on the work of other researchers that the Bering Sea Shelf has absorbed ~35 umol kg^{-1} of anthropogenic CO_2 to depth. This has shifted Ω values for aragonite to undersaturated levels in broad regions across the shelf for several months each year, and calcite undersaturations were observed in 2009. These effects are particularly noticeable in the areas of strong PhyCaSS activity, and at the nearshore where river discharge effects are most noticeable.

The influx of runoff from the coast delivers waters with high pCO_2, low TA, and moderate concentrations of organic matter (OM). The high pCO_2 of the water creates a seasonal source of CO_2 to the atmosphere while reducing carbonate mineral saturation states. Offshore, the upper water column is dominated by sea ice melt in late spring and summer. This creates a highly stratified surface layer where primary production is controlled by the confluence of coastal waters rich in micronutrients and basin water replete in macronutrients. Seasonally high rates of NCP lead to a rapid drawdown of CO_2 at the surface creating a strong seasonal sink for atmospheric CO_2. In 2009, a coccolithophore (Cocc.) bloom was observed in the intermediate shelf waters and lowered TA concentrations at the surface. The varying degree of export production at the surface determined the amount of remineralization that occurred at depth which ultimately controlled saturation states. This PhyCaSS interaction can be observed to varying degrees across the shelf.

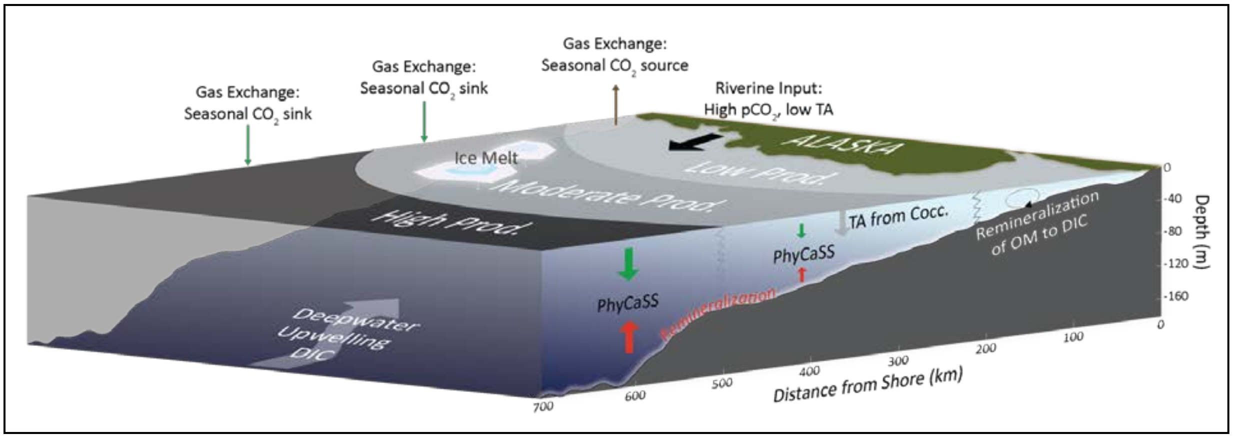

Figure 1. Generalized description of the processes affecting the carbonate chemistry of the eastern Bering Sea shelf.

Project Related Presentations/Publications

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Cross, J.N., and Mathis, J.T., 2011. Controls on Carbonate Mineral Saturation States and Ocean Acidification on the Southeastern Bering Sea Shelf. Woods Hole Oceanographic Institution Ocean Carbon Biogeochemistry Workshop, Woods Hole.

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Mapping and Characterization of Recurring Polynyas and Landfast Ice in the Chukchi Sea

Dr. Hajo Eicken
Dr. Andrew Mahoney

Geophysical Institute
University of Alaska Fairbanks

Period of Performance: 05/07/2009 – 11/06/2012
Cooperative Agreement Number: M09AC15191

Project Overview

This project is the continuation and extension of an earlier project with the same title. The first project (AK-03-06, MMS-71707, active from 2004-2006) was confined to the Beaufort and eastern Chukchi Sea and the time period 1993-2004. The current project extends the study area to cover the entire Chukchi Sea and covers the years 1993-2008 and when complete, will supersede the first project. The aim of this continuing study is to map and document the spatial and temporal distribution of recurring lead systems, coastal polynyas and landfast ice in the Beaufort and Chukchi Seas. The study region encompasses the entire northern coast of Alaska and parts of the Russian and Canadian coasts (as illustrated in Figure 1). This includes oil and gas leases sold in 2008 for which sea-ice information is lacking. The region and its sea ice cover are also of importance to protected marine mammals and birds. Dramatic reductions in Arctic summer sea ice extent since 2005 lend urgency to the need for improved knowledge and understanding of the physical sea ice environment in this region of the Arctic.

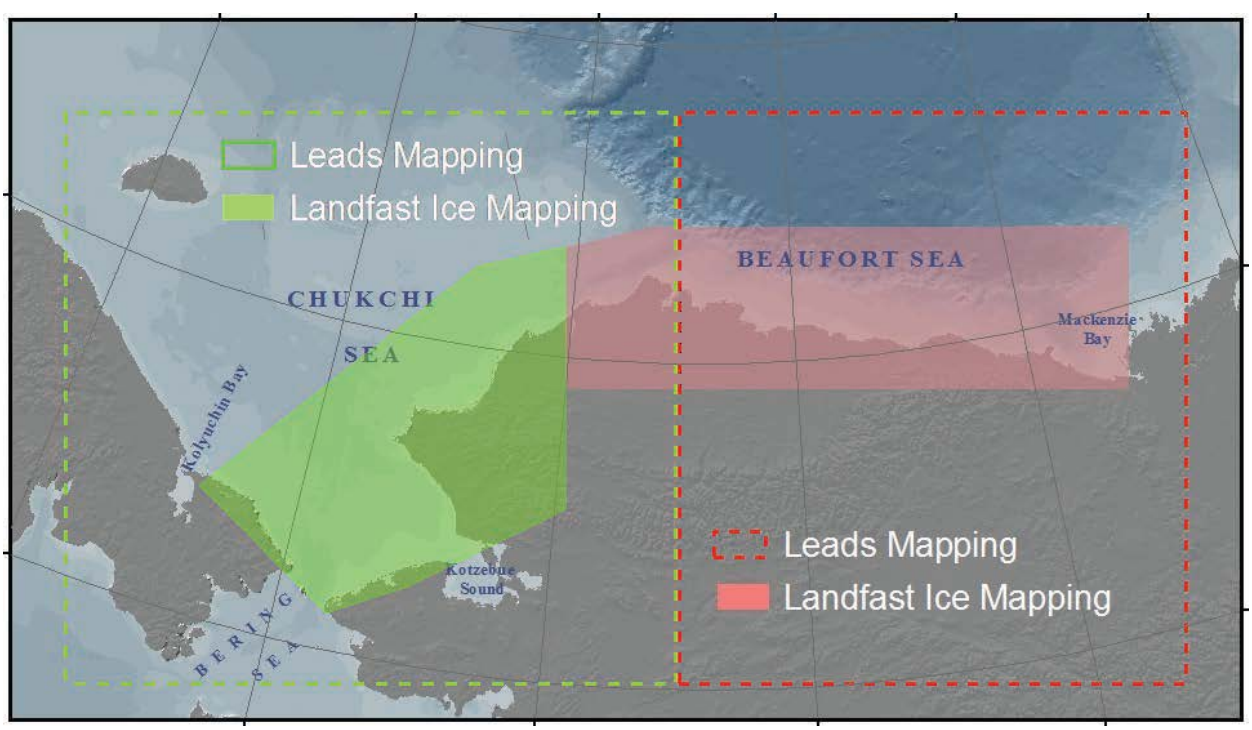

Figure 1. Map showing complete study area for this project with the different subregions for the landfast ice mapping and leads mapping components.

The methods we use for mapping and characterizing leads and landfast sea ice were developed during the first iteration of this project. The full description, final report and summary data for the first project are available at http://mms.gina.alaska.edu. We identify landfast ice by analyzing sequences of mosaic Radarsat Synthetic Aperture Radar (SAR) imagery and identify regions of ice that are 1) adjacent to the coast and 2) remain stationary for a period of approximately 20 days. We identify leads using Advanced Very High Resolution Radiometer (AVHRR) data. Our lead analysis approach combines a qualitative assessment of characteristic patterns with a quantitative analysis of the size, orientation, location and recurrence of individual leads. When the current project is complete, we will have analyzed mapped and characterized recurring leads within the study region for the period 1994-2008. The availability of Radarsat SAR data restricts the landfast ice analysis to the period 1996-2008, but we are also developing a technique using the Phased Array L-band SAR (PALSAR) radar sensor on the Advanced Land Observation Satellite (ALOS).

2011 Update

The project was impacted by the tragic and unexpected loss of Kevin Engle in March 2011. Kevin was chiefly responsible for processing and staging of AVHRR scenes and had been preparing the next step towards automated analysis of the AVHRR data catalog compiled as part of this project. Analysis and archiving of AVHRR data was delayed as new staff were brought into the project. We also encountered unanticipated complications acquiring SAR data that met our strict mosaicking and georeferencing needs. The amount of imagery we have ordered and our level of scrutiny exceeds that of most data users and as a result, our project identified problems that were new to the Alaska Satellite Facility (ASF). We worked with colleagues at ASF over the course of 2011 to overcome these difficulties, but the additional work required has created delays processing the data to map landfast sea ice extent. These delays were exacerbated by other commitments of the research team, which were more demanding than expected. As a result, we were granted a 4-month no cost extension on the project.

