Cruise Report for R/V *Norseman II* 2022-01S, 2022-02S

Robert S. Pickart, Leah McRaven, Frank Bahr, Kali Horn, Evie Fachon, Dave Kulis, Miguel Goni, Dean Stockwell, Stephanie Lim, and Courtney Payne

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Section A: Introduction and General Description

R/V *Norseman II* carried out back-to-back cruises in summer 2022 associated with two collaborative projects funded by the National Science Foundation: (1) “Harmful Algal Blooms in the warming Chukchi Sea”, and (2) “A High-Resolution Multi-Tracer Biogeochemical Study of the Pacific Arctic”. The original plan was to have a single joint cruise, but this was not logistically possible because of the high demand for research vessels due to the COVID pandemic. As such, the first cruise focused predominantly on harmful algal blooms (HABs) with a smaller biogeochemical component, while the opposite was true for the second cruise. Both cruises were highly successful despite windier than normal conditions in the Chukchi and Bering Seas during summer 2022. This was in part due to the hard work and dedication of the ship’s crew who went above and beyond to facilitate effective and safe science operations.

Leg 1 took place from 19 July to 15 August 2022, departing from and returning to Nome, AK. Figure A-1 shows the station map for leg 1. Science operations began in the northern Bering Sea after a delay due to high winds. Sections were done to the east and west of St Lawrence Island, after which we progressed northward through Bering Strait all the way to Barrow Canyon. Extensive sampling was done in the Ledyard Bay region since previous measurements indicated the presence of a large cyst seedbed in this area. The original plan included some sections across the western Beaufort shelf and slope, but the presence of pack-ice immediately to the east of section BCO prohibited us from going any further east. After completing section BCO we steamed back south to the Ledyard Bay region in order to extend the coverage there, particularly for sediment measurements. However, the weather soon prohibited over-the-side operations. Therefore, we commenced with an underway survey which continued all the way to port. During leg 1 we occupied Distributed Biological Observatory (DBO) lines 1-5 (only the northern portion of DBO1 was done).

Leg 2 took place from 17 August to 6 September, departing from and returning to Nome, AK. Figure A-1 shows the station map for leg 2. Since this leg was shorter, it was decided not to do any sampling in the northern Bering Sea. At the same time, it was a priority to sample the northern Chukchi shelf since this was not done during leg 1. Therefore, we extended the DBO4 and DBO5 lines to the northwest all the way to the shelfbreak. The latter crossed over Hanna Shoal. Both extended lines have been occupied on previous cruises. Since leg 2 was later in the season, the pack ice had receded farther northward into the basin allowing us to complete two additional sections on the western Beaufort shelf/slope. On the way back south, we occupied a long section along the US/Russian border. This line has been done many times by the international community, but not at such high resolution (20 km spacing). We also re-occupied the DBO5, BSN, and Bering Strait lines (see Figure A-1).

Throughout both legs, the chief scientist worked with a community observer from Utqiaġvik to send out daily updates to community members, tribal offices, and members of the Alaska Eskimo Whaling Commission. Because of the high levels of *Alexandrium Catenella* measured during the two cruises, multiple risk advisories were issued for health organizations and members of coastal communities. An outreach program was carried out during leg 1 involving a PolarTREC teacher from the town of Brevig Mission, AK. This included a live event from the ship.

A detailed event log for leg 1 and leg 2 are included in Appendix A and B, respectively.

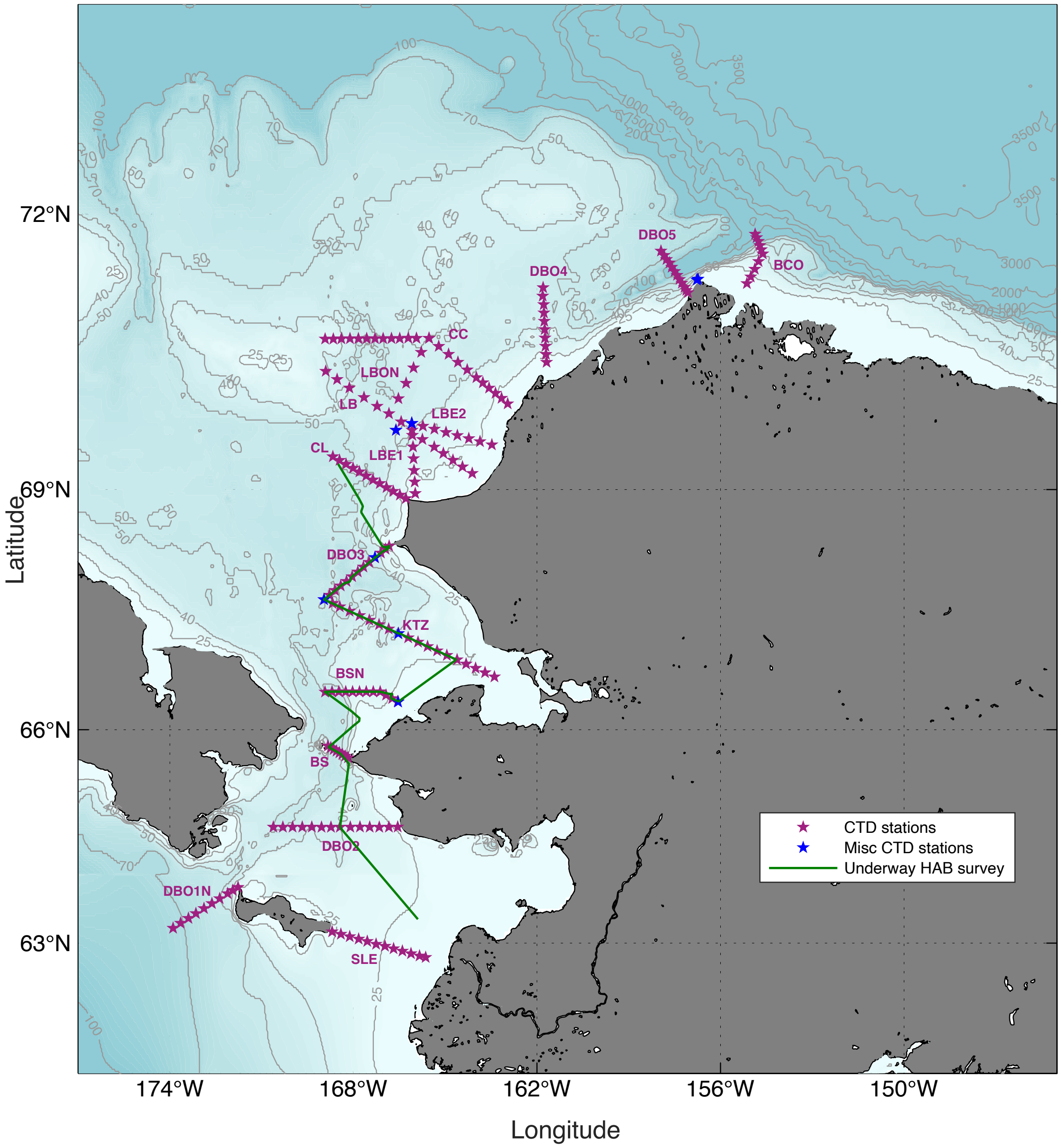

Figure A-1: CTD stations occupied during *Sikuliaq* cruise NRS2022-01S (stars; see legend). The solid green line denotes the underway survey at the end of leg 1.

Abbreviation	Transect Name
SLE	St Lawrence east
DBO1N	Distributed Biological Observatory 1 north
DBO2	Distributed Biological Observatory 2
BS	Bering Strait
BSN	Bering Strait north
KTZ	Kotzebue
DBO3	Distributed Biological Observatory 3
CL	Cape Lisburne

LBE1	Ledyard Bay east 1
LBE2	Ledyard Bay east 2
LB	Ledyard Bay
LBON	Ledyard Bay outer north
CC	Central Channel
DBO4	Distributed Biological Observatory 4
DBO5	Distributed Biological Observatory 5
BCO	Barrow Canyon outer

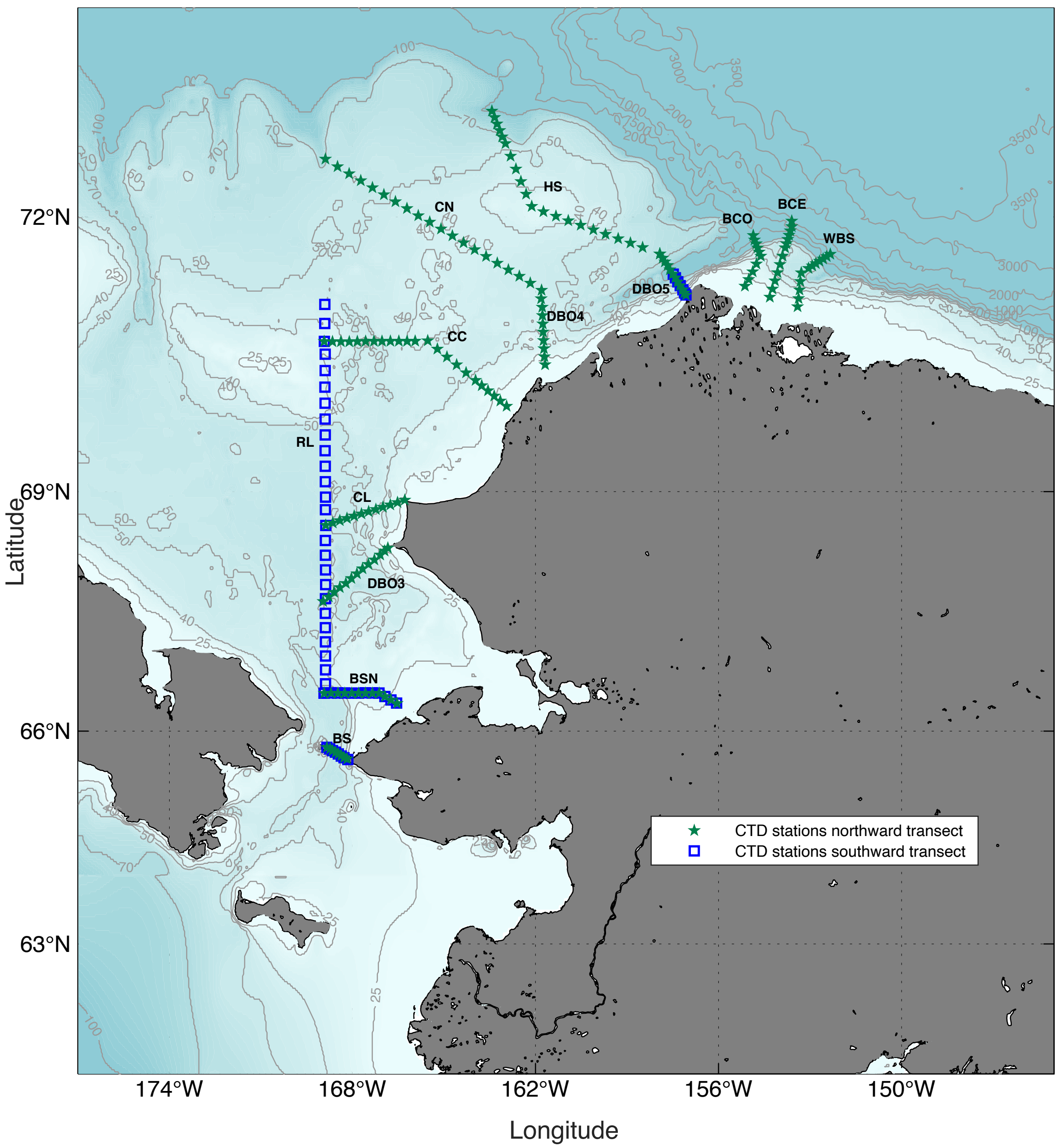

Figure A-2: CTD stations occupied during NRS2022-02S (stars and squares; see legend).

