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CLIMATE-DRIVEN CHANGES IN IMPACTS OF BENTHIC PREDATORS IN THE NORTHERN BERING SEA (NSF-OPP-ARC-0454454)

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A. PROJECT SUMMARY

Perhaps the most striking evidence of global climate change is decreased extent of arctic sea ice and recent studies indicate this is occurring now south of St. Lawrence Island (SLI) in the SLI polynya region (SLIP). Despite research on the consequences of sea-ice change for physical oceanography and weather, effects on arctic marine food webs from microbes to top predators are by comparison very poorly understood. Our field research will investigate a major mechanism by which sea-ice change might affect the very productive, benthic-dominated food webs on shallow arctic shelves -expansion of the ranges and numbers of mobile benthic predators owing to increased temperature of bottom water. When winter sea ice melts on the north-central Bering Sea shelf, a pool of cold bottom water (<1°C) forms that persists through summer and reduces the numbers and growth of crabs and groundfish. The size of the cold pool decreases with decreasing ice extent. This area is currently the sole wintering site of the world population of the benthic-feeding Spectacled Eider (SPEI), a principal top predator. Expansion of competing crab and fish predators as ice cover declines and the cold pool contracts may affect food availability for the eiders. In this project, our main questions are:

Question 1: Is the benthic food web in the north-central Bering Sea limited by top-down control by predators? We will collect data needed to model the total impact of predators on their main benthic prey in the northcentral Bering Sea. These predators include SPEI, groundfish, snow crabs, sea stars, and gastropods.

Question 2: Are the overwinter survival and/or prebreeding condition of SPEI being impacted by climate driven trends in ice cover that are allowing populations of competing crabs and groundfish to expand? We will use past and current data to simulate impacts on the energy balance of the main endotherm predator (SPEI) of variations in crab and groundfish populations expected to occur with changes in ice cover and resulting temperature of bottom water.

Question 3: Are the time-series benthic system changes observed south of St. Lawrence Island continuing and are they forced by bottom-up (hydrographic) or top-down (predator) interactions, or both? We will continue a long-term (1950-2005) record of benthic communities and carbon cycling processes in this area, which is essential to analyses in this project. These data will also indicate whether declines in organic matter supply to sediments that we have measured at a subset of stations have occurred throughout the area, and whether these declines correspond to a decrease in direct precipitation of phytoplankton during and after the ice-edge spring bloom.

B. FIELD SAMPLING

The following schedule is a draft plan for HLY0702 (16 May –18 June, 2007), with the ship sampling time in draft form until at sea:

May 14:	Science party boards Healy in Dutch Harbor
May 16:	Healy departs for study area in northcentral Bering Sea
May 19-21:	Sampling begins with NEC5 and moves NW on the southern most line: NEC5, SEC5, SIL5, SWC5, VNG1, NWC5, DLN 5 (7 stns)
May 22-24:	DLN4, NWC4, VNG3, NWC4A, SWC4, SIL4, SEC4, NEC4 (8 stns)
May 25-26:	SIL3, POP4, SWC4A, VNG3.5, CD1, NWC3, DLN3 (8 stns)
May 27-28:	NWC2.5, VNG4, SWC3A, POP3A, SEC2.5, SEC3, NEC3 (7 stns)
May 29-31:	NEC2, NEC2.5 SEC2, SIL2, SWC2, VNG5, NWC2, DLN2, DLN 1.5 (n=9)
June 1:	move NE around Gambell to Chirikov Basin, begin grid of 12 stations
June 4:	stop at Little Diomede; begin transit south and start Shpanberg line
June 5:	begin nearshore line south of SLI
June 9-15:	reoccupy subset of SLIP stations, depart on June 16 southward
June 18:	arrive Dutch Harbor, AK, 0800, offload personnel
June 20:	Healy departs for Seattle
June 25:	Healy arrives Seattle
June 26:	offload HLY0702 cargo/equipment

B. OVERVIEW SUMMARY OF HLY0702 FIELD SAMPLING

In our shipboard sampling, we use a profiling conductivity-temperature-depth (CTD) and rosette system for collecting physical and hydrochemical samples. Water samples will be taken using 12 30-liter-Niskin bottles. Subsamples from multiple CTD/rosette casts are used for chlorophyll content, nutrients, particulate organic carbon, dissolved organic carbon, zooplankton, benthic population measurements and sediment tracers. In addition, optical equipment (PAR and UV) are lowered to 60-150 m for measurements of variable light penetration in the water column. A vertical net is then used to collect zooplankton for population measurements. Benthic van Veen grabs and a HAPS benthic corer are used to collect benthic fauna and sediment samples for population, community structure, food web, sediment chemistry and metabolism studies. A beam and/or otter trawl will be used to collect epifauna for population and stable isotope and lipid content measurements. Besides the standard ship sensors (atmospheric, seawater temperature, chlorophyll, multibeam), we will collect berrylium-7 (a natural radioisotope used for tracing particulate deposition to the sediments) in precipitation collectors mounted on the deck behind the bridge. Both bridge and helicopter operations will be used for seabird, marine mammal and sea ice surveys.

We plan to occupy approximately 118 stations as we did during HLY0601 (2006) in the northern Bering Sea, starting south of St. Lawrence Island (SLI) and extending to Bering Strait (Fig. 1).