Lead Analysis

- Completed qualitative assessment of daily AVHRR data from 1994-2010, including characterization of recurring lead patterns and identification of clear sky imagery for quantitative analysis.
- Acquired complete set of co-located and calibrated clear-sky AVHRR imagery for quantitative analysis
- Ported lead-analysis software from recently-unsupported NIHImage into ImageJ

Landfast Ice Analysis

- Ordered complete set of Radarsat SAR imagery for Chukchi and Beaufort study regions
- Generated mosaics and delineated seaward landfast ice edge (SLIE) positions in approximately 90% of SAR imagery (10 out of 12 seasons in the Chukchi region and 11 out of 12 seasons in the Beaufort region
- Successfully adapted SLIE analysis software tools from previous study to work with new study region

Preliminary Results - Leads Analysis
The key finding so far from the qualitative assessment of AVHRR data is that what we know about leads patterns in the Beaufort Sea cannot be transferred directly to the Chukchi Sea. Unlike in the Beaufort Sea, sea ice in the Chukchi Sea appears to be almost always unconstrained and easily put into motion. This results in a much greater variety of lead patterns, each of which is typically shorter lived. Figure 2 exemplifies the typical contrast in lead patterns between the two seas. The sea ice in the Chukchi Sea contains numerous intersecting leads where as the Beaufort Sea has fewer, segregated leads. The flaw leads along the Alaska Chukchi coast are indicative of the prevailing northeasterly winds, but small variations in wind direction can lead to significantly different lead patterns. Figure 2 also shows polynyas associated with deep-keeled ice grounded in the shallow water of Hanna and Herald shoals. These are important features of the Chukchi Sea that can influence lead patterns and there are no similar features so far offshore in the Beaufort Sea.

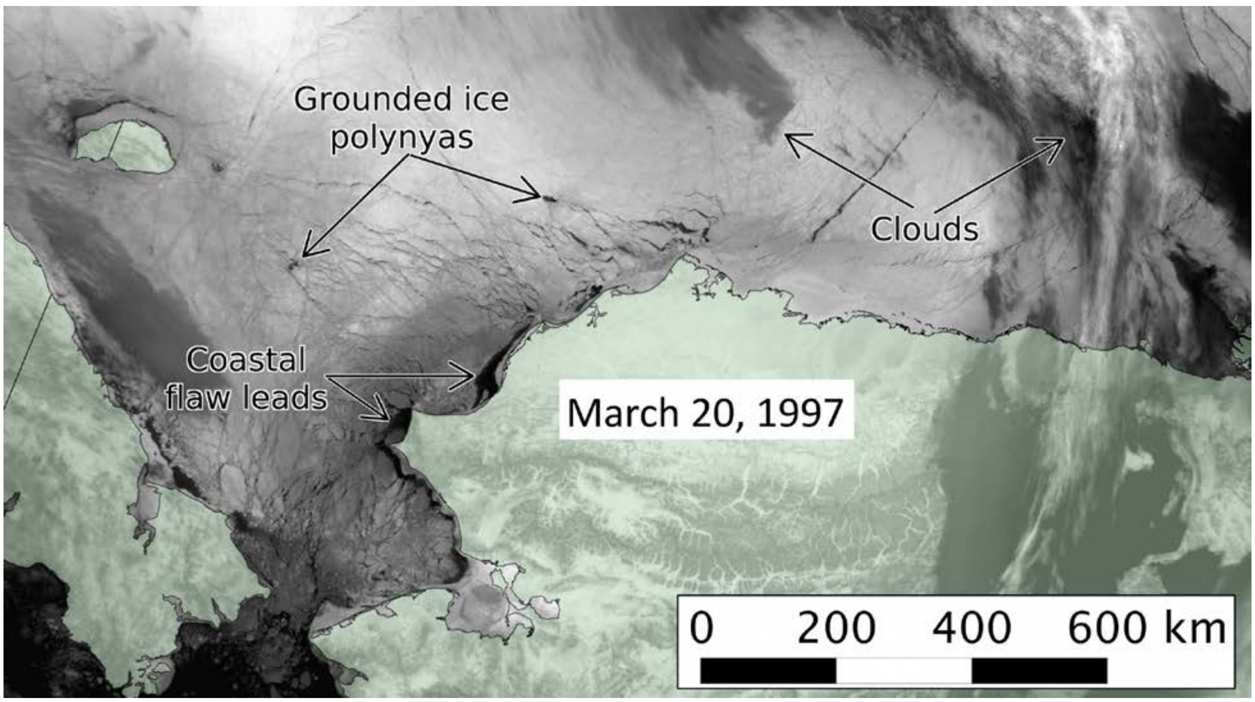

Figure 2. Thermal AVHRR (channel 4) image showing leads patterns in the Chukchi and Beaufort Seas. Bright pixels indicate warm openings in the ice, except those associated with clouds, as indicated.

The features responsible for the grounded ice polynyas shown in Figure 2 are too small to be observable in the AVHRR imagery, but their presence can be inferred from the polynyas they create. As part of the lead pattern analysis, we have also noted the date on which these polynyas can first be identified each year. Figure 3 shows evidence that ice is grounding on Hanna Shoal later in recent years. This finding may be related to the overall thinning of Arctic sea ice, caused in large part by the loss of the oldest and thickest floes from this region.

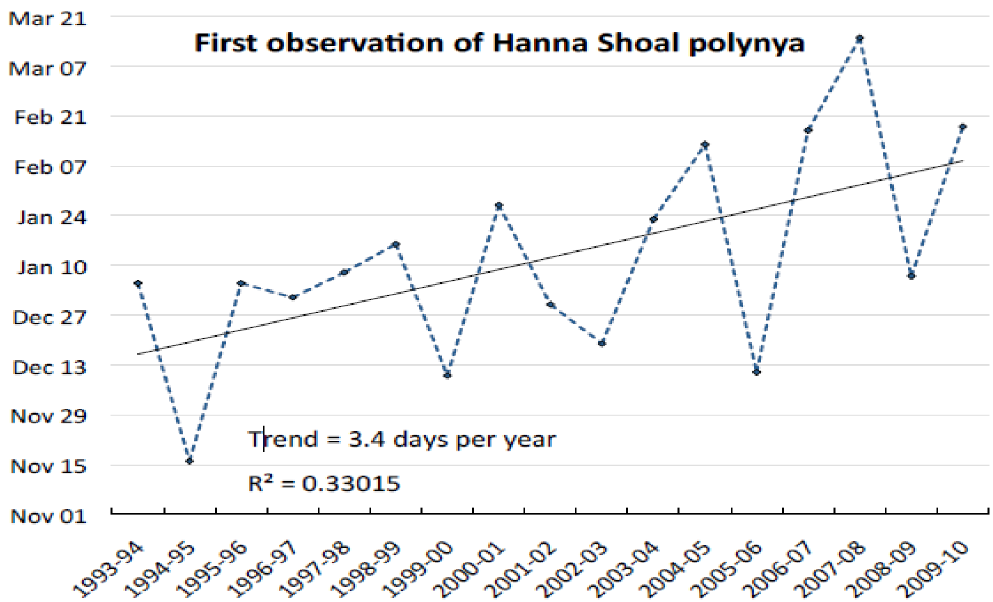

Figure 3. Dates of first observation of the Hanna Shoal polynya.

Preliminary Results - Landfast Ice Analysis

Based on analysis of the SLIE data generated so far, we have replicated the analysis of landfast ice from the previous project for both study regions. The complete analysis will be presented in the final report, due in draft form on March 31, 2012. In the interim, we present some summary plots, which highlight the similarities and differences between the two study regions. For example, Figure 4 shows the mean annual cycle of landfast ice advance and retreat in the Chukchi and Beaufort study regions. The shape of the annual cycle is similar in both regions, with a gradual advance and rapid retreat. However, the mean landfast ice width along the Beaufort coast is approximately three times that along the Chukchi coast.

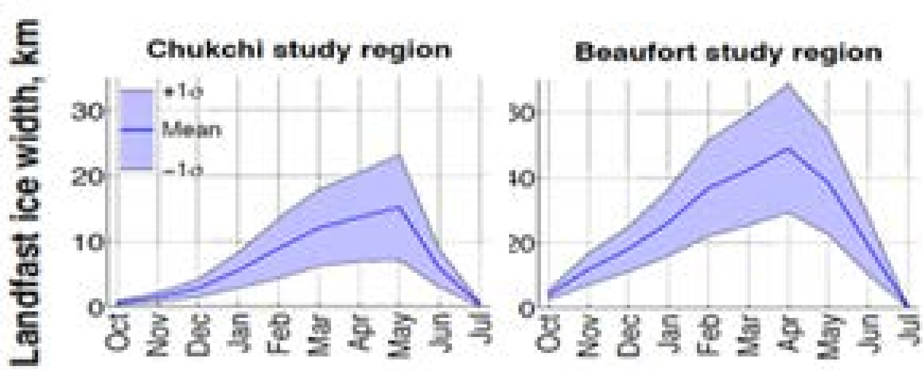

Figure 4: Mean annual cycle of landfast extent in the Chukchi and Beaufort study regions.

Figure 5 shows the minimum, mean and maximum landfast ice extent during March, when landfast sea ice extent is usually greatest. It is notable that the 20 m isobath is a reasonable approximation of the mean SLIE location along the Beaufort Sea coast, but this is not the case in the Chukchi Sea. A more detailed analysis of water depth a t the SLIE location will be presented in the final report.

