Distributed Biological Observatory – Northern Chukchi Integrated Study

Healy 1901 Cruise Report

Chief Scientist: Robert S. Pickart, Woods Hole Oceanographic Institution
Co-Chief Scientist: Jacqueline M. Grebmeier, Chesapeake Biological Laboratory

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Section A: Overview

The third annual of research cruise the Distributed Biological Observatory – Northern Chukchi Integrated Study (DBO-NCIS) took place on the US Coast Guard Cutter *Healy*, from 4–23 August, 2019. The overall goal of DBO-NCIS is to document and understand ongoing changes to the Pacific-Arctic ecosystem in light of the changing physical drivers. The main objectives for the cruise were (1) to occupy key transects on the northern Bering and Chukchi shelves, including DBO lines 1-5, with an extensive suite of water column and benthic measurements; (2) to carry out a high-resolution survey of the Chukchi Slope Current to shed light on its fate; (3) to collect numerous underway measurements of the atmosphere-ocean-ice system; and (4) to service moorings owned by the Japan Agency of Marine Science and Technology (JAMSTEC). In addition to the core components of the DBO-NCIS program, a number of ancillary projects were added which enhanced the breadth of the scientific measurements conducted during the cruise. The list of activities and associated PIs is as follows:

- Water mass properties and circulation, R. Pickart (WHOI)
- Bottle oxygen, nutrients and chlorophyll, C. Mordy (PMEL)
- Dissolved inorganic carbon and total alkalinity, J. Cross (PMEL)
- Mesozooplankton and larval fish, J. Duffy-Anderson (NMFS)
- Macrofauna, sediment characteristics, and sea ice melt tracers ($\delta^{18}O$), J. Grebmeier and L. Cooper (UMCES)
- Harmful Algal blooms, D. Anderson (WHOI)
- Aerosols, J. Creamean (NOAA)
- Microbes, E. Collins (UAF)
- Seabirds, K. Kuletz (USFWS)

In addition to these activities, two Drifting Arctic Meteorological Platform (DAMP) buoys and one Surface Velocity Program (SVP) drifter were launched to measure atmospheric variables and sea surface temperature (I. Rigor, UW), and calibration measurements were taken adjacent to two Saildrones on the Chukchi shelf (J. Cross, PMEL).

Due to inclement weather, *Healy* departed two days later than planned. Despite this loss of shiptime, all of the cruise objectives were met. This is mostly due to the hard work and dedication of *Healy's* crew and the science party. In fact, we were able to occupy a few more transects than originally planned. A map of the station sites is shown in Figure A-1. DBO lines 1-5 were occupied, progressing south to north, with a full suite of interdisciplinary measurements. The "top hat" survey across the Chukchi Slope consisted primarily of physical measurements to measure the Chukchi Slope Current, with the aim of documenting the fate of the current after it leaves Barrow Canyon. Finally, transects were done on either side of Barrow Canyon, including a section of hydrographic measurements across the mouth of the canyon using expendable probes.

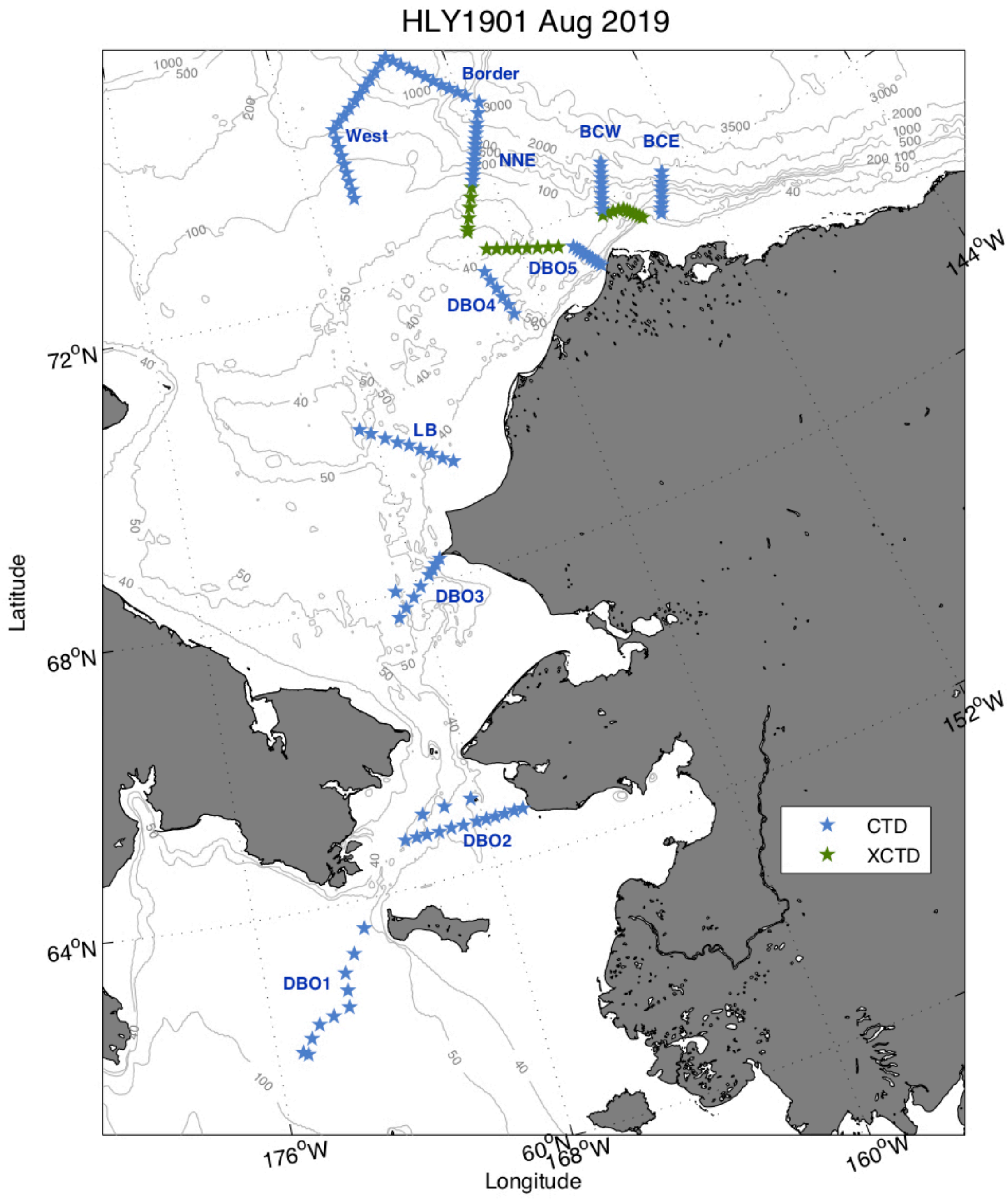

Figure A-1: Stations occupied during the 2019 DBO-NCIS cruise (see the legend). The five DBO lines are labeled. The remaining transects are LB=Ledyard Bay; BCE=Barrow Canyon East; BCW=Barrow Canyon West; NNE=North-northeast; Border=Chukchi Borderlands; West=western-most transect.

A conductivity-temperature-depth (CTD) cast was done at each site (except where expendable CTDs were used), while many of the stations included water sampling, net tows, and benthic work. *Healy's* two vessel-mounted acoustic Doppler current profilers (ADCPs) were operational throughout the cruise, as were the underway CTD and the ship's meteorological sensors. The mooring work was done in Barrow Canyon and along the Chukchi slope to the west of the canyon (explained in detail in the mooring section). Table A-1 summarizes all CTD station operations as well as deployed assets and mooring operations.

The DBO-NCIS PIs welcomed the participation of four SeaGrant and Knauss Fellows, as well as a PolarTrec teacher. The additional participants were a tremendous help at sea as they stood watches and bolstered outreach efforts. Online articles and teacher at sea journals can be found at the following links:

NOAA Research News:
- https://research.noaa.gov/article/ArtMID/587/ArticleID/2480/Searching-for-tiny-clues-to-changing-seas
- https://research.noaa.gov/article/ArtMID/587/ArticleID/2479/Bird-die-offs-provide-window-into-a-changing-Arctic

PolarTREC Expedition Journals:
- https://www.polartrec.com/expeditions/northern-chukchi-integrated-study

Below are the individual reports for each component of the cruise. These include descriptions of the operations, locations of sampling, and, where possible, some brief highlights of initial results. We acknowledge the officers and crew of the *Healy*, whose hard work and dedication enabled us to carry out our science operations in a safe and productive environment. The team of STARC technicians kept the ship's science systems running smoothly throughout the cruise. Lastly, we acknowledge Drs. Emily Osborne and Renee Crain, program directors of NOAA's Arctic Research Program, for supporting the fieldwork.

Table A-1: CTD stations in order of completion and additional operations performed at each station

DBO-NCIS										
HLY1901 Event Log										
	CTD Number	**Station Name**	**Latitude**	**Longitude**	**Latitude**		**Longitude**		**Cor. Depth (m)**	**Station Operations**
			Decimal (N)	**Decimal (W)**	**Deg (N)**	**Min (N)**	**Deg (W)**	**Min (W)**	***indicates approx.**	
TRANSIT										
Test CTD										
8/5/19 21:59	000	test	62.96	173.53	62	57.80	173	31.85	65.40	Bongo tow
Transit to DBO1										
DBO1										
8/6/19 4:44	001	DBO1-1	62.00	175.07	62	0.29	175	4.15	81.20	Water sampling, Bongo tow, 2 Van Veen
8/6/19 6:57	002	DBO1-2	62.04	175.22	62	2.65	175	12.92	81.30	Water sampling, Bongo tow, 7 Van Veen, 8 cores

8/6/19 12:06	003	DBO1-3	62.22	174.88	62	12.97	174	52.52	77.10	CTD only
8/6/19 13:29	004	DBO1-4	62.39	174.56	62	23.52	174	33.85	72.70	Water sampling, Bongo tow, 2 Van Veen
8/6/19 16:03	005	DBO1-5	62.47	174.08	62	28.15	174	5.06	69.40	CTD only
8/6/19 17:37	006	DBO1-6	62.55	173.55	62	33.17	173	33.28	67.00	Water sampling, Bongo tow, 2 Van Veen
8/6/19 20:13	007	DBO1-7	62.79	173.50	62	47.31	173	29.93	69.40	CTD only
8/6/19 21:36	008	DBO1-8	63.03	173.46	63	2.07	173	27.70	72.00	Water sampling, Bongo tow, 7 Van Veen, 8 cores
8/7/19 2:30	009	DBO1-9	63.28	173.07	63	16.61	173	4.44	69.10	CTD only
8/7/19 4:34	010	DBO1-10	63.60	172.59	63	36.14	172	35.19	54.10	CTD only
Transit to Nome for emergency pickup of secondary shipboard CTD sensors										
Transit to DBO2										
DBO2										
8/8/19 6:27	011		64.6695	166.6612	64	40.17	166	39.67	22.7	CTD only
8/8/19 7:34	012		64.6728	166.9555	64	40.37	166	57.33	26.7	Water sampling, Bongo tow, 2 Van Veen
8/8/19 9:14	013		64.6717	167.2817	64	40.3	167	16.9	31.3	CTD only
8/8/19 10:14	014		64.6695	167.597	64	40.17	167	35.82	31.9	Water sampling, Bongo tow, 2 Van Veen
8/8/19 11:53	015		64.6705	167.9062	64	40.23	167	54.37	38.8	CTD only
8/8/19 13:06	016	DBO2-3	64.6742	168.2292	64	40.45	168	13.75	38.9	Water sampling, Bongo tow, 2 Van Veen
8/8/19 15:13	017		64.6722	168.6845	64	40.33	168	41.07	45.8	CTD only
8/8/19 16:35	018	DBO2-2	64.6815	169.0872	64	40.89	169	5.23	45.3	Water sampling, Bongo tow, 2 Van Veen
8/8/19 18:42	019		64.6707	169.4982	64	40.24	169	29.89	45.3	CTD only
8/8/19 20:29	020	DBO2-1	64.6723	169.9172	64	40.34	169	55.03	47.5	Water sampling, Bongo tow, 2 Van Veen
8/8/19 22:34	021		64.6762	170.2585	64	40.57	170	15.51	49.7	CTD only
8/8/19 23:42	022	DBO2-0	64.6718	170.646	64	40.31	170	38.76	48.2	Water sampling, Bongo tow, 2 Van Veen
8/9/19 2:48	023	DBO2-4	64.9623	169.8977	64	57.74	169	53.86	48.90	Water sampling, Bongo tow, 2 Van Veen
8/9/19 5:42	024	DBO2-5	64.993	169.1325	64	59.58	169	7.95	49.10	Water sampling, Bongo tow, 2 Van Veen
8/9/19 8:36	025	DBO2-7	65.003	168.221	65	0.18	168	13.26	46.50	Water sampling, Bongo tow, 5 Van Veen
Transit to SCH mooring										
SCH mooring CTD										

8/9/19 22:14	026		68.0303	168.8223	68	1.82	168	49.34	59.00	Water sampling
dead bird collection										
failed mooring release										
DBO3										
8/10/19 2:29	027	DBO3-8	67.6745	168.939	67	40.47	168	56.34	50.80	Water sampling, Bongo tow, 5 Van Veen, 8 cores
8/10/19 6:12	028	DBO3-7	67.7812	168.6063	67	46.87	168	36.38	50.60	Water sampling, Bongo tow, 2 Van Veen
8/10/19 8:15	029	DBO3-6	67.8933	168.2302	67	53.6	168	13.81	58.40	Water sampling, Bongo tow, 5 Van Veen, 8 cores
8/10/19 12:04	030	DBO3-5	68.0117	167.8857	68	0.7	167	53.14	53.30	Water sampling, Bongo tow, 2 Van Veen
8/10/19 14:08	031	DBO3-4	68.1297	167.4898	68	7.78	167	29.39	50.30	Water sampling, Bongo tow, 1 Van Veen
8/10/19 15:36	032	DBO3-3	68.185	167.3017	68	11.1	167	18.1	48.60	Water sampling, Bongo tow, 1 Van Veen
8/10/19 17:04	033	DBO3-2	68.2432	167.1383	68	14.59	167	8.3	44.40	Water sampling, Bongo tow, 1 Van Veen
8/10/19 18:53	034	DBO3-1	68.3028	166.9432	68	18.17	166	56.59	35.40	Water sampling, Bongo tow, 1 Van Veen
DBO4										
8/11/19 10:41	035	DBO4-1N	71.0852	161.2008	71	5.11	161	12.05	46.6	Water sampling, Bongo tow, 2 Van Veen
8/11/19 12:46	036	DBO4-2N	71.2232	161.2785	71	13.39	161	16.71	49.3	Water sampling, Bongo tow, 5 Van Veen, 8 cores
8/11/19 16:03	037	DBO4-3N	71.3457	161.3978	71	20.74	161	23.87	47.4	Water sampling, Bongo tow, 2 Van Veen
8/11/19 18:32	038	DBO4-4N	71.4793	161.4993	71	28.76	161	29.96	47.6	Water sampling, Bongo tow, 5 Van Veen, 2 cores
8/11/19 22:17	039	DBO4-5N	71.6047	161.6253	71	36.28	161	37.52	46.3	Water sampling, Bongo tow, 2 Van Veen
8/11/19 23:58	040	DBO4-6N	71.7375	161.7335	71	44.25	161	44.01	44.3	Water sampling, Bongo tow, 2 Van Veen, test XCTD, SVP
test xCTD at end of DBO4										
8/12/19 0:16	17099373	test	71.74183	161.7308	71	44.51	161	43.85	43*	XCTD
XCTDs on section North-northeast										
8/12/19 4:14	17099374	NNE-1	72.301	161.8252	72	18.06	161	49.51	39*	XCTD
8/12/19 4:27	17099375	NNE-2	72.34433	161.758	72	20.66	161	45.48	41*	XCTD
8/12/19 5:05	17099376	NNE-3	72.46367	161.5692	72	27.82	161	34.15	45*	XCTD
8/12/19 5:46	17099377	NNE-4	72.58633	161.3737	72	35.18	161	22.42	48*	XCTD
8/12/19 6:31	17099378	NNE-5	72.7045	161.1707	72	42.27	161	10.24	52*	XCTD

8/12/19 7:13	17099379	NNE-6	72.82083	160.9875	72	49.25	160	59.25	55*	XCTD
Section North-Northeast										
8/12/19 7:55	041	NNE-7	72.898	160.8428	72	53.88	160	50.57	57.2	Water sampling, 2 Van Veen
8/12/19 9:17	042	NNE-8	72.9573	160.7407	72	57.44	160	44.44	71.6	
8/12/19 10:00	043	NNE-9	73.0177	160.6458	73	1.06	160	38.75	138.6	Water sampling, 2 Van Veen
8/12/19 11:31	044	NNE-10	73.0795	160.5352	73	4.77	160	32.11	190.7	Water sampling
8/12/19 12:35	045	NNE-11	73.137	160.4497	73	8.22	160	26.98	260.8	Water sampling, Bongo tow, 2 Van Veen
8/12/19 15:17	046	NNE-12	73.1995	160.358	73	11.97	160	21.48	357.5*	CTD stop at 300 m
8/12/19 16:15	047	NNE-13	73.2592	160.2483	73	15.55	160	14.9	646.7*	CTD stop at 300 m, Water sampling, Bongo tow
8/12/19 19:16	048	NNE-14	73.3183	160.156	73	19.1	160	9.36	1206.5*	CTD stop at 300 m
8/12/19 20:21	049	NNE-15	73.3805	160.0643	73	22.83	160	3.86	1378.2*	CTD stop at 300 m, Water sampling
Mooring recovery: NHC tripod mooring										
8/13/19 2:50	050	NNE-16	73.4452	159.9408	73	26.71	159	56.45	1734.9*	CTD stop at 300 m, Release testing
8/13/19 3:54	051	NNE-17	73.5033	159.8383	73	30.2	159	50.3	1977.9*	CTD stop at 300 m
8/13/19 5:02	052	NNE-18	73.561	159.7285	73	33.66	159	43.71	2190.9*	CTD stop at 300 m
8/13/19 6:19	053	NNE-19	73.6775	159.5202	73	40.65	159	31.21	2578.3*	CTD stop at 300 m, Water sampling
8/13/19 8:02	054	NNE-20	73.7988	159.2962	73	47.93	159	17.77	3003.7	Deep CTD, Water sampling, DAMP buoy deployment
Section Boarderland										
8/13/19 11:56	055	BL-10	73.9405	159.7517	73	56.43	159	45.1	2214.7*	CTD stop at 300 m, Water sampling
8/13/19 13:20	056	BL-9	74.0215	160.032	74	1.29	160	1.92	807.3*	CTD stop at 300 m, Water sampling
8/13/19 14:36	057	BL-8	74.0998	160.3278	74	5.99	160	19.67	842.3*	CTD stop at 300 m
8/13/19 15:47	058	BL-7	74.1757	160.6078	74	10.54	160	36.47	492*	CTD stop at 300 m, Water sampling
8/13/19 17:24	059	BL-6	74.2602	160.8968	74	15.61	160	53.81	970*	CTD stop at 300 m
Broke off line for NAP mooring, weather too rough										
8/13/19 21:54	060	BL-5	74.3447	161.1765	74	20.68	161	10.59	1536.3*	CTD stop at 300 m, Water sampling
8/13/19 23:40	061	BL-4	74.4275	161.454	74	25.65	161	27.24	1592.5*	CTD stop at 300 m
8/14/19 0:49	062	BL-3	74.5073	161.7327	74	30.44	161	43.96	1609.3*	CTD stop at 300 m, Water sampling
8/14/19 3:10	063	BL-2	74.5923	162.0482	74	35.54	162	2.89	1685.4*	CTD stop at 300 m
8/14/19 4:21	064	BL-1	74.6742	162.3463	74	40.45	162	20.78	1720.4*	CTD stop at 300 m, Water sampling
Section West										