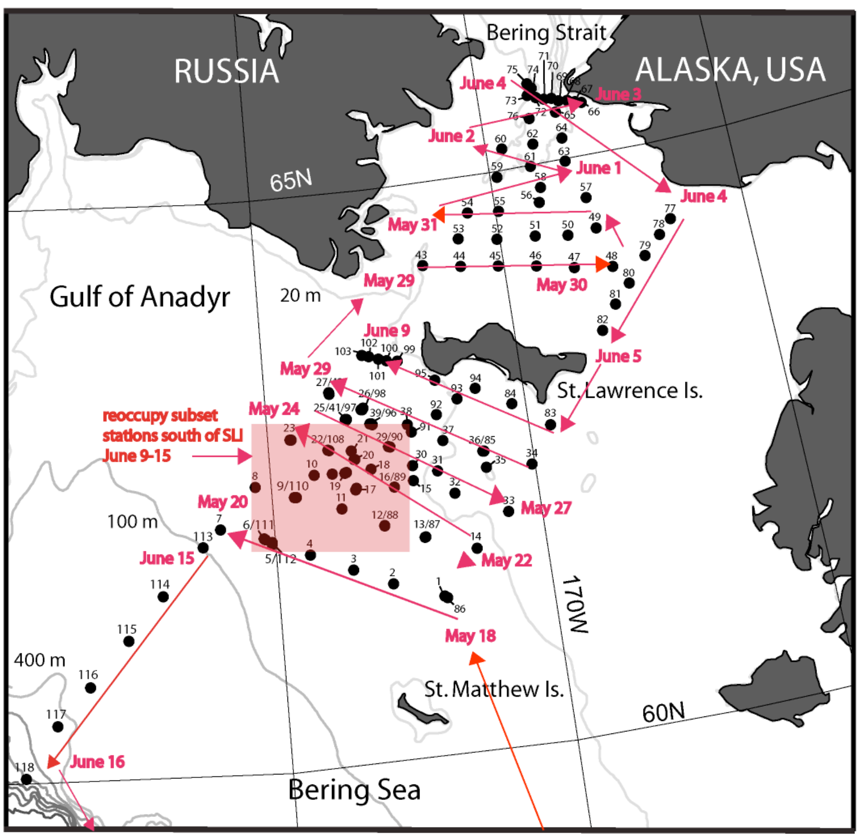

Fig. 1. Final station grid for HLY0702 with station numbers and associated dates for occupation. Note that we remain 30 miles offshore from St. Lawrence Island (SLI) until the first week of June per an agreement with local hunters to minimize contact with marine mammal hunting. Additional stations will be added to the "red box" region SW of SLI as time permits.

Table 1. Daily Plan of Intended Movement (PIM) for HLY0702, with station number, name, estimated arrival time (month/day/year), latitude (°N), longitude (°W), and depth (m). Note that additional stations will occur in the red box in Figure 1, TBD at sea.

Station Number	Station Name	Date (Day/ Month) 2007	Latitude (deg.N)	Longitude (deg W)	Depth (m)
1	NEC5	18-May	61.3881	-171.9500	60

2	SEC5	19-May	61.5643	-172.9138	60
3	SIL5	19-May	61.7216	-173.6072	63
4	SWC5	19-May	61.8931	-174.3639	69
5	VNG1	19-May	62.0183	-175.0622	67
6	NWC5	20-May	62.0562	-175.1991	80
7	DLN5	20-May	62.1482	-176.0231	86
8	NWC4	20-May	62.3876	-174.5503	70
9	NWC4A	21-May	62.5606	-174.1848	64
10	VNG3	21-May	62.5528	-173.8429	62
11	SWC4	21-May	62.2414	-173.7408	56
12	SIL4	21-May	62.0828	-172.9444	56
13	SEC4	22-May	61.9259	-172.2072	49
14	NEC4	22-May	61.7710	-171.3155	47
15	SIL3	22-May	62.4383	-172.3106	48
16	POP4	22-May	62.4003	-172.6906	60
17	SWC4A	23-May	62.4124	-173.4359	55
18	SWC3	23-May	62.5784	-173.0729	62
19	VNG3.5	23-May	62.5687	-173.5721	60
20	CD1	23-May	62.6741	-173.3620	60
21	VNG4	24-May	62.7498	-173.4072	61
22	NWC3	24-May	62.7799	-173.8768	68
23	DLN3	24-May	62.8990	-174.5856	77
24	DLN4	24-May	62.5138	-175.2989	81
25	NWC2.5	25-May	63.0298	-173.4423	65
26	NWC2	25-May	63.1148	-173.1350	72
27	DLN2	25-May	63.2708	-173.7448	74
28	VNG5	26-May	62.9665	-172.9851	60
29	SWC3A	26-May	62.7564	-172.7098	54
30	POP3A	26-May	62.5678	-172.2941	43
31	SEC2.5	27-May	62.4967	-171.8469	42
32	SEC3	27-May	62.2808	-171.5641	47
33	NEC3	27-May	62.0569	-170.6288	35
34	NEC2	27-May	62.4272	-170.0591	30
35	NEC2.5	28-May	62.4728	-170.9581	42
36	SEC2	28-May	62.6060	-170.9483	37
37	SIL2	28-May	62.7567	-171.6736	50
38	SWC2	28-May	62.9141	-172.2867	50
39	VNG5	28-May	62.9600	-172.9825	67

40	NWC2	28-May	63.1109	-173.1197	62
41	NWC2.5	29-May	63.0342	-173.4615	64
42	DLN2	29-May	63.2659	-173.7466	68
43	DLN0	29-May	64.2907	-171.6143	49
44	KIV1	29-May	64.2287	-170.8618	34
45	KIV2	29-May	64.1865	-170.1266	37
46	KIV3	30-May	64.1202	-169.3340	30
47	KIV4	30-May	64.0646	-168.6094	30
48	KIV5	30-May	64.0139	-167.8699	39
49	NOM5	30-May	64.3620	-168.0281	38
50	NOM4	30-May	64.3523	-168.6530	40
51	NOM3	31-May	64.3841	-169.2968	41
52	NOM2	31-May	64.4221	-170.0608	43
53	NOM1	31-May	64.4691	-170.8423	45
54	RUS1	31-May	64.6917	-170.5875	42
55	RUS2	1-Jun	64.6588	-169.9507	47
56	RUS3	1-Jun	64.6759	-169.0943	44
57	RUS4	1-Jun	64.6419	-168.1290	33
58	RUS-A	1-Jun	64.7994	-169.0324	40
59	KNG1	1-Jun	64.9533	-169.8976	48
60	CPW1	2-Jun	65.1776	-169.6724	45
61	KNG2	2-Jun	64.9875	-169.1475	50
62	CPW2	2-Jun	65.1755	-169.0355	53
63	KNG2	2-Jun	65.0080	-168.4088	46
64	CPW3	2-Jun	65.1770	-168.3980	47
65	LDI2	3-Jun	65.4118	-168.4333	59
66	BRS-A8	3-Jun	65.4486	-167.8427	27
67	BRS-A7	3-Jun	65.4723	-167.9767	39
68	BRS-A6	3-Jun	65.4944	-168.1197	37
69	BRS-A5	3-Jun	65.5001	-168.3016	60
70	BRS-A4	3-Jun	65.5227	-168.4472	60
71	BRS-A3	3-Jun	65.5439	-168.6401	56
72	BRS-A2	3-Jun	65.5657	-168.7927	52
73	BRS-A1	3-Jun	65.5901	-168.9657	46
74	LDI3	4-Jun	65.7122	-168.9488	38
75	LDI4	4-Jun	65.6503	-168.8584	50
76	LDI1	4-Jun	65.4081	-169.0268	57
77	SPH6	4-Jun	64.3221	-166.5365	27