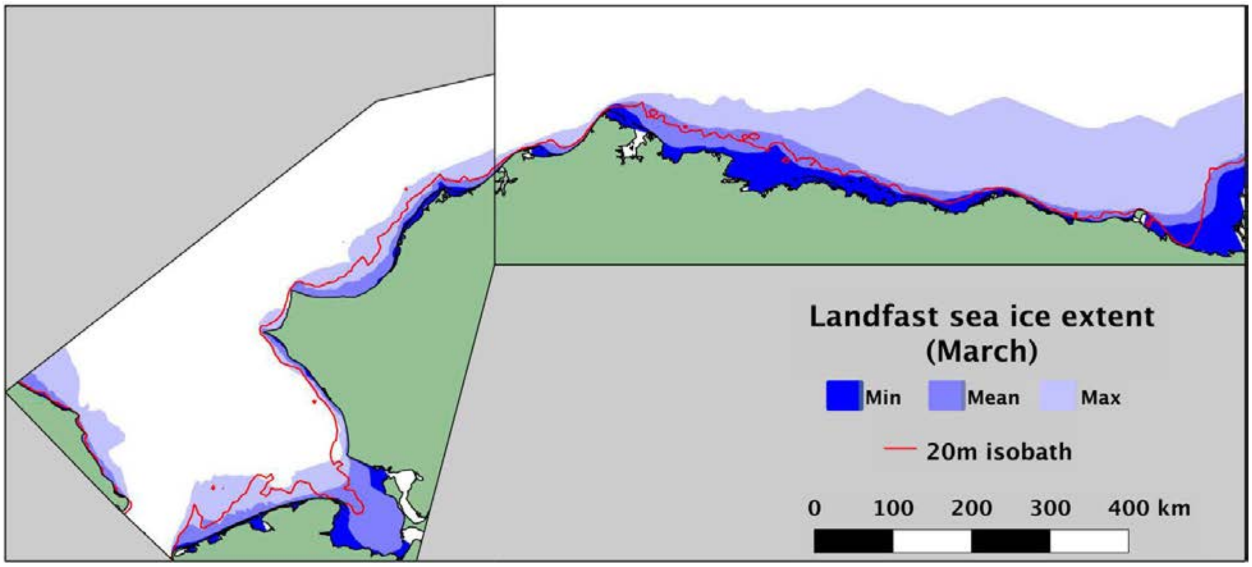

Figure 5: Minimum, mean and maximum landfast sea ice extent for the month of March, together with the location of the 20m isobath.

Project Related Presentations/Publications

Early preliminary results were presented at the 2011 Alaska Marine Science Symposium in Anchorage, Alaska. In addition, the following peer-reviewed paper was published presenting results of our efforts to find an alternative method to analyzing landfast sea ice extent in the absence of readily-available Radarsat SAR data after 2008:

Meyer, F. J., A. R. Mahoney, H. Eicken, C. L. Denny, H. C. Druckenmiller, and S. Hendricks (2011), Mapping arctic landfast ice extent using L-band synthetic aperture radar interferometry, Remote Sensing of the Environment, 115(12), 3029-3043

Subsistence Use and Knowledge of Beaufort Salmon Populations

Dr. Courtney Carothers
Shelly Woods (student)

School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

Period of Performance: 06/29/2009 – 12/30/2012
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Project Overview

The designation of the entire Outer Continental Shelf of the Beaufort Sea as Essential Fish Habitat for Pacific salmon populations combined with local observations of increasing numbers of salmon in subsistence fisheries has generated a need for more information about salmon use, distribution, and survival in the North Slope region. Ethnographic research conducted in Barrow and Nuiqsut with 32 expert fishermen and elders suggests that salmon are widely perceived to be more abundant in the region than in the past. Salmon are relatively less important as a subsistence resource compared to whitefish, char, and other fish species; however, many fishermen participating in the growing Elson Lagoon gillnet fishery near Barrow are beginning to target salmon, particularly the commonly caught chum salmon (*Oncorhynchus kata*) and the occasionally caught Chinook salmon (*O. tshawytscha*). New stream systems east of Barrow have been positively identified to have pink (*O. gorbuscha*), chum, and Chinook salmon presence and potential spawning sites. In both study communities we found that active and knowledgeable fishermen consistently misidentify salmon at the species level, and in Nuiqsut in particular there is conflation of salmon and char species. Some fishermen have become interested in salmon identification and are using guides to differentiate the fish caught in their nets. Expert fishermen in both communities reported developing new knowledge of salmon and are increasing their use of salmon as a subsistence resource.

As local ecological factors are changing in this region, local elders and fishermen are among the most knowledgeable sources of information concerning salmon distribution. This study documents the historic and current importance of salmon as a subsistence resource and also contextualizes salmon among the suite of subsistence resources in this region. Interviews for this project have taken place in Barrow and Nuiqsut. Discussions of subsistence harvest areas and observations have spanned across the North Slope region. The specific tasks and objectives of this project are to:

(1) Establish strong rapport with local community residents and regional experts.
(2) Document the current subsistence use of Beaufort Sea salmon populations in Barrow and Nuiqsut.
(3) Document the local and traditional ecological knowledge of historic and recent trends in salmon use, abundance, and distribution in the North Slope region.
(4) Better understand the Iñupiaq context for ecological observations and appropriate uses of such knowledge.
(5) Use spatial and ethnographic data to identify streams and coastal areas where salmon have been harvested or observed.

2011 Update

In 2011, we continued to build relationships with community residents and experts, finalized our ethnographic data collection in Barrow and Nuiqsut, completed our qualitative data analysis and thematic coding in Atlas.ti, and are composing our draft ethnographic data report. We are also preparing maps that summarize ethnographic and spatial data of reported salmon catches and occurrences.

The research team interviewed informants in Nuiqsut from March 14-18, 2011. We interviewed 12 active fishermen and elders (4 women and 12 men) and also had a group interview with 3 younger fishermen (ages 25-40). We presented our project and attended the Kuukpik Subsistence Oversight Panel (KSOP) board meeting. We received verbal support from the board to conduct our research. During our visit in the community, we were able to take a drive on the ice road to view fish camp locations along the Nigliq Channel. No fishing activity was occurring at this time. Shelley Woods and a graduate assistant were able to attend two *Nalukataqs* in the community of Nuiqsut and conducted follow-up ethnographic research from June 20-26, 2011. We were invited to travel to a fish camp on the Itkillik River to observe fishing practices, but mechanic problems with the boat engine and low water levels in the Colville River prevented this trip. Shelley Woods held an internship with the North Slope Borough Department of Wildlife Management from July 14-August 17, 2011. Although she was conducting supplementary research for her M.S. degree and thesis, this position provided her an opportunity to continue to build rapport with Barrow fishermen and regional partners. The PI conducted follow up ethnographic field research and participant observation in Barrow from August 15-20, 2011 in Barrow. We were able to observe numerous subsistence fishing activities in Elson Lagoon during this time.

All of the Barrow and Nuiqsut interviews have been transcribed (and translated as necessary) and analysis for thematic content in Atlas.ti. A GIS consultant has been hired to assist with map generation.

The research team continues their collaboration with the Alaska Department of Fish and Game (ADFG). ADFG researchers are conducting a project of similar scope in the communities of Wainwright and Point Lay. We have shared initial findings and are working together to incorporate our research findings to provide an overall assessment of knowledge about, and use of, salmon species across the North Slope.

Preliminary Results and Discussion

Introduction

While the political dimensions of global climate change continue to produce debate, a scientific consensus has emerged that temperature global temperatures are increasing with particularly dramatic impacts predicted for arctic ecosystems (Ford and Furgal 2009; ACIA 2005). Arctic regions have experienced the most pronounced warming trends in recent decades. Since the 1950s, mean annual temperatures have risen by 2 to 3°C, and winter temperatures have risen by 4°C (ACIA 2005). Temperatures are predicted to rise by another 5 to 8°C by 2100 (Leiserovitz et al. 2006). Warmer temperatures are causing permafrost melting, a reduction in summertime sea ice extent, decreasing sea ice thickness, glacial retreat, increases in precipitation, decreases in the length of snow cover; one global model predicts a completely ice-free arctic in the summertime by 2011 (ACIA 2005). The effects of climate change on fisheries in the arctic are multiple (Schrank 2007). Warmer conditions in the Bering Sea and increases in food sources are predicted to extend the range of habitat suitable for Pacific salmon species northward, but large oceanic weather patterns and cycles may also create unfavorable conditions during some years (Ruggerone et al. 2007; Moss et al. 2009).

The global phenomenon of climate change and the regional intensity of change in the arctic is experienced at local scales. In the Iñupiat communities of the Arctic Slope, people share a close connection with the land which spans biophysical and spiritual aspects. Weather patterns are studied closely by the Iñupiaq so that hunting, fishing, and food gathering can be done effectively and safely. Predictability of weather patterns and other natural patterns such as ice conditions and resource distribution are important for survival and the persistance of practices. The shifts brought about by climate change have important implications for the persistance of subsistence practices in the arctic (Reidlinger 1999; Leiserovitz et al. 2006; Schrank 2007; Eisner et al. 2009; Ford 2009).

This project explores local perceptions of climate change with a particular focus on recent shifts in subsistence salmon fisheries. In the past, traditional ecological knowledge (TEK) of fish species has rarely been documented, or if documented is not readily available. Biological data on anadromous fish species has been collected across the North Slope region and has been used by to guide development and resource protection in specific areas. The continued documentation of TEK resources makes an invaluable contribution to the state of knowledge about salmon and other fisheries in the region, as well to the understanding of the importance of subsistence fisheries to Iñupiaq people (Brewster et al. in review).