8/14/19 5:41	065	W-1	74.7508	162.621	74	45.05	162	37.26	1668.3*	CTD stop at 300 m, Water sampling
8/14/19 7:11	066	W-2	74.6872	162.9697	74	41.23	162	58.18	1507.4*	CTD stop at 300 m
8/14/19 8:24	067	W-3	74.6147	163.3185	74	36.88	163	19.11	1260.7*	CTD stop at 300 m, Water sampling
8/14/19 9:43	068	W-4	74.552	163.6557	74	33.12	163	39.34	947.8*	CTD stop at 300 m
8/14/19 10:47	069	W-5	74.4847	163.9932	74	29.08	163	59.59	621.3*	CTD stop at 300 m, Water sampling
8/14/19 12:01	070	W-6	74.42	164.3255	74	25.2	164	19.53	438.9*	CTD stop at 300 m
8/14/19 13:06	071	W-7	74.355	164.6605	74	21.3	164	39.63	383.8*	CTD stop at 300 m, Water sampling
8/14/19 14:25	072	W-8	74.2888	164.9972	74	17.33	164	59.83	316*	CTD stop at 300 m
8/14/19 15:36	073	W-9	74.2202	165.3528	74	13.21	165	21.17	273.4*	CTD stop at 300 m, Water sampling, 2 Van Veen
Broke off line for NAP mooring recovery										
8/15/19 8:25	074	W-7	74.3542	164.6385	74	21.25	164	38.31	383.8*	*repeat of station W-7
8/15/19 9:32	075	W-8	74.2867	165.0048	74	17.2	165	0.29	316*	*repeat of station W-8
8/15/19 10:30	076	W-9	74.2208	165.3413	74	13.25	165	20.48	273.4*	*repeat of station W-9
8/15/19 11:32	077	W-10	74.1573	165.6782	74	9.44	165	40.69	229.6	
8/15/19 12:37	078	W-11	74.09	166.0063	74	5.4	166	0.38	211.8	DAMP buoy deployment
8/15/19 15:10	079	W-12	73.9707	166.0023	73	58.24	166	0.14	160.7	
8/15/19 16:16	080	W-13	73.8533	166.0117	73	51.2	166	0.7	137.1	
8/15/19 18:45	081	W-14	73.7435	166.004	73	44.61	166	0.24	119.1	Release testing
8/15/19 20:09	082	W-15	73.6335	165.9962	73	38.01	165	59.77	110.1	
8/15/19 22:38	083	W-16	73.521	166.0057	73	31.26	166	0.34	92.3	Bongo Tow
8/15/19 23:39	084	W-17	73.4065	166.0147	73	24.39	166	0.88	76.5	
8/16/19 1:26	085	W-18	73.2922	166.0013	73	17.53	166	0.08	67.5	
8/16/19 2:26	086	W-19	73.1792	166.019	73	10.75	166	1.14	63.3	
XCTDs on transit to DBO5										
8/16/19 11:04	17099380		72.01	161.32	72	0.45	161	19.35	32.1*	XCTD
8/16/19 11:52	17099381		71.96	160.92	71	57.68	160	55.36	37.3*	XCTD
8/16/19 12:40	17099382		71.92	160.52	71	55.01	160	31.07	40.5*	XCTD
8/16/19 13:26	17099383		71.87	160.12	71	52.37	160	7.04	44*	XCTD
8/16/19 14:14	17099384		71.83	159.72	71	49.64	159	43.44	49.8*	XCTD
8/16/19 15:04	17099341		71.78	159.31	71	46.80	159	18.76	49.8*	XCTD
8/16/19 15:49	17099342		71.73	158.89	71	44.01	158	53.50	56.4*	XCTD

8/16/19 16:35	17099343		71.69	158.50	71	41.32	158	29.70	55.7*	XCTD
DBO5										
8/16/19 17:56	087	DBO5-10	71.618	157.9172	71	37.08	157	55.03	63.1	Water sampling, Bongo tow, 2 Van Veen
8/16/19 19:41	088	DBO5-9	71.5742	157.8047	71	34.45	157	48.28	65.8	Water sampling, Bongo tow, 2 Van Veen
8/16/19 21:31	089	DBO5-8	71.5343	157.7352	71	32.06	157	44.11	73.5	Water sampling, Bongo tow, 2 Van Veen
8/16/19 23:14	090	DBO5-7	71.4938	157.6458	71	29.63	157	38.75	87.5	Water sampling, Bongo tow, 2 Van Veen
8/17/19 1:02	091	DBO5-6	71.4503	157.5792	71	27.02	157	34.75	112.4	Water sampling, Bongo tow, 2 Van Veen
8/17/19 2:38	092	DBO5-5	71.4047	157.4598	71	24.28	157	27.59	125.9	Water sampling, Bongo tow, 2 Van Veen
8/17/19 4:44	093	DBO5-4	71.3717	157.3893	71	22.3	157	23.36	112.6	Water sampling, Bongo tow, 2 Van Veen
8/17/19 6:40	094	DBO5-3	71.3242	157.3215	71	19.45	157	19.29	87.2	Water sampling, Bongo tow, 2 Van Veen
8/17/19 8:36	095	DBO5-2	71.289	157.2193	71	17.34	157	13.16	55.6	Water sampling, Bongo tow, 2 Van Veen
8/17/19 9:48	096	DBO5-1	71.251	157.1557	71	15.06	157	9.34	48	Water sampling, Bongo tow, 2 Van Veen
Mooring recovery: NBC tripod mooring										
Barrow Canyon West										
8/18/19 1:01	097	BCW-1	72.4722	155.4207	72	28.33	155	25.24	1915.3*	CTD stop at 300 m, Water sampling
8/18/19 2:09	098	BCW-2	72.4153	155.5032	72	24.92	155	30.19	1648.7*	CTD stop at 300 m
Stopped work for crew rest										
Mooring recoveries: BCW, BCC, and BCE										
JAMSTEC XCTD line										
8/18/19 23:42	16124167	J-XCTD-1	71.59	154.80	71	35.45	154	48.20	38.1*	
8/18/19 23:54	17025009	J-XCTD-2	71.63	154.90	71	37.62	154	54.27	52.6*	
8/19/19 0:18	17025011	J-XCTD-3	71.66	155.00	71	39.75	154	59.83	98.2*	
8/19/19 0:32	17025012	J-XCTD-4	71.70	155.09	71	41.76	155	5.19	165.5*	
8/19/19 0:55	17025014	J-XCTD-5	71.73	155.18	71	43.83	155	11.06	289.4*	
8/19/19 1:11	17025015	J-XCTD-6	71.76	155.27	71	45.67	155	16.24	217.2*	
8/19/19 1:32	17025016	J-XCTD-7	71.80	155.38	71	48.00	155	23.02	148.9*	
8/19/19 1:58	17025017	J-XCTD-8	71.82	155.59	71	48.95	155	35.16	119.3*	
8/19/19 2:20	17025018	J-XCTD-9	71.82	155.82	71	49.48	155	49.22	90.2*	
8/19/19 2:43	19018667	J-XCTD-10	71.83	156.04	71	49.96	156	2.33	83.7*	

8/19/19 3:06	19018668	J-XCTD-11	71.84	156.27	71	50.15	156	16.00	79.6*	
Barrow Canyon West take 2										
8/19/19 3:48	099	BCW-10	71.9082	156.1932	71	54.49	156	11.59	67.5	Water sampling, Bongo tow, 2 Van Veen
8/19/19 5:12	100	BCW-9	71.9705	156.1073	71	58.23	156	6.44	73.1	
8/19/19 5:55	101	BCW-8	72.0308	156.028	72	1.85	156	1.68	141.8	Water sampling, Bongo tow, 2 Van Veen
8/19/19 7:39	102	BCW-7	72.1003	155.9415	72	6.02	155	56.49	208.2	
8/19/19 8:25	103	BCW-6	72.1557	155.8478	72	9.34	155	50.87	266.6	Water sampling, Bongo tow, 2 Van Veen
8/19/19 10:58	104	BCW-5	72.2222	155.7663	72	13.33	155	45.98	392.3*	CTD stop at 300 m, Water sampling
8/19/19 11:58	105	BCW-4	72.2858	155.6862	72	17.15	155	41.17	1075.3*	CTD stop at 300 m
8/19/19 12:47	106	BCW-3	72.3473	155.6042	72	20.84	155	36.25	1172.5*	CTD stop at 300 m, Water sampling
Mooring deployments BCW, BCC, and BCE										
Barrow Canyon East										
8/20/19 2:34	107	BCE-1	71.5357	154.0313	71	32.14	154	1.88	46.8	Water sampling, Bongo tow, 2 Van Veen
8/20/19 3:48	108	BCE-2	71.5957	153.9502	71	35.74	153	57.01	48.2	Water sampling
8/20/19 4:30	109	BCE-3	71.6498	153.8398	71	38.99	153	50.39	48.5	Water sampling, Bongo tow, 2 Van Veen
8/20/19 5:43	110	BCE-4	71.7147	153.7393	71	42.88	153	44.36	54.4	Water sampling
8/20/19 6:38	111	BCE-5	71.7815	153.63	71	46.89	153	37.8	133.2	Water sampling, Bongo tow, 2 Van Veen
8/20/19 8:19	112	BCE-6	71.8387	153.5562	71	50.32	153	33.37	191.4	Water sampling
8/20/19 9:08	113	BCE-7	71.8928	153.459	71	53.57	153	27.54	661.1*	CTD stop at 300 m, Water sampling
8/20/19 10:13	114	BCE-8	71.9517	153.3652	71	57.1	153	21.91	1386.8*	CTD stop at 300 m, Water sampling
8/20/19 11:08	115	BCE-9	72.0202	153.2562	72	1.21	153	15.37	1736.2*	CTD stop at 300 m, Water sampling
UAF mooring recoveries										
Ledyard Bay										
8/21/19 21:16	116	LB-13	70.2613	168.5183	70	15.68	168	31.1	43.7	Water sampling
8/21/19 22:34	117	LB-12	70.1705	168.1275	70	10.23	168	7.65	47.1	Water sampling, Bongo tow, 2 Van Veen
8/22/19 0:39	118	LB-11	70.0582	167.6458	70	3.49	167	38.75	49.5	Water sampling
8/22/19 1:59	119	LB-10	69.9595	167.2257	69	57.57	167	13.54	47.9	Water sampling, Bongo tow, 2 Van Veen
8/22/19 3:42	120	LB-9	69.883	166.8177	69	52.98	166	49.06	47	Water sampling

8/22/19 4:57	121	LB-8	69.785	166.452	69	47.1	166	27.12	45.5	Water sampling, Bongo tow, 2 Van Veen
8/22/19 6:40	122	LB-7	69.6875	166.094	69	41.25	166	5.64	41.9	Water sampling
8/22/19 7:51	123	LB-6	69.584	165.7427	69	35.04	165	44.56	38.9	Water sampling, Bongo tow, 2 Van Veen
8/22/19 9:25	124	LB-5	69.5012	165.3765	69	30.07	165	22.59	34.9	Water sampling

Section B: Hydrographic Measurements

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Overview

A total of 124 CTD casts were occupied on the cruise, comprising 11 transects (Figure A-1; Table A-1). The instrument package consisted of a Sea-Bird 911plus CTD measuring temperature and conductivity (dual sensors), pressure, oxygen, beam transmission, fluorescence, and PAR. This was mounted on a 24-position rosette with 10 liter Niskin bottles. An altimeter was used to bring the package approximately 2 m above the sea floor on the shelf stations (5 m in rough weather), and approximately 10 m above the sea floor on the stations seaward of the shelfbreak. Water samples were generally taken every 10 m on the shelf, including at the bottom of the cast, just below the surface, and at the subsurface fluorescence maximum (when it was present). For the stations seaward of the shelfbreak the CTD casts were limited to 300m except station 54. (Table A-1). Bottle salinity samples were taken at the bottom of most of the shelf stations (usually in a bottom mixed-layer), and over a range of depths at the deep station. See the CTD calibration report below for details regarding the instrument set up, data processing, and in-situ calibration of the two conductivity sensors.

The overall CTD data quality was excellent. Downcast 1-db pressure-averaged files were produced following each cast. At the conclusion of the cruise a small number of density inversions were interpolated over, and the salinity data were calibrated using the deep bottle measurements. The resulting accuracy is 0.002 for both the primary and secondary sensors (see the CTD calibration report). The final quality-controlled, calibrated CTD files will be posted to the DBO-NCIS web site for use by the science party.

Using the downcast files, we constructed vertical sections of CTD variables and absolute geostrophic velocity for each transect. The plots include the soundspeed-corrected bottom topography from the ship's Knudsen recorder (smoothed to remove noise). We also constructed sections of the primary water masses present at each transect, an example of which is shown in Figure B-1 for the BCE line.

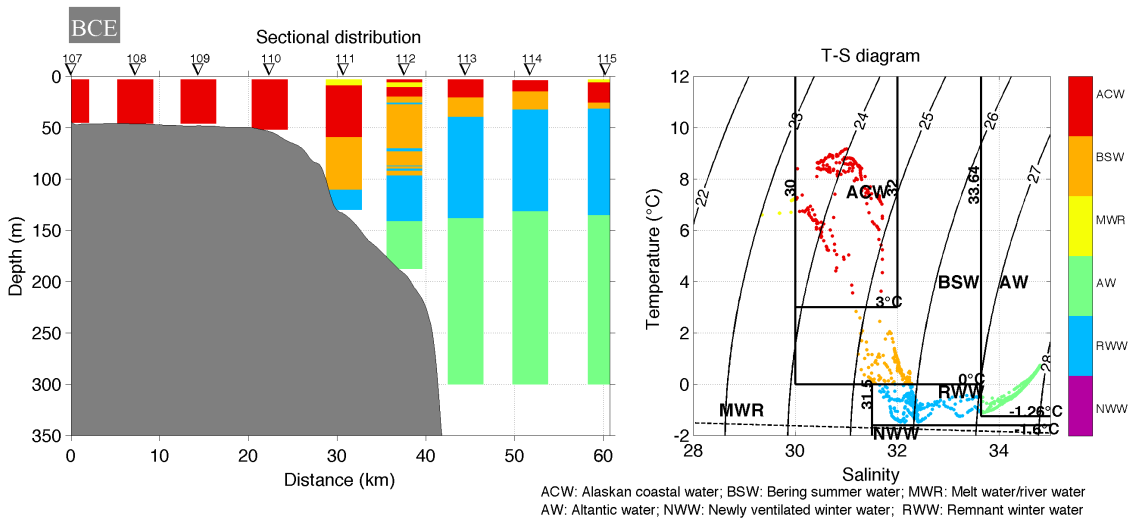

Figure B-1: Left-hand panel: Distribution of water masses at the BCE line, based on the definitions shown in the T-S diagram in the right-hand panel. The water masses are color-coded according to the colorbar on the right. The abbreviations are: ACW = Alaskan coastal water; BSW = Bering summer water; NWW = newly ventilated Pacific winter water; RWW = remnant Pacific winter water; MWR = melt water / river runoff; AW = Atlantic water.

Both of *Healy's* hull-mounted ADCPs – an Ocean Surveyor (OS) 150 kHz unit and a 75 kHz unit – collected measurements of the water column velocity throughout the cruise. Only the OS150 returned good data on the shallow shelf, while both the OS150 and OS75 returned good data on the continental slope. Ocean current products are described below in the Shipboard ADCP report. The underway throughflow system provided timeseries of temperature, salinity, and various other properties at a depth of 8 m. Using data from the different wind sensors on the ship, we will construct a quality-controlled timeseries of wind speed and direction, post-cruise. Both the underway throughflow and wind products are described below in the Underway shipboard data report.

Brief Highlights

The scientific analysis of the 2019 DBO-NCIS physical data is now underway. One of the present aims is to better understand why there is a benthic hotspot in the center of Barrow Canyon along the DBO5 line. A possible clue for why this is the case can be seen in the vertical sections of DBO5 associated with the 2019 occupation of the line (Fig. B-2). During this time the Alaskan Coastal Current (ACC) was strong (absolute geostrophic velocity exceeding 50 cm s^{-1}), advecting warm Alaskan Coastal Water on the eastern side of the canyon. A notable feature of the section is nearly vertically oriented isopycnals in the center of the canyon below a depth of ~30 m. There is a plume of high oxygen and high fluorescence extending to the bottom along the isopycnals. This plume occurs on the westward (cyclonic) side of the ACC, where it is expected that downwelling should occur due to the dynamics of the flow. The implication is that, during the warm months of the year – whenever the ACC is strong and there is a subsurface phytoplankton bloom – carbon will be strongly pumped to the sediments providing a food source for the benthic fauna. This localized vertical advection would then result in a biological hotspot. This is presently being investigated using an analytical dynamical model in conjunction with the collection of DBO5 crossings occupied to date.