Abbreviation	Transect Name
BS	Bering Strait
BSN	Bering Strait north
DBO3	Distributed Biological Observatory 3
CL	Cape Lisburne
CC	Central Channel
DBO4	Distributed Biological Observatory 4
CN	Chukchi north
DBO5	Distributed Biological Observatory 5
HS	Hanna Shoal
BCO	Barrow Canyon outer
BCE	Barrow Canyon east
WBS	Western Beaufort Sea
RL	Russian line

Acknowledgements. We thank the captain and crew of the R/V *Norseman II*, whose hard work and dedication enabled us to carry out our science operations in a safe and productive environment. The ship's technician was extremely helpful in all facets of the science operations. We also thank S. Hameister for his extensive help during the cruise planning process.

Section B: Hydrographic and SADCP survey

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Hydrographic data collection

The fieldwork was comprised of two back-to-back cruises, Leg 1, and Leg 2, on the R/V *Norseman II* during the summer months of 2022. While the *Norseman II* operates regularly as a research vessel, it does not own/maintain/operate its own shipboard conductivity-temperature-depth (CTD) system. As such, M. Swartz from the Woods Hole Oceanographic Institution (WHOI) prepared and shipped a comprehensive CTD system to be used for both legs. This was comprised of a CTD rosette with 12 10-liter Niskin bottles, a Sea-Bird 911plus CTD and deck unit, SBE sensors (dual temperature and conductivity, dissolved oxygen, two types of fluorescence, beam transmission, photosynthetically active radiation, and altimeter), appropriate connectors, equipment for .322 termination, as well as a computer for data acquisition in the main lab.

The system was loaded onto the ship in Homer, AK, and installed in Nome, AK prior to departure for Leg 1. Once installed, the ship's GPS device was found to be incompatible with the installed CTD system, preventing time/position data from being logged by the Sea-Bird CTD system for the first 12 CTD stations. M. Swartz installed a WHOI-owned GPS device, which was compatible with the system. Beginning with station 13, the issue was resolved, and GPS values were properly recorded by the CTD system and saved within the station files. Hand-written GPS time/positions were recorded in sample logs for the first 12 stations and are available in Appendix A of the cruise report.

No additional problems with the CTD system were encountered. It performed extremely well, especially given no opportunity for a system shakedown. In total, 196 and 239 CTD stations were completed during Leg 1 and Leg 2, respectively. For each cast, water samples were collected at up to 24 discrete intervals.

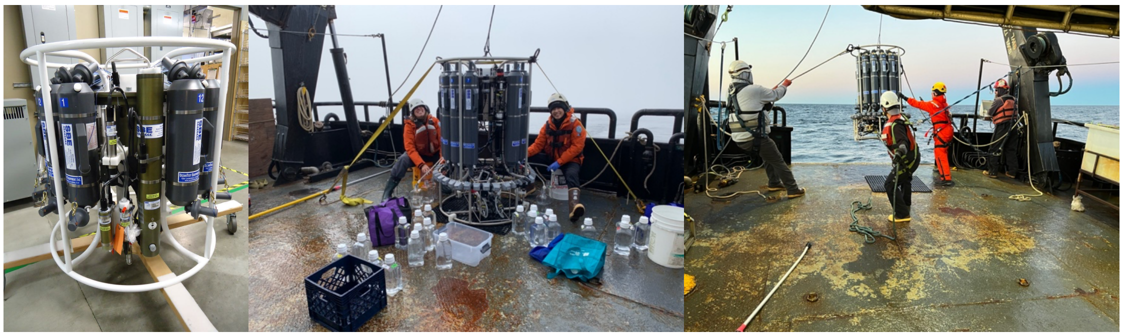

Figure B-1: Left: CTD rosette, Niskin, and sensor configuration (photo: M. Swartz); Middle: Secured CTD location for transits and Niskin sampling (photo: S. Lim); Right: CTD deployment off the ship's stern (photo: M. Goni)

SADCP data collection

Shipboard acoustic Doppler current profiler (ADCP) data were collected during both legs by the vessel's TRDI WH300 transducer. F. Bahr of WHOI visited the ship prior to the transit from Homer to Nome to setup the WH300. Using TRFI's VmDAS collection program, the ADCP was programmed to collect 65 vertical bins of 2m length in "broadband mode" (WB1) that were averaged in time over 5 minutes. During the transit, M. Goni sent test files back to shore to evaluate this configuration, which appeared to work fine.

Starting with the beginning of leg 1 in Nome, ADCP files (.LTA and .VMO) were sent back to WHOI regularly, typically after the completion of each section. They were processed ashore using the University of Hawaii's CODAS software and returned to the ship in Matlab data files as well as overview plots.

The raw ADCP data were generally clean but required a few ship-specific editing steps. It is not uncommon to occasionally encounter "data below the bottom" when the ADCP reports velocity estimates from below the bottom depth. Using backscatter as well as the unrealistic velocity signature, these instances were easily identified but required careful and somewhat tedious manual editing. Strong ship accelerations from turns or station arrival/departure often led to barotropic outlier profiles, presumably caused by heading issues. While this issue has been observed on other ships as well, its pattern was somewhat unusual here in that it appeared to relate to water depth, occurring more frequently in shallow water for reasons that are unclear. Another known issue referred to as underway bias, whereby noise etc. may lead to a velocity bias in the direction of the ship's travel, was only observed during a few occasions. It seemed to relate to weather conditions, as it typically does, indicated here by the timeseries of ship speed becoming more ragged. To enable this to be detected on long transits without stations, a few course changes ("zigzags") were added to these otherwise straight lines.

As a last step, estimates of barotropic tides obtained from the TPXO9 model version 3 were removed.

Section C: Harmful Algal Bloom survey

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Summary:

Recent events have shown that harmful algal blooms (HABs) are occurring in the Chukchi Sea, 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 in the Chukchi and Beaufort Seas. Observations from 2018 - 2022 documented the presence of a large cyst seedbed of the toxin-producing dinoflagellate *Alexandrium catenella* in the Chukchi Sea, with planktonic bloom-forming cells also observed in the region. In response to these observations, the dedicated HAB measurements on the *Norseman II* comprehensively assessed the distribution and dynamics of harmful algal species in the region. The HAB team collected sediment and water samples for detection of these harmful algal species, monitored underway phytoplankton imagery, sampled benthic invertebrate and phytoplankton communities for algal toxins, and collected core samples for underway incubations to assess germination activity of algal cells (Figure C-1).

During Leg 1, Lugol's-preserved water samples for enumeration of *A. catenella* were collected from the rosette (n=329) and underway seawater system (n=25), for a total of 354 samples. Water samples (n=300) collected from the Niskin bottles were filtered for community composition and domoic acid (DA) content of diatoms in the genus *Pseudo-nitzschia*. Additional water samples were collected from the underway seawater system. Net tows (20 uM mesh) were conducted at 33 stations to concentrate planktonic biomass from the upper 30m of the water column. Concentrated samples were preserved for microscopy, population genetics, and toxin analysis. An additional 19 concentrated toxin samples were collected from the underway seawater system (Table 1).

A Smith-McIntyre grab was deployed at 106 stations. Invertebrates from each grab were identified and frozen for toxin content analysis. At DBO3-12 (cast 194), over 100 clams were collected for an underway toxin depuration experiment, and several (n=5) were dissected and frozen for gut content analysis. Additionally, surface sediments from each grab were preserved for *Alexandrium* cyst enumeration. In order to assess patchiness of cyst distributions, and also to compare between grab and coring methodologies, replicate Smith-McIntyre, Van Veen, and multi-cores (n=5) were conducted at a single station (LBON-6, cast 190). The HAB team deployed a multicorer at 6 stations. At 5 of those stations cores were used for Plankton Emergence Trap Studies (PETs). In addition to the cores collected for PET experiments, replicate multi-cores from 5 sites (n=3) were sectioned to assess vertical *Alexandrium* cyst abundance. At each station, one multicore was saved as an archive core for Oregon State University (OSU). All sediment sampling operations during Leg 1 were supported by a technician from OSU's Marine Sediment Sampling (MARSSAM) group.

During Leg 2, operations and personnel for HAB sampling were significantly reduced. Despite this, over 200 water samples collected from the rosette were filtered for community composition and domoic acid (DA) content of diatoms in the genus *Pseudo-nitzschia* and 317 samples were Lugol's-preserved for enumeration of *A. catenella*. Net tows (20 uM mesh) were conducted to concentrate planktonic biomass at 9 stations and were preserved for microscopy and toxin analysis. Concentrated toxin samples were also collected from the underway seawater system (n=18). A Smith-McIntyre grab was deployed at 8 stations to collect invertebrates for toxin content analysis and surface sediments for *Alexandrium* cyst enumeration.

An Imaging FlowCytobot (IFCB) was configured to sample from the underway seawater system, collecting near-continuous imagery of phytoplankton during both legs. This instrument allowed the team to detect an exceptionally large bloom of *Alexandrium catenella* in the Bering Strait and Chukchi Sea which persisted throughout both legs of the cruise, renewing alarms about the implications of HABs for regional ecosystem and public health.

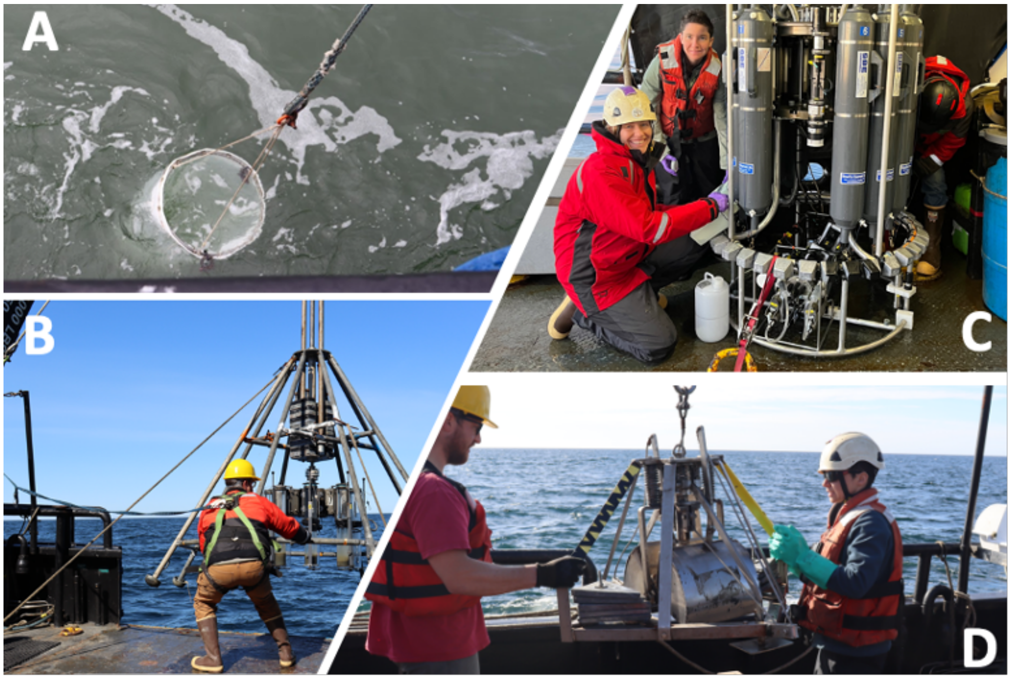

Figure C-1. Sampling operations aboard the R/V *Norseman II*. A) net tow B) MC-800 multi core C) CTD Rosette D) Smith-McIntyre grab

Table C-1: Summary of samples collected for HAB detection during the cruise.