Methods

We analyzed our ethnographic interview data with a codebook (Table 1). Strikingly the most commonly occurring specific code in our interview data was "non-salmon species," reflecting the cultural salience of other fish species in the region. Salmon species, while emerging as an important subsistence resource for some fishermen in Barrow and Nuiqsut, still remain a relatively minor fishery in these communities. Expert fishermen in both communities reported developing knowledge of salmon and are increasing their use of salmon as a subsistence resource. We provide examples sections summarized in our developing ethnographic data report below.

Salmon Abundance

Pink Salmon

While the experiences of fishermen we interviewed are varied based on their level of fishing effort, location of their nets, and many other social and environmental conditions, informants in both Barrow and Nuiqsut generally agree that salmon catches have increased over the last 10 to 15 years. Some elders remember catching salmon when they were young, and others consider

Table 1: List of codes and counts of occurrences in qualitative interview data.

Primary Code	Specific Code	Number of Occurrences
Salmon Knowledge	Abundance	91
Salmon Knowledge	Identification	65
Salmon Knowledge	Geographic Distribution	59
Salmon Knowledge	Run timing	59
Salmon Knowledge	Spawning	41
Salmon Knowledge	Species interactions	2
Salmon Use	Gear	66
Salmon Use	Fishing locations	139
Salmon Use	Fish processing	29
Salmon Use	Sharing	48
Salmon Use	Selling	21
Salmon Use	Preparation	43
Salmon Use	Preferences	59
Salmon Use	Cultural transmission	16
Salmon Species	Pink	66
Salmon Species	Chum	76
Salmon Species	Sockeye	18
Salmon Species	Coho	27
Salmon Species	King	58
Fishing	Subsistence fishing	44
Fishing	Fish quality	14
Fishing	Learning	18
Fishing	Fish camp	62
Fishing	Non-salmon species	159
Fishing	Motivation	78
Fishing	History	115
Fishing	Unusual species	22
Environmental Change	Erosion	16
Environmental Change	Weather change	35
Environmental Change	Water levels	21
Environmental Change	Permafrost	3
Environmental Change	Ice conditions	16
Environmental Change	Travel	15
Environmental Change	Outside information-climate	7
Environmental Change	Break-up	19
Environmental Change	Freeze-up	16
Environmental Change	Access to resources	21
Environmental Change	change normal/no change	12
Socioeconomic	High cost of subsistence	13
Socioeconomic	Development	42
Socioeconomic	Jobs, employment	12
Cultural	Youth	39
Cultural	Lifestyle change	43
Cultural	Iñupiaq	17
Cultural	Gender	8
Cultural	Elders	47
Cultural	Spirituality/prophesy	8

salmon to be a new migrant to the region. One elder stated that it was in the late 1940s that her family "first saw that salmon come up this far" (just east of Barrow). She noted that her parents had no knowledge about these kinds of fish, but they did eat them when they first encountered them. Several elders in Nuiqsut mention not knowing what to call salmon because neither they, nor their parents had had experience seeing, catching or eating salmon (see *Species Identification* below). Two active fishermen in Barrow said that they do not remember catching salmon in the 1970's when they first embarked on setting gillnets in the Elson Lagoon area although both noted that they were not paying close attention to species in those days. As one informant noted, "I wasn't up on fish."

Several elders confirmed in our interviews that pink salmon have been caught along the North Slope for as long as they can remember. Decades earlier, elders also confirm pink salmon presence, but not preference. Brewster et al. (in review) report that elders note that pink salmon were not targeted traditionally, and if caught were not used. In the Elson Lagoon gillnet fishery in Barrow, pink salmon catches appear to be increasing overall, but follow an even year cycle. During our interviews in 2010, several informants stated over the past couple of year pink salmon were too abundant and clogged their fishing nets. One fisherman stated that fishing conditions have "… gotten to the point where there's too many pinks to deal with." Another noted: "we get more of the humpies (pink salmon), a lot of the humpies, and last two years there's been mostly humpies." The catch rates of pink salmon were also noted to be high in 1980s when the gillnet fishery was developing.

In Nuiqsut, informants note that a high abundance of pink salmon that also appears to cycle every two or three years. Informants note that there are thousands of pink salmon during years when they are running. Some fishermen catch pinks on a regular basis while others note only an occasional catch (often dependent on the timing when fishing nets are set). Nuiqsut fishermen utilize a broad fishing region spread out over many rivers and channels. One elder fisherman posited that pink salmon were driven from the Itkillik River in the 1950s due to development in that region. This coincides with what another fisherman said about the same river, that there is now "…beginning to be a lot of pinks, especially on the Itkillik River" and the fish may be returning to an area in which they used to be seen regularly. One informant with a fish camp at the mouth of the Itkillik River said that thousands of pink salmon started showing up in the Itkillik only about five years ago.

Chum Salmon

Chum salmon are a consistent source of protein and many are caught throughout the summer and fall in Barrow. During the peak of the chum run there can be approximately 30 chums per net per day caught in gillnets in Elson Lagoon near Barrow. In Nuiqsut, however, the presence and abundance of chum salmon is less certain (see also *Species Identification*). An elder informant, for instance, does not remember catching chum salmon when he was young fishing at fish camps along the Colville River. Several other informants confirm that chum salmon are a relatively recent migrant to the Colville and Itkillik systems. A middle-aged fisherman stated that he used to catch a lot of chum when he was younger in the 1970's and 1980's but they are declining now. A young fisherman in his 20s recollects catching more salmon today than when he was younger. These observations suggest that the abundance of chum salmon in the Colville River have been variable over the past few decades.

Chinook Salmon

In Barrow, there has been a lot of discussion about increasing catches of king salmon. Our informants note that the first king was caught in Barrow between 10 and 20 years ago. One informant stated that a fisherman from Southeast Alaska was the first to catch a king salmon on a fishing rod. Some locals have also started fishing for kings with fishing rods. Another informant noted that he caught two king salmon in 1992 that were over both 4 feet long. One very active informant stated that he caught his first king salmon in 2002 or 2003, and has only caught one other king since. He noted that he mistook his first king salmon for a seal before he pulled in his net. He needed to use a harpoon to get the huge king salmon out of his net and into his boat. Another informant stated that the caught a 98 pound king salmon at Elson Lagoon.

The North Slope Borough, Department of Wildlife Management data (Bacon et al. 2009) note, and our informants confirm that 2003 was a notable year for king salmon abundance. Bacon et al. (2009) report 229 king salmon caught in Barrow during that year. Informants note that year was an anomaly. During most seasons, informants report that each fisherman who catches one or two kings is considered lucky, whereas in 2003, every two to three days fishermen were consistently catching two or three king salmon. Informants in both Barrow and Nuiqsut state that they catch very few king salmon. One Barrow informant noted that he has observed a cycle of king salmon abundance (about every three years according to his estimation). During a good king year, he catches about a dozen king salmon total. As discussed below, species misidentification is widespread in both Barrow and Nuiqsut. During our observation of local fisheries we noted several occasions of large chum salmon, approximately 30 inches in length, called "king" salmon by local fishermen.

Sockeye & Coho Salmon

Because of the species identification issues described below, we were not able to generalize about sockeye and coho salmon species. George et al. (2009) report that sockeye salmon are uncommon in Barrow, but appear to be increasing in recent years. Coho salmon are the rarest of all Pacific salmon in arctic waters (Stephenson 2006). Stephenson (2006) reports only two confirmed coho captures in the Canadian arctic waters (one reported by Babaluk et al. 2000 captured in 1987, and one captured as part of Stephenson's study in 1998), concluding these to be strays. George et al. (2009) note only a few recorded catches of coho salmon in Barrow. Craig and Haldorson (1986) note occasional coho salmon presence near Prudhoe Bay. The continued reporting of "silver" salmon caught in subsistence fisheries in both the US and Canadian Arctic in current reports is problematic (e.g., NPFMC 2009). We recommend future reports reclassify "silver" salmon counts as "unidentified species."

Geographic Distribution

Pink Salmon

East of Barrow, the Ikpikpuk River, Fish Creek, Judy Creek, and the Colville, Itkillik, Sagavanirktok (including West Channel), Staines, West Canning, and Canning rivers are confirmed to have pink salmon presence in the Anadromous Waters Catalog (Figure 1). The Chipp, Ikpikpuk, Kuparuk, Sagavanirktok, Kavik Rivers are identified as spawning rivers for pink salmon (Figure 2). The Ikpikpuk River is also noted to offer rearing habitat to pink salmon. Nuiqsut informants confirm the presence and potential spawning of pink salmon in the Itkillik River. One informant with a fish camp at the mouth of the Itkillik River (where it feeds into the Colville), said that thousands of pink salmon started showing up in the Itkillik only about five years ago. He noted that they congregate in one spot and remain there (about 3-4 miles up the Itkillik River). One Nuiqsut informant noted that he saw pink salmon in the Chandlar and Anaktuvuk Rivers.