78	SPH5	4-Jun	64.2000	-166.8184	23
79	SPH4	5-Jun	64.0486	-167.1797	31
80	SPH3	5-Jun	63.8458	-167.6054	35
81	SPH2	5-Jun	63.6832	-167.9583	32
82	SPH1	5-Jun	63.4869	-168.3185	28
83	NEC1	5-Jun	62.7551	-169.5866	49
84	SEC1	5-Jun	62.9915	-170.2677	40
85	SEC2	6-Jun	62.6165	-170.9515	45
86	NEC5	6-Jun	61.4142	-171.9914	62
87	SEC4	6-Jun	61.9420	-172.2180	57
88	SIL4	6-Jun	62.0787	-172.9544	58
89	POP4	7-Jun	62.4063	-172.6902	57
90	SWC3A	7-Jun	62.7583	-172.7129	60
91	SWC2B	7-Jun	62.8618	-172.2479	56
92	SWC2C	7-Jun	62.9830	-171.7253	55
93	SWC2D	7-Jun	63.0955	-171.2935	
94	SIL1	7-Jun	63.0953	-171.2921	50
95	SWC1	7-Jun	63.2912	-171.7004	50
96	VNG5	8-Jun	62.9754	-172.9985	67
97	NWC2.5	8-Jun	63.0278	-173.4766	71
98	NWC2	8-Jun	63.1116	-173.1374	72
99	NWC1	9-Jun	63.4938	-172.3624	51
100	ANSA	9-Jun	63.5046	-172.5663	47
101	ANSB	9-Jun	63.5254	-172.7173	57
102	ANSC	9-Jun	63.5556	-172.8973	53
103	DLN1	9-Jun	63.5800	-173.0458	64
104	VNG4	9-Jun	62.7551	-173.4357	70
105	CD1	9-Jun	62.6867	-173.3983	67
106	SWC4A	10-Jun	62.4163	-173.4430	63
107	VNG4	10-Jun	62.5774	-173.5751	67
108	NWC3	10-Jun	62.7790	-173.8924	73
109	DLN3	10-Jun	62.8983	-174.5849	77
110	NWC4	10-Jun	62.3979	-174.5938	73
111	NWC5	11-Jun	62.0395	-175.2029	80
112	VNG1	11-Jun	62.0124	-175.0607	79
113	DBSA	11-Jun	62.0197	-176.3491	100
114	DBSB	11-Jun	61.6110	-177.1322	117
115	DBSC	12-Jun	61.2341	-177.7911	145

116	DBSD	12-Jun	60.8374	-178.5044	173
117	DBSE	12-Jun	60.5046	-179.1008	430
118	DBS1	12-Jun	60.0469	-179.6632	2375

NOTE: There are two moorings in our study area that should be surrounded by a "DO NOT GET CLOSER THAN 5 MILES CIRCLE":
1. 06BS-8 Mooring (Top Instrument at 22 meters), 62° 11.6334'N/ 174° 40.0587'W
2. 06BSP-8 (ADCP at 60 meters), 62° 11.727'N/ 174° 39.591'W

C. GENERAL APPROACH
The overall approach and station activities in this study will be as follows and in this order:

1. Mount precipitation buckets (Lee Cooper, core work) and optical sensor (Jinping Zhao-Appendix F) on forecastle deck for tracer and optical studies, respectively.
2. Satellite observations of ice will be evaluated via normal bridge obtained imagery and free web accessed products during the course of the cruise (Karen Frey, VIMS-Appendix B).
3. Collection of seawater from shipboard science seawater system for carbon degradation experiments to determine the composition and age of the terrestrial fraction of particulate organic matter being delivered to the Bering Sea from rivers and coastal erosion. (Laura Belicka-Appendix C).
4. Determine optical (radiance, irradiance and turbidity) characteristics of seawater (Jinping Zhao, -Appendix F). In addition, we will hand deploy a UV vertical measuring meter in the water column to 100 m depth before/after retrieval of the CTD (Lee Cooper, core work), although this operation may be modified with collaboration with Jinping Zhao's efforts.
5. Deploy the first CTD to determine profiles of salinity and temperature, macronutrients, $\delta^{18}O$ values, and chlorophyll *a* in the water column at each station from CTD rosette samples. These data will provide an oceanographic water mass context for our study, including data to analyze contributions of nutrients, sea ice melt, brine and runoff contributions. Water samples for stable isotopes, fatty acids, selenium and POM in seawater at three depths will be collected at each station (Jim Lovvorn, core work) and DOC content (Marjorie Brooks-Appendix E), as well as collections vertically for particulate matter (Jinping Zhao.-Appendix F) and microbial content (Yinxin Zeng-Appendix G). See water budget for more details on volume collections (separate attachment).
6. Deploy a second CTD each morning to determine primary production (via C-13 method) and phytoplankton species composition in the water and sediments (Sang H. Lee, KOPRI, S. Korea, Appendix H).
7. Conduct controlled seawater experiments to investigate the nature of dissolved organic matter (DOM) photooxidation in the Arctic (Marjorie Brooks-Appendix E).
8. Continue time-series benthic measurements with multiple van Veen and HAPS benthic corer deployments (Grebmeier, core work). We will provide sediment subsamples for paleoclimate studies to U Massachusetts (Beth Cassie-Appendix A) and Polar Research Institute of China (PRIC, Yinxin Zeng-Appendix G), along with infauna for a calorimetric study (Bluhm-Appendix M)..
9. Measure the densities (by size class) of clams, predatory gastropods, sea stars (asteroids), snow crabs, and groundfish in the wintering area of (SPEI) collected via trawling (Lovvorn, core work).
10. Determine microbial composition in water and sediments (Yinxin Zeng-Appendix G).
11. Investigate the diets of predators collected by van Veen grabs and benthic trawls through analyses of gut contents, stable isotopes, and fatty acids to determine the diets of predators. We will measure prey size class of both predators and prey when possible. Based on the literature, we will develop estimates of the food intake per individual per day of the predators, considering the size classes of each predator (Lovvorn, core work).

12. We will have observations of seabirds and marine mammals by the USFWS (Elizabeth Labunski and Kathy Kuletz, USFWS-Appendix D)
13. Peter Boveng/Michael Cameron (NMML) will have a combination of shipboard surveys, aerial surveys via helicopter flights, and off-ship small boat operations for seal tagging. NMML ice seal survey-Appendix:I).
14. Gay Sheffield (ADFG) will investigate ice seal stock structure, migration routes, and dispersal patterns of ice seals that occur in the northern Bering Sea as well as assist in the NMML effort (Appendix J, pending).
15. POLAR-PALOOZA will include two media representatives on the ship the last week of May, with pick-up by helo as we round the corner past Gambell, Alaska and offload to Nome for commercial flights south before the ship heads back to Dutch Harbor-Appendix K.
16. ARCUS/PolarTREC will have one representative participate for a week during the cruise (Appendix L).
17. Scientific cargo transfer from Little Diomede Island to Healy during Bering Strait sampling.