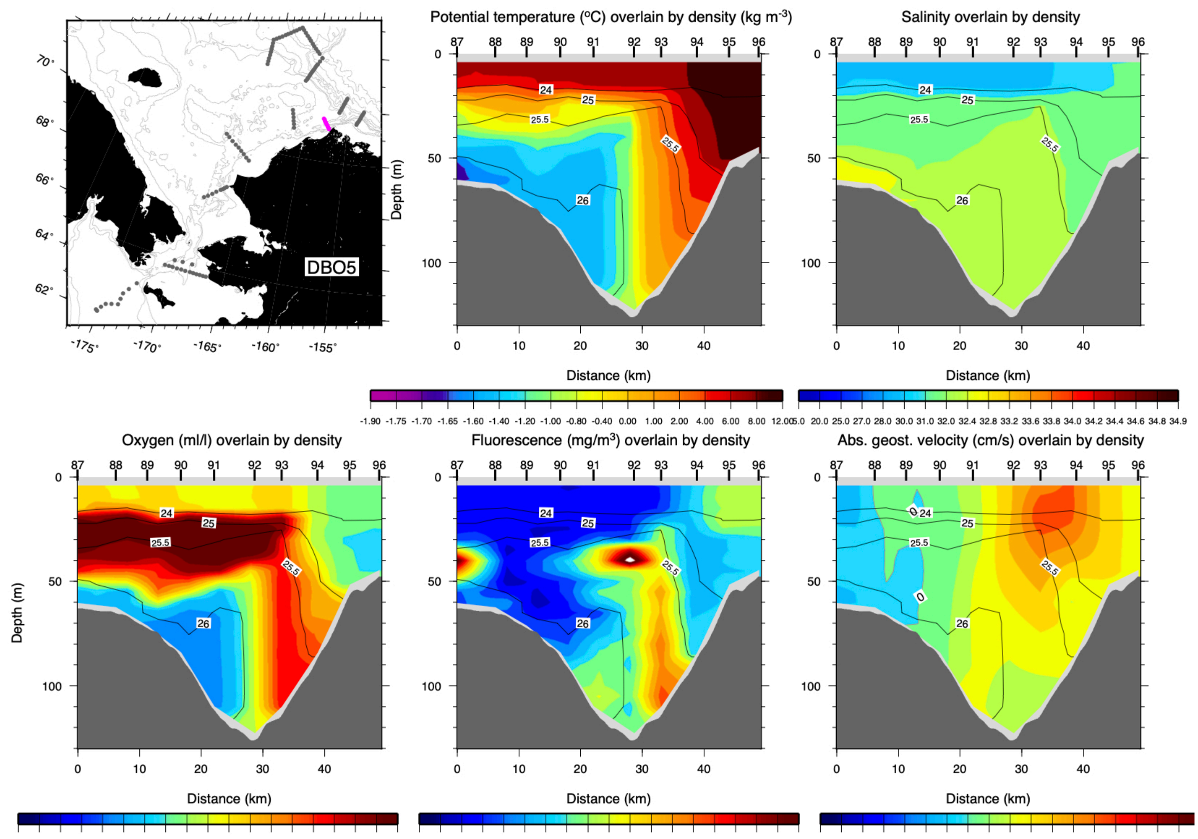

Figure B-2: Vertical sections of different variables from the DBO5 line. The upper-left panel shows the location of the line (magenta circles) in relation to the other transects occupied during the cruise. The contours are potential density (kg m^{-3}). The station locations are marked along the top of each plot. The bottom depth comes from the ship's echosounder.

Section C: Moorings, Drifters, and Floats

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Overview

Oceanographic moorings continuously measure oceanographic parameters (temperature, salinity, currents, oxygen, chlorophyll, pH, ice thickness) through the year. Three physical oceanographic moorings (BCW-18, BCC-18, BCE-18) in the Barrow Canyon and three sediment trap moorings (NHC-17t, NAP-18t, NBC-18t) in the Beaufort Sea are recovered. Three physical oceanographic moorings are re-deployed (BCW-19, BCC-19, BCE-19) in the Barrow Canyon.

Figure C1. Moorings locations that were services during the HY1901 cruise.

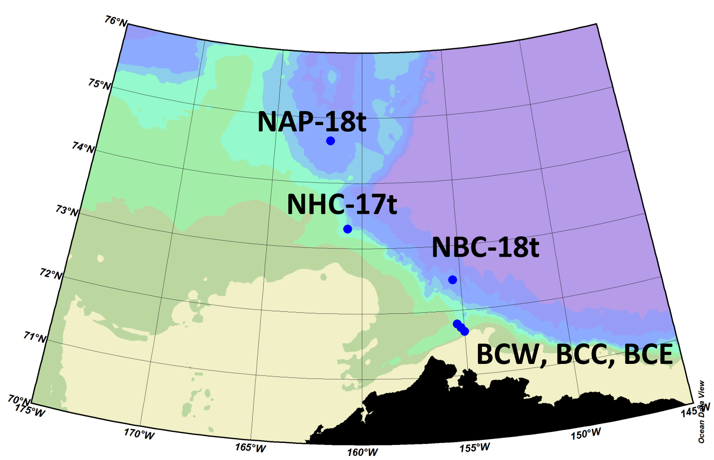

Table C1. Moorings recovered by HY1901

Mooring Name	Recovered Time (UTC)	Latitude	Longitude
NHC-17t	2019/8/13	73-18.232'N	160-47.023'W
NAP-18t	2019/8/15	74-39.018'N	161-50.342'W
NBC-18t	2019/8/17	72-28.307'N	155-24.118'W
BCW-18	2019/8/18	71-47.771'N	155-20.777'W
BCC-18	2019/8/18	71-44.0582'N	155-09.6632'W
BCE-18	2019/8/19	71-40.3514' N	154-59.9752' W

Table C2. Moorings deployed by HY1901

Mooring Name	Recovered Time (UTC)	Latitude	Longitude
BCW-19	2019/08/19	71-47.766'N	155-20.777'W
BCC-19	2019/08/19	71-44.049'N	155-09.624'W
BCE-19	2019/08/20	71-40.368'N	154-59.923'W

Physical Oceanographic Moorings

The purpose of mooring measurements in the Barrow Canyon is to monitor the variations of volume, heat and fresh water flux of Pacific Water through the Barrow Canyon. Pacific water is a predominant source of heat and freshwater in the Canada Basin. The heat and freshwater fluxes through Bering Strait has increased recently and the warm Pacific Water has contributed to both sea-ice melt in summer and a decrease in sea-ice formation during winter. Most part of warm Pacific Water is buoyancy driven Alaskan Coastal Current flowing along the Alaskan Coast to Barrow Canyon. Therefore, Barrow Canyon is a key location to monitor Pacific Water into the Arctic Basin.

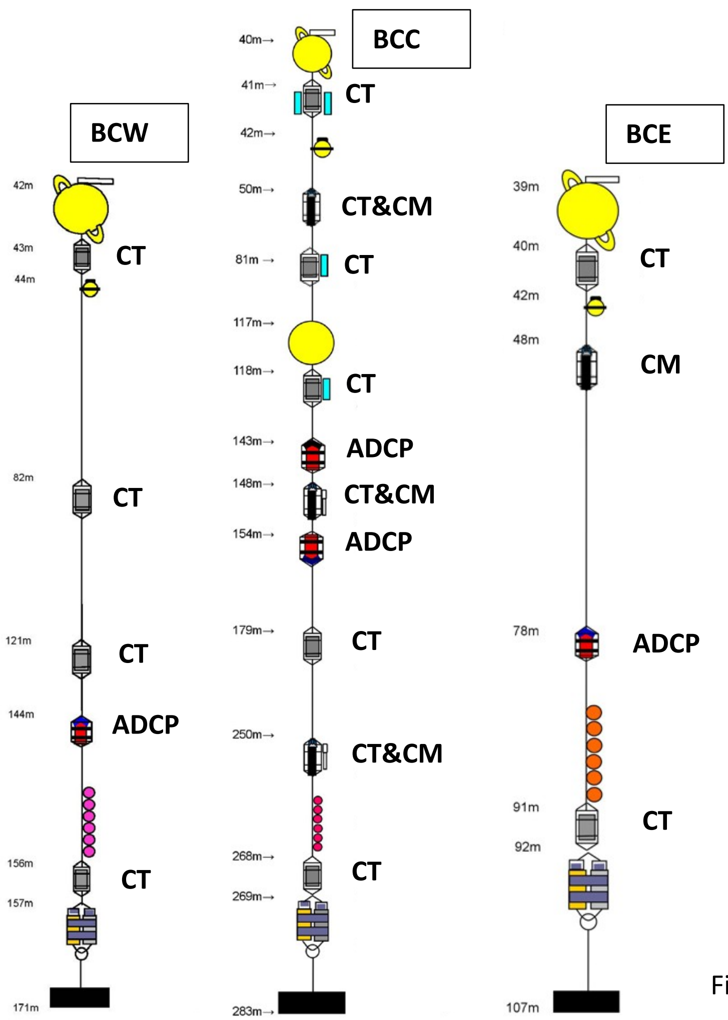

Figure C2. Mooring diagrams

Sediment trap moorings

In order to monitor hydrographic condition and the influence to lower-trophic marine ecosystem and biogeochemical cycles, JAMSTEC has conducted deployment of sediment trap moorings in the western downstream region of Pacific side of the Arctic Ocean since 2010. In this cruise, three of bottom-tethered sediment trap moorings were recovered from the Northern Hanna Canyon (NHC), southern part of Northwind Abyssal Plain (NAP), and the north of Barrow Canyon (NBC). The planned redeployment at Station NAP was cancelled because much ship time for mooring was consumed for the recovery.

Before the start of cruise, the mooring technician of WHOI, our mooring technician, and the boatswain of Healy met and discussed about the mooring operation on the fantail deck at the timing of loading at the Seattle in June. In addition to TSE winch, a travelling block, “snap” shackle, and Yale-grip from JAMSTEC were used for these mooring operations.

The equipment deployed are tabulated with the recovery log in Table 3. Roughly estimated daily mean sedimentation rate based on sediment thickness in trap bottles is shown in Figure 3. The maximum sedimentation at NHC17t was due to clogging trouble of sediment trap. The samples from shallower trap of NBC18t look like sludge which is probably because of spilling out of antiseptic when we deployed the trap last year. The higher sedimentation rate was observed at NBC, and lower sedimentation rate was observed at Station NAP.

Table C3. Summary on the recovery of NHC17t

Coordinate	73°18.2324’N 160°47.0225’W		
Water depth	425 m		
Release confirm time	Aug. 12, 2019, 22:44 (UTC)		
Equipment	**Planned Depth (m)**	**Time on deck (UTC)**	**Comment on data/sample recovery**
Transponder	49	23:19	
CT, Chl, Turbidity, DO	51	23:19	Chl & Turb. didn’t work.
CT	76	23:40	
ADCP (single layer), CT, pH	100	23:50	
ADCP	136	00:00, Aug. 13	
CT, DO	151	00:15	
Sediment Trap, CT, Camera	201	00:29	
Releasers	402	00:58	

Table C4. Summary on the recovery of NAP18t

Coordinate	74°39.012'N 161°50.340'W		
Water depth	1820 m		
Release confirm time	Aug. 14, 2019, 23:44 (UTC)		
Equipment	**Planned Depth (m)**	**Time on deck (UTC)**	**Comment on data/sample recovery**
Ice profiler, CT, Chl, Turbidity	24	1:37, Aug. 15	
Transponder	26	1:37	No response
McLane Moored Profiler	30-130	2:06	It didn't work
ADCP	134	2:16	
CT, DO, pH	171	2:39	
Sediment Trap, CT	194	2:53	
Sediment Trap	987	4:05	
Releasers	1799	5:02	

Table C5. Summary on the recovery of NBC18t

Coordinate	72°28.307'N 155°24.118'W		
Water depth	2000 m		
Release confirm time	Aug. 17, 2009, 18:08 (UTC)		
Equipment	**Planned Depth (m)**	**Time on deck (UTC)**	**Comment on data/sample recovery**
Transponder	47	19:25	
CTD, Chl, DO	49	19:32	
CT	80	19:47	
CT	120	19:53	
ADCP	135	20:02	
ADCP, CT, DO, CO2, pH	180	20:21	
Sediment Trap	230	20:36	Loss of antiseptic at deployment
Sediment Trap	1300	21:36	
Releasers	1972	22:06	

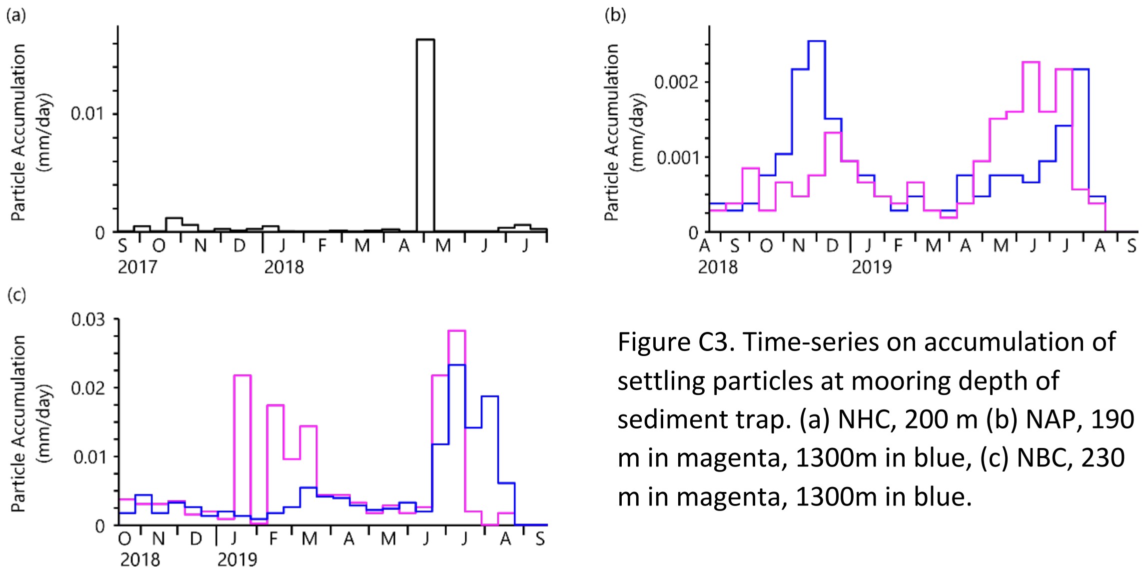

Figure C3. Time-series on accumulation of settling particles at mooring depth of sediment trap. (a) NHC, 200 m (b) NAP, 190 m in magenta, 1300m in blue, (c) NBC, 230 m in magenta, 1300m in blue.

Section D: Macrofauna, sediment characteristics, and sea ice melt tracers (δ^{18}O)

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FUNDING: NOAA Arctic Program Office (ARP), Silver Spring, MD

SUMMARY: A research group from the Chesapeake Biological Laboratory (CBL) of the University of Maryland Center for Environmental Sciences (UMCES) undertook both water column and sediment sample collections during the HLY1901 (Aug 3-Sept 23, 2019) cruise. Primary objectives were to occupy the Distributed Biological Observatory (DBO) transect lines in the northern Bering Sea (DBO1 south of St. Lawrence Island (SLI), DBO2 north of SLI), southeast Chukchi Sea (DBO3), in the NE Chukchi Sea (DBO 4N), and upper Barrow Canyon (BC, DBO5), all areas of regionally high benthic biomass, diversity, and observed change evaluated through time series studies. A secondary aspect of the cruise was to participate in the Northern Chukchi Integrated Study (NCIS) focused on the Chukchi Sea slope current, primarily through CTDs, although we also collected benthic macrofauna and sediments on the NEE and NW lines (50-300m). Our NCIS component included measurements in the water column of oxygen-18/oxygen16 ratios (a proxy tracer of melted sea ice content in surface waters and the Bering Strait inflow that contributes to the upper Arctic Ocean halocline), with additional focused water column collections at the 33.1 salinity depth where Pacific water moves northward into the Arctic Basin.

Over the shelf surface sediment samples collected included subsamples for sediment chlorophyll a, total organic carbon and nitrogen content, grain size, and the isotopic content of

the organic fractions. We also undertook sediment oxygen metabolism experiments, using sediment oxygen consumption as an indicator of organic carbon supply to the benthos as well as measurements of nutrient fluxes. This focused experimental work included both variable temperature and food supply experiments on both the cores and individual dominant animals. Finally, collected benthic samples for macroinfaunal community structure and biomass through use of multiple grabs from the sea floor at each station. Members of our shipboard team also collected sediment sediments for analysis of phytoplankton cysts for harmful algal blooms (PI Don Anderson/WHOI), dominant animals for toxic phytoplankton analyses (PI Kathi Lefebvre/NOAA Fisheries), and other sediments paleoclimatic studies (PhD candidate Caitlin Meadows, U Chicago). Knauss Fellow Kelly Uhlig collected sediment samples for microplastics. Note that Kelly Kapsar (MSU) worked both on the benthic team and undertook marine mammal surveys from the bridge.

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D-A. SAMPLING AND METHODOLOGY. Table D-A1 summarizes the location of stations sampled during the cruise.

D-A1. Water column: Seawater was collected at surface and bottom depths in 8 mL glass vials for O-18 at all DBO stations (Cooper). In addition, for select casts, full depths were collected. In addition, water column collections were collected at the 33.1 salinity value for the NCIS boundary current study from the outer shelf to the Arctic Basin.

D-A2. We collected seawater for phytoplankton taxonomy using a combination of 100 ml of seawater at standard depths for phytoplankton identifications that will immediately be preserved in Lugol's solution and formaldehyde for post-cruise species identification (Grebmeier). Briefly, 100 ml of seawater from each standard depth will be gently mixed in a small container, with a subsequent 100ml aliquot preserved by addition of 2.5 ml of Lugol's solution and subsequently stored in the refrigerator for 24 hrs. At the end of that period 5 mL of 37% formaldehyde will be added to the 100ml seawater sample to a final concentration of ~2% (v/v), gently mixed, and stored for subsequent shipment to Poland (Institute of Oceanology, Sopot) for phytoplankton identifications.

D-A3. Surface sediments were collected throughout the cruise from the top of the 0.1 m2 single van Veen grab before it was opened to minimize disturbance of surface sediments. These collections included determination of inventories of chlorophyll a in surface sediments shipboard as well as subsamples that were frozen and will be analyzed to determine total organic carbon (TOC) and nitrogen (TON) content, C/N ratios, $\delta^{13}C$ and $\delta^{15}N$, and grain size determination at CBL. Below is a description of the parameters measured or to be measured in post-cruise processing activities, with Table D-A1 listing all the parameters collected at each station by the UMCES research team.