Samples Collected	Leg 1	Leg 2	Total
Filtered water samples for *Alexandrium* enumeration	355	317	672
Pseudo-nitzschia DNA filters	301	202	503
Pseudo-nitzschia toxin filters	301	205	506
Surface sediments for *Alexandrium* cyst enumeration	113	22	135
Invertebrates	291	4	295
Net Tows	33	9	42
Underway concentrated toxin samples	19	18	37
Sectioned multicores for *Alexandrium* distribution	15	0	15

Sampling Methods:

1.1 *Surface Sediments for Cyst Enumeration:*

A Smith-McIntyre grab, provided by MARSSAM, was deployed off the A-frame at a subset of CTD stations (n=106). A sediment plug of the top 0-3 cm was extracted from the surface of each grab. The sediment was homogenized, any visible macrofauna and rocks were removed, and a 10 mL aliquot was stored in the dark at 4°C. Additional sediments were collected for use in laboratory physiology experiments.

1.2 *Invertebrate Collections:*

After sediment plugs were collected, the remainder of the grab was sieved, and any invertebrates (bivalves, worms, amphipods) present were identified, photographed and frozen. These specimens were sent to K. Lefebvre (NOAA/NWFSC, Seattle) for tissue analysis where they will be tested for domoic acid and saxitoxin. At DBO3-12 (cast 194), four additional grabs were deployed to collect ~100 live clams, *Macoma calcarea*, for a toxin depuration experiment conducted by graduate student E. Fachon (WHOI). Several clams (n=20) were frozen from this site for HPLC toxin analyses.

1.3 *Multicores for Vertical Cyst Abundance:*

Replicate multicores from 5 sites (n=3) were sectioned to assess vertical cyst abundance at previously identified cyst "hotspots". Each core was sectioned by 0-1 cm and then in two-centimeter intervals to the bottom of the core. From each section, the sediment was homogenized and a 10 mL aliquot was collected then stored in the dark at 4°C. These subsamples are being processed by the Anderson Lab (WHOI) resulting in a vertical profile of cyst abundance. Additional subsamples from these cores are being analyzed for stable isotopes, including Pb-210, Th-234, Pb-214 and Cs-137, to determine the age of the sediments where cysts were present.

1.4 *Multicores for PET studies:*

Replicate multicores (n=6) were collected for Plankton Emergence Trap (PET) studies from 5 sites. The objective of the PET studies is to assess the germination flux of *Alexandrium* cysts from the sediments into the water column. All PET incubations and sample processing took place in the van on the focsle deck. Cores from the first 2 sites were used to pilot the experimental set up, including tests for appropriate aeration of experimental chambers and water sampling intervals. After these tests, cores were collected from 3 additional sites. Each multicore was extruded to the sediment-water interface and subsampled. A section from 0-6 cm was removed using the PET incubation chamber and a 0-3 cm surface plug was taken to determine initial surface cyst density. Filtered seawater was added very slowly to each PET chamber so as not to disturb the surface sediment and then transferred to an incubator set to match the bottom water temperature (2-6˚C). After 24 h of incubation, the seawater was filtered through a 15µm mesh sieve and preserved in Lugol's Iodine solution for visual inspection for *A. catenella* cells that may have emerged from the sediments. The water was quickly replaced with fresh filtered seawater and allowed to incubate for another 24 h period. This sampling occurred for five days after the cores were initially collected.

1.5 *Sampling for Pseudo-nitzschia spp. and domoic acid detection:*

At a subset of CTD stations, water was collected from the rosette at depths selected to target different water masses and surface and chlorophyll maxima, and samples were filtered/frozen for analysis of *Pseudo-nitzschia* community structure and DA content. Additional water samples were collected from the underway seawater system during transits. From each depth, 250-500 mL of water was filtered through duplicate HV and GFF 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. Additionally, 2L from each depth was filtered through a 15µm mesh sieve and preserved in Lugol's Iodine solution for visual inspection of *Pseudo-nitzschia*. These samples were sent to the laboratory of K. Hubbard (Florida Fish and Wildlife Conservation Commission) for analysis via the ARISA method and electron microscopy.

1.6 *Imaging FlowCytobot:*
An Imaging FlowCytobot (IFCB) was configured to sample from the underway seawater system, collecting near-continuous imagery of phytoplankton from along the cruise track. This allowed for real-time bloom identification and reactive sampling. Data from the IFCB are available at: https://habon-ifcb.whoi.edu/timeline?dataset=arctic&bin=D20220713T202645_IFCB145

Outreach and Communication:

HAB Alerts
Prior to the cruise, a communication plan was established in collaboration with shore-based stakeholders (Alaska Harmful Algal Bloom Network, Alaska Sea Grant, Norton Sound Health Corporation) to address how communities would be notified of any potentially dangerous blooms were detected during the cruise. When high densities of Alexandrium cells (>1000 cells/L) were observed in the IFCB data, science party members summarized observations and produced an advisory, which included information about algal cell densities and bloom location, as well as general information about the impacts of algal toxins, steps to be taken to avoid sickness, and relevant public/ecological health contacts. These advisories were circulated through shore contacts for feedback before being distributed to local communities.

The first advisory was sent on 26 July in response to high densities of *Alexandrium* cells observed near St. Lawrence Island. A second advisory was sent on 11 August when high cell densities were observed in Kotzebue Sound. Additional notifications were sent out during Leg 2 in response to exceptionally high densities of *Alexandrium* in Bering Strait near coastal communities, and a final notification was distributed after the conclusion of the cruise on 13 September.

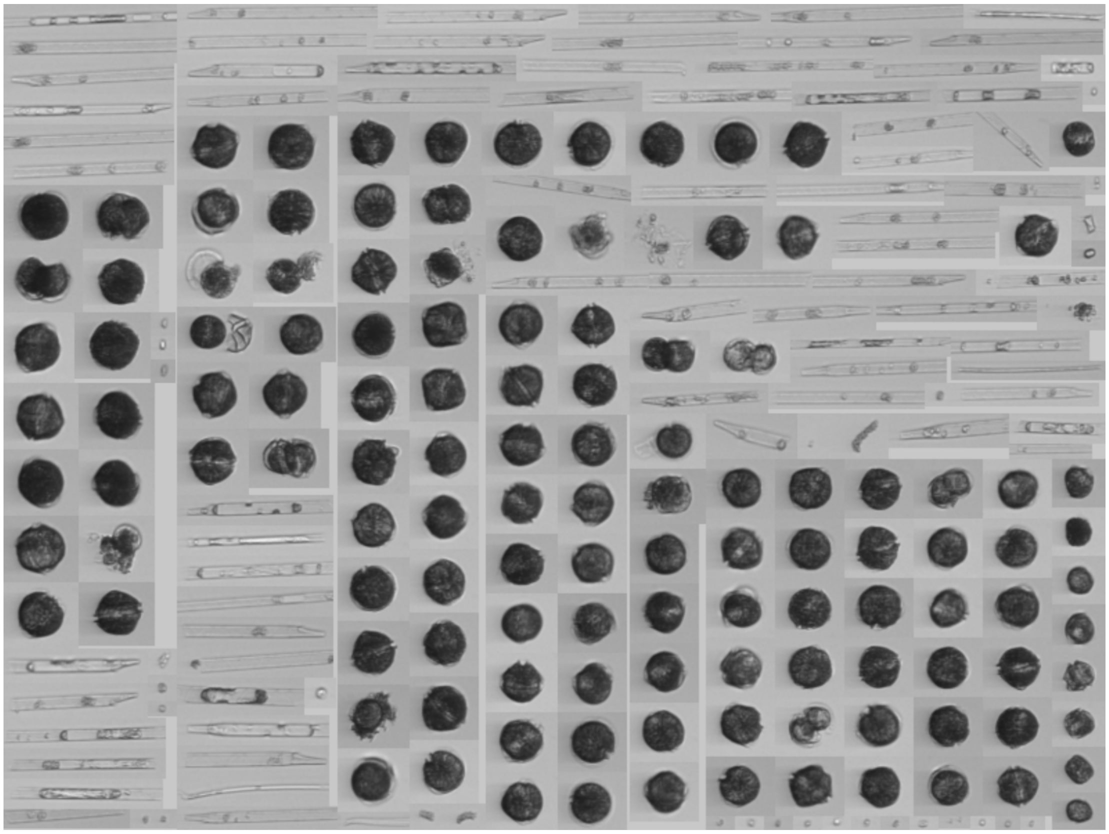

Figure C-2. IFCB dashboard displaying high densities of *Alexandrium* in Bering Strait (August 19 2022)

PolarTREC

Through the PolarTREC program, educator Rebecca Siegel (Brevig Mission School, Brevig Mission AK) joined the science party on Leg 1. Ms. Siegel participated in all aspects of sampling (sediment collection, core processing, water collection), hosted a live PolarConnect webinar from the ship (August 4th), and documented the activities of the cruise on the PolarTREC blog: https://www.polartrec.com/expeditions/harmful-algal-blooms-in-arctic-waters.

Discussion and Next Steps:

The several thousand physical samples that were collected during both cruises will take time to process, but their analysis is already well underway. Invertebrate samples are being analyzed by the laboratory of K. Lefebvre at NOAA Northwest Fisheries Science center, and *Pseudo-nitzschia* filters are being processed by K. Hubbard's team at the Florida Fish and Wildlife Conservation Commission. The Anderson HAB team based out of WHOI have processed many of the sediment and *Alexandrium* water samples. IFCB classifications are being annotated to check the accuracy of *Alexandrium* abundance estimates, and underway imagery is being compared with hybridized water samples to confirm species identity. Phytoplankton pellets are being processed for HPLC toxin analysis. An undergraduate student from Northeastern University has been recruited to assist in sample processing this winter, which will accelerate the timeline of these analyses.

Surface sediments are being used to create an updated cyst map (Fig C-3). This map shows that the cyst bed is similar in extent and coverage compared to prior years, but that cyst densities were somewhat lower, particularly at the epicenter of the cyst bed. Additional sediment samples were collected this fall aboard the R/V *Sikuliaq* and will be compared with the results from the summer cruises.