D. SPECIFIC FIELD OPERATIONS AND ORDER OF SAMPLING AT STATIONS

Equipment to be deployed during the cruise includes optical instruments on separate winch (1/4 inch off port side), a CTD/rosette, zooplankton net, van Veen grab, HAPs multicorer, and a beam trawl. The following summary provides the lead contact for the major work responsibilities:

- **Jackie Grebmeier (Chief Scientist)** and **Lee Cooper (PI)** have the lead for CTD/rosette collections for chlorophyll, nutrients, O-18, bottom water for respiration cores, and benthic collections (van Veen grabs, HAPs multi-corer). Within their component sediment collections will be made for paleorecord determination (Beth Cassie), fish collections (Sherry Ciu), and caloric content of prey (Bodil Bluhm).
- **Jim Lovvorn (Co-chief scientist)** has lead responsibility for zooplankton vertical tows, beam trawling and oversight for seabird investigations and coordinating participants doing opportunistic marine mammal and seabird observations from the bridge (Kathy Kuletz, USFWS). He is also responsible for oversight of his graduate students and technicians responsible for trawl collections and identification.
- **Lee Cooper** has lead oversight of on satellite ice observations and UV measurements (Karen Frey) and optical observations (Jinping Zhao).
- **Jackie Grebmeier** has lead oversight on primary production phytoplankton collections (Lee), microbial collections water and sediments (Zeng), and ice seal survey and marine mammal tagging (Peter Boveng/Michael Cameron group).

The following listing describes the operations in more details, including water and sediment needs:

1. A hand-held UV/PAR detector will be lowered from the starboard side-mid-ship position to 100 m maximum (Cooper). In addition, Jinping Zhao will lower another optical device to 1% light level using a winch (Appendix F). We need a small winch on the starboard side near the CTD operations for the Zhao deployment.

2. Deployment of the CTD

i. **CTD #1:** Collection of subsamples for nutrients, O-18, chlorophyll (Cooper and Grebmeier), phytoplankton (Lee), microbial identification (Zeng), with dedicated rosette bottles collected at the surface, middle and bottom depths for Lovvorn and Brooks components. In addition, Grebmeier will collect 4-8 L of bottom water for sediment respiration experiments.

ii. **CTD#2 (1/day): Collection of water for primary production experiments** (primary production, DIC, nutrients between the hours 0700-0900 (Lee).

3. A vertical zooplankton net will be deployed from the stern for one haul collection per station.

4. Benthic sampling-van Veen grabs and HAPS multi-core deployments
We will collect benthic samples (7 grabs, 1-2 multi-Haps corers, and 1 beam/otter trawl) at each station on our grid (Fig. 1). Benthic predators will be sampled by two methods: van Veen grab (area sampled 0.1 m^2) and beam trawl (4.3 m long, mesh size 1.9 cm, opening 3.1 m wide and 0.7 m high), the latter collected after the multi-HAPS corer deployments. The grabs will be used to determine densities of smaller gastropod species, whereas the trawls will yield densities of sea stars, crabs, groundfish, and larger gastropods by the "area swept" method. <u>Note that an additional otter and/or beam trawl will be collected at 8 stations during the cruise for statistical sampling comparisions.</u>

Infaunal samples from the first grab will be both preserved and frozen for a comparative caloric analysis (Bluhm-Appendix M). Animals frozen from the last two grabs will be analyzed for stable isotope ($\delta^{13}C$, $\delta^{15}N$) and fatty acid signatures. Gut contents of smaller invertebrates will be examined. For crabs and fish, muscle tissue will be analyzed for $\delta^{13}C$ and $\delta^{15}N$, and whole-body homogenates (without carapace) will be analyzed for fatty acids. Gut contents of crabs, fish, and sea stars will also be sorted and the dry mass of different food items determined by size class of both predator and prey.

The following information provides specifics on the sampling plan:

i. 0.1 m2 van Veen grabs (7): Benthic samples will be taken at each station with a 0.1-m^2 van Veen grab and rinsed over a 1-mm sieve. From four grabs, organisms retained by the sieve will be preserved in 10% buffered formalin; organisms from the other three grabs will be frozen for later analyses, outlined below.

a. The first grab will be used for surface sediment collections and frozen (e.g. grain size, sed chl, TOC/TON, C-13, radioisotopes; Cooper) and microbial content (Zeng).
b. The next four grabs will be sieved and preserved for faunal identification (Grebmeier).
c. The final two grabs will be sieved and frozen foregut-content, stable isotope, and fatty acid analyses of faunal collected (Lovvorn).

ii. A 4-barrel HAPs multi-corer (subcores 133 cm^2, ≤30 cm deep) will be used for sediment core collections (2 deployments) as follows:

a. For two of the four cores, the top 1 cm will be analyzed for indicators of recent and longer-term sedimentation (grain size, chlorophyll a, TOC/TON, $\delta^{13}C$, natural radionuclide ^7Be, and biomarkers (Belicka). These cores will be sectioned at 1-cm intervals down to 4 cm.
b. In general, two HAPS cores will be used for shipboard sediment flux incubations (dissolved oxygen, nutrients, alkalinity, pH, total CO_2). Bottom water for experiments will be collected from the bottom water bottle on the CTD. Sediment cores will be kept in the dark with motorized paddles at in-situ bottom temperatures for 12-18 h in the forward, starboard walk-in low temp room. Measurements will be made at the start and end of an experiment, with O_2 flux calculated from concentration differences. Sediments will be sieved after experiments to determine faunal composition. <u>Note that an additional multi-core deployments will occur at 10 stations during the cruise for additional core collections for time series sediment respiration comparisons (Grebmeier and Cooper).</u>
c. A single HAPS corer will be used in the sandy sediments of the Chirikov Basin if the multi-Haps does not work, thus multiple collections will be made, but the overall sampling is about the same as two multi-Haps corer deployments.

5. Benthic sampling: A beam and/or otter trawl will be used for epifaunal and fish collections.
Trawls will be towed for 10-20 min at a speed of 3 kt.

i. From trawl samples, all crabs will be sexed, their carapace width measured, and their instar determined and a representative sample will be frozen.

ii. All fish will separated, identified, sized, weighed, and frozen. If time permits, stomach will be removed and frozen separately.

iii. All sea stars will be counted, measured, and a representative sample frozen. Large gastropods that are often captured in trawls but not in grabs, will also be frozen.

6. Sensors on ship: Lee Cooper will have the lead for activities to mount and maintain two Be-7 precipitation collectors (on flying bridge, upwind of exhaust stacks) flying bridge)

7. Satellite sensor study: Karen Frey will have lead on satellite sea ice observations and analyses.

8. Ice seal observations, aerial surverys and tagging. Peter Boveng's NMML group will undertake periodic small boat deployments for observing, tagging and collected tissues from ice seals during the cruise. A proposed use of helicopter time is also requested. See appendices below for further details.