D-A3a. Surface sediment chlorophyll a (chl-a). Replicate 0-1 cm surface sediments were collected using cut-off 10 cc syringes, with sediment plugs extruded into tared and labelled Falcon centrifuge tubes for fluorometric analyses. 10 mL of 90% acetone was added to each tube, and mixed. Subsequently measurements for chl a were made shipboard using a Turner Designs Model AU-20 fluorometer (non-acidification or Welschmeyer method) following a 12-hour (sediment) in the dark extraction period in 90% acetone at 4°C. Calibration of the fluorometer was performed using Turner Designs liquid chlorophyll standards acquired immediately before the cruise and kept at -20°C shipboard. The liquid chlorophyll standards were measured at the start and end of the cruise to check for instrument drift. We also monitored performance of the instrument by use of Turner Designs dry standards throughout the cruise. Preliminary analysis of the instrument over the month-long cruise did not indicate any significant instrumental drift in performance.

D-A3b. Surface sediment for TOC/TON, $\delta^{13}C$ and $\delta^{15}N$, and grain size. The top 0-1 cm of surface sediments was collected and placed into a labelled 4 ounce Whirlpak bag (filled 2/3 full) and frozen for post-cruise analyses. TOC/TON, and $\delta^{13}C$ and $\delta^{15}N$ values of the organic fraction of these sediments will be measured at CBL using an elemental analyzer coupled to the same stable isotope mass spectrometer used for the oxygen isotope analyses mentioned above. Sediments will be de-carbonated using 0.1 N HCl prior to analysis. Grain size will also be determined using standard methods in our laboratory. The remaining sediment in this grab was sieved through a one mm metal sieve screen boxes with running seawater periodically for Caitlin Meadows live-dead assemblage study (See Section D-C) and the HABs study (Don Anderson, Table D-A1).

D-A3c. Grab samples were collected using a 0.1m^2 van Veen grab and sieved through one mm metal sieve screen boxes with running seawater, with the animals subsequently placed in small sieve pans (with screen size 1 mm or less). The retained animals were placed in labelled plastic containers and preserved in 10% buffered seawater formalin. Post-cruise analyses include identification to lowest taxon possible, with counts and biomass determinations.

D-A3d. A single benthic HAPS corer (133 cm^2 diameter cores) was used to collect sediment core samples for metabolism experiments (sediment oxygen uptake and nutrient exchange) at 6 stations. For the DBO regions core were collected at the following locations: two sites were collected on the DBO1 line (DBO1.2 and DBO1.6), DBO3 (DBO3.6 and DBO 3.8), and the DBO4 New line (DBO4.2N, DBO4.4N). See Goethel et al. (section D-C1) for further details of the experimental work.

Table A1. HLY1901 station listing from CTD header file and data parameter listing of water, sediment and macrofauna. *=CTD stopped sampling at 300m depth.

CTD Station Number	Station Name (Historic)	Date and Time Occupied (GMT)	Latitude (deg/min N)	Longitude (deg/min W)	Bot Depth (m)	O-18	Phyto ID	Sed Chl	TOC & phi size	Macrofaunal grabs for JG	Macrofauna grabs: HABS &/or Meadows	HAPs cores
001	DBO1-1 (SLIP1)	8/6/19 4:44	62.0048	175.0692	81	x		x	x	1	x	
002	DBO1-2 (SLIP2)	8/6/19 6:57	62.0442	175.2153	81	x	x	x	x	1 + 2 for CG	x	x-8
003	DBO1-3	8/6/19 12:06	62.2162	174.8753	77	CTD only						
004	DBO1-4 (SLIP3)	8/6/19 13:29	62.3920	174.5642	73	x		x	x	1	x	
005	DBO1-5	8/6/19 16:03	62.4692	174.0843	69	CTD only						
006	DBO1-6 (SLIP5)	8/6/19 17:37	62.5528	173.5547	67	x		x	x	1	x	
007	DBO1-7	8/6/19 20:13	62.7885	173.4988	69	CTD only						
008	DBO1-8	8/6/19 21:36	63.0345	173.4617	72	x	x	x	x	1 + 2 for CG	x	x-8
009	DBO1-9	8/7/19 2:30	63.2768	173.0740	69	CTD only						
010	DBO1-10	8/7/19 4:34	63.6023	172.5865	54	CTD only						
011		8/8/19 6:27	64.6695	166.6612	23	CTD only						
012	DBO2-B	8/8/19 7:34	64.6728	166.9555	27	x		x	x	x	x	
013		8/8/19 9:14	64.6717	167.2817	31	CTD only						
014	DBO2-D	8/8/19 10:14	64.67	167.60	32	x		x	x	x	x	
015		8/8/19 11:53	64.6705	167.9062	39	CTD only						
016	DBO2-3	8/8/19 13:06	64.6742	168.2292	39	x		x	x	x	x	
017		8/8/19 15:13	64.6722	168.6845	46	CTD only						
018	DBO2-2	8/8/19 16:35	64.6815	169.0872	45	x		x	x	x	x	
019		8/8/19 18:42	64.6707	169.4982	45	CTD only						
020	DBO2-1 (UTBS5)	8/8/19 20:29	64.6723	169.9172	48	x		x	x	x	x	
021		8/8/19 22:34	64.6762	170.2585	50	CTD only						
022	DBO2-0	8/8/19 23:42	64.6718	170.6460	48	x		x	x	x	x	
023	DBO2-4	8/9/19 2:48	64.9623	169.8977	49	x		x	x	x	x	
024	DBO2-5	8/9/19 5:42	64.993	169.1325	49	x		x	x	x	x	
025	DBO2-7	8/9/19 8:36	65.003	168.221	47	x		x	x	x	x	
026		8/9/19 22:14	68.0303	168.8223	59	x						
027	DBO3-8 (SEC1=UTN5)	8/10/19 2:29	67.6745	168.939	51	x	x	x	x	1 + 2 for CG	x	x-8
028	DBO3-7 (SEC2)	8/10/19 6:12	67.7812	168.6063	51	x		x	x	1	x	
029	DBO3-6 (SEC3)	8/10/19 8:15	67.8933	168.2302	58	x	x	x	x	1 + 2 for CG	x	x-8
030	DBO3-5 (SEC4)	8/10/19 12:04	68.0117	167.8857	53	x		x	x	1	x	
031	DBO3-4 (SEC5)	8/10/19 14:08	68.1297	167.4898	50	x		x	x	1	x	
032	DBO3-3 (SEC6)	8/10/19 15:36	68.1850	167.3017	49	x		x	x	1	x	
033	DBO3-2 (SEC7)	8/10/19 17:04	68.2432	167.1383	44	x		x	x	1	x	
034	DBO3-1 (SEC8)	8/10/19 18:53	68.3028	166.9432	35	x		x	x	1	x	
035	DBO4-1N	8/11/19 10:41	71.0852	161.2008	47	x		x	x	1	x	
036	DBO4-2N	8/11/19 12:46	71.2232	161.2785	49	x	x	x	x	1 + 2 for CG	x	x-8
037	DBO4-3N	8/11/19 16:03	71.3457	161.3978	47	x		x	x	1	x	
038	DBO4-4N	8/11/19 18:32	71.4793	161.4993	48	x	x	x	x	1 + 2 for CG	x	x-2
039	DBO4-5N	8/11/19 22:17	71.6047	161.6253	46	x		x	x	1	x	
040	DBO4-6N	8/11/19 23:58	71.7375	161.7335	44	x		x	x	1	x	
041	NNE-7	8/12/19 7:55	72.8980	160.8428	57	x		x	x	1	x	
042	NNE-8	8/12/19 9:17	72.9573	160.7407	72	CTD only						
043	NNE-9	8/12/19 10:00	73.0177	160.6458	139	x		x	x	1	x	
044	NNE-10	8/12/19 11:31	73.0795	160.5352	191	x						
045	NNE-11	8/12/19 12:35	73.137	160.4497	261	x		x	x	1	x	
046	NNE-12	8/12/19 15:17	73.1995	160.358	357.5*	CTD only						
047	NNE-13	8/12/19 16:15	73.2592	160.2483	647*	x						
048	NNE-14	8/12/19 19:16	73.3183	160.1560	1206.5*	CTD only						
049	NNE-15	8/12/19 20:21	73.3805	160.0643	1378*	x						
050	NNE-16	8/13/19 2:50	73.4452	159.9408	1734.9*	CTD only						
051	NNE-17	8/13/19 3:54	73.5033	159.8383	1977.9*	CTD only						
052	NNE-18	8/13/19 5:02	73.561	159.7285	2190.9*	CTD only						
053	NNE-19	8/13/19 6:19	73.6775	159.5202	2578.3*	x						
054	NNE-20	8/13/19 8:02	73.7988	159.2962	3003.7	x-all						
055	BL-10	8/13/19 11:56	73.9405	159.7517	2214.7*	x						
056	BL-9	8/13/19 13:20	74.0215	160.0320	807.3*	x						
057	BL-8	8/13/19 14:36	74.0998	160.3278	842.3*	CTD only						
058	BL-7	8/13/19 15:47	74.1757	160.6078	492*	x						
059	BL-6	8/13/19 17:24	74.2602	160.8968	970*	CTD only						
060	BL-5	8/13/19 21:54	74.3447	161.1765	1536.3*	x						
061	BL-4	8/13/19 23:40	74.4275	161.4540	1592.5*	CTD only						
062	BL-3	8/14/19 0:49	74.5073	161.7327	1609.3*	x						
063	BL-2	8/14/19 3:10	74.5923	162.0482	1685.4*	CTD only						

Table A1 (cont). HLY1901 station listing from CTD header file and data parameter listing of water, sediment and macrofauna. *=CTD stopped sampling at 300m depth.

CTD Station Number	Station Name (Historic)	Date and Time Occupied (GMT)	Latitude (deg/min N)	Longitude (deg/min W)	Bot Depth (m)	O-18	Phyto ID	Sed Chl	TOC & phi size	Macrofaunal grabs for JG	Macrofauna grabs: HABS &/or Meadows	HAPs cores
064	BL-1	8/14/19 4:21	74.6742	162.3463	1720.4*	x						
065	W-1	8/14/19 5:41	74.7508	162.6210	1668.3*	x						
066	W-2	8/14/19 7:11	74.6872	162.9697	1507.4*	CTD only						
067	W-3	8/14/19 8:24	74.6147	163.3185	1260.7*	x						
068	W-4	8/14/19 9:43	74.552	163.6557	947.8*	CTD only						
069	W-5	8/14/19 10:47	74.4847	163.9932	621.3*	x						
070	W-6	8/14/19 12:01	74.42	164.3255	438.9*	CTD only						
071	W-7	8/14/19 13:06	74.355	164.6605	383.8*	x						
072	W-8	8/14/19 14:25	74.2888	164.9972	316*	CTD only						
073	W-9	8/14/19 15:36	74.2202	165.3528	273.4*	x		x	x	2	x	
074	W-7	8/15/19 8:25	74.3542	164.6385	383.8*	CTD only						
075	W-8	8/15/19 9:32	74.2867	165.0048	316*	CTD only						
076	W-9	8/15/19 10:30	74.2208	165.3413	273.4*	CTD only						
077	W-10	8/15/19 11:32	74.1573	165.6782	229.6	CTD only						
078	W-11	8/15/19 12:37	74.09	166.0063	211.8	x		x	x	1	x	
079	W-12	8/15/19 15:10	73.9707	166.0023	160.7	CTD only						
080	W-13	8/15/19 16:16	73.8533	166.0117	137.1	x		x	x	1	x	
081	W-14	8/15/19 18:45	73.7435	166.004	119.1	CTD only						
082	W-15	8/15/19 20:09	73.6335	165.9962	110.1	x		x	x	2	x	
083	W-16	8/15/19 22:38	73.521	166.0057	92.3	CTD only						
084	W-17	8/15/19 23:39	73.4065	166.0147	76.5	x		x	x	1	x	
085	W-18	8/16/19 1:26	73.2922	166.0013	67.5	CTD only						
086	W-19	8/16/19 2:26	73.1792	166.019	63	x		x	x	1	x	
087	DBO5-10 (BarC10)	8/16/19 17:56	71.618	157.9172	63	x		x	x	1	x	
088	DBO5-9 (BarC9)	8/16/19 19:41	71.5742	157.8047	66	x		x	x	1	x	
089	DBO5-8 (BarC8)	8/16/19 21:31	71.5343	157.7352	74	x		x	x	1	x	
090	DBO5-7 (BarC7)	8/16/19 23:14	71.4938	157.6458	88	x		x	x	2	x	
091	DBO5-6 (BarC6)	8/17/19 1:02	71.4503	157.5792	112	x		x	x	1	x	
092	DBO5-5 (BarC5)	8/17/19 2:38	71.4047	157.4598	126	x		x	x	1	x	
093	DBO5-4 (BarC4)	8/17/19 4:44	71.3717	157.3893	113	x		x	x	1	x	
094	DBO5-3 (BarC3)	8/17/19 6:40	71.3242	157.3215	87	x		x	x	1	x	
095	DBO5-2 (BarC2)	8/17/19 8:36	71.289	157.2193	56	x		x	x	1	x	
096	DBO5-1 (BarC1)	8/17/19 9:48	71.251	157.1557	48	x		x	x	1	x	
097	BCW-1	8/18/19 1:01	72.4722	155.4207	*300m	x						
098	BCW-2	8/18/19 2:09	72.4153	155.5032	*300m	CTD only						
099	BCW-10	8/19/19 3:48	71.9082	156.1932	67.5	x		x	x	1	x	
100	BCW-9	8/19/19 5:12	71.9705	156.1073	73.1	CTD only						
101	BCW-8	8/19/19 5:55	72.0308	156.028	141.8	x		x	x	1	x	
102	BCW-7	8/19/19 7:39	72.1003	155.9415	208.2	CTD only						
103	BCW-6	8/19/19 8:25	72.1557	155.8478	266.6	x		x	x	1	x	
104	BCW-5	8/19/19 10:58	72.2222	155.7663	*300m	x						
105	BCW-4	8/19/19 11:58	72.2858	155.6862	*300m	x						
106	BCW-3	8/19/19 12:47	72.3473	155.6042	*300m	x						
107	BCE-1	8/20/19 2:34	71.5357	154.0313	46.8	x		x	x	1	x	
108	BCE-2	8/20/19 3:48	71.5957	153.9502	48.2	x						
109	BCE-3	8/20/19 4:30	71.6498	153.8398	48.5	x		x	x	1	x	
110	BCE-4	8/20/19 5:43	71.7147	153.7393	54.4	x						
111	BCE-5	8/20/19 6:38	71.7815	153.63	133.2	x		x	x	1	x	
112	BCE-6	8/20/19 8:19	71.8387	153.5562	191.4	x						
113	BCE-7	8/20/19 9:08	71.8928	153.459	*300m	x						
114	BCE-8	8/20/19 10:13	71.9517	153.3652	*300m	x						
115	BCE-9	8/20/19 11:08	72.0202	153.2562	*300m	x						
116	LB-13	8/21/19	70.259	168.530	43	x						
117	LB-12	8/21/19	70.164	168.127	41	x		x	x	x	x	
118	LB-11	8/21/19	70.058	167.649	47	x						
119	LB-10	8/21/19	69.957	167.216	45	x		x	x	x	x	
120	LB-9	8/21/19	69.882	166.815	47	x						
121	LB-8	8/21/19	69.781	166.439	41	x		x	x	x	x	
122	LB-7	8/21/19	69.683	166.083	41	x						
123	LB-6	8/21/19	69.582	165.739	31	x		x	x	x	x	
124	LB-5	8/21/19	69.498	165.370	33	x						
Total Number of Stations						**88**	**6**	**57**	**57**	**57**	**57**	**8**

D-B. PRELIMINARY RESULTS

D-B1. Summary of sample collections

Water column O-18 subsamples were collected from the CTD/rosette cast at 88 stations and phytoplankton samples at 6 stations (Table D-A1). These samples will be analyzed at CBL. Sediment and macrofaunal samples were collected at 57 stations along the DBO1-5 transect lines and a subset of hyrographic lines from the slope to the Arctic Basin using a van Veen grab up to 300m depth, as well as the Ledyard Bay transect line. Surface sediment chl-a content was collected at all benthic stations and analyzed shipboard. Another subset of surface sediment was collected at 57 stations, frozen and returned to CBL for post-cruise processing for TOC/N, C and N stable isotope content, and sediment grain size. We undertook sediment metabolism experiments at 6 stations using a single HAPS benthic corer (8 cores per station, except station DBO4.2 where 2 cores were collected due to rough seas) for oxygen uptake determinations (an indicator of organic carbon supply to the benthos) and for nutrient exchange flux measurements. In 2019 we ran two temperature and two feeding levels to evaluate these parameter impacts on carbon cycling, along with respirations studies on dominant macrofauna at the sites (see Goethel D-C1. report below).

The following description briefly outlines the results from our core Grebmeier/Cooper benthic team, with additional summary paragraphs by graduate student collaborators from our sediment and benthic animal collections (C1. Christina Goethel/CBL, C2. Caitlin Meadows/UChicago), and C3. Keely Uhlig/NOAA Knaus Fellow). Finally, we collected sediments to assist a Harmful Algal Bloom (HAB) study for Don Anderson/Woods Hole Oceanographic Institution (WHOI) that are reported separately in this cruise report by his shipboard participant, Evie Fachon (WHOI). In addition, we collected and identified dominant macrofaunal samples for Kathi Lefrebvre (NOAA Fisheries) for HAB toxicity studies. See **Table D-A1** for listing of locations of sample collections for these two HAB collections.