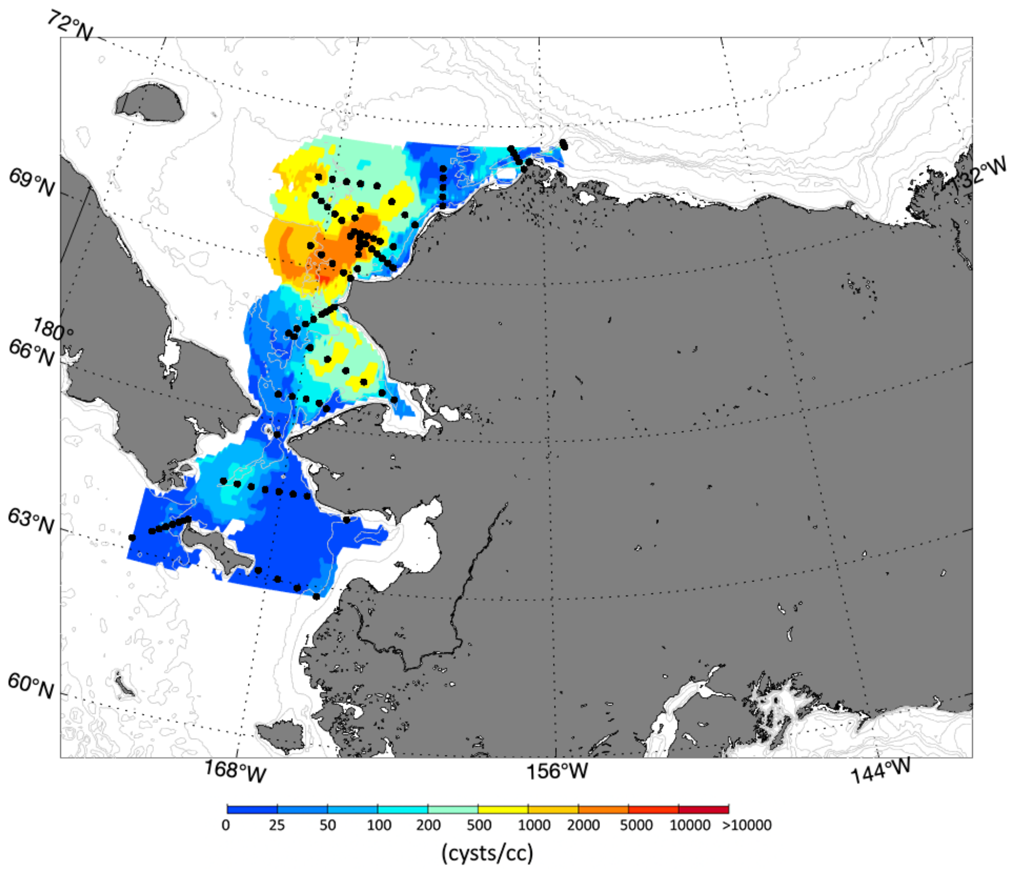

Figure C-3. Preliminary map of cyst abundances based on surface sediment cyst counts from Leg 1.

Section D: Biogeochemistry

Contributing authors: Miguel Goni (miguel.goni@oregonstate.edu), Dean Stockwell (dastockwell@alaska.edu)

Cruise Objectives

The Pacific Arctic region, including the northern Bering and Chukchi seas, is undergoing unprecedented and accelerated ecological change. As one of the main gateways into the Arctic Ocean, the Pacific Arctic is critical because the transformations that occur along its transport pathway set to a large extent the biogeochemistry of the Central Arctic. In order to address the fundamental knowledge gaps related to physical changes and their biogeochemical responses, our research seeks to simultaneously measure key biogeochemical tracers that give unique insights into ecosystem processes, including dissolved gases (O_2, Ar, and CO_2), particulate organic matter (POM), photosynthetic pigments, and dissolved nutrients.

Cruise Accomplishments

1) Surface Underway Measurements:

Ahead of the transit leg (NRS2022-01T) from Homer to Nome, our team installed a number of instruments that were connected to a surface underway science seawater system installed in the ship's lazeret with the help of the R/V *Norseman II's* crew. The surface underway installation included a four-position manifold that allowed surface underway water to be sampled manually, flow into an instrumented 'water wall' and directed into a small-volume reservoir from which additional automated sampling was possible. The water wall was instrumented with a de-bubbler, a programmable pre-filter system, a flow meter, and two optical instruments: a) a Wetlabs Epoch that measured chlorophyll fluorescence, backscatter, and CDOM; and b) a LISST system that measured particle concentrations and size. Furthermore, we also installed a mass spectrometer (EIMS) that sampled water from the small volume reservoir and continuously measured a range of dissolved gases, including nitrogen, oxygen, and argon. In addition, during leg 2 (NRS2022-02S) we had enough space in the main lab above the lazeret to install an automated nutrient analyzer that sampled surface underway water on a continuous basis. The auto-analyzer had some technical problems associated with damage during shipping, hence we only had limited coverage in nitrate analyses but were able to complete phosphate analyses throughout leg 2. Overall, the optical instruments and EIMS systems ran continuously during all three legs (NRS2022-01T, -01S and -02S), collecting over 2 months of surface underway data throughout the study period.

2) Surface Underway Sampling:

Using the surface underway manifold, the biogeochemical team from Oregon State University/University of Alaska Fairbanks/University of Hawaii (OSU/UAF/UH) collected a number of samples for different analyses, including particulate organic carbon and nitrogen (POC, PN; ~600 samples), chlorophyll pigments (Chl; ~ 50 samples for sensor calibration), and dissolved oxygen/argon and oxygen isotopic ratios (O_2/Ar and

$^{17}\Delta$ratios; ~ 60 samples). Analyses of these samples will be done back in the shore-based labs.

3) Water Column Sampling:

In close collaboration with WHOI's CTD team, we participated in the deployment and recovery of the CTD/Rosette system in over 420 stations during legs 1 and 2 (NRS2022-01S and 02S). In a subset (~200) of those stations, we collected and processed water samples from multiple depths to conduct a number of measurements including: a) dissolved nutrients (~600 samples), b) pigments, including Chl and phaeopigments (~600 samples) where a subset of these samples were fractionated by size (>20 µm, <20>5 µm and <5 µm), c) Fast Repetition Rate Fluorometry to evaluate phytoplankton nutritional status (~600 samples), d) POC and PN (~800 samples), and e) dissolved oxygen (~200 samples). Analyses of these samples will be done back in the shore-based labs.

Once analyzed, we expect we will be able to evaluate the surface and subsurface sample results in the context the shipboard ADCP and hydrography data collected by the WHOI team. By combining these datasets, we expect our multi-tracer approach to quantitatively discriminate different processes (e.g., advection, upwelling, and mixing) and their biogeochemical/ecological response (e.g., productivity, respiration, export, and shifts in community composition) in an unprecedented temporal and spatially-resolved manner.

4) Primary Productivity Incubations

During Leg 2, primary production estimates were made at 14 stations. These experiments evaluated the uptake of ^{13}C, $^{15}NO3$ and $^{15}NH4$. Samples were incubated on deck for approximately 6 hours in incubation bottles with screens approximating the light regime in which the samples were collected. Typically, 100%, 50%, 30%, 15%, 5% and 1% of surface PAR (photosynthetically active radiation) were used, depending on water column depth. A subset of these samples were fractionated by size (>20 µm, <20>5 µm and <5 µm).

5) Surface Sediment Sampling:

In collaboration with WHOI's HAB team, we were able to collect surface sediment samples from a number of locations (~150 grabs; ~10 multicores). These samples will be analyzed for basic biogeochemical measurements, including POC and PN, which will provide valuable data on the distribution of organic matter in surface sediments from the study area. We expect this information will be useful to the HAB team in evaluating sediment characteristics in regions sampled for HAB cysts.

6) Training and outreach

During NRS2022-02S, the OSU team included two graduate students and four undergraduate students who gained valuable experience in oceanographic techniques. Specifically, the four undergraduate students completed ship-based internships in field oceanography as part of OSU's Undergraduate Oceanography degree. One of the students also maintained a cruise blog that described on-board activities.

Section E: Organic Nitrogen

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Objective

The Organic Nitrogen team participated on leg 2 of the R/V *Norseman II* cruises. Our objective was to characterize dissolved organic nitrogen (DON) distributions in the Alaskan Arctic and measure DON uptake by phytoplankton. Of particular interest is whether DON enables summer blooms of the harmful algal bloom dinoflagellate Alexandrium in surface waters where dissolved inorganic nitrogen (DIN) is depleted.

DON distribution sampling

We collected water samples at 79 stations to measure the concentration of total dissolved nitrogen (TDN). These stations always corresponded with either a water station where other biogeochemical measurements were being taken or with one of our experiment stations, described below. In most cases, one sample was taken at the surface and a second at the depth of the subsurface chlorophyll maximum. Samples were often taken by the CTD watch standers (E. Launderville and C. Lee). The concentration of DON will be calculated as DON = TDN – DIN, where DIN = nitrate + nitrite + ammonium. We will largely rely on the DIN measurements from the biogeochemistry team (D. Stockwell) for this calculation, except for the stations where we collected DIN samples from the surface cast for our experiments. There are a few water stations (estimate <10) where we accidentally collected TDN samples but D. Stockwell was not collecting DIN, so we probably will not end up measuring these.

Nitrogen uptake experiments

We completed 13 experiments to measure the uptake rate of different nitrogen species by the phytoplankton community. Experiments were initiated once per day, within a few hours of estimated solar noon. As much as possible, we collected water for our experiments at a water station, in order to have the full biogeochemical and Alexandrium profiles to contextualize our results. Seawater was taken from the surface and used to fill clear 2-L plastic bottles. There were four different types of tracer treatments—15N nitrate, 15N ammonium, 13C15N urea, and 13C15N dissolved free amino acids—as well as a control treatment that was not spiked with any isotopes. We note that while our experiments were casually referred to as “prods” during the cruise, we actually did not conduct any 13C bicarbonate experiments. The 13C is used as a dual label in the organic N (urea and amino acids) experiments to understand N recycling. Experiments were incubated in an on-deck incubator with flow-through surface seawater and shaded to about 50% of ambient sunlight. Experiments were terminated after 14-19 hours.

Samples for the following measurements were taken from each experimental station: chlorophyll-a, phytoplankton community composition via FlowCam, DIN, DON, urea, and dissolved free amino acids. From each experimental treatment, we took particulate samples to calculate 15N uptake rates by the bulk community and to run on the NanoSIMS (nanoscale secondary ion mass spectrometry). The NanoSIMS measures the isotopic composition and distribution of individual cells and will allow for the determination of single-cell 15N uptake rates. In particular, we hope that this will illuminate *Alexandrium's* N preferences in comparison with that of other phytoplankton. Based on the IFCB images, we think that many of our experiments initiated in the southern Chukchi Sea had high numbers of *Alexandrium*, while those initiated in the northern Chukchi and Beaufort Seas had low numbers of *Alexandrium*.

Current status

All samples have been returned to Stanford University, where they will be analyzed or shipped off to other labs for analysis. We intended to measure the chlorophyll-a samples on ship, but within the first few days we determined that our fluorometer was broken. Thus, we instead froze and shipped the chlorophyll-a samples from all but our first few experiments. The resulting data will be used to understand the relationships between *Alexandrium* and other phytoplankton concentrations and the availability and uptake of various N species. The data will be made available to all collaborators on the cruise.