APPENDICES FOR COLLABORATIVE PROJECTS ONBOARD HLY0702

APPENDIX A. Modern Surface Sediment Dataset: Beth Cassie and Kenna Wilkie (PI: Julie-Brigham Grette), University of Massachusetts, Amherst, MA
In order to be able to base inferences about sea-ice duration on diatom assemblages, a training set of modern sediments would need to include a more evenly distributed set of sites for each length of time sea-ice might be present. Participation in the HLY0702 cruise will allow contemporary surface sediment collections for comparison with overlying water column production and sea ice conditions. Surface sediment samples (0-2 cm) will be collected from one of the multi-HAPS corer collections as part of the core benthic sampling plan, so no additional wire time is necessary.
Participants: 2

APPENDIX B. Impacts of sea ice variability on biological productivity in the Bering Sea, PI: Karen Frey, College of William and Mary, Virginia Institute of Marine Science
The Bering Sea is among the most productive marine ecosystems in the world, supporting important commercial fisheries, subsistence resources for Native Alaskans, and large populations of marine birds and mammals that have fluctuated in the past as a result of cyclic regime changes. However, some higher trophic organisms have moved into the threatened (Spectacled Eiders) or endangered (Stellars sea lions) category, suggesting ecosystem change may be in progress. With additional shifts becoming apparent as seasonal sea ice declines as a dominant feature in this high-latitude shelf environment, we have no clear understanding of how climate warming and associated changes in sea ice cover will influence ecosystem structure and function. This proposed research will utilize satellite remote sensing data to investigate linkages between sea ice variability, polynyas (persistent openings in sea ice cover), and chlorophyll biomass throughout the northern Bering Sea region. The approach of the study will be to integrate measurements of sea ice extent and melt onset (through QuikSCAT, ERS radar scatterometer, and SSM/I passive microwave data) with phytoplankton blooms (through SeaWIFS and Terra/Aqua-MODIS derived concentrations of chlorophyll-*a*). These measurements will be validated during two research cruises in May 2006 and 2007.
Participant: 1

APPENDIX C: Character and Reactivity of Sources of Organic Matter to the Bering Sea: Laura Belicka, University of Maryland (PI: Rodger Harvey), University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory
Accumulating evidence shows that large portions of terrestrial carbon are preserved relative to marine carbon in the modern Arctic. This data implies that marine carbon is recycled rapidly in the Arctic water column, leaving the more recalcitrant terrestrial organic matter to be preserved in sediments. With climate warming, it has been hypothesized that increasing amounts of ancient terrestrial carbon are being transported to the Arctic Ocean. It remains unclear how this relict carbon will impact the organic carbon

cycle in the Arctic Ocean. This project seeks to determine the composition and age of the terrestrial fraction of particulate organic matter being delivered to the Bering Sea from rivers and coastal erosion. I will also perform degradation experiments to determine if the reactivity of terrestrial organic carbon sources differs from marine organic carbon (i.e., how different are the rates of microbial degradation between marine and terrestrial organic carbon), and are the degradation rates of different fractions of organic matter dependent on temperature? Briefly, offshore water will be collected from the shipboard science seawater system and filtered through 1.0 μm cartridge filters to remove larger particles and grazers, leaving the microbial fraction. This 1.0 μm filtered water will be placed into carboys, and varying organic matter substrates will be added. Carboys will be incubated in the dark at -1°C and 5°C in the shipboard temperature control rooms for the duration of the cruise, and sampled at several pre-determined timepoints for POC and lipid biomarker analysis. Approximately 4 linear ft of bench space is requested in the wet-lab, preferably adjacent to a sink. Also, space for 7 20L carboys in a -1C and 5C temperature cold room is also required.
Participant: 1

APPENDIX D. Seabird Opportunistic Observations: Elizabeth Labunski, Kathy Kuletz (PI), US Fish and Wildlife Service (USFWS), Anchorage, AK
The U. S. Fish and Wildlife Service (USFWS) is undertaking an at-sea program utilizing ships of opportunity, with the goal to update our seabird database and improve efforts to use them as indicators of change in the North Pacific/Arctic oceans. Seabird observers will be onboard HLY0702 to take advantage of oceanographic and biological data in relation to seabird distribution and abundance. The USFWS anticipates implementation of an at-sea seabird-monitoring program in 2007, by utilizing vessels of opportunity such as the HYL0702 oceanographic cruise. The USFWS seabird observer will be equipped with all necessary field gear, including a laptop computer with integrated GPS for data recording. Following established protocols, the observer will conduct surveys during daylight hours, recording all marine birds and mammals within a set transect width.
Participants: 2

APPENDIX E: Properties and photooxidation of DOM and POM: Marjorie Brooks (PI), University of Wyoming
Dissolved organic matter (DOM) protects aquatic biota from ultraviolet (UV) radiation and plays an important role as an energy resource. However, DOM is photochemically unstable. In the span of a few days, most DOM loses 15 to 20% of its dissolved organic carbon (DOC, which comprises about half of DOM; Molot and Dillon 1997, Xie et al. 2004). However, DOM from pure cultures of algae is not photomineralized (Obernosterer and Benner, 2004). Independent of source, sunlight destroys chromophoric DOM (CDOM) that absorbs, and thus protects, biota from biologically damaging UV radiation (Lehmann et al. 2004) and may regulate primary productivity (Hérnandez et al. 2007). Such photobleaching indicates altered chemical composition (e.g., loss of sp^2 hybridized bonds such as double bonds of aromatics) of both allochthonous DOM (Moran et al., 2000; Del Vecchio and Blough, 2002) and DOM in pure algal cultures (Obernosterer and Benner, 2004).

Other researchers have conducted descriptive field studies of the role of CDOM and DOC in the North Water Polynya and the eastern Arctic and sub-Arctic. Observational studies indicate that a combination of photooxidation and advective processes determine carbon loss in Baffin Bay (Miller et al. 2002). Turnover rate constants for photochemical removal of dimethylsulfide in the northeast subarctic Pacific (Bouillon et al. 2006) were similar to those reported from low latitudes, possibly suggesting that photooxidation rates of DOC might also be similar. However, controls on CDOM production and loss in the North Water Polynya differed from those at low latitudes. Spectral quality and DOC concentration of terrigenous DOM vary among riverine sources (Clark et al. 2004, Retamal et al. 2007). Moreover, sea-ice algae may have a significant biologic effect on CDOM character in addition to physically freshening the water (Scully and Miller 2000, Belzile et al. 2000). The effect of photooxidation on DOM and CDOM in the Bering Sea is unknown. To my knowledge, aside from an iron-enrichment study on dimethylsulfide photooxidation (Bouillon et al. 2006), no one has conducted controlled experiments investigating the nature of DOM photooxidation in the Arctic

Potential study questions:
1. How does the nature of DOM photooxidation change with salinity?
2. How does source alter the spectral and photochemical behavior of DOM?
3. Does source-dependent behavior continue after algal-derived DOM is advected downward into saltier substrata?
4. How do absorbance and photooxidation differ between POM and DOM?
5. Does DOM from ice photoreact differently from DOM in the water column?