D-B2. Preliminary results

The pattern of sediment chlorophyll during HLY1901 indicates recent phytodetritus deposition at all of the DBO sites (**Fig. D-B1**). For the DBO1 site south of St. Lawrence Island in the northern Bering Sea have values ranging from 11-44 mg chl-a /m^2, with the highest values in the northern stations of DBO1. For the DBO2 in the Chirikov Basin the highest values were observed in the offshore stations, from 16-44 mg chl-a/m2, with the lowest values to the east under Alaska Coastal Water (<10 mg chl-a/m^2). In DBO3 (SE Chukchi Sea) sediment chl-a values ranged from 16-48 mg/m^2 along the transect line, with high values offshore (**Fig. D-B1**). The DBO3 region is known for the highest benthic biomass of bivalves for the Chukchi Sea. Sediment chl-a values varied along the Ledyard Bay and further north on the DBO-N line SE of Hanna Shoal, with the highest values in offshore waters (21-44 mg chl-a/m^2). The region SE of Hanna Shoal is an important site for summer walrus foraging. For DBO5, the highest sediment chl-a was found on the upper slopes of Barrow Canyon as well as the west side of the canyon and lowest values in the shallow eastern side of Barrow Canyon (**Fig. D-B1**). As part of DBO-NCIS in 2019 we occupied shelf and upper slope areas of the northern Chukchi Sea, with higher values at the 80-200 m depth, averaging 11-15 mg chl-a/m2and decreasing with depth.

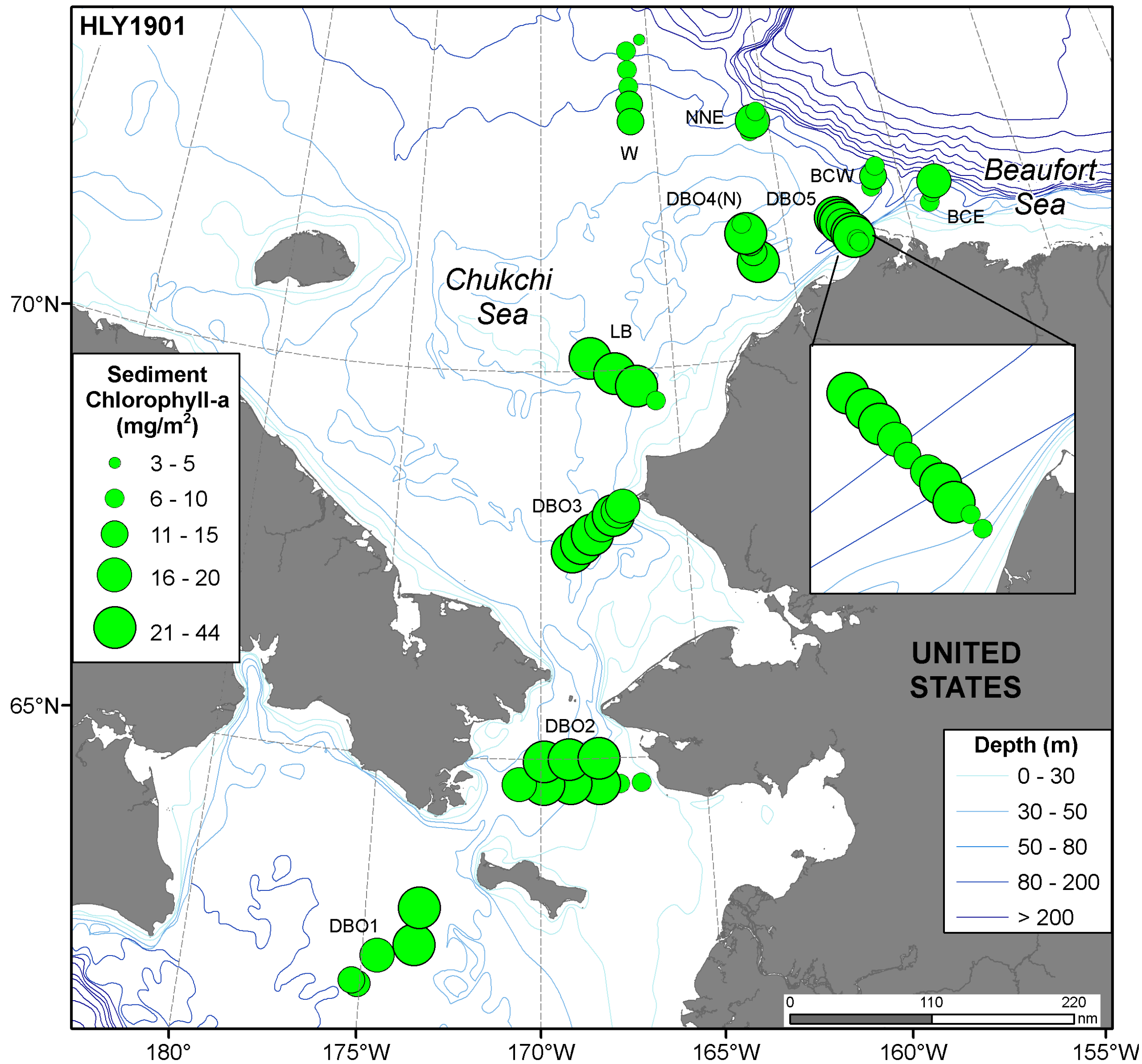

Figure D-B1. Distribution of surface sediment chlorophyll-a during HLY1901.

Sediments south of SLI (DBO1) are fine grained, becoming sandy in the Chirikov Basin (DBO2) of the northern Bering Sea. By comparison, the southern (DBO3) and northern (DBO4) Chukchi Sea sites ranged from sand in the central channel and closer to the Alaska shoreline, whereas muddy sediments occurred in the offshore regions, with coarse sediments in the shallower portions of Hanna Shoal region. The highest bivalve biomass was observed in fine sediments in the DBO 3.6-3.8 sites in the southern Chukchi Sea and just south and southeast of Hanna Shoal, particularly in the vicinity of the Chukchi Environmental Observatory (CEO) biophysical mooring

SE of Hanna Shoal, and in the central stations of the DBO4 (New line). This newly re-located DBO4 line was initiated in 2018 to help determine and confirm the best relocation of the DBO4 sites around the CEO, which is centered on the NE Chukchi Sea benthic hotspot. Based on the 2017 DBO-NCIS study, higher bivalve biomass region was located around the CEO biophysical mooring, meaning that the hotspot was north of the previously designated DBO4 line. From previous findings we know that astartid bivalves are dominant in the NE Chukchi Sea, along with maldanid polychaetes, whereas tellinid bivalves dominate the offshore SE Chukchi Sea DBO3 hotspot. Ampeliscid amphipods are dominant in the eastern stations of DBO, whereas the western time series stations have changed to being dominated by bivalves and polychaetes.

D-C. SUMMARY STATEMENTS FROM OTHER BENTHIC TEAM COMPONENTS

D-C1. Christina Goethel (CBL/UMCES): Experimental Sediment Cores and Bivalve (and Amphipod) Respiration

Eight cores were collected from the single HAPs benthic corer (133 cm^2 diameter cores) at two sites in three of the DBO regions (DBO1, DBO3, and DBO4) (Table D-C1) for sediment community oxygen consumption (SCOC) experiments (sediment oxygen uptake and nutrient exchange). Bottom water was collected from the rosette at the same stations for core experiments, as well as later individual respiration experiments. Cores were held in one of four treatments (two cores per treatment), 1-2°C unfed; 1-2°C fed, 4-5°C unfed, and 4-5°C fed. Those that were fed were given ½ a mL of Shellfish Diet 1800. Temperature manipulations were conducted by holding cores in one of the shipboard incubation rooms for the 1-2°C and an insulated large cooler inside the incubation room for cores held at 4-5°C. Temperature inside the cooler was manipulated by adding blue ice if it was too warm or warm water if it was too cold. At DBO4.4N weather prevented the collection of the full eight cores, so two cores were collected and run at ambient conditions (1°C, unfed). Following the experiments, cores were sieved for macrofauna on a 1mm screen mesh and preserved in 10% buffered seawater formalin for post-cruise processing. Oxygen measurements were measured using two methods for all cores- Winkler titrations and a PreSens oxygen meter and associated probes. Values from the two methods will be compared back in the lab, but rates were relatively similar between the two methods from experiments run aboard HLY1801.

Individual respiration rates were measured from the same sites as the cores. At least 12 individuals of the dominant organism (Table D-C1) were collected from extra van Veen grabs. Three individuals were run in each of the same four treatments that the cores were held in to understand individual dominant species' contributions to the overall system respiration in each of the conditions. Fed individuals were given ¼ mL of Shellfish Diet 1800TM. Individual respirations were run for 12-48 hours depending on the site and the species using a FireSting O2 sensor with four associated fiber optic oxygen probes and one temperature sensor. Individuals were held in sealed, airtight 100mL jars or large mason jars. One probe was placed into each one of the individual containers and dissolved oxygen concentration (µmol/L) was recorded every two minutes. After the allotted time, a sample was taken for ammonium, water volume (mL) was measured, and individuals were frozen for length and weight measurements back at CBL. Respiration rates for each individual clam will be determined from the slope of the line (decline in oxygen) over time and then normalized to the size of the individual. Once cores from the larger sediment incubation experiments have been processed, individual rates will be compared to the larger system.

Table D-C1. Sediment respiration core sampling locations and dominant animals.

Station	Number of Cores	Dominant Animal for Individual Respiration
DBO1.2	8	*Macoma calcarea*
DBO1.4	8	*Enucula tenuis*
DBO3.8	8	*Macoma calcarea*
DBO3.6	8	*Macoma calcarea*
DBO4.2N	8	*Ampeliscidae*
DBO4.4N	2	*Macoma calcarea*

D-C2. Caitlin Meadows (University of Chicago)- Paleoecology, Taphonomy

Purpose. The N Pacific Arctic waters are able to quickly erode aragonite. To understand the rate and process of erosion of biogenic aragonite, I planned to collect bivalve shells from key stations during the HLY1801 cruise and to preserve them with minimally erosive methods. The damage patterns found on these shells will help determine the rate of dissolution of cold water carbonate, the extent of pre-mortem erosion in acidic environments, and the effects of formalin and other preservation methods on shell integrity. The bivalves gathered here will also be added to ecologic data gathered throughout the DBO region.

In addition to shells collected for taphonomic studies, some bivalves were collected for stable isotope sclerochronology. The stable isotopic records of bivalve aragonite record the diversity of carbon sources ($\delta^{13}C$) and water mass movement ($\delta^{18}O$). These benthic climate records will be compared to records of sea ice concentration.

The flesh and organic phase of the shells will also be used to characterize the organic carbon food sources for the benthic organisms in this region. The $\delta^{13}C$ values of the organic and flesh of bivalves will be compared with the $\delta^{13}C$ values of water column primary productivity, organic carbon in the surface sediment, and organic carbon in buried sediment, all collected on this cruise. Each organic sample will be analyzed for bulk $\delta^{13}C$ values and with advanced processing for $\delta^{13}C$ values of essential and non-essential amino acids.

Materials. 1 Van Veen grab of material was collected and picked for desired individual specimens. Each live collected bivalve was frozen while dead collected bivalves were dried. Mud was collected from the surface of this van Veen grab and from the bottom after the grab was opened, then frozen. Water was collected from the chlorophyll max (when available) or the

Surface (one deep water sample was collected), then filtered onto glass fiber filters (GFF, ~0.2 µm pore size), and frozen. All materials are listed in Table D-C1.

Table D-C2. Material collected while on board Healy, Live = live collected animals, frozen, Dead = dead collected, Dry, SSed= sediment from the top of the van Veen Grab, DSed = sediment from bottom of the van Veen Grab, Water = filters from water collected in niskin bottles (Volume (L), water depth (m)). If station is not listed, no material was taken.

Station Number	Station Name	Date	Water	SSed	DSed	Live	Dead
1	DBO1-1	8/5/19		Frozen	Frozen	Frozen	DRY
4	DBO1-4	8/6/19	1.5 L, CHL MAX	Frozen	Frozen		
6	DBO1-6	8/6/19	2.5 L, CHL MAX	Frozen	Frozen	Frozen	Dry
12	DBO2-B	8/8/19				Frozen	
14	DBO2-D	8/8/19	2.5 L, SURFACE	Frozen	Frozen	Frozen	Dry
18	DBO2-2	8/8/19	4 L, SURFACE	Frozen	Frozen	Frozen	
20	DBO2-1	8/8/19	3 L, SURFACE	Frozen	Frozen	Frozen	
22	DBO2-0	8/8/19				Frozen	
23	DBO2-4	8/8/19	3.2 L, SURFACE	Frozen	Frozen	Frozen	
25	DBO2-7	8/8/19					DRY
27	DBO3-8	8/9/19				Frozen	
28	DBO3-7	8/10/19		Frozen	Frozen	Frozen	
29	DBO3-6	8/10/19	2.5 L, SURFACE			Frozen	
30	DBO3-5	8/10/19	4.5 L, SURFACE	Frozen	Frozen	Frozen	
31	DBO3-4	8/10/19				Frozen	DRY
32	DBO3-3	8/10/19				Frozen	DRY
33	DBO3-2	8/10/19	3 L, SURFACE			Frozen	DRY
35	DBO4-1N	8/11/19				Frozen	
36	DBO4-2N	8/11/19	5.4 L, Surface	Frozen	Frozen	Frozen	DRY
37	DBO4-3N	8/11/19				Frozen	DRY
38	DBO4-4N	8/11/19	3.5 L, Surface	Frozen	Frozen	Frozen	Dry
39	DBO4-5N	8/11/19	3.5 L, Chl Max	Frozen	Frozen	Frozen	DRY

40	DBO4-6N	8/11/19		Frozen	Frozen	Frozen	DRY
41	NNE-7	8/12/19		Frozen	Frozen	Frozen	
43	NNE-9	8/12/19		Frozen	Frozen		
45	NNE-11	8/12/19		Frozen	Frozen		
76	W-9	8/15/19		Frozen	Frozen		
82	W-15	8/15/19	5.5 L, SURFACE	Frozen	Frozen	Frozen	
84	W-17	8/15/19		Frozen	Frozen	Frozen	
86	W-19	8/15/19		Frozen	Frozen	Frozen	Dry
87	DBO5-10	8/16/19	4.85 L, SURFACE	Frozen	Frozen	Frozen	
88	DBO5-9	8/16/19		Frozen	Frozen	Frozen	
89	DBO5-8	8/16/19				Frozen	
90	DBO5-7	8/16/19				Frozen	Dry
91	DBO5-6	8/16/19				Frozen	Dry
92	DBO5-5	8/16/19	6.5 L Surface water, 3.5 L Bottom water	Frozen	Frozen	Frozen	
93	DBO5-4	8/16/19				Frozen	
94	DBO5-3	8/17/19				Frozen	Dry
95	DBO5-2	8/17/19	5 L, Surface	Frozen	Frozen	Frozen	Dry
96	DBO5-1	8/17/19				Frozen	
117	LB12	8/21/19	6 L Surface, 4.5 L Bottom	Frozen	Frozen	Frozen	Dry
120	LB9	8/22/19				Frozen	
123	LB6	8/22/19	5 L Surface			Frozen	

D-C3. Kelley Uhlig-NOAA: Microplastics in the sediment of the Northern Bering & Chukchi Seas

Microplastics pollution is suspected to be ubiquitous throughout the marine environment, including the Arctic Ocean (Peekin et al. 2018). Most of the focus on Arctic Ocean microplastics has been on sea ice and the surface waters, though it is known that the sea floor is a major sink for microplastic debris. Only two studies to date has looked at plastics in Arctic seafloor sediments (Woodal et al. 2014; Bergmann et al. 2017) on Southwest Svalbard and the Fram Strait in the Atlantic Sector. In the Pacific Sector, microplastic particles have been identified in benthic fauna in the Northern Bering and Chukchi Seas (Fang et al. 2018), but there is no information on what might be present in the sediments themselves.

The objective of this project is to collect preliminary data on the presence of microplastics in the sediments along select DBO lines. Approximately 200 g of surface sediment was collected in duplicate from a van Veen grab from each station listed below. The sediments will be analyzed according to a protocol developed by NOAA's Office of Response and Restoration Marine Debris Program, modified to account for how much sediment was able to be collected. In short, sediments will be dried, de-aggregated, sieved, and then density separated. Those particles that float will be processed further by wet peroxide oxidation, another round of density separation, and manual visual analysis with the aid of a microscope. Pieces selected as plastics will be verified by FTIR, if possible.

Table D-C3. Location of sediment samples for marine plastics.

Site	Lat	Long	Approx. Depth (m)
DBO2-7	65 00.00	168 13.32	55
DBO3-6	67 53.85	168 14.04	58
DBO4-1	71 05.31	161 11.88	48
DBO4-5	71 36.57	161 37.66	46
DBO4-6	71 44.52	161 44.51	43
W7	74 21.15	164 40.07	361
W19	73 10.95	166 00.05	61
DBO5-8	71 32.19	157 43.98	72
DBO5-6	71 27.34	157 34.44	109
LB-10	69 29.89	165 22.17	33
LB-8	69 57.43	167 12.93	45
LB-6	70 20.97	168 53.89	39

References:

Peekin, I., et al., 2018: Microplastics in the Marine Realms of the Arctic with Special Emphasis on Sea Ice Arctic Report Card 2018, https://www.arctic.noaa.gov/Report-Card.
Woodall, L. C., et al., 2014: The deep sea is a major sink for microplastic debris. Roy. Soc. Open Sci., 1, 140317, doi: 10.1098/rsos.140317.
Bergmann, M., et al., 2017: High quantities of microplastic in Arctic deep-sea sediment from the HAUSGARTEN observatory. Environ. Sci. Technol., 51, 11000-11010, doi:
Fang, C., et al., 2018: Microplastic contamination in benthic organisms from the Arctic and sub-Arctic regions. Chemosphere, 209, 298-306, doi: 10.1016/j.chemosphere.2018.06.101.

D-D. Acknowledgements

We thank the Captain, officers and crew of the USCGS Healy for the assistance collecting scientific samples during HLY1901. Also we extend our thanks to the lead PIs Grebmeier and

Cooper and the full benthic team for the efforts over the 24 hour sampling periods, including Christina Goethel (PhD student, CBL), Nicole Villeneuve (volunteer technical support, CBL/UMCE); Caitlin Meadows, PhD student, UChicago), Piper Bartlett-Browne (PolarTrec teacher), Kelley Uhlig (Knauss Marine Policy Fellow), and Kelly Kaspar (volunteer from MSU). Caitlin Meadows and Christina Goethel had the lead for collections and identification of benthic macrofauna for Kathi Lefebrve (NOAA) for HAB analyses.

Section E: Bottle oxygen, nutrients and chlorophyll

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Personnel
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Caitlin Kollander (UAA)

Oxygen
For calibration of the CTD oxygen probe, 114 samples were collected for dissolved oxygen. The samples were fixed with Winkler reagents, and the flare of each oxygen flask was filled with distilled water and sealed. The samples were analyzed shipboard using the Winkler method with an amperometric oxygen titrator.