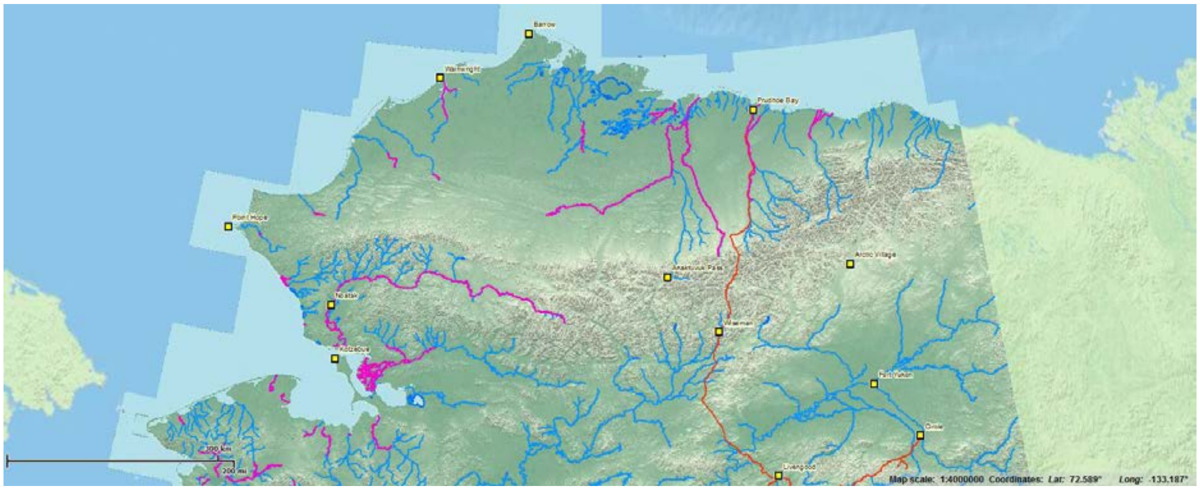

Figure 1. Map of North Slope Region showing stream systems with confirmed presence of pink salmon in pink. (Generated through Anadromous Waters Catalog, ADFG 2011).

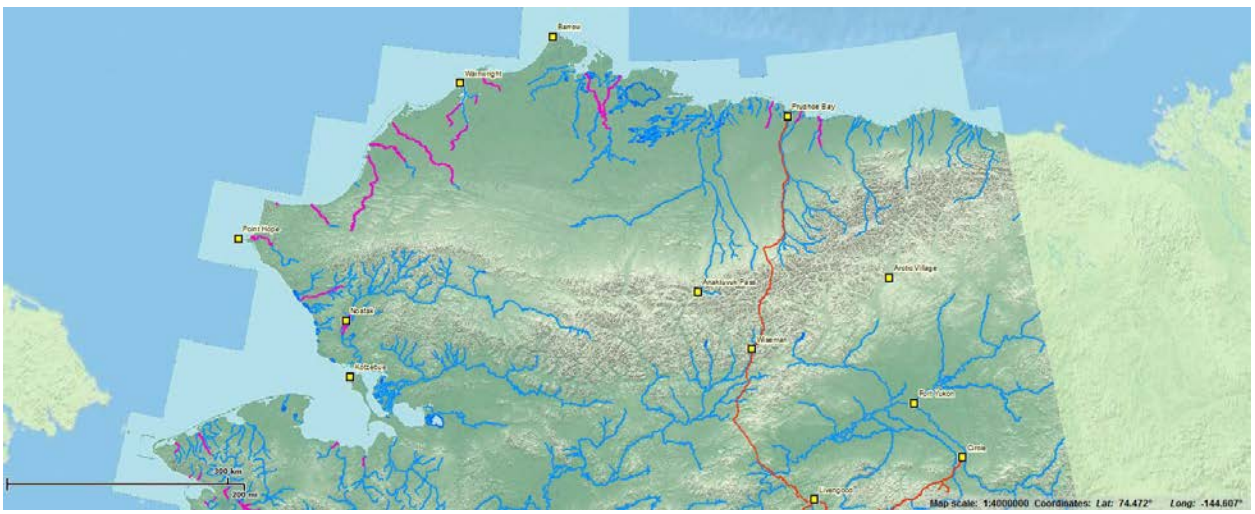

Figure 2. Map of North Slope Region showing stream systems with confirmed spawning of pink salmon in pink. (Generated through Anadromous Waters Catalog, ADFG 2011).

Chum Salmon

East of Barrow and north of the Brooks Range, the Chipp River, Ikpikpuk River, Fish Creek, Judy Creek, and the Colville, Itkillik, Sagavanirktok (including West Channel), Canning, Kongakut (and an additional unnamed stream west of Kongakut) Rivers are confirmed to have chum salmon presence in the Alaska Department of Fish and Game's Anadromous Waters Catalog (ADFG 2011; Figure 3). Chum salmon are confirmed to spawn in the Meade, Itkillik, and Colville Rivers (Figure 4). George et al. (2009: 34) note that chum salmon "likely spawn" in the Ikpikpak River. No chum salmon rearing areas have been identified. One of our informants noted catching one chum salmon in Ikroavic Lake (connected to Iko Bay via Avak Creek) while fishing in mid to late October just after the lake had frozen over. Nuiqsut informants confirm the presence and potential spawning of chum salmon in the Itkillik River and the presence of chum in Fish Creek.

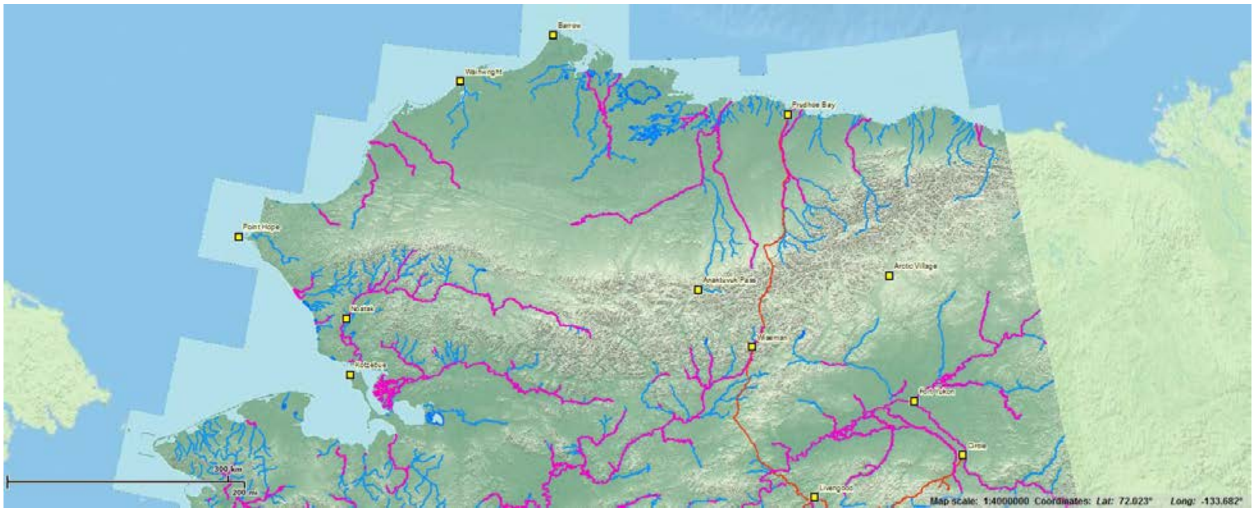

Figure 3. Map of North Slope Region showing stream systems with confirmed presence of chum salmon in pink. (Generated through Anadromous Waters Catalog, ADFG 2011).

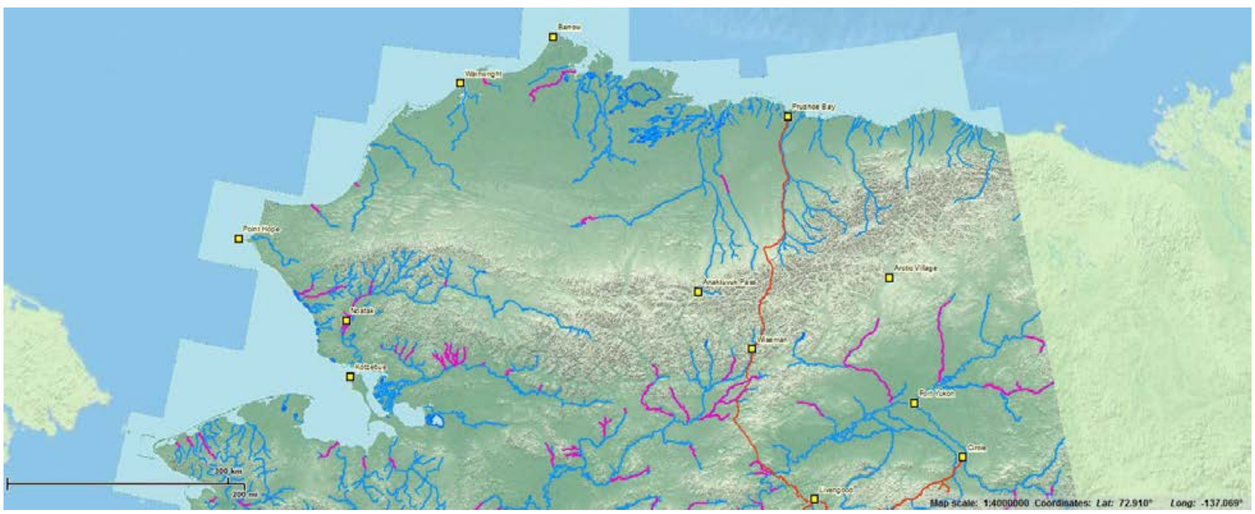

Figure 4. Map of North Slope Region showing stream systems with confirmed spawning of chum salmon in pink. (Generated through Anadromous Waters Catalog, ADFG 2011).

Chinook Salmon

East of Barrow and north of the Brooks Range, Chinook salmon have only been confirmed to be present in Fish Creek by the Anadromous Waters Catalog (ADFG 2011). No stream systems in this region have been noted on the catalog as spawning or rearing areas for Chinook salmon. George et al. (2009: 36) report a potential spawning population in the Kugrua River (Peard Bay). Several of our informants confirm that local knowledge suggests that king salmon have always passed through Peard Bay. One informant noted taking two Chinook salmon at the elbow point at Nuvuk. Another informant stated that he caught a 98 pound king salmon in Elson Lagoon. Nuiqsut informants note that rarely a king salmon will be caught in the Colville River.