Methods

In photooxidation experiments, unfiltered water from varying depths and from sea ice will be exposed to ambient sunlight for about 3 days. I will collect water samples to measure POM concentrations (>0.7µm) and absorbance at 254, 310, 440, and 670 nm during time-series exposures. Integrated measures of continuous UV radiation will be collected with polysulfone dosimeters during exposures. Rates of photooxidative processes combined with measures of the vertical attenuation of UV radiation in the water column will provide calculations of bulk quantum yield in the water column.

Research requirements

- Seawater: 1 L of water from 3 depths at 10 stations
- Space: In freezer, room for 1 cooler (0.5 x 0.25 x 0.3 m).
- On deck, unshaded space for deployment of exposure tubes (0.5 x 0.25 m)
- MST support: If possible, flow-through cooling system consisting of low-flow seawater inflow hose that I will return to the sea via an outflow hose.
- Station time: Nothing beyond typical time at each station. It will take me ~30 min to deploy the radiometer during grab and coring activities.

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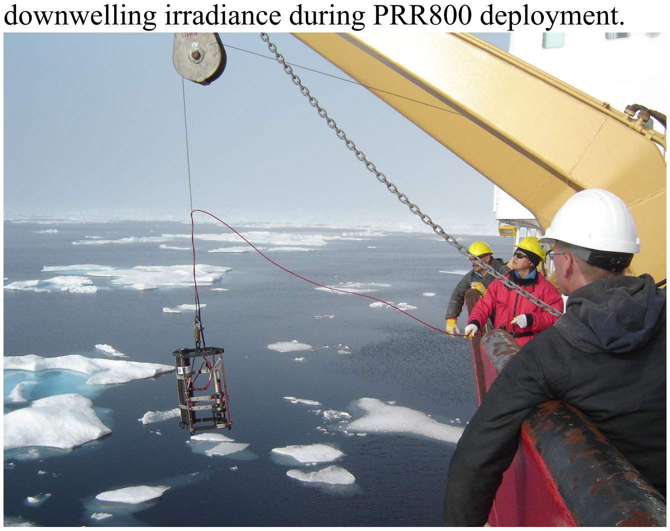
APPENDIX F: Polar Oceanography and Global Ocean Change: PI: Dr. Jinping Zhao, Ocean University of China
A high resolution Profiling Reflectance and Radiometer (PRR, 18 wavelengths at 313-875 nm) including profiler PRR800 (down welling irradiance and upwelling radiance sensors) and surface sensor PRR810 (down welling irradiance sensors) will be used for optical observations on HLY0702. A Compact-CTD (MCTD) with chlorophyll and turbidity sensors will be used to collect reference data for the optical studies. PRR800 and MCTD were mounted on a frame and were lowered to the 1% light level depth (<100 m) from ship at the side facing to the sun (or at any side when the sun is invisible). PRR810 was set up near the deployment location to observe the down welling irradiance at surface for reference. PRR/MCTD profiling casts were conducted at most CTD/Rosette stations when light, open water and time were suitable. The sampling frequency of PRR800/810 is 5Hz and for MCTD is 10Hz. During a recent Canadian cruise the deployment usually took 20 minutes and was conducted simultaneously with CTD/Rosette cast.

Four kinds of samples for optical analysis will be obtained by filtering a water sample: a film (diameter 47mm, aperture 0.7μm) for detritus (particulate), two films (25mm, 0.7μm; one in tinfoil, one in plastic box) for phytoplankton and a bottle of 100 ml water filtered through 0.2μm film for gelbstoff (yellow matter). Water samples at depth of 5 m, 20m and chlorophyll maximum will be collected from the Niskin bottles after CTD/rosette is on the deck (referred as Phyto in the rosette sampling log). All samples will be stored and frozen in the -20°C freezer at ship.

A surface sensor PRR810 will be temporally mounted on the ship to observe downwelling irradiance with a sampling interval of 60 seconds. If a suitable ice flow is found while on station the MCTD and PRR800 will be lowered to the depth about 120 m successively in an ice hole by an under-ice frame to measure the irradiance and radiance under ice. A surface sensor PRR810 will be mounted at ice surface to observe downwelling irradiance during PRR800 deployment.



Participants: 2

APPENDIX G: Microbial work in water column and benthos, PI: Dr. Yinxin Zeng, Polar Research Institute of China (PRIC), China

A. Project summary

As one of the dominant component of marine ecosystems and the pelagic marine food webs, microbial communities control the processes within the marine environments, such as primary production, turnover of biogenic elements, degradation of the organic matter and mineralization of xenobiotics and pollutants.

There exist strong and unique biogeochemical processes in the sediment environment, in which microbial communities play an important role. Thus, studies on biodiversity and community composition of microorganisms both in the water column and the sediments will be significant to our integrated understanding of the ecosystem processes and functions.

The objectives of this project are:

- to take better understanding of microbial diversity and community in the water column and sediment environments;
- to look into the microbial phylogenetic information;
- to further crossing-study of biology and geology, and coupling the biological and biogeochemical processes;
- to link to the objectives of HLY0702 Cruise ;
- to make contributions to PAG Science Themes.

Work onboard the ship will concentrated on sampling sea water samples in the water column from CTD/ Rosette, the surface and core sediment samples from van Veen grab or/and HAPS multi-core deployment. The community and diversity of bacteria will be analyzed by 16S rDNA-DGGE fingerprint and culture-based approaches to obtain the regional feature of bacterial community and diversity in Bering Sea. The research plan of the project will involve a set of shipboard sampling, pre- processing of seawater and sediment samples, cultivation of bacteria, and follow-on land-based laboratory work to analyze the 16S rDNA sequences of marine bacteria by PCR amplification and DGGE fingerprint. Further studies will cooperate with Dr. Jackie and other US scientists to make efforts to take better understanding of coupling of biochemical, physiological and molecular biological data.