Macronutrients
Macronutrient samples were collected at all process stations in support of the benthic studies and net tows. A total of 457 nutrient samples were filtered through 0.45 micron polycarbonate filters and stored frozen at -80 degrees C. The samples will be transported to the Pacific Marine Environmental Laboratory (PMEL) for determination of nitrate, nitrite, ammonium, silicic acid and phosphate concentrations.

Phytoplankton taxa and biomass (chlorophyll-a)
Total chlorophyll-*a* (a rough estimate of phytoplankton biomass for the whole community) samples were collected (350 total samples) using Niskin bottles at standard depths (surface, 10, 20, 30, 40, and 50m depth). Sample volumes were filtered using 25 mm Whatman GF/F filters under low vacuum. Filters were frozen at -80 °C at sea. Frozen samples will be analyzed in laboratories at PMEL after the cruise; the resulting total chlorophyll-*a* data may then be used to post-calibrate the fluorometer on the CTD package.

Section F: Carbonate Chemistry

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Project Title **Acidification in the Distributed Biological Observatory**

Funding Source NOAA Arctic Research Program

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Project Summary

The Distributed Biological Observatory is a network of rapidly changing and biologically important sites designed as a change detection array from the northern Bering Sea to the Arctic Basin. Since 2010, the DBO has provided a framework to focus and coordinate sampling and analytical efforts that link biological changes to physical drivers in a rapidly changing Arctic. While these biophysical connections are extremely valuable for ecosystem research, this 'physics to whales' perspective often skips over another key element of Arctic change: ocean biogeochemistry. A growing body of recent research is showing that the oceans in the Pacific Arctic Region (and the DBO) have rapidly acidified over the last several decades, in part due to the intrusion of anthropogenic CO_2. This ocean acidification (OA) can create corrosive conditions that cover up to 40% of the Chukchi Sea benthos seasonally and persist for more than 80% of the year in some hotspots. These vulnerable ecosystems are experiencing sustained exposure to corrosive waters every year. This project is designed to provide a comprehensive carbonate chemistry assessment of US DBO activities during FY17-FY19.

Methods

In conjunction with the DBO-NCIS sampling plan outlined earlier in this cruise report, carbonate chemistry samples were collected at DBO stations at standard depths for the hydrographic sampling team: Surface, 10m, 20m, 30m, 40m, 50m, and bottom. Discretionary samples were also taken in deeper waters and at depths identified as chlorophyll maxima. In the NCIS region, samples were collected on the BCE, BCW, BL, NNE, W, and LB lines. While samples in shallow water followed standard shelf sampling, samples in deeper water (e.g., >50m) followed Repeat Hydrography standard sampling schema. Overall, 642 samples were collected at 85 stations.

Station Name	Stations Sampled	Water Samples
BCE	5	42
BCW	6	60
BL	6	68
DBO1	6	39
DBO2	9	50
DBO3	8	48
DBO4 (N)	6	37
DBO5	10	72
NNE	9	85
W	10	91
LB	10	50

During 2019, samples were not analyzed on board. We plan to run the samples on shore using the same instrumentation and methods as during 1702 and 1801. Samples for Total Inorganic Carbon (TIC) will be analyzed using a precise and accurate system based on gas extraction and IR detection of CO2 (Marine Analytics and Data Automated Infra-Red Inorganic Carbon Analyzer, or MARIANDA-AIRICA). Samples will be analyzed for Total Alkalinity (TA) by potentiometric titration using a MARIANDA Versatile Instrument for the Detection of Total Alkalinity (VINDTA, model 3S). This analysis will include corrections to TA using phosphate and silicate data analyzed by PI Mordy where available, as these nutrients can substantially change the alkalinity of some samples collected in nutrient-rich areas. Routine analysis of Certified Reference Materials (CRMs, provided by A.G. Dickson, Scripps Institute of Oceanography) will be used to ensure the accuracy and stability of the analyses for both TIC and TA.

TIC and TA data will be used to resolve other components of the marine carbonate system (e.g., pH, calcium carbonate saturation states) using the CO2calc software (Robbins et al., 2010). This program relies on specified carbonate dissociation constants. While there are many sets of equilibrium constants commonly used in the literature, we expect to apply those from Millero et al (2006). These were shown to provide the best comparison between calculated carbon system variables and discrete samples for $p\mathrm{CO_2}$ in the Arctic (Evans et al., 2015). Full post-processing should be completed by the end of FY2020.

Usage Guidelines

Final post-processed data for discrete samples will be shared via the NOAA-NCEI Ocean Carbon Data System (OCADS). Public release and access will be arranged through NCEI's Geoportal. This data will become publicly available by the end of FY20 in conjunction with federal requirements for public release, accessibility, and archiving of federal scientific data.

Prior to free public release, post-processed data may be shared with the cruise participants for research and purposes on a case-by-case basis. Data access should be arranged through the managing PI on this project. Contact information is provided in the header of this cruise report section. Data usage prior to public release entails co-authorship on any product manuscripts, presentations, abstracts, or white papers.

Section G: Ichthyoplankton and zooplankton

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Principal Investigator: Libby Logerwell: NOAA/NMFS/AFSC

Personnel:
Janet Duffy-Anderson: NOAA Fisheries/AFSC
Jan Benson: NOAA Fisheries/AFSC
Chrissy Hayes: NOAA Knauss Fellow

Overview:

Zooplankton and ichthyoplankton samples were collected using a paired 60-cm bongo net (505 um mesh) and a paired 20–cm bongo net (153 um mesh) that was towed obliquely from the surface to 10 m off-bottom or to a maximum depth of 300 m. All nets were equipped with flow meters to quantify volume filtered. A FastCAT CTD (Sea-bird Scientific, USA) was attached in-line between the wire and the net array to collect Temperature, Salinity, and Depth over the towed path. The primary nets from each of the 60-cm Bongo and 20-cm Bongo nets were preserved for quantitative identification of zooplankton and ichthyoplankton. The organisms collected in the secondary nets were utilized for onboard counts and identification of broad taxonomic groups (RZA: Rapid Zooplankton Assessment), and for additional projects including carbon and nitrogen stable isotope analyses of fish and plankton, plankton genetics, Harmful Algal Bloom work, lipid content, and fatty acid analyses. Profiles from FastCAT casts were logged and plotted for each station.

Preliminary results:

Samples were collected at 53 stations (Fig G-1) and RZA was performed at a subset of 50 stations. Ichthyoplankton samples collected for stable isotope analyses included saffron cod and arctic cod. Taxa saved for genetic analyses included capelin, Bering flounder, walleye pollock, stickleback, yellowfin sole, and sand lance.

Zooplankton samples indicated a proliferation of small zooplankton at lower latitude stations, an abundance of crab megalope and zoeae at inshore stations, and krill and large zooplankton at high latitude stations. Samples will be further processed in the laboratory for data on zooplankton size, stage, and for species identifications.

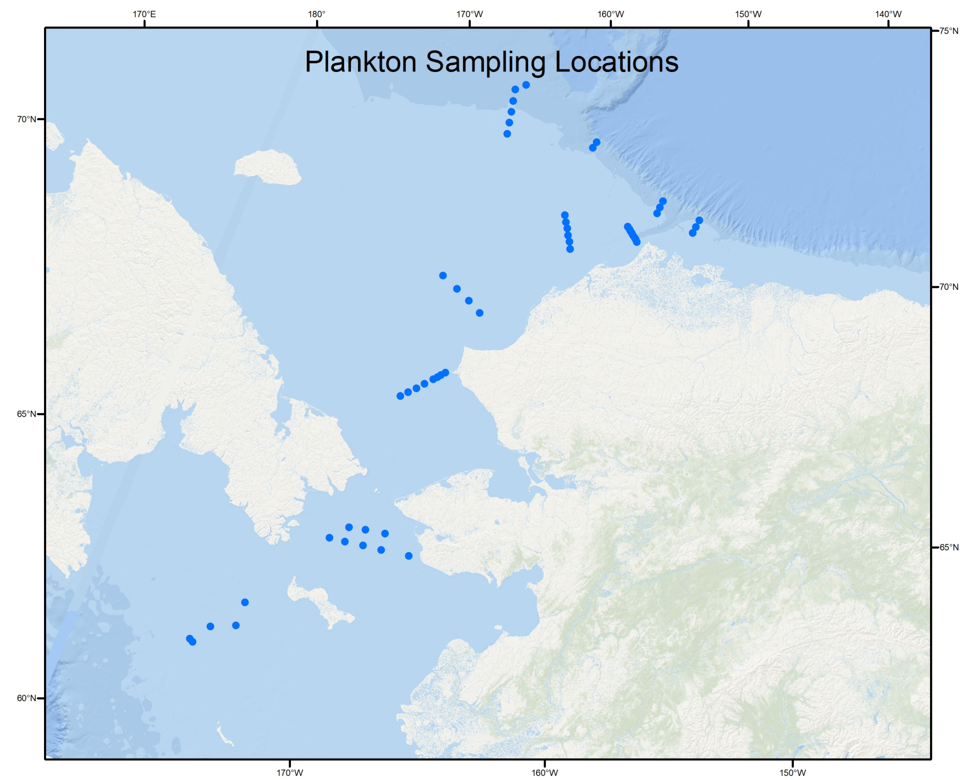

Figure G-1.

Section H: Distribution and Prevalence of Harmful Algal Blooms in Arctic Waters

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Funding Sources: NOAA Ocean Observing and Monitoring Division through the Cooperative Institute for the North Atlantic Region (#NA14OAR4320158), Woods Hole Center for Oceans and Human Health (NIH Grant 1P01ES028938 and NSF Grant #OCE-1840381)

Summary

Recent events have shown that harmful algal blooms (HABs) are occurring in the Chukchi Sea and adjacent waters, but their origin and spatiotemporal extent have yet to be determined. The objective of this project is to determine the distribution and prevalence of HAB species on the Chukchi shelf. Observations from 2018 indicate the presence of a large cyst seedbed of *Alexandrium catenella* in the Chukchi Sea, with planktonic bloom-forming cells also observed in the region. Sampling methods from the 2018 field season (HLY 1801 & 1803) were repeated during HLY1901. Surface sediments were sampled at each process station to examine the distribution of cysts of the toxin-producing dinoflagellate *Alexandrium catenella*. Cysts isolated and germinated from these sediments will be used to establish laboratory cultures to examine genetic connectivity and toxin profiles of *A. catenella* across the study region. Water samples collected using Niskin bottles and from the underway seawater system will be used to determine abundance of planktonic *A. catenella* cells as well as the community structure and domoic acid (DA) content of diatoms in the genus *Pseudo-nitzschia*. Visual inspection of concentrated seawater samples allowed preliminary estimates of cell abundance to be calculated at a subset of locations. Toxin samples for HPLC analysis were collected from stations with significant concentrations of *Alexandrium*-like cells. Zooplankton and benthic invertebrate samples, collected from process stations by the AFSC and CBL/UMCES teams respectively, will be analyzed for toxins as part of a separate but related project characterizing trophic transfer of algal toxins in the region.

Sampling Methods

Surface Sediments for Cyst Enumeration: In collaboration with the CBL/UMCES team, a plug of the top 0-3 cm was extracted from the surface of one Van Veen grab at every process station. The sediment was homogenized, any visible macrofauna were removed, and a 10 mL aliquot was stored in the dark at 1°C.

Sampling for *Pseudo-nitzschia* spp. and domoic acid detection: At each process station, water was collected from the CTD rosette from the surface, 10 m, and chlorophyll maximum, and preserved to determine *Pseudo-nitzschia* community structure and DA content. Additional water samples were collected from the underway seawater system during transit. From each depth, 300-500 mL of water was filtered through duplicate 0.45 μm HA/HV filters using a manifold and vacuum pump. Sample volume was reduced at some stations when high particulate loads caused filters to become obstructed. Filters were stored at -80°C. In addition, 125 mL from each depth was preserved in Lugol's Iodine solution.

Sampling for *A. catenella* enumeration: At each process station, 2L of water was collected from the CTD rosette from the surface, 10m, and chlorophyll maximum. Additional samples were collected from the underway seawater system during transit. Water was sieved and concentrated on a 15 μm nitex sieve, backwashed into a 15mL tube, preserved with 0.75 mL formalin, and stored at 1°C. Within 48 hours, samples were spun down (10 min at 3000 *g*), seawater-formalin mixture was aspirated, and flocculent pellet was resuspended in methanol.

Cell abundance estimations and toxin collection. A preliminary, on-board evaluation of the presence of HAB species at a subset of locations was carried out using light microscopy. At each location, 2L of seawater from the underway seawater system was sieved, and concentrated contents were backwashed to a volume of 10 mL. A 1 mL aliquot of each concentrated seawater sample was examined, and cells resembling *Alexandrium* were enumerated. These counts were used to estimate cell abundance and determine potential bloom locations. At stations where cell abundance was high (>1000 cells/L) a 20μM plankton net was used to concentrate large volumes of water from the underway seawater system (40-80 L). Contents of the plankton net were backwashed and centrifuged in order to pellet cells. Seawater was aspirated and replaced with 1 mL 0.05M acetic acid. Toxins from these pellets will be extracted for HPLC analysis.

Preliminary Observations

Based on a preliminary assessment carried out shipboard using light microscopy, few cells were observed south of the Bering Strait at DBO1 or DBO2. The first significant concentration of *Alexandrium*-like cells was observed at DBO3, with abundances estimated at 7200 cells/L at offshore stations of this transect. These cells were observed concurrently with a series of bird mortalities (Figure H-1). It is important to note that *Alexandrium catenella* cannot be definitively identified by light microscopy; official counts are pending laboratory analysis by fluorescence in-situ hybridization using a molecular probe specific to *A. catenella*. Cell concentrations appeared to decrease while moving inshore along DBO3, and were almost entirely absent at the innermost stations.

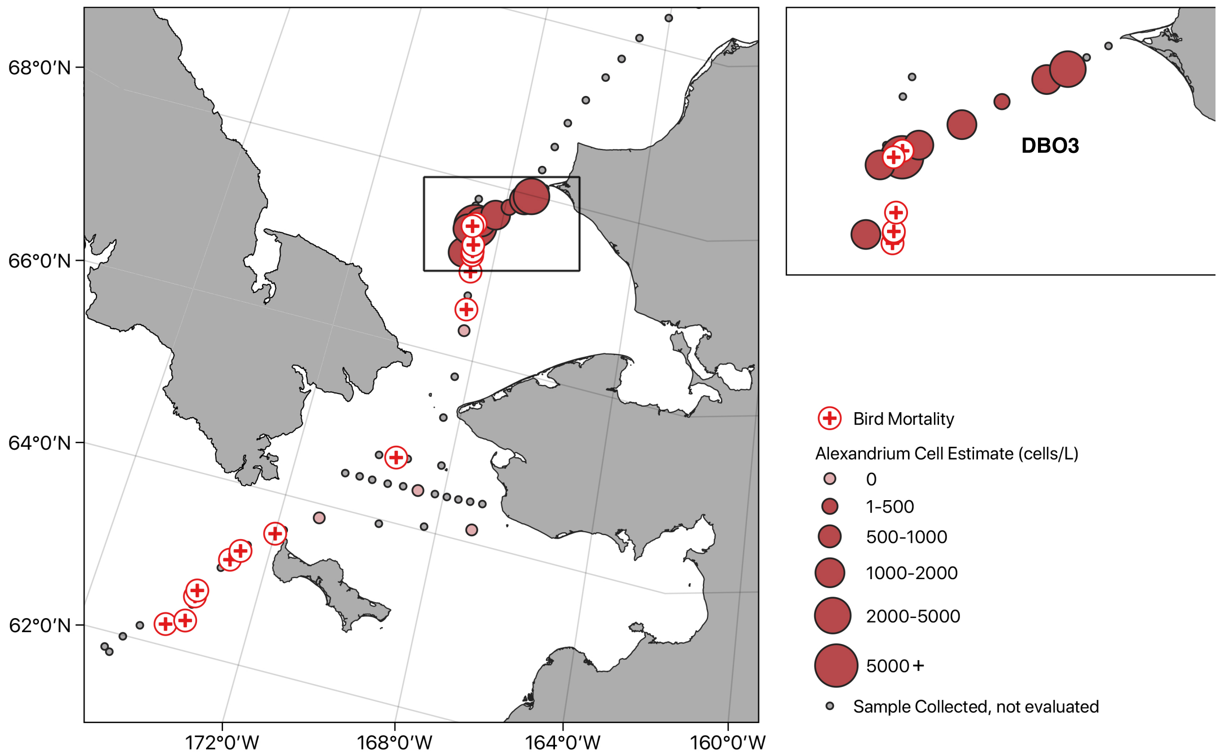

Figure H-I. Estimated concentrations of *Alexandrium* cells along the DBO3 line, displayed with bird mortalities (recorded by observers Charlie Wright and Linnaea Wright.) Note that these data are preliminary and subject to change.

Few *Alexandrium*-like cells were observed during the transit from DBO3-DBO4, as well as along DBO4 and DBO5. However, a large concentration of cells was observed at Barrow Canyon East (BCE), starting at the inshore station of this line. Cell concentrations were estimated at 2600 cells/L. Initial laboratory analysis using FISH and species-specific DNA probes indicated that the concentration of *A. catenella* at this location was lower than estimates produced using shipboard microscopic analysis, ~600 cells/L. Additional analyses will be carried out to determine whether another species of *Alexandrium* (e.g., *A. ostenfeldii*) may also have been present. That species is capable of producing two different toxin families – saxitoxins and spirolides. Water temperatures recorded along the BCE line were abnormally high on the shelf.

During the return transit from Barrow to Ledyard Bay, significant concentrations of cells were observed in samples collected from the underway seawater system. Cell concentrations decreased quickly moving inshore along the Ledyard Bay line. This transect was of particular interest, because it is where large concentrations of planktonic cells were observed during HLY1801. Underway sampling was continued during the return transit in order to capture repeat observations of the DBO3 region. Upon return to this area it appeared that the bloom observed at the beginning of the cruise was no longer present.

Next Steps

Sediments collected from Van Veen grabs will be used determine cyst density and to establish cultures for genetic and toxin analysis. Plankton samples will be hybridized in the laboratory and *A. catenella* (and perhaps *A. ostenfeldii)* will be enumerated. *Pseudo-nitzschia* DNA and toxin filters, along with Lugol's preserved samples, will be sent to the laboratory of Katherine Hubbard for analysis of community structure. Zooplankton and invertebrate samples were shipped to Kathi Lefebvre (NWFSC) in Seattle. A HAB-focused cruise aboard the Healy is scheduled for 2020.