Sockeye & Coho Salmon

The Anadromous Waters Catalog reports no streams in this region to have confirmed sockeye salmon presence, spawning or rearing. George et al. (2009: 37) note that sockeye salmon are locally believed to spawn in the Colville River. Several of our informants also noted that they had heard about occasional red salmon catches. One informant noted that he had heard about red salmon smolts in the Colville River area. One of our expert informants noted that he caught a red salmon in 2009 at Cape Simpson in Smith Bay. Given the widespread misidentification of salmon species in the region, this informant was careful to note that this fish was not a chum salmon as it was “totally different” than any other fish he had ever caught. “The meat was very red.” Several Nuiqsut informants noted catching red salmon, in conversation about occasional catches of ‘king’ or ‘silver’ salmon. One young Nuiqsut informant noted catching a sockeye salmon on a rod and reel on the Colville River near Ocean Point. The Anadromous Waters Catalog reports no streams in this region to have confirmed coho salmon presence, spawning or rearing.

Salmon, Undefined Species
Informants in both Barrow and Nuiqsut often talked about salmon generally without differentiating between species (see *Species Identification*). Occasionally in Barrow, and often in Nuiqsut, informants also groups salmon and char together in their discussion of geographic distributions. One informant noted that salmon and char will go up the Singaruak River (south along the coast from the Will Rogers and Wiley Post Memorial). Nuiqsut informants note taking salmon and char near Umiat (six to eight hour boat ride from Nuiqsut up the Colville River).

Salmon Identification
In both study communities we found that active and knowledgeable fishermen consistently misidentify salmon at the species level, and in Nuiqsut in particular there is conflation of salmon and char species. Recently, fishermen in Barrow have become interested in salmon identification. Prior to our study, some fishermen would communicate with the North Slope Borough (NSB) Department of Wildlife Management to help them identify what salmon species were caught in their gillnets. Through our participant observation of the subsistence gillnet fishery, we were able to examine several salmon in person at the fishing sites or view pictures taken of fish that could not be identified. One common identification error we encountered was informants tending to refer to chum salmon as “silver” salmon. Barrow fishermen are catching their fish in brackish water and the salmon are still a brilliant silver color. The calico appearance of chum spawning colors is usually faint when Barrow fishermen harvest them. Several informants also referred to large chum salmon as “king” salmon. We found that pink salmon were more often identified correctly because of the difference in size and the texture of their meat.

Some fishermen, however, have taken it upon themselves to have an identification key and keep a logbook with their catches so that the appearance of species may be recorded. Fishermen are often proud of the range of species identification that they can provide during an interview. One fisherman noted that “We’ve officially recorded every species incoming. I think all of them do get here.” As a collective fishing community, the fishermen have worked with the biologists at the NSB Department of Wildlife Management, the Native Village of Barrow, and the Alaska Department of Fish and Game to learn to distinguish between the species of salmon using pictures and by collecting age/sex/weight/length and genetics samples. We were asked by the Native Village of Barrow to provide ID cards for use by local fishermen. In addition to supplying these cards, we also provided identification tips to interested fishermen and gave a community lecture on salmon identification.

Not all Barrow fishermen are concerned with species identification. One of our informants who is identified locally as being an important fisherman, stated that "if they're not humpies I call 'em silvers, because they're silver… they all look the same to me." This fisherman is interested in getting as many fish as he needs to feed his family and to share with the rest of the community. Consistent with George et al.'s (2009) Iñupiat nomenclature, Barrow elders and knowledgeable fishermen tend to use two Iñupiaq names for salmon – *iqalugruaq* and *amaqtuuq*. We found our informants us *iqalugruaq* to refer to big silver salmon and *amaqtuuq* are the smaller pink salmon. George et al. (2009) note that *iqalugruaq* is a name also used for king salmon. It is unclear if Iñupiat elders differentiate these species; as noted above it is common for large coho salmon to be called king salmon in English. Other Alaska Native groups in Alaska have five (or more) names for different salmon species. The occurrence of only two names for salmon in this region illustrates that the Iñupiaq have not had much experience with the other three species that are now being caught in the region.

In Nuiqsut, when we first introduced the study to the Kuukpik Subsistence Oversight Panel, one of the members cautioned us that fishermen in Nuiqsut refer to char and salmon species with one name – *iqalukpik* (translated in George et al. (2009) as dolly varden char), so species level identification would likely be problematic. When asking a translator in Nuiqsut about the Iñupiaq names for pink (*amaqtuuq*) and chum (*iqalugruaq*) salmon, he said "these are not the names that we normally hear in Colville region," rather *iqalukpik* ("sort of like big salmons") is normally used to refer to arctic char and salmon species. The majority of elders and fishermen in Nuiqsut that we interviewed used the name "*iqalukpik*" to refer to salmon. Only two elders used the name "*iqalugruaq*," one specifically to refer to chum salmon ("These got teeth. We call them *iqalugruaq*."). When discussing pink salmon one elder in Nuiqsut said, "They call it the *iqalukpik*. My grandfather would call them *iqalukpik*. He called them that because he did not know what else to call them…*Iqalukpik* and *iqalugruaq*." One elder did use the Iñupiaq term "*amaqtuuq*" to refer to pink salmon in Nuiqsut, discussing specifically the hump characteristic of the species. When probing about the Iñupiaq nomenclature in this region, one informant emphasized that many of these species collectively called *iqalukpik* in this community run at the same time during the summer. Furthermore, some years many salmon show up and other years they do not. An elder informant in Barrow put it best, "Every year is different for the salmon migrations. Sometimes they come and sometimes they don't. It's different every year." While informants often discussed salmon and char species interchangeably, many were able to offer general species-specific informant on presence and distribution of pink and chum salmon in local river and stream systems.

Salmon Harvest

Salmon are harvested mainly by gillnet near Barrow in Elson Lagoon or along the Colville River near Nuiqsut. A Barrow elder remembers gillnets in Elson Lagoon when he first moved to Barrow in 1938. Gillnets in the lagoon in the early 1900s were targeting young seals, not fish as they are intended for today. Today between 20 and 30 fishermen set many 1-2 gillnets in the lagoon to catch whitefish, salmon, and trout species. There are a variety of mesh sizes from 3 inches for smaller species such as whitefish to 8 inches to target large fish such as Chinook salmon. The material that the mesh of gillnets is made of is usually monofilament fibers today, but in the past it was a cotton twine. The monofilament is more difficult for the fish to see and has more success, according to a Barrow fisherman, when the wind is calm and the water is less turbid. Before cotton or monofilament was introduced one elder remembers his grandparents using sinew from caribou, whales, and seals braided into rope and used for gillnets.

The lengths of the nets vary from 20 feet to over 300 feet, depending on the conditions and the amount of fish sought. Fishermen in Barrow and Nuiqsut set their gillnets and return the next day or twice a day, depending on the distance required to travel, the weather, and the amount of gas they can afford for the trip. Barrow residents can drive to their nets with a truck or an ATV, and some use large boats. Nuiqsut fishermen usually travel by boat as the nets are set along the Nigliq channel of the Colville River and this area is not accessible by truck or ATV. Generally the gillnets are attached to a heavy item and a buoy that keeps the net afloat in a stationary position and staked to shore to keep the net at a 90 degree angle from the shore to maximize the amount of fish passing the shoreline. If the area is shallow enough, fishermen can pick the fish from their net in chest waders, otherwise fishermen use small boats. In Barrow a few of the fishermen fish by attaching gillnet to a single line connected at both the seaward and shore ends of the net, a method employed by Point Hope fishermen,. There is a pulley system so the net can be pulled ashore without having to use a boat or chest waders to remove fish from the net. This system is less expensive because the net comes to fishermen and they do not have to go out into the water using a boat or other gear. Also, this setup can be hauled in during inclement weather so fishermen are not exposed to any danger when waves are high or water is deep.

Salmon Preference

In both Barrow and Nuiqsut, residents expressed a wide range of preferences for salmon. There are some elders and younger people who stated explicitly that they especially enjoyed eating salmon, while others noted their aversion to salmon. Pink salmon in particular received more disregard for taste and consistency. The pinks have large humps on their backs that can become oily and have a foul smell when they near spawning condition. They can also be hard to preserve successfully. One Nuiqsut informant stated, "And *Amaqtuuq*, once in awhile we get these but we don't eat them." When asked why, she said, "on this broad part (the hump), they are stink. You have to (take) it out, that part, to cook (it)." Brewster et al. (in review) also noted a diversity of opinions about pink salmon: "We used to get lots of those *amaqtuuq* (pink salmon)…We just throw them away…*Amaqtuuq* are not good at all;" "*Amaqtuuq*, they have a big hump on the back full of oil. They take the oil off and cook it. It's good;" "Those *amaqtuuqs*. Pinks. They're good eating."

Evident in our interviews is the evolving taste preferences for salmon in the Barrow and Nuiqsut region. One elder in Barrow noted that he did not eat salmon until he was older and went into the military. He stated, "(We) never did have much salmon when I was growing up. Once I got out of high school and went into the military that's where most of us started eating salmon. Now it's a big thing, everybody wants salmon." One elder in Nuiqsut noted that chum salmon taste preference is evolving. She said that when she was growing up chum salmon were only used for feeding sled dogs. Now, she noted that young people have really developed a taste for it. One young fisherman in Nuiqsut stated, "I love our salmon. That's basically why I go fishing in the summertime."