The total number of around 42 stations is preplanned to take the sea water and sediment samples for this project, although this may be modified in discussions with the full lead science party. Station locations for water and sediment sample collections: NEC5, SIL5, VNG1, DLN5, NWC4, SWC4, SEC4, SWC3, NWC3, DLN3, NWC2, POP3A, SEC3, NEC3, SEC2, SWC2, DLN0, KIV2, KIV5, RUS1, RUS4, CPW1, CPW3, BRSA8, BRSA6, BRSA4, BRS12, LD13, LD14, SPH6, SPH3, SPH1, NEC1, SWC2D, NWC1, ANSB, DLN1, DBS1A, DBS1C, DBS1E, DBS1. 2L sea water samples at each selected stations will be collected with dedicated rosette bottles at the surface, middle (station with depth>90m) and near bottom depths. 50-100g surface sediment samples or/and sediment core samples at each selected stations will be collected with van Veen grab or/and HAPS multi-core deployment.

B. General approach

The overall approach in this study will be as follows: Determine microbial composition in sediments. Samples will be collected with van Veen grab or/and HAPS multi-core deployment. The sediment subsamples will be placed into sterile tubes immediately and stored at 4 °C and –80°C, respectively, until extraction of DNA in land-based Lab. Determine microbial composition in seawater. Water samples will be collected with CTD at the surface, middle (station with depth>90m) and near bottom depths. 2 L of water subsample will be filtered through 0.22 µm pore size filter using a filtration device. The filter will be placed in sterile tube and covered with lysis buffer (50mM Tris pH 8.0, 20mM EDTA-Na, 50mM sucrose). After processing, the tubes will be immediately frozen and stored at –80 °C until DNA extraction. 100-µl seawater subsamples will be spread directly on pre-cooled marine agar 2216 medium (Difco) and incubated at 4-6 °C for some days. Strains will maintain on marine agar slopes at 4 °C.
Participant=1

APPENDIX H: Current primary production and phytoplankton species composition in the Northern Bering Sea. Sang H Lee (PI: Sung Ho Kang), Korean Polar Research Institute (KOPRI), and Terry Whitledge (UAF)

Introduction

Recently, Schell (2000) suggested that seasonal primary productivity has decreased by 30-40 % in the northern Bering Sea over several decades, based on the recent decline from 1977 to 1997 in average $\delta^{13}C$ values on the baleen plates of bowhead whales, which reflects their food sources. In addition, Grebmeier and Cooper (2004) showed that the decline of benthic biomass related to a decrease in the carbon flux in the northern Bering Sea has continued into the late 1990s and early 2000s. Another retrospective assessment of primary productivity based on evidence from stable carbon isotopes in seabirds supports this hypothesis of a decline in the primary production on the Bering/Chukchi shelf (Abromaitis 2000). It is therefore particularly important to measure the current primary production and identify the species composition in the northern Bering Sea insofar as processes there both reflect changes in the Bering Sea and affect regional biological production in the Western Arctic Ocean

Objectives

The goal of this proposed research is to collect nutrient, carbon and nitrogen productivity data to assess the nutrient uptake and growth of major phytoplankton populations in the northern Bering Sea in relation to ambient light fields. Samples will also be collected for phytoplankton taxonomy at the productivity stations and other stations to assess recent composition of phytoplankton community. The obtained data will be compared to similar data from the northern Bering Sea in previous studies.

Scientific approach

Phytoplankton taxonomy

Water sample (100-200 ml) per each light depth (100, 50, 30, 12, 5, and 1 % PAR) will be collected from Niskin bottles at 15-20 productivity stations, added with 4 ml Glutaraldehyde, and filtered through GN/6 membrane filter 25 mm (0.45 um). The filters will be stored in a cover glass and 2 or 3 drops of HPMA (Hydroxylpropyl methacrylate) for sliding. After that, they will be dried at 40°C in a dry oven on the ship.

Inorganic nutrient analysis

Water samples (about 100 ml) for inorganic nutrients (nitrate, nitrite, ammonium, silicate, and phosphate) will be obtained from Niskin bottles mounted on CTD/rosette samplers. They will be stored in a freezer right after samplings and analyzed back to the lab using an automated nutrient analyzer (ALPKEM RFA model 300) following methods of Whitledge et al. (1981).

Carbon and nitrogen uptake rates of phytoplankton

Daily carbon and nitrogen uptake rates will be estimated from six light depths (100, 50, 30, 12, 5, and 1 % penetration of the surface photosynthetically active radiation, PAR) at 15-20 productivity stations, using a ^{13}C-^{15}N dual isotope tracer technique. Each light depth will be determined from an underwater PAR sensor or a secchi disk. Seawater sample (about 5 L) of each light depth will be transferred from the Niskin bottles to 1L polycarbonate incubation bottles which are covered with stainless steel screens for each light depth. Water samples will be inoculated with labeled nitrate ($K^{15}NO_3$), ammonium ($^{15}NH_4Cl$), and carbon ($NaH^{13}CO_3$) substrates (Dugdale and Goering 1967; Hama et al. 1983). The bottles will be incubated in a deck incubator cooled with surface seawater. The 4-7 hour incubations will be terminated by filtration through pre-combusted (450 °C) GF/F glass fiber filters (24 mm). The filters will be immediately frozen and preserved for mass spectrometric analysis at the stable isotope laboratory of the University of Alaska Fairbanks.

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<u>Participant: 1</u>

APPENDIX I: Ice seal shipboard surveys, aerial surveys, and satellite tagging

Ice seal field research methods, PI: <u>Peter Boveng/Michael Cameron</u>, NMML/NOAA, Seattle, WA

<u>Justification:</u> The shelf and slope of the Bering Sea provide productive habitats for bearded, spotted, ringed, and ribbon seals. Determining the seasonal patterns of seal abundance and distribution is key to understanding the ecological interactions involving these apex predators and the ecosystem "hotspots" where they are often found. Different species integrate the environment across variable spatial and

temporal scales, with the composite result reflecting oceanographic primary and secondary productivity derived from transport processes and mesoscale oceanographic features. During the 2007 Healy cruise our main focus will be seals in the sea ice zone: bearded seals (benthic foragers), and spotted, ringed, and ribbon seals (fish and crustacean predators). Specific research objectives of our project are to: 1) determine seal distribution, relative abundance and habitat associations via visual surveys, 2) describe seal habitat selection, haul-out behavior and foraging behavior via satellite tags deployed on captured animals, and 3) integrate measures of seal relative abundance and habitat use derived from visual surveys and remote sensing with measures of oceanographic structure and prey availability.

Shipboard surveys One or two observers would conduct line-transect sighting surveys from the recon tower whenever the ship is underway during daylight hours in ice of sufficient floe size to support seals. Species, group size, distance from the ship's track, location, and ice characteristics would be recorded for all seals sighted.