Now that two years of observations are nearly complete from Healy 1801, 1803, and 1901, we will begin reporting results in one or several manuscripts. The findings of these two years of surveys are highly significant, as for the first time, the widespread distribution and abundance of toxic *A. catenella* cysts and cells has been characterized in a region with virtually no prior experience or exposure to the risk from toxic HABs. Our data suggest that Arctic blooms may be derived from both advected as well as in situ populations, with strong potential for recurrent blooms in the future. *A. catenella* populations thus represent a new and significant threat to Alaskan Arctic communities who are justifiably concerned about their health and the health of the ecosystems on which they depend for food.

Section I: Linking sources of microbial atmospheric and oceanic ice nucleating particles

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Principle Investigator: Jessie Creamean (jessie.creamean@colostate.edu)

Cruise participants: Jun Uetake (Colorado State University)

Objective: To evaluate the efficiency in which aerosol particles from local marine sources have the potential to impact Arctic cloud ice formation.

Methods:

1. A series of two collectors for physical samples of aerosols for size-resolved and non-size-resolved offline ice nucleation measurements
2. One filter unit sampler for offline DNA sequencing of aerosol
3. Collection of seawater samples from underway system and CTD for source characterization

Initial results: Placement of the samplers on the fly bridge was advantageous to avoid self-generated sea spray while steaming. In total, 200 CTD samples from DBO1 – DBO5, and 187 aerosol samples were collected. Samples of seawater and aerosol will be analyzed for INPs and DNA in the laboratory in CSU. Future results, including cumulative ice nucleation spectra and DNA sequencing, will be used to compare to results from HLY1702 and HLY1801.

Other remarks: The crew was extremely helpful with equipment placement and loading. We are incredibly appreciative of the crew for the extra effort in making these measurements successful, in addition to creating a fun and exciting environment while at sea.

Section J: Microbes

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Principal Investigator: Eric Collins (recollins@alaska.edu)

Aims:

The goal of the Microbes group from the University of Alaska Fairbanks was to collect samples representing the diversity of marine microbes in the Chukchi and Bering Seas. In the lab at the University of Alaska Fairbanks (UAF) we will conduct DNA barcoding to identify bacteria, phytoplankton and protists using 16S and 18S ribosomal RNA gene sequencing. Extending previous research, these analyses may tell us which (if any) sea ice microbes are endemic to sea ice versus those that were in the water when it froze.

Additional samples of surface seawater were taken at 15 locations to culture Synechococcus.

Collaborator Pachiadaki from Woods Hole Oceanographic Institution collected samples from various stations and depths (see table below) for single cell genomics, total microbial counts, metagenomics and metatranscriptomics. The microbial abundance and biomass are indicative of the system productivity and the amount of carbon available for the higher trophic levels, while single genomics will be used to construct the first reference genomic databases of uncultivated arctic microorganisms. The metatranscriptomic samples will be used as a proxy of microbial activity.

Finally, for a pilot project, samples of surface seawater were collected for quantification and qualification of microplastics from 9 locations.

Methods:

For DNA barcoding, a total of 194 samples were collected from surface water, mid-depth water (e.g. subsurface chlorophyll maximum, halocline, thermocline, and oxygen minimum), and bottom water by filtration of 1L of seawater through a 0.2 um Sterivex filter. Samples were stored at -80°C until further processing at UAF.

For the culturing of Synechococcus, 50ml of surface water was filtered through a 5um filter, to remove larger phytoplankton, and added to 200ml of f/40 culturing medium. Each 250ml culturing bottle was incubated at in situ temperatures of 9-10°C with light.

For single cell genomics, 1ml of water was mixed with 100µl of the cryoprotectant glycerol-TE and stored at -80°C. For metagenomics and metatranscriptomics 2L of seawater was filtered through a 0.2um Sterivex. Samples were stored at -80°C. For total microbial counts, 250ml of seawater was fixed with 2% formaldehyde and after ~1h was filtered. 5 and 20ml of the fixed material was passed through membrane filters of pore size 0.2um while the rest was collected in a 3um membrane. All filters were stored at -20°C.

For microplastics, approximately 500ml of surface water was filtered through a 0.2um anodisk membrane. Filters were stored at -20°C.

The table below lists all the stations sampled and how many depths were sampled at each.

Stations	UFA barcoding	UFA Syn cultivation	WHOI omics	Micro-plastics
DBO1-1	4	x		x
DBO1-2	4		4	
DBO1-4	4			
DBO1-6	4			
DBO1-8	4	x	2	x
DBO2-B	4	x		
DBO2-D	4			
DBO2-3	4	x		
DBO2-2	4			
DBO2-1	3			
DBO2-0	2	x	2	x
DBO2-4	3			
DBO2-5	3			
DBO2-7	4			x
Mooring Location	3			
DBO3-8	4	x	4	x
DBO3-7	2			
DBO3-6	4			
DBO3-5	4			
DBO3-4	4			
DBO3-3	3			
DBO3-2	3			
DBO3-1	3	x	2	x
DBO4-1	4	x	5	x
DBO4-2	4			
DBO4-3	3			
DBO4-4	4			
DBO4-5	3			
DBO4-6	3	x	4	x
NNE7	4			
NNE19	4			
NNE20	4		4	
BL9	4	x		
BL7	4			
NNE13		x	5	
BL3	4			
BL1	3			

W1			4	
W5	4			
W11	4		4	
W15	4			
W19	3			
DBO5-10	4	x	4	
DBO5-9	4			
DBO5-8	4			
DBO5-7	4			
DBO5-6	4			
DBO5-5	3		4	
DBO5-4	4			
DBO5-3	3			
DBO5-2	3			
DBO5-1	3	x		x
BCW1	4		4	
BCW10	3	x		
BCE-1	3			
LB13	4			
LB11	4			
LB8	3			
LB6	3	x		

Section K: Marine mammal watch and Passive acoustic monitoring

Contributing author: Kelly Kapsar (kapsarke@msu.edu)

A watch for marine mammals was conducted from the bridge of the USCGC HEALY (height = 18.3m) during the transit from Nome, then to the DBO study area in the NE Chukchi Sea, then southbound returning to Nome. Most watches were conducted between 0730 and 2130, whenever the marine mammal watch stander was not participating in benthic sampling activities. The lone marine mammal watch stander was aided in spotting mammals by two seabird observers, various science party members, and the ship's crew. The purpose of the watch is to detect marine mammals and identify sightings to species at temporal and spatial sampling scales coincident with the oceanographic sampling. The overarching goal is to improve integration of upper-trophic species distribution and relative abundance with measures of biophysical variability in the Pacific Arctic marine ecosystem.

A total of 62 hours of watch effort were completed between 4 August and 22 August (Table K-1). During this period, the observer recorded a total of 78 independent sightings with a total of between 187 and 215 marine mammals. A total of 11 species (7 cetaceans and 4 pinnipeds) were positively identified during the trip. Humpback whales were the most commonly observed species of marine mammal (N=74-100). Notably, they were seen to the north of the Bering Strait on several occasions. Walruses were seen in pairs (including cow/calf) or singletons near to DBO 4 when the Healy broke from the line briefly to rendezvous for sail drone calibrations (11 August), but never in large aggregations.

Highlights

> 6 August: We passed by a pod of killer whales southwest of St. Lawrence Island (to the northwest of DBO 1). After the event, Linnaea Wright (bird observer) identified a minke whale amongst the pod of killer whales in her photos. It's possible that they were hunting at the time we observed them.

> 12 August: A juvenile fur seal was spotted by Piper Bartlett Browne (Polar Trec teacher) swimming right next to the fantail at Station 5 of DBO 4. The seal appeared to be alone and was north of its typical range.

Table K-1. HEALY 1901: Marine Mammal Watch Summary
Hours of watch effort (EFT) and number of individuals (min/max) by species

Date	EFT	CT	GW	FW	HW	MW	KW	HP	DP	PN	WS	RS	FS	BS
8/4/2019	2.08	0	0	0	0	0	0	0	0	0	0	0	0	0
8/5/2019	4.52	1	0	2	0	0	0	0	0	0	0	0	0	0
8/6/2019	5.47	7	0	0	38/53	0	18	0	2	0	0	0	2	0
8/7/2019	2.35	0	0	0	0	0	0	0	0	0	0	0	0	0
8/8/2019	1.17	3	4	0	0	0	0	0	0	1	0	0	0	0
8/9/2019	3.18	6/7	9	3	14/20	5	0	1/2	0	0	0	0	0	0
8/10/2019	5.8	1	0	0	0	0	0	0	0	0	0	0	0	0
8/11/2019	2.75	0	0	0	0	0	0	0	0	1	12	0	0	0
8/12/2019	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
8/13/2019	1.35	0	0	0	0	0	0	0	0	0	0	0	0	0
8/14/2019	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0
8/15/2019	3.08	0	0	0	0	0	0	0	0	0	0	0	0	0
8/16/2019	2.53	0	0	0	0	0	0	0	0	2	0	0	0	0
8/17/2019	2.78	0	0	0	0	0	0	0	0	0	0	0	0	0
8/18/2019	2.35	0	0	0	0	0	0	0	0	1	0	0	0	0
8/19/2019	1.53	0	0	0	0	0	0	0	0	0	0	0	0	0
8/20/2019	4.37	0	0	0	0	0	0	0	0	3	0	1	0	0
8/21/2019	9.53	2	0	0	23/26	1	0	0	0	14	1	2	0	1
8/22/2019	4.78	7	0	0	1	0	0	0	0	0	0	0	0	0
Totals:	62.62	27/28	13	5	74/100	6	18	1/2	2	22	13	3	2	1

KEY: CT=unID Cetacean; GW=gray whale; HW=humpback whale; FW=fin whales; DP=Dall's porpoise; WS=walrus; BS=bearded seal; RS= ringed seal; SP = spotted seal; FS=fur seal; PN=unID Pinniped; BH = bowhead whale; MW = minke whale

Section L: Marine bird surveys

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Background:

The U.S. Fish and Wildlife Service (USFWS) conducted seabird surveys during the Distributed Biological Observatory (DBO) and Northern Chukchi Integrated Study (NCIS) projects onboard the US Coast Guard Cutter Healy. The USFWS is supported by an Interagency Agreement with the Bureau of Ocean Energy Management (M17PG00017) for project AK-16-07c: Seabird Community Structure and Seabird-Prey Dynamics. This study will combine data collected during the DBO-NCIS cruise with data from other USFWS seabird surveys to examine the distribution of marine birds relative to prey and oceanographic properties. It will also be used to describe seasonal and interannual changes in marine birds and their communities in the Chukchi Planning Areas. Marine birds and mammals were surveyed from 4 to 22 August, 2019, starting from Nome heading southwest of St. Lawrence Island, northward through the Bering Sea and Chukchi Sea, between sampling stations in the northern Bering and Chukchi seas, and returning south to Nome. The seabird survey data will be archived in the North Pacific Pelagic Seabird Database (http://alaska.usgs.gov/science/biology/nppsd).

Methods:

Marine birds and mammals were surveyed from the port side of the bridge, with marine bird surveys using standard USFWS seabird survey protocols, thus mammal observations cannot be used to calculate densities. Observations were conducted during daylight hours while the vessel was underway. The observer scanned the water ahead of the ship using hand-held 10x42 binoculars if necessary for identification and recorded all birds and mammals. Bird surveys used a modified strip transect methodology with four distance bins from the center line: 0-50 m, 51-100 m, 101- 200 m, 201-300 m. Rare birds, large flocks, and mammals beyond 300 m or on the starboard side (‘off transect’) were also recorded but will not be included in density calculations. We recorded the species, number of animals, and behavior (on water, in air, foraging). Birds on the water or actively foraging were counted continuously, whereas flying birds were recorded during quick ‘Scans’ of the transect window. Scan intervals were based on ship speed, ranging during this cruise from 39 sec to 97 sec, with the median at 39 sec.

Geometric and laser hand-held rangefinders were used to determine the distance bin to bird sightings. Observations were directly entered into a GPS-interfaced laptop computer using the

DLOG3 program (Ford Ecological Consultants, Inc., Portland, OR). Location data were also automatically written to the program in 20-second intervals, which allowed us to track survey effort and simultaneously record changing weather conditions, Beaufort Sea State, glare, and ice coverage (no ice was encountered during this cruise). Other environmental variables recorded at the beginning of each transect included wind speed and direction, cloud cover, sea surface temperature, and air temperature.

We encountered variable weather and survey conditions during this cruise, with calm (at times glassy) seas in the northern Bering Sea, and generally rougher seas in the Chukchi. Fog was especially pervasive in the northern Chukchi and restricted the survey window on several days. Two additional days of surveying occurred on 20 and 21 August during our southward transit from Pt Barrow to the Bering Strait region, which is not included in the maps presented here.

Preliminary Results

We surveyed a total of 2601 km, with 658 km surveyed in the northern Bering Sea and 1943 km in the Chukchi Sea (Fig. L-1). On transect we recorded a total of 11,205 birds (Table L-1). In the northern Bering Sea, roughly 4.9 birds were recorded per linear km surveyed, while the rate was slightly lower in the Chukchi Sea at 4.1 birds per km. We recorded 22 seabird species on transect, with species richness higher in the Chukchi (19 species) than in the Bering (17 species) as a result of greater survey effort in the Chukchi. Four areas of relatively high marine bird abundance were identified, including the Chirikof Basin near St. Lawrence Island, outer Hope Basin in the Chukchi Sea, Barrow Canyon, and nearshore waters at Point Barrow (Fig. L-2).

Marine birds

Short-tailed shearwater was the most numerous species on this cruise overall, accounting for 62% of individuals on transect (Table L-1). While the species was detected from the lowest (61°N) to the highest latitudes surveyed (75°N), shearwaters were particularly predominant in the Chukchi Sea (86% of birds there). Short-tailed shearwaters breed near New Zealand and this cruise coincided with their non-breeding period. The largest numbers of shearwaters were near Point Barrow and on the eastern edge of Barrow Canyon, marginally in the Beaufort Sea (Fig. L-3). Large flocks (1000-5000) were observed on the water near Barrow Canyon, mainly off transect and thus not included in Table L-1 or Fig. L-3. Farther south, shearwaters were observed offshore of Ledyard Bay in small flocks, foraging in association with humpback whales. We also noted some shearwaters being chased by parasitic jaegers attempting to steal their food.

Northern fulmars totaled 5% of birds observed in the northern Bering Sea, but the species was almost absent (0.2% of total) from the Chukchi Sea (Table L-1). We observed a group of fulmars foraging on a dead walrus, and another scavenging a freshly dead least auklet (Fig. L-7).

The Alcidae were the most diverse family, with 9 species observed. Thick-billed murres and common murres were in small flocks offshore of Cape Lisburne (Fig. L-4), with many of the thick-billed murres carrying small fish, indicative of breeding activity in the area. A few horned puffins were also observed carrying food in the same area. Tufted puffin were detected in higher proportion in the northern Bering Sea (3.8% of total) than the Chukchi Sea (0.4% of total observations; Table L-1).

Aethia auklets, which are small planktivorous alcids, comprised 21% of total birds overall (Table L-1). Crested auklets were the most abundant of the auklets in the northern Bering Sea near St Lawrence Island, where large breeding colonies are located, but were also in the northern Chukchi Sea (Fig. L-5). Least auklets and parakeet auklets were primarily found in the Bering Strait region (Fig. L-5).

Marine mammals

We recorded marine mammal detections during surveys, but because we used seabird survey protocols, our observations cannot be used to calculate densities. The USFWS observers recorded 148 marine mammals of 12 species, including off-transect individuals, with seven species of cetaceans and five species of pinnipeds (Table L-2). Small groups of killer whales (Orcinus orca) were observed southwest of St Lawrence Island and northeast of Point Barrow in the Beaufort Sea. Other whales were in highest abundance and species richness in the Chukchi Sea, especially offshore of Point Hope. Walrus were observed as groups of 1-4 individuals swimming, especially in the vicinity of Hanna Shoal. Northern fur seals were the only pinniped observed in the Bering Sea, while bearded, ringed, and spotted seals were all found in the Chukchi Sea. A single long-dead walrus near Ledyard Bay was the only dead marine mammal observed on this cruise.

Unusual observations

A group of 16 male Steller's eiders was observed offshore of Woolley Lagoon on the Seward Peninsula, an area where this threatened species is seldom observed in numbers.

This survey encountered 18 dead birds near DBO-1 and the area south and west of DBO-3 (Fig. L-6). Fourteen of the dead birds were identified to species or genus, mainly from photos taken as the boat moved past the floating birds. Short-tailed shearwater was the most frequently identified species (5 individuals). A successful small boat operation allowed us to salvage a freshly dead and emaciated short-tailed shearwater that will be examined for evidence of cause of death at the National Wildlife Health Center in Madison, WI.

In addition to dead birds, seabirds were observed in a weakened state. An ailing least auklet was found aboard the ship near King Island, and another was swimming lethargically off Point Hope. In the same area where the emaciated short-tailed shearwater was collected off Point Hope, other shearwaters in the area (30-40 individuals) were unresponsive to boat approach and sat with heads very low to the water, seemingly unwell.

Table L-1. Marine bird observations, on transect, during the DBO-NCIS cruise, August 4-22, 2019.