Appendix A

HABs 2022									
NRS2022-1s Event Log									
	CTD Number	Latitude	Longitude	Latitude		Longitude		Cor. Depth (m)	Station Operations
		Decimal (N)	Decimal (W)	Deg (N)	Min (N)	Deg (W)	Min (W)		
Test station									
7/22/22 2:47	n/a	64.3297	164.9800	64	19.78	164	58.80	26.2	Grab, Net
1: SLE									
7/23/22 16:35	001	62.7875	165.6445	62	47.25	165	38.67	14.9	Niskins
7/23/22 21:12	002	62.8097	165.8391	62	48.58	165	50.34	16.8	Niskins, Grab, *NMEA was not working, station location was manually logged
7/23/22 23:14	003	62.8437	166.1182	62	50.62	166	7.09	19.9	*NMEA was not working, station location was manually logged
7/24/22 0:32	004	62.8816	166.3990	62	52.89	166	23.94	22.4	*NMEA was not working, station location was manually logged
7/24/22 3:04	005	62.9174	166.6867	62	55.04	166	41.20	23.9	Niskins, Grab, Multi-core, *NMEA was not working, station location was manually logged
7/24/22 5:25	006	62.9548	166.9678	62	57.29	166	58.07	27.5	*NMEA was not working, station location was manually logged
7/24/22 6:46	007	62.9843	167.2588	62	59.06	167	15.53	36.4	*NMEA was not working, station location was manually logged
7/24/22 8:09	008	63.0261	167.5465	63	1.56	167	32.79	33.6	Niskins, Grab, Net, *NMEA was not working, station location was manually logged
7/24/22 10:06	009	63.0609	167.8294	63	3.66	167	49.76	23.3	*NMEA was not working, station location was manually logged
7/24/22 11:16	010	63.0967	168.1211	63	5.80	168	7.27	35.7	*NMEA was not working, station location was manually logged
7/24/22 12:30	011	63.1328	168.4098	63	7.97	168	24.59	48.9	Niskins, Grab, *NMEA was not working, station location was manually logged
7/24/22 14:07	012	63.1683	168.6959	63	10.10	168	41.76	23.6	*NMEA was not working, station location was manually logged
2: DBO1n									
7/26/22 12:33	013	63.2213	173.8947	63	13.28	173	53.68	75.2	Niskins, Grab
7/26/22 14:23	014	63.2948	173.6492	63	17.69	173	38.95	73.4	
7/26/22 15:52	015	63.366	173.3935	63	21.96	173	23.61	70.9	
7/26/22 17:13	016	63.4362	173.1485	63	26.17	173	8.91	67.8	Niskins, Grab, Net
7/26/22 19:07	017	63.51	172.8847	63	30.6	172	53.08	61.8	Niskins, Grab, Net
7/26/22 20:51	018	63.5823	172.6247	63	34.94	172	37.48	52.5	Niskins, Grab, Net, Multi-core
7/26/22 23:23	019	63.653	172.3733	63	39.18	172	22.4	52.5	Niskins, Grab, Net
7/27/22 1:16	020	63.7257	172.112	63	43.54	172	6.72	37.5	Grab, Net
7/27/22 2:29	021	63.7725	171.9417	63	46.35	171	56.5	31.5	Grab, Net
7/27/22 3:36	022	63.8167	171.7708	63	49	171	46.25	30.0	Niskins, Grab, Net
3: DBO2									
7/27/22 10:46	023	64.6727	170.6175	64	40.36	170	37.05	47.6	Niskins, Grab, Net
7/27/22 12:27	024	64.672	170.3057	64	40.32	170	18.34	48.3	
7/27/22 13:40	025	64.6727	169.9895	64	40.36	169	59.37	47.3	Niskins, Grab
7/27/22 15:13	026	64.6723	169.6717	64	40.34	169	40.3	46.0	

7/27/22 16:24	027	64.6727	169.3602	64	40.36	169	21.61	43.9	Niskins, Grab, Net
7/27/22 17:57	028	64.6708	169.0427	64	40.25	169	2.56	44.3	
7/27/22 19:09	029	64.6707	168.7342	64	40.24	168	44.05	43.5	Niskins, Grab
7/27/22 20:29	030	64.672	168.443	64	40.32	168	26.58	41.7	
7/27/22 21:48	031	64.6723	168.1022	64	40.34	168	6.13	35.9	Niskins, Grab, Net
7/27/22 23:19	032	64.6742	167.7865	64	40.45	167	47.19	34.8	
7/28/22 0:34	033	64.6723	167.4675	64	40.34	167	28.05	27.7	Niskins, Grab
7/28/22 1:57	034	64.6712	167.155	64	40.27	167	9.3	29.9	
7/28/22 3:14	035	64.6728	166.8405	64	40.37	166	50.43	25.1	Niskins, Grab, Net
7/28/22 4:54	036	64.6737	166.5523	64	40.42	166	33.14	15.4	
4: BS									
7/28/22 13:45	037	65.6257	168.1773	65	37.54	168	10.64	31.9	Niskins
7/28/22 14:18	038	65.6472	168.2682	65	38.83	168	16.09	44.5	
7/28/22 14:54	039	65.6703	168.3618	65	40.22	168	21.71	51.0	Niskins, Net
7/28/22 15:43	040	65.692	168.4577	65	41.52	168	27.46	52.8	
7/28/22 16:16	041	65.714	168.5527	65	42.84	168	33.16	52.0	
7/28/22 16:56	042	65.7368	168.646	65	44.21	168	38.76	50.8	Niskins, Net, Grab
7/28/22 17:55	043	65.7602	168.7388	65	45.61	168	44.33	52.5	
7/28/22 18:31	044	65.7828	168.8332	65	46.97	168	49.99	47.7	Niskins, Net
5: BSN									
7/28/22 23:56	045	66.4967	168.9275	66	29.8	168	55.65	55.9	Niskins, Grab, Net
7/29/22 1:21	046	66.5	168.699	66	30	168	41.94	52.3	
7/29/22 2:22	047	66.5005	168.4767	66	30.03	168	28.6	51.3	
7/29/22 3:21	048	66.5007	168.251	66	30.04	168	15.06	36.7	Niskins, Grab
7/29/22 4:24	049	66.4998	168.0272	66	29.99	168	1.63	24.4	
7/29/22 5:17	050	66.4998	167.8018	66	29.99	167	48.11	24.1	
7/29/22 6:06	051	66.5	167.5802	66	30	167	34.81	26.3	Niskins, Grab, Net
7/29/22 7:17	052	66.4995	167.3513	66	29.97	167	21.08	28.8	
7/29/22 8:16	053	66.4997	167.1245	66	29.98	167	7.47	29.7	
7/29/22 9:08	054	66.4558	166.9332	66	27.35	166	55.99	30.1	Niskins, Grab
7/29/22 10:16	055	66.4118	166.7335	66	24.71	166	44.01	21.1	
7/29/22 11:09	056	66.3718	166.5532	66	22.31	166	33.19	15.1	Niskins, Grab
6: KTZ									
7/29/22 21:41	057	66.6938	163.3903	66	41.63	163	23.42	21.4	Niskins, Grab, Net
7/29/22 23:11	058	66.7483	163.697	66	44.9	163	41.82	22.0	
7/30/22 0:20	059	66.805	164.0063	66	48.3	164	0.38	23.5	Niskins, Grab, Multi-core
7/30/22 2:23	060	66.8597	164.3165	66	51.58	164	18.99	24.4	
7/30/22 3:32	061	66.914	164.6113	66	54.84	164	36.68	26.2	
7/30/22 4:51	062	66.9705	164.946	66	58.23	164	56.76	26.0	Niskins, Grab
7/30/22 6:22	063	67.0278	165.2643	67	1.67	165	15.86	27.2	
7/30/22 7:36	064	67.0832	165.576	67	4.99	165	34.56	24.5	
7/30/22 8:54	065	67.139	165.8877	67	8.34	165	53.26	29.7	Niskins, Grab, Net
7/30/22 10:36	066	67.194	166.2098	67	11.64	166	12.59	37.3	
7/30/22 11:58	067	67.2487	166.5268	67	14.92	166	31.61	42.1	
7/30/22 13:34	068	67.3052	166.8473	67	18.31	166	50.84	43.6	Niskins, Grab
7/30/22 15:21	069	67.3605	167.162	67	21.63	167	9.72	44.0	
7/30/22 16:51	070	67.4165	167.4805	67	24.99	167	28.83	43.7	
7/30/22 18:57	071	67.4745	167.7993	67	28.47	167	47.96	44.7	Niskins, Grab
7/30/22 20:31	072	67.5283	168.126	67	31.7	168	7.56	46.2	
7/30/22 21:51	073	67.5838	168.4455	67	35.03	168	26.73	48.0	
7/30/22 22:52	074	67.6258	168.6822	67	37.55	168	40.93	49.1	Niskins, Grab, Net

7: DBO3									
7/31/22 0:38	075	67.6725	168.9618	67	40.35	168	57.71	49.6	Niskins, Grab
7/31/22 2:07	076	67.728	168.7792	67	43.68	168	46.75	49.5	
7/31/22 3:02	077	67.7877	168.6042	67	47.26	168	36.25	49.4	Niskins, Grab
7/31/22 4:30	078	67.8427	168.4147	67	50.56	168	24.88	51.6	
7/31/22 5:45	079	67.8988	168.2255	67	53.93	168	13.53	57.1	Niskins, Grab
7/31/22 7:15	080	67.9565	168.0407	67	57.39	168	2.44	58.5	
7/31/22 15:17	081	68.0143	167.8572	68	0.86	167	51.43	52.1	Niskins, Grab, Net
7/31/22 16:43	082	68.0748	167.6727	68	4.49	167	40.36	53.8	
7/31/22 17:47	083	68.1317	167.4883	68	7.9	167	29.3	49.0	Niskins, Grab
7/31/22 19:05	084	68.1863	167.2918	68	11.18	167	17.51	47.1	Niskins, Grab
7/31/22 20:24	085	68.2447	167.1013	68	14.68	167	6.08	42.1	Niskins, Grab, Net
7/31/22 21:39	086	68.2913	166.9498	68	17.48	166	56.99	33.6	Niskins, Grab
7/31/22 22:39	087	68.3278	166.8318	68	19.67	166	49.91	25.1	Niskins
8: CL									
8/1/22 8:39	088	69.3828	168.6723	69	22.97	168	40.34	51.1	Niskins, Grab, Net
8/1/22 10:01	089	69.3405	168.4542	69	20.43	168	27.25	50.6	
8/1/22 11:02	090	69.2957	168.2398	69	17.74	168	14.39	50.5	
8/1/22 12:05	091	69.2497	168.0117	69	14.98	168	0.7	50.2	Niskins, Grab
8/1/22 13:15	092	69.2075	167.8035	69	12.45	167	48.21	49.8	
8/1/22 14:14	093	69.1605	167.5815	69	9.63	167	34.89	50.6	
8/1/22 15:15	094	69.1138	167.3598	69	6.83	167	21.59	48.9	Niskins, Grab
8/1/22 16:28	095	69.0718	167.1377	69	4.31	167	8.26	47.5	
8/1/22 17:28	096	69.0248	166.9165	69	1.49	166	54.99	45.7	
8/1/22 18:26	097	68.98	166.6982	68	58.8	166	41.89	42.4	Niskins, Grab
8/1/22 19:35	098	68.936	166.4812	68	56.16	166	28.87	35.7	
8/1/22 20:30	099	68.895	166.2827	68	53.7	166	16.96	21.9	Niskins, Grab
9: LBE1									
8/1/22 22:11	100	68.9548	165.9793	68	57.29	165	58.76	16.4	Niskins
8/1/22 23:30	101	69.09	165.996	69	5.4	165	59.76	24.8	Grab
8/2/22 0:54	102	69.2237	166.0188	69	13.42	166	1.13	31.1	
8/2/22 2:13	103	69.36	166.0345	69	21.6	166	2.07	35.0	Niskins, Grab
8/2/22 3:43	104	69.4957	166.0523	69	29.74	166	3.14	38.3	Niskins, Grab, Multi-core
8/2/22 5:47	105	69.6273	166.0718	69	37.64	166	4.31	40.1	Niskins, Grab
8/2/22 7:12	106	69.7623	166.093	69	45.74	166	5.58	42.5	Niskins, Grab
9: LBE2									
8/2/22 8:45	107	69.731	165.7282	69	43.86	165	43.69	42.5	Grab
8/2/22 10:18	108	69.6977	165.3537	69	41.86	165	21.22	39.2	Grab
8/2/22 11:43	109	69.66	164.9733	69	39.6	164	58.4	36.6	Niskins, Grab
8/2/22 13:14	110	69.6252	164.6017	69	37.51	164	36.1	33.0	
8/2/22 14:24	111	69.5898	164.2277	69	35.39	164	13.66	28.3	Grab
8/2/22 15:52	112	69.555	163.862	69	33.3	163	51.72	22.3	
8/2/22 17:06	113	69.5188	163.4743	69	31.13	163	28.46	23.1	Niskins
10: LB									
8/2/22 20:20	114	69.1892	164.116	69	11.35	164	6.96	17.0	Grab
8/2/22 21:46	115	69.2652	164.435	69	15.91	164	26.1	23.0	Niskins, Grab, Net
8/2/22 23:14	116	69.3423	164.7462	69	20.54	164	44.77	26.9	Grab
8/3/22 0:38	117	69.4202	165.0603	69	25.21	165	3.62	30.9	Niskins, Grab
8/3/22 2:00	118	69.4933	165.3578	69	29.6	165	21.47	33.8	Grab
8/3/22 3:44	119	69.5803	165.7452	69	34.82	165	44.71	37.9	Niskins, Grab
8/3/22 5:49	120	69.7625	166.0928	69	45.75	166	5.57	42.6	Multi-core, Gravity Core