Aerial surveys The patchy nature of the ice seals' distribution may be difficult to characterize from shipboard sampling alone. The distributions can be detected and quantified much more thoroughly by complementing the shipboard sampling with aerial transects away from the ship's track. Line-transect surveys would be conducted from the ship's helicopter(s) while the vessel is on sampling stations. Two survey observers would record species, counts, and distance of seals from the track line on both sides of a helicopter, which are the elements required for estimation of seal densities. The helicopter(s) would be equipped with downward-looking digital video or still cameras to quantify the distribution of various types of ice cover and to validate a critical assumption in line transect estimation, that all seals on the track line are detected. A provisional estimate of helicopter flight hours is included as Appendix A to illustrate the typical considerations in planning these surveys

Satellite tagging A team of researchers would use inflatable boats to gain access to seals on ice floes. Seals would be captured with hoop nets, physically restrained, and fitted with geo-locating satellite-linked recorders of diving and haul-out behavior. We intend also to begin using a new type of recorder that includes a CTD. This capability has the potential to dramatically increase the spatial and temporal coverage of oceanographic sampling because these seal-borne CTDs would be carried for 2-3 months before shedding during the seal's annual molt. These seal capture operations can be completed in 1.5 hours from launch to recovery of the small boats, making it possible to conduct them simultaneously with oceanographic sampling stations occupied for similar or longer duration. The National Marine Mammal Laboratory can supply all the equipment (inflatable boats, motors, nets, etc) required for this work.

Participants:(pending, although a maximum of 6 berths for scientists is requested). If fewer berths, say 3-5 are available, some or all of the proposed seal research could be likely be accomplished by sharing personnel with other projects. If fewer than 3 berths were available, the seal projects would likely be limited to the shipboard surveys. National Marine Mammal Laboratory (NMML) researchers have experience conducting all of these methods in a not-to-interfere basis. The sampling schedule can be tailored to make efficient use of the vessel's resources in cooperation with a wide variety of other research. The minimal worthwhile configuration would be a small team conducting the shipboard transect surveys. If sufficient helicopter time could be secured, that would increase the utility of the project many-fold.

Helicopter request: Our estimates of flight time requirements are based on our recent experiences flying survey protocols identical to the ones proposed here in the Arctic (46 flight hours over 15 days during SLIPP2001 aboard the USCGC *Polar Star,* Mar 2001 and Antarctic (48 flight hours over 5 days aboard the USCGC *Polar Star*, Feb 2000; 178 flight hours over 39 days aboard the R/V *N.B. Palmer*, Dec 1999-Feb 2000). Line transect aerial surveys will be conducted whenever the ship is within survey range of sea ice, but only during safe flying conditions when weather allows suitable lateral visibility (1 km at 100 m altitude). In the Bering Sea, these conditions are typically restricted to (at best) 2 days out of 3, so we anticipate perhaps about 15-20 days when there will be suitable aerial survey conditions. With one helicopter available and 2 survey flights per day under ideal conditions, it is anticipated that about 20-30 survey flights could be flown during the cruise. At about 1.5 per flight, up to 45 hours of helicopter support are requested for marine mammal surveys. We also propose to bring some electronic equipment aboard the helicopters to record data during survey flights. This equipment would be the same as gear that we have used on previous survey efforts on helicopters operating from the R/V *N.B. Palmer* and

USCGC *Polar Star*, and includes laptop computers, GPS receivers, and a downward-looking digital video recorder (to film the ice in the observers' "blind spot" under the helicopter).
Participants: 5 (w/local hunters from Gambell and Savoonga), pending Gay Sheffield, ADFG

APPENDIX J. Biopsy and instrumentation of ice seals in the St. Lawrence Island Polynya, Gay Sheffield, Alaska Dept Fish and Game, Fairbanks, AK
In Alaska, four species of seals (i.e. Bearded, ribbon, ringed, and spotted) are closely associated with the sea ice and are commonly referred to as "ice seals". Gay Sheffield will investigate ice seal stock structure, migration routes, and dispersal patterns of ice seals that occur in the northern Bering Sea. Seals will be live-captured and instrumented with satellite transmitters to provide information about seasonal movements, dive depths/duration, and regional habitat use. Additionally, skin biopsies will be collected from all species for genetic analysis. Gay Sheffield will also assist with the ice seal survey and tagging be undertaken by the NMML group.
Participants: 1

APPENDIX K. POLAR-PALOOZA-An outreach activity for IPY (2007-2009) "PASSPORT TO KNOWLEDGE", (PI: Geoffrey Haines-Stiles; **"POLARPALOOZA"** (http://passporttoknowledge.com/polar-palooza/) is the working title for a series of high-profile public events, presented in cooperation with science centers, universities, and libraries across America, designed to give large and diverse audiences an opportunity to meet and interact directly with polar experts, to learn about these little understood areas, and to understand why the Poles and the research being done there are relevant to their lives. Designed as a 2-day event at each host site, **POLARPALOOZA** will feature a variety of individualized programs that will meet the needs of several targeted constituencies (see list below), but the centerpiece is a presentation for the general public (both adults and families) featuring a team of polar researchers who weave essential information and current science into an engaging and accessible performance, "STORIES FROM A CHANGING PLANET." THE STORYLINE will be supported by High Definition Video clips, photo blow-ups, authentic polar artifacts ("props"), and evocative location audio (underwater penguin calls, ice crashing into the ocean from melting glaciers), the **POLARPALOOZA** team will describe the unique geography, climate, and inhabitants of the Poles. They will show that our planet is and always has been changing, but that change seems to have accelerated in the recent past, perhaps in part due to human activity, and that this change has long-lasting implications for all living things, everywhere on Earth. They'll show dramatic images of the most unique aspects of the Poles: miles-thick ice, frozen lakes, the months of continuous darkness and light, and look at how humans and other living things have adapted to life in the inhospitable cold and dark. They will demonstrate evidence of environmental changes on a global level today, and explain why the Poles are critical in understanding why change is occurring and how researchers are measuring and monitoring developments. Visit http://passporttoknowledge.com/polar-palooza/pp06.php/ for media products (podcasts, blogs, and vlogs).
Participants: 2

APPENDIX L. ARCUS Polar_TREC "Live from IPY", (Janet Warburton);
PolarTREC (http://www.polartrec.com/) will send teachers to the Arctic and Antarctic as members of research teams studying a topic relevant to IPY, with "Live from IPY" calls, Internet presentations, and podcasts, journals, interactive bulletin boards, photo galleries, online rseource and activities. View http://www.arcus.org/TREC/VBC/index.php?autocom=custom&page=ecological_change/ to see results from the last years HLY0601 cruise for this science program.

APPENDIX M. Undergraduate Project on Infaunal Calorimetry", (PI: Bodil Bluhm and Dominic Hondolero, University of Alaska Fairbanks)
This is an undergraduate student calorimetry/benthic energetics project funded through a CIFAR IPY stipend to compare calorimetric content of preserved vs frozen) benthic infauna common in the northern Bering and Chukchi Seas.