		N. Bering		Chukchi		All Regions	
Common Name	Scientific Name	No. Birds	% Total	No. Birds	% Total	Total	% Total
Steller's Eider	*Polysticta stelleri*	16	0.5			16	0.1
King Eider	*Somateria spectabilis*	3	0.1			3	<0.1
Red Phalarope	*Phalaropus fulicarius*	6	0.2	83	1.0	89	0.8
Pomarine Jaeger	*Stercorarius pomarinus*	6	0.2	22	0.3	28	0.2
Parasitic Jaeger	*Stercorarius parasiticus*			11	0.1	11	0.1
Common Murre	*Uria aalge*	40	1.2	109	1.4	149	1.3
Thick-billed Murre	*Uria lomvia*	148	4.6	210	2.6	358	3.2
Unidentified Murre	*Uria spp.*	89	2.8	205	2.6	294	2.6
Kittlitz's Murrelet	*Brachyramphus brevirostris*			1	<0.1	1	<0.1
Ancient Murrelet	*Synthliboramphus antiquus*	40	1.2	1	<0.1	41	0.4
Parakeet Auklet	*Aethia psittacula*	41	1.3	31	0.4	72	0.6
Least Auklet	*Aethia pusilla*	451	14.1	191	2.4	642	5.7
Crested Auklet	*Aethia cristatella*	1446	45.1	177	2.2	1623	14.5
Unidentified Auklet	*Aethia spp.*	2	0.1	6	0.1	8	0.1
Horned Puffin	*Fratercula corniculata*	33	1.0	41	0.5	74	0.7
Tufted Puffin	*Fratercula cirrhata*	122	3.8	34	0.4	156	1.4
Black-legged Kittiwake	*Rissa tridactyla*	140	4.4	166	2.1	306	2.7
Sabine's Gull	*Xema sabini*			51	0.6	51	0.5
Glaucous Gull	*Larus hyperboreus*			13	0.2	13	0.1
Arctic Tern	*Sterna paradisaea*			18	0.2	18	0.2
Pacific Loon	*Gavia pacifica*	2	0.1	5	0.1	7	0.1
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	2	0.1			2	<0.1
Northern Fulmar	*Fulmarus glacialis*	178	5.5	15	0.2	193	1.7
Short-tailed Shearwater	*Ardenna tenuirostris*	443	13.8	6607	82.6	7050	62.9
		3208		7997		11205	

Table L-2. Marine mammals observed on transect (≤300 m on port side) and off transect (≥300 m from vessel or on starboard side) during seabird surveys on the DBO-NCIS cruise, August 4-22, 2019

Common Name	Scientific Name	N. Bering	Off Transect	Chukchi	Off Transect	Total
Fin Whale	*Balaenoptera physalus*		2		3	5
Gray Whale	*Eschrichtius robustus*		1	2	7	10
Humpback Whale	*Megaptera novaeangliae*				9	9
Minke Whale	*Balaenoptera acutorostrata*			1		1
Unidentified Whale	*Cetacea spp.*	1	7	1	8	17
Killer Whale	*Orcinus orca*	8	18		4	30
Dall's Porpoise	*Phocoenoides dalli*	3				3
Harbor Porpoise	*Phocoena phocoena*	4		1	2	7
Walrus	*Odobenus rosmarus*			20	17	37
Northern Fur Seal	*Callorhinus ursinus*		4			4
Bearded Seal	*Erignathus barbatus*			2		2
Ringed Seal	*Pusa hispida*			1		1
Spotted Seal	*Phoca largha*			7		7
Unidentified Seal	*Phocidae spp.*	1		9	4	14
Unidentified Pinniped	*Pinnipedia spp.*			1		1

Figure L-1. Marine bird survey tracklines surveyed August 4-22, 2019.

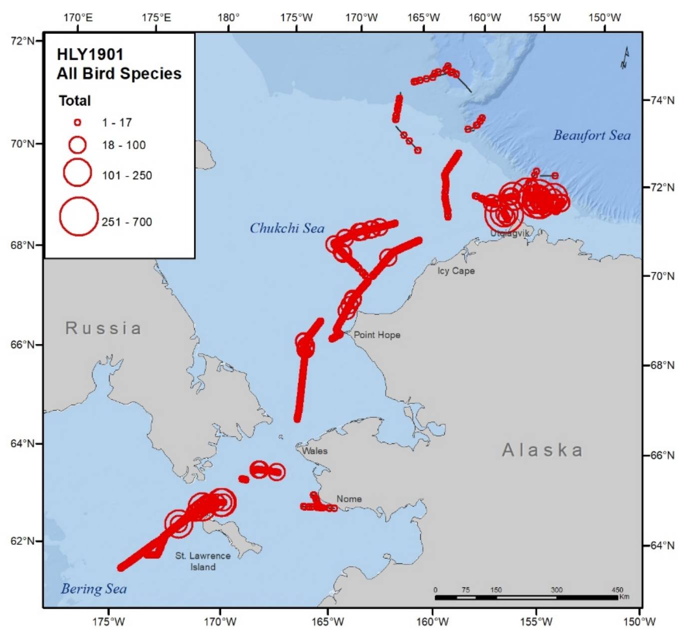

Figure L-2. Distribution of total birds during marine bird surveys on HLY1901 cruise.

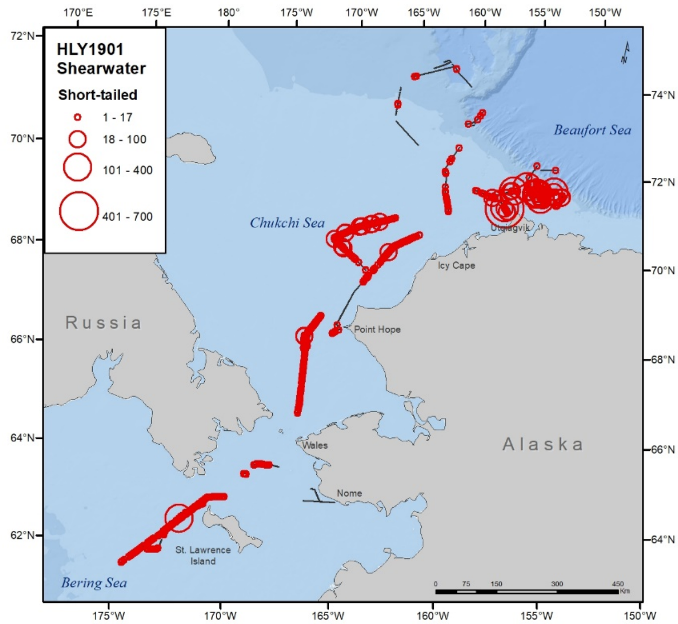

Figure L-3. Distribution of short-tailed shearwaters observed on transect during HLY1901 cruise.

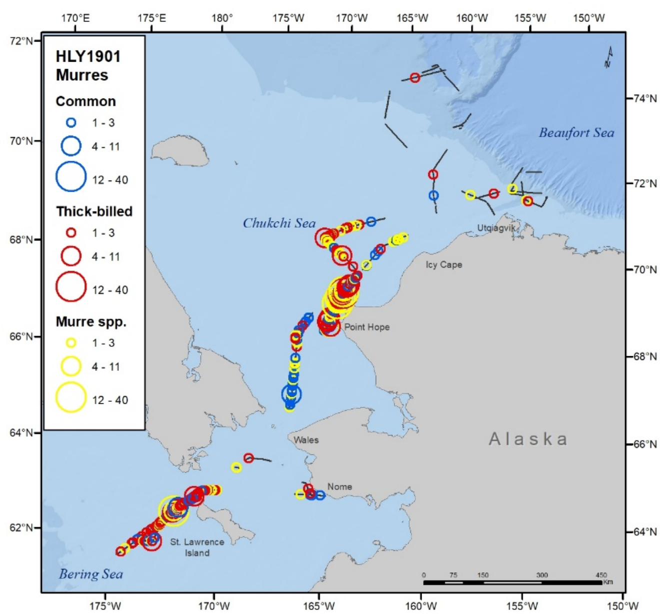

Figure L-4. Distribution of murres (common, thick-billed, and unidentified murre) observed on transect during HLY1901 cruise.

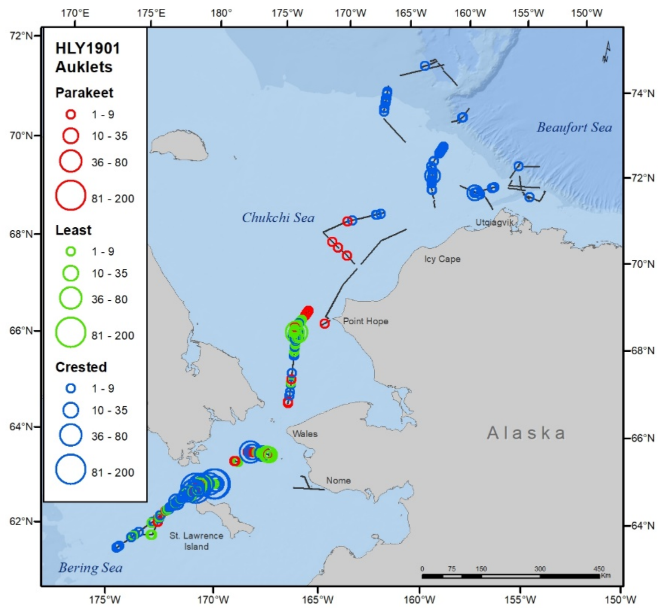

Figure L-5. Distribution of Aethia auklets (crested, least, and parakeet) observed on transect during HLY1901 cruise.

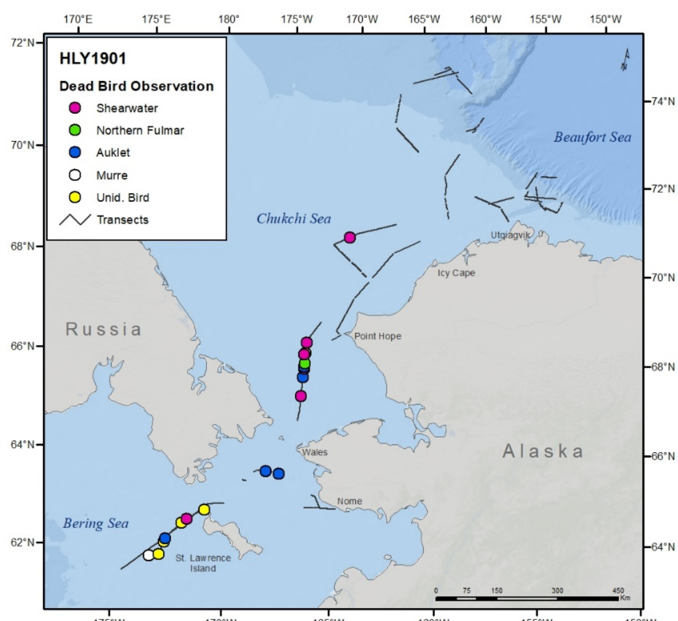

Figure L-6. Distribution of dead birds encountered on HLY1901 cruise.

Figure L-7. Northern fulmar scavenging dead least auklet in northern Bering Sea, August 6, 2019. Photo: C. Wright

Section M: Saildrone Survey

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Project Summary

Climatic pressures are causing Arctic sea ice to melt back earlier, retreat over increasingly large areas, and freeze later. These changes have important implications for the marine environment and ecosystem services in this area. However, traditional ship-based mission operations are time, space, and cost-limiting in this harsh and expansive area. Now, new mobile autonomous technologies are rapidly expanding NOAA's operational capacity in this region. These new tools represent a unique opportunity to cost-effectively monitor continuing Arctic environmental transitions.

For this project, the NOAA Arctic Research Program partnered with the Innovative Technology for Arctic Exploration (ITAE) testbed to deploy one wind- and solar-powered autonomous surface vehicle (ASV) in conjunction with the DBO-NCIS mission. This ASV was equipped with new sensing technologies for sea-air carbon dioxide (CO_2) flux measurements. Adding this capability to ASVs is key to the NOAA Climate Observation Divisions central goal to constrain global anthropogenic CO_2 storage. Like ocean heat, increased open water area allows for greater exchange of CO_2 between the atmosphere and upper ocean, contributing to accelerating rates of ocean acidification and decreases in ocean pH. Saildrone CO_2 flux measurements represent a clear technological breakthrough that could fully survey the regional CO_2 sink and constrain the extent, duration, and intensity of ocean acidification events.

Methods

The saildrone, a novel wind- and solar-powered ASV, has been used with great success by the ITAE program during several development missions. ITAE scientists have co-developed this platform with Saildrone, Inc. to tailor its capabilities to NOAA's unique observational needs. Dramatically enhanced speed, endurance, and maneuverability allow the saildrone to launch and recovery from shore and cover extremely large areas over extended research missions. These types of platforms are critical for growing Arctic research and monitoring needs.

The basic saildrone sensor suite measures a total of 58 parameters, providing information about meteorological and atmospheric conditions (winds, air temperature, and humidity, barometric pressure, ocean skin temperature) and water properties (temperature, salinity, dissolved oxygen, and fluorescence) near the sea surface. This mission sensor configuration also included sensing for surface water and atmospheric pCO_2 through the newly developed ASVCO2 system, from which sea-air CO_2 fluxes can be calculated; and a 300 kHz RDI Acoustic Doppler Current Profiler (ADCP).

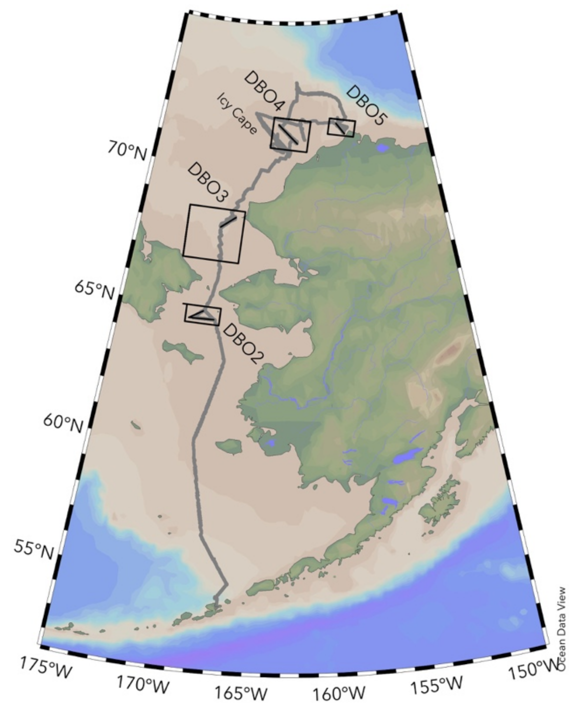


Figure 2. Map showing the path of 1033 during the 2019 mission, as well as highlights indicating the 4 DBO transects occupied. Icy Cape is also shown.

Mission Summary

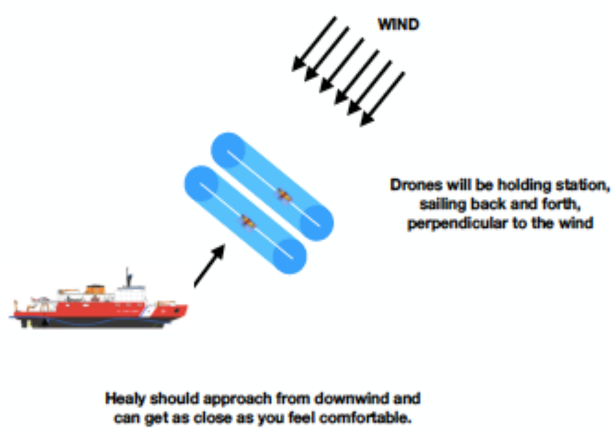
On this mission, one saildrone was launched from Dutch Harbor on June 30 and sailed north through the Bering Sea towards the planned study area, which included DBO2, DBO3, DBO4, DBO5 and some opportunistic sampling along the Icy Cape line and between DBO4 and DBO3. A map is shown at right.

SD1033 visited the DBO2 time series line from 3 June to 11 June for three repeat transects. After crossing through Bering Strait, SD1033 visited DBO3 during a period of low winds for approximately 5 repeat transects from 16 June to 22 June. Some opportunistic sampling took place during icy conditions from 27 June to 8 July. After ice melt, SD1033 visited DBO4 for 7 repeat transects for 9 to 19 July. After this period, SD 1033 joined another ITAE mission for approximately ten days, consistent with the lease time provided by ITAE. DBO5 was occupied very quickly during a period of very high winds, from 1 Aug to 7 Aug.

On 12 August 2019, 1033 proceeded to DBO3 for a ship-to-saildrone calibration activity with USCGC Healy. The AIS systems were activated for the morning calibration activity at ~0900 local time on 12 Aug 2018.

The activity was conducted according to the figure at right, which shows the drone transiting on short (2 nm) transects with 0.25 nm tolerance perpendicular to the wind. Positioning the saildrone perpendicular to the wind direction ensures the minimum route tolerance possible (e.g., to minimize tacking) as well as the best wind propulsion efficiency (e.g., never slowing down to fight prevailing winds, especially when winds are slow). Healy approached from downwind at the instruction of Saildrone, Inc. Healy came within less 1 nm of the route tolerance of the saildrone paths.

Figure 2: Saildrone calibration with USCGC Healy including route diagrams, courtesy Saildrone, Inc.



Ten replicate calibration samples were collected from the USCGC Healy underway system. We hope to compare the drones, its internal standards, the discrete samples, and the Healy's own underway pCO_2 system and its internal calibration system to show which is the best possible type of calibration, and to estimate "how good is good enough" for future calibration activities.

During the previous calibration activity in 2018, we learned that the wing acts as a misleading "arrow" for the visual observer. By pointing this out to the bridge and navigation officers from the beginning, we were able to avoid this misunderstanding. Also according to our previous experience, we made distances, route tolerances, and degree-minute latitude and longitude readily available for the bridge prior to the calibration activity.

It should be noted for future calibration activities that the AIS can be seen within approximately 4 nm of the saildrone, while the radar reflector can be inconsistently spotted at approximately 5 nm distance from the drones. Note that wave action can sometimes mask the radar reflector on the drone, especially given its position at the water surface.

After the calibration activity, 1033 proceeded to the Icy Cape line for a potential rendezvous with the Ocean Starr. Following this activity, cloud cover and weather dictated that the drone maintain a holding pattern to recharge batteries and stay clear of shore. Following these charging days, the drone then proceeded to a racetracked survey between DBO4 and DBO3. This survey was just beginning at the time of submission of this cruise report.

Next Steps

Data collected by this program will be processed using the US IOSS QARTOD QA/QC standards for most variables, and post-processed for carbon and ADCP data by the Pacific Marine Environmental Laboratory and the Ocean Acidification Research Center at the University of Alaska, Fairbanks.

Usage Guidelines

Given that this project contains experimental platforms and sensors, data will be released publicly only once the data quality can be verified. If public release is deemed appropriate, and is approved by each partner in this project, final post-processed data will be shared by the NOAA-NCEI NODC and OCADS programs for oceanographic and ocean carbon data. Public release and access will accordingly be arranged through NCEI's Geoportal.

Prior to free public release, experimental data may be shared on a case-by-case basis for research and QA/QC purposes. Data access can be requested through the managing PIs on this project. Contact information is provided in the initial section of this cruise report. Permission for publication of these data and associated results will also be assessed on a case-by-case basis. Images and text associated with this cruise report may be used for presentations or white papers with permission from the managing PI.