8/3/22 8:13	121	69.685	166.0827	69	41.1	166	4.96	41.1	Grab
8/3/22 9:50	122	69.7803	166.4392	69	46.82	166	26.35	45.0	Niskins, Grab
8/3/22 17:04	123	69.9555	167.2245	69	57.33	167	13.47	47.1	Niskins, Grab
8/3/22 19:09	124	70.0537	167.6537	70	3.22	167	39.22	48.6	Grab
8/3/22 21:09	125	70.1592	168.1317	70	9.55	168	7.9	46.2	Niskins, Grab
8/3/22 22:49	126	70.2537	168.533	70	15.22	168	31.98	42.4	Grab
8/4/22 0:24	127	70.344	168.9045	70	20.64	168	54.27	38.9	Niskins, Grab, Net
11: CC									
8/4/22 6:39	128	70.6953	168.925	70	41.72	168	55.5	32.2	Niskins, Grab, Net
8/5/22 4:09	129	70.6945	168.6573	70	41.67	168	39.44	34.4	
8/5/22 5:10	130	70.6973	168.394	70	41.84	168	23.64	40.2	
8/5/22 6:15	131	70.6993	168.112	70	41.96	168	6.72	42.8	Niskins, Grab
8/5/22 7:28	132	70.6988	167.837	70	41.93	167	50.22	48.9	
8/5/22 8:31	133	70.6997	167.5662	70	41.98	167	33.97	51.9	
8/5/22 9:32	134	70.6993	167.2937	70	41.96	167	17.62	52.7	Niskins, Grab, Multi-core
8/5/22 11:21	135	70.6993	167.0282	70	41.96	167	1.69	50.0	
8/5/22 12:26	136	70.7008	166.7558	70	42.05	166	45.35	46.8	
8/5/22 13:28	137	70.7007	166.4855	70	42.04	166	29.13	41.2	Niskins, Grab
8/5/22 14:40	138	70.7053	166.2055	70	42.32	166	12.33	40.8	
8/5/22 15:35	139	70.7032	165.9387	70	42.19	165	56.32	42.1	
8/5/22 16:55	140	70.703	165.5278	70	42.18	165	31.67	43.2	Niskins, Grab
8/5/22 18:21	141	70.6162	165.2112	70	36.97	165	12.67	42.8	
8/5/22 19:35	142	70.5298	164.889	70	31.79	164	53.34	44.5	
8/5/22 20:47	143	70.4428	164.5825	70	26.57	164	34.95	44.2	Niskins, Grab
8/5/22 22:14	144	70.359	164.2802	70	21.54	164	16.81	41.0	
8/5/22 23:36	145	70.2737	163.9787	70	16.42	163	58.72	36.5	
8/6/22 0:37	146	70.2172	163.768	70	13.03	163	46.08	32.6	Niskins, Grab
8/6/22 1:39	147	70.158	163.5665	70	9.48	163	33.99	27.4	
8/6/22 2:34	148	70.1003	163.3547	70	6.02	163	21.28	27.0	
8/6/22 3:25	149	70.0448	163.1568	70	2.69	163	9.41	21.1	Niskins, Grab
8/6/22 4:28	150	69.9825	162.9567	69	58.95	162	57.4	16.1	
12: DBO4									
8/6/22 12:19	151	70.4422	161.6862	70	26.53	161	41.17	20.1	Niskins, Grab
8/6/22 13:26	152	70.529	161.7055	70	31.74	161	42.33	25.9	
8/6/22 14:27	153	70.6175	161.7228	70	37.05	161	43.37	38.6	Niskins, Grab
8/6/22 15:51	154	70.7067	161.7375	70	42.4	161	44.25	41.1	
8/6/22 16:51	155	70.7977	161.7483	70	47.86	161	44.9	43.3	Niskins, Net, Grab
8/6/22 18:05	156	70.8865	161.7612	70	53.19	161	45.67	43.4	
8/6/22 19:00	157	70.9755	161.7722	70	58.53	161	46.33	44.8	Niskins, Grab
8/6/22 20:05	158	71.064	161.7802	71	3.84	161	46.81	44.4	
8/6/22 21:04	159	71.1543	161.8132	71	9.26	161	48.79	45.9	Niskins, Grab
8/6/22 22:15	160	71.243	161.7992	71	14.58	161	47.95	47.3	
13: DBO5									
8/7/22 7:43	161	71.6237	157.9462	71	37.42	157	56.77	60.9	Niskins
8/7/22 8:29	162	71.5793	157.8462	71	34.76	157	50.77	63.5	Niskins, Grab
8/7/22 9:24	163	71.537	157.7652	71	32.22	157	45.91	69.9	
8/7/22 10:06	164	71.5013	157.6677	71	30.08	157	40.06	82.4	Niskins, Grab
8/7/22 11:02	165	71.4567	157.5947	71	27.4	157	35.68	108.2	
8/7/22 11:48	166	71.4122	157.4997	71	24.73	157	29.98	123.6	Niskins, Grab, Net
8/7/22 12:57	167	71.3725	157.421	71	22.35	157	25.26	110.7	
8/7/22 13:38	168	71.3288	157.3408	71	19.73	157	20.45	90.7	Niskins, Grab

8/7/22 14:42	169	71.2905	157.2628	71	17.43	157	15.77	59.7	
8/7/22 15:20	170	71.2465	157.1757	71	14.79	157	10.54	47.4	Niskins, Grab
8/7/22 16:18	171	71.2143	157.119	71	12.86	157	7.14	37.7	
8/7/22 16:46	172	71.1908	157.0638	71	11.45	157	3.83	18.8	Niskins, Grab
Monitoring stations									
8/7/22 18:14	173	71.3227	156.7718	71	19.36	156	46.31	17.6	Niskins, Grab, Net
8/7/22 19:00	174	71.3328	156.737	71	19.97	156	44.22	17.5	Niskins, Grab, Net
14: BCO									
8/8/22 0:22	175	71.286	155.1383	71	17.16	155	8.3	15.1	Niskins, Grab
8/8/22 1:14	176	71.3552	155.0112	71	21.31	155	0.67	20.3	Grab
8/8/22 2:10	177	71.436	154.88	71	26.16	154	52.8	26.8	Niskins, Grab
8/8/22 3:10	178	71.516	154.7548	71	30.96	154	45.29	31.0	Grab, Multi-core
8/8/22 4:35	179	71.5948	154.6167	71	35.69	154	37	37.4	Niskins, Grab
8/8/22 5:14	180	71.6382	154.6655	71	38.29	154	39.93	48.6	Grab
8/8/22 5:57	181	71.6803	154.7158	71	40.82	154	42.95	61.5	Niskins, Grab
8/8/22 6:47	182	71.724	154.7597	71	43.44	154	45.58	115.5	
8/8/22 7:47	183	71.7618	154.8207	71	45.71	154	49.24	167.6	
8/8/22 8:37	184	71.7968	154.8688	71	47.81	154	52.13	246.8	Niskins
15: LBON									
8/9/22 14:45	185	70.7038	165.5277	70	42.23	165	31.66	42.9	Niskins
8/9/22 16:21	186	70.5512	165.7838	70	33.07	165	47.03	43.6	Grab
8/9/22 18:10	187	70.3812	166.0347	70	22.87	166	2.08	44.4	Niskins, Grab
8/9/22 20:07	188	70.2117	166.2768	70	12.7	166	16.61	45.5	Grab
8/9/22 22:07	189	70.0403	166.5288	70	2.42	166	31.73	45.7	Niskins, Grab
8/10/22 0:10	190	69.8722	166.8383	69	52.33	166	50.3	45.9	Niskins, Grab, Multi-core
16: LBOS									
8/10/22 4:59	191	69.7628	166.092	69	45.77	166	5.52	42.4	Niskins
8/10/22 6:52	192	69.6852	166.6103	69	41.11	166	36.62	45.5	Grab
Zigzag stations									
8/11/22 5:06	193	68.1905	167.2968	68	11.43	167	17.81	47.2	Niskins, Net, Grab
8/11/22 12:05	194	67.6732	168.9612	67	40.39	168	57.67	49.8	Niskins, Net, Grab
8/11/22 20:37	195	67.2467	166.5372	67	14.8	166	32.23	41.8	Niskins, Net, Grab
8/12/22 10:42	196	66.3672	166.5382	66	22.03	166	32.29	15.1	Niskins, Grab