Another Barrow elder remembers his grandma had a name for salmon that means "to vomit," in Iñupiaq, although none of our other informants confirmed this assertion. This same elder said that he remembers people beginning to eat salmon, and more cooked food in general, when widespread development occurred across the region. One man who currently fishes in Barrow remembers that when he was younger they would spend about three months at fish camp. He recalls eating fish for three square meals per day and today he does not have a taste for fish. Although this fisherman does not prefer to eat fish he still fishes every summer to provide for his extended family and others in the community.

Because of varying taste preferences, some fishermen view pink salmon as a nuisance species that clog fishing nets, especially in years of large pink salmon runs. Some fishermen note that they do not set their nets during large pink runs. One informant who did not set his net in 2009 was told by an active fisherman during that year: “You ain’t missing nothing. I ain’t getting much, or it’s a bunch of pinks.” He replied: “Yeah, somebody needs to shoot them things.”

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Carothers, C. Climate Change and Subsistence Fisheries in Northern Alaska, Presentation at the Society for Applied Anthropology, Seattle, WA, April 2011.

Carothers, C. Eruptions of Subsistence and Oil in Arctic Alaska. Presentation at the American Anthropological Association, Montreal, Canada, November, 2011.

Carothers, C. Total Environment of Change: Climate Change and Subsistence Fisheries in Northern Alaska. Presentation at Department of Anthropology Colloquium, UAF, Fairbanks, AK, November 2011.

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Trophic Links – Forage Fishes, Their Prey, and Ice Seals in the Northeastern Chukchi Sea

Dr. Brenda Norcross
Dr. Laura Horstmann-Dehn
Brenda A. Holladay
Sara S. Carroll (student)

School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

Period of Performance: 06/01/2009 – 12/31/2012
Cooperative Agreement Number: M09AC15432

Project Overview

Oil exploration is likely taking place in the northeast Chukchi Sea simultaneously with increasing rates of global climate change. The area from Point Hope to Barrow is undergoing increased oil and gas resource survey and development pressure, i.e., Lease Sale 193. The paucity of data and limited ecological knowledge on the current status of pelagic and demersal fishes in Lease Sale 193 is insufficient to discern the extent or cause of future effects on this arctic ecosystem. Moreover, a loss of sea ice habitat has resulted in two arctic phocid species being proposed for listing as threatened under the Endangered Species Act by the National Oceanic and Atmospheric Administration Fisheries Services. Climate change and sea ice reduction may lead to modifications of food-web structure in the Arctic, which in turn could impact foraging of ice-associated predators. Fishes are primary contributors to ice-seal diets. Thus, trophically relating fishes and their prey to ice seals and their diets in the Chukchi Sea is essential to understanding potential effects of oil and gas exploration or impacts of climate change on food-web structure.

We hypothesize that dietary differences among forage fishes in the vicinity of Lease Sale 193 area may propagate to higher trophic levels such as ice seals. The present research uses stomach content analysis of fishes and stable nitrogen and carbon isotope ratios of fishes, fish prey, seal liver, seal muscle, and seal claws as tools to test this hypothesis and establish baseline information on trophic links within the Chukchi Sea food web.

2011 Update

All seal samples planned for stable isotope analysis have been processed, with the exception of 15 liver samples that will be processed and analyzed during the first quarter of 2012. During summer 2011, a total of 68 seal claws were analyzed for stable nitrogen and carbon isotope ratios. Results showed ringed seals fed at a lower trophic level during spring/summer 2006 through fall/winter 2008 compared to other years in the data set. High isotopic variation among claws within a species illustrated opportunistic foraging strategies and flexibility to changes in food-web structure. Muscle samples from ringed, bearded, and spotted seals were collected during Alaska Native subsistence harvests in 2003 and 2008–2010. A total of 399 muscle samples were analyzed for stable nitrogen and carbon isotope ratios. These isotopic signatures, together with stable nitrogen and carbon isotope ratios of fishes and invertebrate prey items, contributed to mixing models. Results of the mixing model analyses showed a decline in benthic prey and increase in planktonic prey to the diet of bearded seals over the years examined.

Carbon and nitrogen stable isotope analysis of fishes and fish prey is still in progress. Analysis of the larger length class, i.e., ≥71 mm, of fish collected during 2009 has been completed. About 140 smaller fishes remain to be processed. A total of 442 prey samples extracted from stomach contents of fish collected during 2009 and 2010 have been processed. The remainder of tissues from fishes and fish prey will be processed and stable isotopes analyzed during spring 2012.

Stomach content analysis of fishes has been completed. A total of 960 fishes that had consumed prey were examined from two length classes when available, ≤70 mm and ≥71 mm of five key fish species from three collection years (2008–2010). We analyzed stomach contents of 355 Arctic cod (*Boreogadus saida*), 133 Arctic staghorn sculpin (*Gymnocanthus tricuspis*), 206 stout eelblenny (*Anisarchus medius*), 156 polar eelpout (*Lycodes polaris*), and 110 Bering flounder (*Hippoglossoides robustus*). These numbers exclude empty stomachs or those that only contained parasites. During 2008, samples were not available for either length class of polar eelpout or the smaller length class of Arctic cod and stout eelblenny. For additional fish species, proposed to be examined during a single year, a total of 174 stomachs were analyzed and include 21 capelin (*Mallotus villosus*), 43 Pacific sand lance (*Ammodytes hexapterus*), 10 Pacific herring (*Clupea pallasii*), 20 saffron cod (*Eleginus gracilis*), 40 shorthorn sculpin (*Myoxocephalus scorpius),* and 40 slender eelblenny (*Lumpenus fabricii*). Samples were not available of the small length class of capelin, Pacific herring, or saffron cod.

Prioritization of sample analysis was changed to support Ms. Carroll's project completion and timely graduation. Stable isotope analysis of seal muscle, liver, and claws were given priority over fishes and fish prey samples. Ms. Carroll's thesis research incorporated the development of mixing models and this task is ahead of targeted deadline (June 2012). Stable isotope analysis of fishes and fish prey will resume in January 2012 as will analyses of prey data from stomach analysis. A 6 month cost extension will be requested which will ensure a thorough analysis and report of the inter-annual changes in the diet of fishes and ice seals during 2008–2010. Carroll's thesis work incorporated many side studies to assess the appropriate methodology for processing samples and investigated the uses of isotopic mixing models. Her work also documented inter-annual changes in the diet of seals. Ms. Carroll's continued analyses and contributions to this project during 2012 will add to the merit of this research. The extension will allow the incorporation of stable isotope of fishes and their prey to be added to the mixing model analysis that Ms. Carroll is revising.

Ben Gray, UAF Fisheries Oceanography Laboratory, has assisted with fish stomach analysis in his present position as a Fisheries MS graduate student as well as during previous positions as undergraduate student employee and laboratory technician. He will contribute to overall project analysis and will co-author the final report.

A manuscript titled, "Interannual variations in the diet of ice seals assessed by isotopic mixing models," written as a portion of S. Carroll's thesis, was submitted to Marine Mammal Science. A second manuscript is titled, "Diet history of ice seals recorded by stable isotope ratios within claws," discussing results of analyses of stable nitrogen and carbon isotopes together with other interannual patterns detected for ice seals was prepared this year and will be part of S. Carroll's thesis. Both manuscripts will be submitted to the Canadian Journal of Zoology.

Preliminary Results – Stomach Content Analysis of Arctic cod (Boreogadus saida)
Previous annual reports to the CMI have included selected results of stable carbon isotope analyses of ice seals and an index of fish diet. This report presents the interannual diet of small and large Arctic cod based on the Index of Relative Importance (IRI). This robust diet index considers the number, weight and occurrence of each prey taxon. IRI = (N+W)*O, where N is numerical percentage, W is weight percentage, and O is percentage of predators that consumed the prey taxon (Pinkas et al. 1971 as modified by Hacunda et al. 1981). Arctic cod was selected from among the several species examined, because it is one of the most abundant fishes in the study area. Both length classes of Arctic cod consumed both pelagic and benthic prey. Pelagic calanoid copepods were the dominant prey of Arctic cod ≤70 mm in length. These small fish also ate benthic prey such as harpacticoid copepods and bivalves, and prey that could be either pelagic or benthic such as shrimp/euphausiid/mysids. As with smaller fish, pelagic calanoid copepods were a dominant prey of Arctic cod ≥71 mm. Other prey of high importance to large Arctic cod included benthic gammarid amphipods, pelagic hyperiid amphipods, and pelagic or benthic shrimp/euphausiid/mysids. Overall, larger Arctic cod consume a more varied diet than smaller Arctic cod, which are more dependent on calanoid copepods.

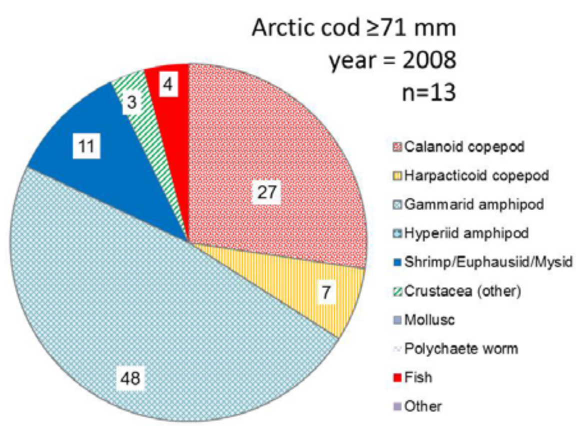

Figure 1. Percentage IRI of prey taxa in diets of Arctic cod ≥71 mm in length, captured during 2008. No smaller fish were available from 2008 collections. Gammarid amphipods and calanoid copepods were the most important prey. Smaller contributors to diet included shrimp/euphausiids/mysids, harpacticoid copepods, fishes, and other crustaceans.