Appendix B

HABs 2022									
NRS2022-2s Event Log									
	CTD Number	Latitude	Longitude	Latitude		Longitude		Cor. Depth (m)	Station Operations
		Decimal (N)	Decimal (W)	Deg (N)	Min (N)	Deg (W)	Min (W)		
Pre									
8/17/22 21:15	001	64.4285	165.285	64	25.71	165	17.1	21.2	Niskins
8/17/22 22:53	002	64.4283	165.2782	64	25.7	165	16.69	21.4	Niskins
1: BS									
8/18/22 22:26	003	65.6228	168.1758	65	37.37	168	10.55	33.0	Niskins
8/18/22 23:17	004	65.6467	168.2703	65	38.8	168	16.22	46.0	
8/19/22 13:55	005	65.6262	168.1762	65	37.57	168	10.57	33.0	Niskins
8/19/22 14:27	006	65.6452	168.2715	65	38.71	168	16.29	46.0	
8/19/22 15:01	007	65.6718	168.3677	65	40.31	168	22.06	53.0	
8/19/22 15:34	008	65.6935	168.4605	65	41.61	168	27.63	55.0	Niskins, Net
8/19/22 16:35	009	65.715	168.5503	65	42.9	168	33.02	53.0	
8/19/22 17:08	010	65.7393	168.651	65	44.36	168	39.06	52.0	Niskins
8/19/22 17:45	011	65.7638	168.7325	65	45.83	168	43.95	53.0	
8/19/22 18:31	012	65.7832	168.836	65	46.99	168	50.16	48.0	Niskins
2: BSN									
8/20/22 0:40	013	66.5003	168.9263	66	30.02	168	55.58	57.0	Niskins, Net
8/20/22 1:50	014	66.5017	168.7008	66	30.1	168	42.05	53.0	
8/20/22 2:48	015	66.501	168.4743	66	30.06	168	28.46	53.1	Niskins
8/20/22 3:54	016	66.4997	168.2503	66	29.98	168	15.02	37.8	
8/20/22 4:50	017	66.4998	168.0217	66	29.99	168	1.3	25.3	
8/20/22 5:46	018	66.499	167.7975	66	29.94	167	47.85	24.8	Niskins
8/20/22 6:40	019	66.4998	167.5758	66	29.99	167	34.55	27.0	
8/20/22 7:33	020	66.4997	167.3457	66	29.98	167	20.74	29.4	
8/20/22 8:26	021	66.5002	167.123	66	30.01	167	7.38	30.1	Niskins
8/20/22 9:19	022	66.4565	166.9322	66	27.39	166	55.93	30.5	
8/20/22 10:10	023	66.4125	166.7382	66	24.75	166	44.29	21.8	
8/20/22 11:01	024	66.3673	166.5375	66	22.04	166	32.25	15.2	Niskins
Retermination test									
8/22/22 21:20	600	68.3183	166.8372	68	19.1	166	50.23	28.0	
3: DBO3									
8/22/22 21:56	025	68.328	166.8392	68	19.68	166	50.35	26.0	Niskins
8/22/22 22:46	026	68.292	166.9455	68	17.52	166	56.73	35.0	
8/22/22 23:35	027	68.2438	167.0902	68	14.63	167	5.41	42.0	Niskins
8/23/22 0:09	527	68.2427	167.1023	68	14.56	167	6.14	42.0	Niskins
8/23/22 1:13	028	68.1838	167.281	68	11.03	167	16.86	48.0	Niskins
8/23/22 2:18	029	68.1293	167.477	68	7.76	167	28.62	50.4	
8/23/22 5:36	030	68.0757	167.67	68	4.54	167	40.2	54.0	
8/23/22 6:45	031	68.015	167.8533	68	0.9	167	51.2	53.8	
8/23/22 7:50	032	67.9565	168.0352	67	57.39	168	2.11	59.6	Niskins
8/23/22 9:03	033	67.8955	168.2158	67	53.73	168	12.95	58.7	
8/23/22 10:14	034	67.8443	168.4147	67	50.66	168	24.88	53.1	Niskins
8/23/22 11:32	035	67.7862	168.5995	67	47.17	168	35.97	50.9	

8/23/22 12:40	036	67.7285	168.7735	67	43.71	168	46.41	50.7	
8/23/22 13:45	037	67.6718	168.962	67	40.31	168	57.72	51.0	Niskins, Grab, Net
4: CL									
8/23/22 21:27	038	68.602	168.8757	68	36.12	168	52.54	53.0	
8/23/22 22:27	039	68.6293	168.6443	68	37.76	168	38.66	53.0	
8/23/22 23:19	040	68.6573	168.4132	68	39.44	168	24.79	52.0	
8/24/22 0:15	041	68.684	168.1795	68	41.04	168	10.77	52.0	Niskins
8/24/22 0:48	541	68.6853	168.1828	68	41.12	168	10.97	52.0	Niskins
8/24/22 1:43	042	68.7112	167.9418	68	42.67	167	56.51	51.0	
8/24/22 2:38	043	68.7373	167.7043	68	44.24	167	42.26	51.2	
8/24/22 3:32	044	68.7638	167.4692	68	45.83	167	28.15	48.0	Niskins
8/24/22 4:29	045	68.7902	167.2323	68	47.41	167	13.94	44.2	
8/24/22 5:22	046	68.817	166.9997	68	49.02	166	59.98	42.5	
8/24/22 6:19	047	68.8443	166.7585	68	50.66	166	45.51	43.8	Niskins
8/24/22 7:13	048	68.8722	166.523	68	52.33	166	31.38	36.9	
8/24/22 8:06	049	68.9003	166.2838	68	54.02	166	17.03	24.5	Niskins
5: CC									
8/24/22 23:19	050	70.6955	168.9252	70	41.73	168	55.51	34.0	Niskins
8/24/22 23:51	550	70.6958	168.927	70	41.75	168	55.62	34.0	Niskins
8/25/22 0:43	051	70.6927	168.6538	70	41.56	168	39.23	35.0	
8/25/22 1:34	052	70.6927	168.3778	70	41.56	168	22.67	41.0	
8/25/22 2:23	053	70.6918	168.1032	70	41.51	168	6.19	44.5	Niskins
8/25/22 3:14	054	70.6948	167.8403	70	41.69	167	50.42	50.3	
8/25/22 4:02	055	70.6965	167.568	70	41.79	167	34.08	53.4	
8/25/22 4:53	056	70.697	167.2952	70	41.82	167	17.71	54.5	Niskins
8/25/22 5:46	057	70.6972	167.031	70	41.83	167	1.86	51.5	
8/25/22 6:37	058	70.6977	166.7557	70	41.86	166	45.34	47.8	
8/25/22 7:27	059	70.6983	166.4787	70	41.9	166	28.72	42.0	Niskins
8/25/22 8:23	060	70.6973	166.2092	70	41.84	166	12.55	42.0	
8/25/22 9:15	061	70.699	165.9443	70	41.94	165	56.66	43.0	
8/25/22 10:29	062	70.7027	165.5318	70	42.16	165	31.91	44.0	Niskins
8/25/22 11:50	063	70.6127	165.2165	70	36.76	165	12.99	44.2	
8/25/22 13:05	064	70.5265	164.9018	70	31.59	164	54.11	45.5	
8/25/22 14:18	065	70.4408	164.5837	70	26.45	164	35.02	45.0	Niskins
8/25/22 15:32	066	70.3532	164.2755	70	21.19	164	16.53	42.0	
8/25/22 16:45	067	70.2695	163.9645	70	16.17	163	57.87	37.0	
8/25/22 17:36	068	70.2105	163.7625	70	12.63	163	45.75	33.0	Niskins
8/25/22 18:26	069	70.1543	163.5558	70	9.26	163	33.35	28.0	
8/25/22 19:15	070	70.0953	163.353	70	5.72	163	21.18	27.0	Niskins
8/25/22 20:04	071	70.0395	163.1523	70	2.37	163	9.14	21.0	
8/25/22 20:53	072	69.981	162.9465	69	58.86	162	56.79	16.0	Niskins
8/25/22 21:15	572	69.9832	162.949	69	58.99	162	56.94	17.0	Niskins
8/25/22 21:42	672	69.9825	162.9523	69	58.95	162	57.14	17.0	Niskins
6: DBO4									
8/26/22 4:42	073	70.4418	161.685	70	26.51	161	41.1	21.3	Niskins
8/26/22 5:40	074	70.5288	161.7065	70	31.73	161	42.39	26.7	
8/26/22 6:30	075	70.617	161.723	70	37.02	161	43.38	40.0	
8/26/22 7:20	076	70.7055	161.738	70	42.33	161	44.28	42.3	Niskins
8/26/22 8:24	077	70.797	161.7493	70	47.82	161	44.96	45.0	
8/26/22 9:17	078	70.8847	161.7608	70	53.08	161	45.65	44.8	
8/26/22 10:11	079	70.9745	161.773	70	58.47	161	46.38	46.5	Niskins

8/26/22 11:14	080	71.063	161.7792	71	3.78	161	46.75	46.0	
8/26/22 12:10	081	71.1533	161.8152	71	9.2	161	48.91	48.0	
8/26/22 13:01	082	71.2427	161.8007	71	14.56	161	48.04	49.0	Niskins
7: CN									
8/26/22 14:17	083	71.3175	162.1708	71	19.05	162	10.25	46.0	
8/26/22 15:34	084	71.3897	162.5285	71	23.38	162	31.71	48.0	
8/26/22 16:42	085	71.456	162.8878	71	27.36	162	53.27	45.0	
8/26/22 17:52	086	71.5257	163.252	71	31.54	163	15.12	44.0	Niskins
8/26/22 19:13	087	71.5965	163.619	71	35.79	163	37.14	44.0	
8/26/22 20:27	088	71.6662	163.993	71	39.97	163	59.58	41.0	
8/26/22 21:39	089	71.7367	164.357	71	44.2	164	21.42	38.0	Niskins
8/26/22 22:17	589	71.7342	164.362	71	44.05	164	21.72	38.0	Niskins
8/26/22 23:30	090	71.808	164.7243	71	48.48	164	43.46	41.0	
8/27/22 0:42	091	71.8777	165.0967	71	52.66	165	5.8	42.0	
8/27/22 1:55	092	71.9477	165.466	71	56.86	165	27.96	43.0	Niskins
8/27/22 3:15	093	72.0127	165.8418	72	0.76	165	50.51	46.5	
8/27/22 4:31	094	72.0852	166.213	72	5.11	166	12.78	48.0	
8/27/22 5:48	095	72.1538	166.5913	72	9.23	166	35.48	48.8	Niskins
8/27/22 7:07	096	72.224	166.9688	72	13.44	166	58.13	49.3	
8/27/22 8:27	097	72.294	167.3437	72	17.64	167	20.62	50.0	
8/27/22 9:51	098	72.3638	167.7273	72	21.83	167	43.64	52.0	Niskins
8/27/22 11:12	099	72.4327	168.1083	72	25.96	168	6.5	54.5	
8/27/22 12:26	100	72.5025	168.4895	72	30.15	168	29.37	55.6	
8/27/22 13:46	101	72.5772	168.8857	72	34.63	168	53.14	64.0	Niskins
8/27/22 14:24	701	72.5763	168.8743	72	34.58	168	52.46	64.0	Niskins
8: HS									
8/28/22 1:03	801	72.9457	164.5192	72	56.74	164	31.15	69.0	Niskins
8/28/22 3:53	102	73.0422	163.4292	73	2.53	163	25.75	106.0	Niskins
8/28/22 4:41	103	72.981	163.341	72	58.86	163	20.46	85.0	
8/28/22 5:19	104	72.9188	163.2618	72	55.13	163	15.71	77.0	
8/28/22 5:57	105	72.8553	163.1723	72	51.32	163	10.34	74.0	Niskins
8/28/22 6:38	106	72.7937	163.0928	72	47.62	163	5.57	69.0	
8/28/22 7:17	107	72.7288	162.9842	72	43.73	162	59.05	57.8	
8/28/22 8:22	108	72.6057	162.8158	72	36.34	162	48.95	42.5	Niskins
8/28/22 9:29	109	72.479	162.6405	72	28.74	162	38.43	42.4	
8/28/22 10:33	110	72.3552	162.4777	72	21.31	162	28.66	40.9	
8/28/22 11:40	111	72.2298	162.3068	72	13.79	162	18.41	37.2	Niskins
8/28/22 12:54	112	72.107	162.1232	72	6.42	162	7.39	28.3	
8/28/22 13:57	113	72.0535	161.7403	72	3.21	161	44.42	30.8	Niskins
8/28/22 15:06	114	72.008	161.329	72	0.48	161	19.74	34.0	
8/28/22 16:19	115	71.9618	160.9247	71	57.71	160	55.48	38.0	
8/28/22 17:31	116	71.9165	160.5173	71	54.99	160	31.04	42.0	Niskins
8/28/22 18:45	117	71.87	160.1032	71	52.2	160	6.19	45.0	
8/28/22 19:54	118	71.8243	159.704	71	49.46	159	42.24	51.0	
8/28/22 21:06	119	71.7785	159.2887	71	46.71	159	17.32	53.0	Niskins
8/28/22 22:20	120	71.734	158.8878	71	44.04	158	53.27	54.0	
8/28/22 23:30	121	71.688	158.4888	71	41.28	158	29.33	56.0	Niskins
8/29/22 0:15	821	71.688	158.4825	71	41.28	158	28.95	56.0	Niskins
9: DBO5									
8/29/22 3:05	122	71.6218	157.9245	71	37.31	157	55.47	63.6	Niskins
8/29/22 3:52	123	71.5782	157.8328	71	34.69	157	49.97	65.7	Niskins

8/29/22 4:33	124	71.5393	157.7587	71	32.36	157	45.52	72.7	Niskins
8/29/22 5:18	125	71.5023	157.667	71	30.14	157	40.02	85.5	
8/29/22 6:05	126	71.457	157.5955	71	27.42	157	35.73	111.0	Niskins
8/29/22 6:55	127	71.4118	157.5	71	24.71	157	30	128.0	Niskins, Net
8/29/22 8:13	128	71.373	157.4145	71	22.38	157	24.87	116.0	Niskins
8/29/22 9:34	129	71.3288	157.3387	71	19.73	157	20.32	94.0	
8/29/22 10:26	130	71.2903	157.265	71	17.42	157	15.9	61.7	Niskins
8/29/22 11:11	131	71.247	157.1755	71	14.82	157	10.53	49.9	
8/29/22 11:49	132	71.2145	157.1215	71	12.87	157	7.29	39.8	
8/29/22 12:28	133	71.1917	157.067	71	11.5	157	4.02	21.5	Niskins
10: BCO									
8/29/22 22:33	134	71.8115	154.8617	71	48.69	154	51.7	276.0	Niskins
8/29/22 23:48	834	71.8115	154.864	71	48.69	154	51.84	276.0	Niskins
8/30/22 0:37	135	71.765	154.8218	71	45.9	154	49.31	176.0	
8/30/22 1:15	136	71.7265	154.7627	71	43.59	154	45.76	120.0	
8/30/22 1:46	137	71.6838	154.7203	71	41.03	154	43.22	65.0	Niskins
8/30/22 2:21	138	71.6413	154.6667	71	38.48	154	40	50.8	
8/30/22 2:51	139	71.599	154.6145	71	35.94	154	36.87	39.5	
8/30/22 3:41	140	71.5177	154.7568	71	31.06	154	45.41	32.5	Niskins
8/30/22 4:30	141	71.4365	154.8798	71	26.19	154	52.79	26.4	
8/30/22 5:18	142	71.3557	155.0112	71	21.34	155	0.67	21.2	
8/30/22 6:01	143	71.2862	155.1353	71	17.17	155	8.12	15.7	Niskins
11: BGC									
8/30/22 8:43	144	71.1698	154.3193	71	10.19	154	19.16	18.1	Niskins
8/30/22 9:32	145	71.2555	154.2313	71	15.33	154	13.88	22.6	
8/30/22 10:20	146	71.3415	154.1505	71	20.49	154	9.03	32.5	Niskins
8/30/22 11:08	147	71.4275	154.0655	71	25.65	154	3.93	41.2	
8/30/22 11:57	148	71.5123	153.984	71	30.74	153	59.04	49.0	Niskins, Grab
8/30/22 13:20	149	71.5997	153.9013	71	35.98	153	54.08	48.0	
8/30/22 14:11	150	71.6855	153.8173	71	41.13	153	49.04	50.0	Niskins, Grab, Net
8/30/22 15:09	151	71.7273	153.7772	71	43.64	153	46.63	62.0	
8/30/22 15:57	152	71.7715	153.731	71	46.29	153	43.86	113.0	Niskins, Grab
8/30/22 16:58	153	71.814	153.69	71	48.84	153	41.4	163.0	
8/30/22 17:34	154	71.859	153.6488	71	51.54	153	38.93	218.0	Niskins
8/30/22 18:29	854	71.8568	153.6515	71	51.41	153	39.09	218.0	Niskins
8/30/22 19:43	155	71.9022	153.6002	71	54.13	153	36.01	307.0	
8/30/22 20:39	156	71.9442	153.57	71	56.65	153	34.2	1025.0	
8/30/22 23:13	856	71.9585	153.6	71	57.51	153	36	1000.0	Niskins
12: WBS									
8/31/22 3:43	157	71.619	152.3358	71	37.14	152	20.15	323.0	Niskins
8/31/22 4:37	158	71.595	152.4538	71	35.7	152	27.23	181.0	
8/31/22 5:12	159	71.5692	152.571	71	34.15	152	34.26	133.0	
8/31/22 5:43	160	71.5463	152.6897	71	32.78	152	41.38	95.1	Niskins
8/31/22 6:20	161	71.5215	152.8105	71	31.29	152	48.63	66.7	
8/31/22 6:49	162	71.4972	152.9267	71	29.83	152	55.6	59.6	Niskins
8/31/22 7:23	163	71.4718	153.0508	71	28.31	153	3.05	62.3	
8/31/22 8:11	164	71.4258	153.2868	71	25.55	153	17.21	59.0	Niskins, Grab, Net
8/31/22 9:31	165	71.3352	153.317	71	20.11	153	19.02	58.0	
8/31/22 10:22	166	71.2458	153.3465	71	14.75	153	20.79	39.1	Niskins
8/31/22 11:15	167	71.155	153.3753	71	9.3	153	22.52	26.0	
8/31/22 12:05	168	71.0685	153.4103	71	4.11	153	24.62	17.4	Niskins

13: partial DBO5									
8/31/22 23:13	169	71.1925	157.0683	71	11.55	157	4.1	23.0	
8/31/22 23:35	170	71.2138	157.1125	71	12.83	157	6.75	38.0	
9/1/22 0:01	171	71.2465	157.1677	71	14.79	157	10.06	48.0	
9/1/22 0:33	172	71.2903	157.2553	71	17.42	157	15.32	60.0	
9/1/22 1:05	173	71.331	157.334	71	19.86	157	20.04	93.0	
9/1/22 1:37	174	71.373	157.4135	71	22.38	157	24.81	116.0	
9/1/22 2:17	175	71.4108	157.4837	71	24.65	157	29.02	129.0	
14: RL									
9/2/22 17:37	176	71.0922	168.905	71	5.53	168	54.3	47.0	Niskins
9/2/22 19:20	177	70.8885	168.9073	70	53.31	168	54.44	40.0	
9/2/22 20:58	178	70.6953	168.9197	70	41.72	168	55.18	33.0	Niskins
9/2/22 21:25	878	70.6992	168.9192	70	41.95	168	55.15	33.0	Niskins
9/2/22 22:42	179	70.5565	168.8925	70	33.39	168	53.55	38.0	
9/3/22 0:13	180	70.3768	168.8943	70	22.61	168	53.66	39.0	
9/3/22 1:42	181	70.195	168.894	70	11.7	168	53.64	39.0	Niskins
9/3/22 2:17	881	70.1935	168.9023	70	11.61	168	54.14	39.0	Niskins
9/3/22 3:49	182	70.0142	168.897	70	0.85	168	53.82	38.0	
9/3/22 5:19	183	69.8357	168.8953	69	50.14	168	53.72	46.8	
9/3/22 6:49	184	69.6558	168.8912	69	39.35	168	53.47	53.1	Niskins, Grab, Net
9/3/22 8:57	185	69.4752	168.896	69	28.51	168	53.76	52.5	
9/3/22 10:31	186	69.2957	168.8912	69	17.74	168	53.47	52.5	
9/3/22 12:05	187	69.1158	168.8882	69	6.95	168	53.29	53.8	Niskins, Grab, Net
9/3/22 14:12	188	68.935	168.8818	68	56.1	168	52.91	54.0	
9/3/22 15:36	189	68.7865	168.885	68	47.19	168	53.1	54.0	
9/3/22 17:26	190	68.5988	168.8738	68	35.93	168	52.43	54.0	Niskins
9/3/22 17:52	890	68.5987	168.8763	68	35.92	168	52.58	54.0	Niskins
9/3/22 19:38	191	68.4183	168.8868	68	25.1	168	53.21	58.0	
9/3/22 21:17	192	68.24	168.8855	68	14.4	168	53.13	57.0	
9/3/22 22:50	193	68.0607	168.8818	68	3.64	168	52.91	59.0	Niskins
9/3/22 23:12	893	68.0585	168.883	68	3.51	168	52.98	59.0	Niskins
9/4/22 0:42	194	67.88	168.8782	67	52.8	168	52.69	53.0	
9/4/22 2:09	195	67.7058	168.8847	67	42.35	168	53.08	51.0	
9/4/22 3:39	196	67.5228	168.8883	67	31.37	168	53.3	51.0	Niskins
9/4/22 5:10	197	67.3422	168.8865	67	20.53	168	53.19	50.5	
9/4/22 6:36	198	67.1623	168.8848	67	9.74	168	53.09	49.5	
9/4/22 8:06	199	66.9818	168.8825	66	58.91	168	52.95	48.0	Niskins
9/4/22 9:38	200	66.8038	168.8823	66	48.23	168	52.94	44.6	
9/4/22 11:12	201	66.623	168.8823	66	37.38	168	52.94	47.8	
9/4/22 12:22	202	66.5005	168.9283	66	30.03	168	55.7	58.0	Niskins
15: BSNr									
9/4/22 16:27	203	66.5043	168.7027	66	30.26	168	42.16	54.0	
9/4/22 17:21	204	66.503	168.4805	66	30.18	168	28.83	52.0	
9/4/22 18:14	205	66.503	168.2535	66	30.18	168	15.21	38.0	Niskins
9/4/22 19:08	206	66.5015	168.0317	66	30.09	168	1.9	25.0	
9/4/22 19:58	207	66.5015	167.8033	66	30.09	167	48.2	25.0	
9/4/22 20:47	208	66.505	167.5802	66	30.3	167	34.81	27.0	Niskins, Grab, Net
9/4/22 21:26	908	66.4985	167.5698	66	29.91	167	34.19	27.0	
9/4/22 22:29	209	66.5035	167.353	66	30.21	167	21.18	29.0	
9/4/22 23:20	210	66.503	167.1295	66	30.18	167	7.77	30.0	
9/5/22 0:07	211	66.4572	166.9358	66	27.43	166	56.15	31.0	Niskins

9/5/22 0:57	212	66.412	166.7383	66	24.72	166	44.3	22.0	
9/5/22 1:41	213	66.3712	166.5533	66	22.27	166	33.2	16.0	Niskins
16:BSr									
9/5/22 10:28	214	65.7833	168.8382	65	47	168	50.29	49.0	Niskins
9/5/22 11:07	215	65.7615	168.7483	65	45.69	168	44.9	54.0	
9/5/22 11:43	216	65.7383	168.6545	65	44.3	168	39.27	52.5	Niskins
9/5/22 12:30	217	65.718	168.5588	65	43.08	168	33.53	53.0	
9/5/22 13:11	218	65.694	168.4628	65	41.64	168	27.77	55.0	Niskins
9/5/22 13:58	219	65.6653	168.365	65	39.92	168	21.9	52.2	
9/5/22 14:32	220	65.643	168.2763	65	38.58	168	16.58	46.4	
9/5/22 15:17	221	65.6188	168.1508	65	37.13	168	9.05	27.7	Niskins