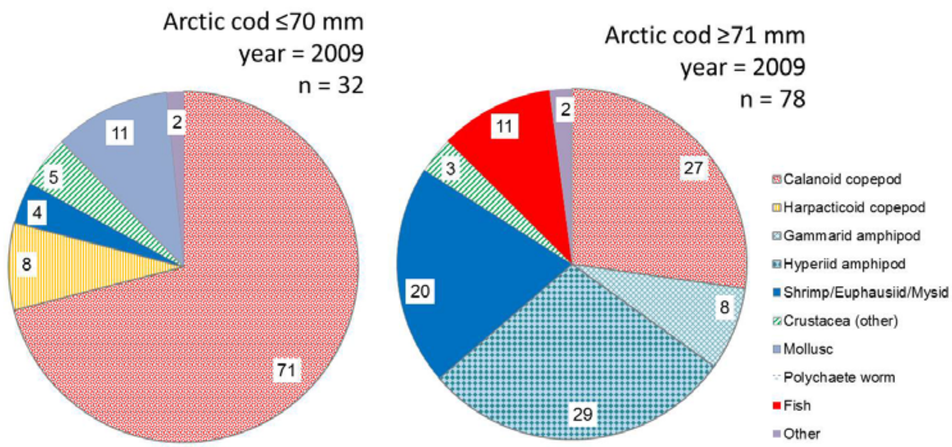

Figure 2. Percentage IRI of prey taxa in diets of Arctic cod less or greater than 70 mm in length, captured during 2009. Prey that were important to both fish length classes were calanoid copepods, shrimp/euphausiid/mysids, other crustaceans, and other animals. Calanoid copepods were the dominant prey of small fish. Lesser contributors to the diet of small fish included molluscs, harpacticoid copepods, other crustaceans, shrimp/euphausiid/mysid, and other animals. Hyperiid amphipods, calanoid copepods, and shrimp/euphausiid/mysids were of similar high importance to the diet of large Arctic cod. Lesser contributors to the diet of large fish were fishes, gammarid amphipods, other crustaceans, and other animals.

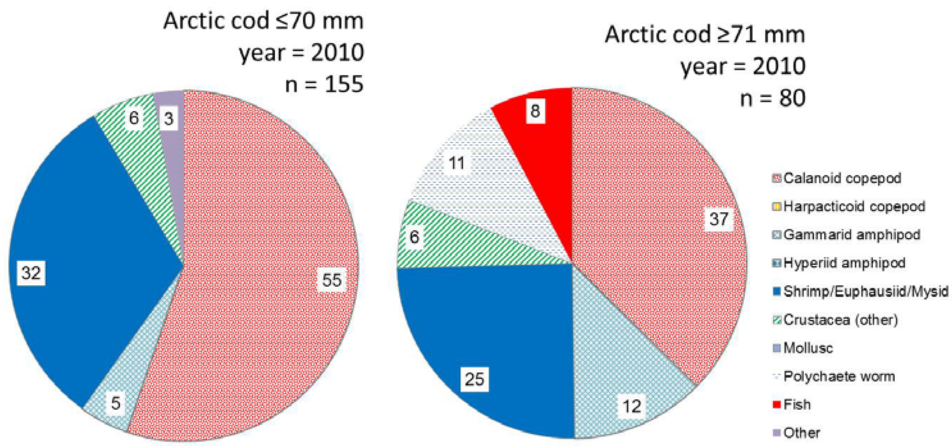

Figure 3. Percentage IRI of prey taxa in diets of Arctic cod less or greater than 70 mm in length, captured during 2010. Calanoid copepods, and to a lesser extent, shrimp/euphausiid/mysids, were the dominant prey of both sizes of fish. Also important to both sizes of fish were gammarid amphipods and other crustaceans. Small fish also consumed a small portion of other animals. Large fish also consumed polychaetes and fishes.

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CMI Funding and Cost Share Partners

The total BOEM funding committed to Alaska CMI projects through calendar year 2011 is approximately $17.5 million. All CMI funded projects require a one-to-one cost share with non-federal monies. The following partial list of cost share partners demonstrates the breadth of support for CMI-funded programs:

Afognak Native Corporation

Alaska Department of Environmental

Alaska Department of Fish and Game (ADF&G)

Alaska Department of Transportation and Public Facilities

Alyeska Pipeline Service Company

BP Amoco

Canadian Wildlife Service

Cominco Alaska, Inc.

Cook Inlet Regional Citizens Advisory Council

Department of Fisheries and Oceans Canada

Frontier Geosciences, Inc.

Japanese Marine Science and Technology Center (JAMSTEC)

Littoral Ecological & Environmental Services

Oil Spill Recovery Institute

Pollock Conservation Cooperative Research Center

Simon Frasier University

University of Alaska Fairbanks

Frontier Research System for Global Change, IARC

Institute of Marine Science

School of Agriculture & Land Resources Management

School of Management

University of Alaska Museum

University of Alaska Southeast

University of Northern Iowa

Wadati Fund

Woods Hole Oceanographic Institution

Water Research Center

Alaska Beluga Whale Committee

Conservation (ADEC)

ADF&G – Kachemak Bay Research Reserve

Alaska Science and Technology Foundation

Ben A. Thomas Logging Camp

BP Exploration (Alaska) Inc.

CODAR Ocean Sensors

ConocoPhillips Alaska, Inc.

Cook Inlet Spill Prevention & Response, Inc.

Exxon Valdez Oil Spill Trustee Council

Golden Plover Guiding Co.

Kodiak Island Borough

North Slope Borough

Phillips Alaska, Inc.

Prince William Sound Aquaculture Corporation

University of Alaska Anchorage

College of Science, Engineering & Mathematics

Institute of Arctic Biology

International Arctic Research Center (IARC)

School of Fisheries and Ocean Sciences

School of Mineral Engineering

University of Alaska Natural Resources Fund

University of California, Los Angeles

University of Texas

CMI Funded Student Support

Fiscal Year	Number of Students		MMS Funds	Matching Funds
1994	PhD	1	$22,558	$9,220
	M.S.	6	$65,107	$37,411
	Undergrad	1	$4,270	$0
	Source Total		**$91,935**	**$46,631**
1995	PhD	4	$53,061	$9,523
	M.S.	8	$90,367	$64,380
	Undergrad	5	$4,297	$13,933
	Source Total		**$147,725**	**$87,836**
1996	PhD	5	$75,499	$8,499
	M.S.	5	$80,245	$18,661
	Undergrad	2	$4,644	$0
	Source Total		**$160,388**	**$27,160**
1997	PhD	2	$37,714	$0
	M.S.	2	$22,798	$0
	Undergrad	2	$2,610	$0
	Source Total		**$63,122**	**$0**
1998	PhD	2	$17,109	$17,109
	M.S.	2	$26,012	$7,200
	Undergrad	2	$0	$2,548
	Source Total		**$43,121**	**$26,857**
1999	PhD	6	$66,750	$38,073
	M.S.	4	$31,650	$8,730
	Undergrad	4	$0	$10,704
	Source Total		**$98,400**	**$57,507**
2000	PhD	6	$61,383	$30,551
	M.S.	2	$5,868	$10,135
	Undergrad	7	$0	$21,299
	Source Total		**$67,251**	**$61,985**
2001	PhD	2	$19,159	$22,019
	M.S.	1	$0	$5,800
	Undergrad	3	$10,983	$5,761
	Source Total		**$30,142**	**$33,580**
2002	PhD	3	$48,476	$0
	M.S.	5	$66,676	$7,500
	Undergrad	0	$0	$0
	Source Total		**$115,152**	**$7,500**

Fiscal Year	Number of Students		MMS Funds	Matching Funds
2003	PhD	3	$45,032	$12,000
	M.S.	5	$79,448	$7,500
	Undergrad	1	$1,349	
	Source Total		**$125,829**	**$19,500**
2004	PhD	4	$55,365	$15,000
	M.S.	2	$34,715	$0
	Undergrad	0	$0	$0
	Source Total		**$90,080**	**$15,000**
2005	PhD	2	$30,942	$0
	M.S.	2	$6,385	$0
	Undergrad	1	$1,398	$0
	Source Total		**$38,725**	**$0**
2006	PhD	2	$21,132	$6,667
	M.S.	1	$0	$0
	Undergrad	2	$0	$0
	Source Total		**$21,132**	**$6,667**
2007	PhD	0	$0	$0
	M.S.	1	$82,635	$0
	Undergrad	0	$0	$0
	Source Total		**$82,635**	**$0**
2008	PhD	0	$0	$0
	M.S.	2	$124,086	$27,423
	Undergrad	0	$0	$0
	Source Total		**$124,086**	**$27,423**
2009	PhD	0	$0	$0
	M.S.	2	$0	$0
	Undergrad	0	$0	$0
	Source Total		**$0**	**$0**
2010	PhD	1	$66,332	$17,288
	M.S.	3	$97,740	$82,114
	Undergrad	1	$34,620	$0
	Source Total		**$198,692**	**$99,402**
2011	PhD	0	$0	$0
	M.S.	1	$6,841	$0
	Undergrad	1	$2,979	$0
	Source Total		**$9,820**	**$0**

	MMS	Matching
Totals to Date	**$1,508,235**	**$517,048**

CMI Publications

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