Bar Harbor Cruise Ship Monitoring Report 2018

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Executive Summary

Water quality in the port of Bar Harbor was monitored between May and November 2018 by staff and volunteers from the Community Laboratory at MDI Biological Laboratory in Salisbury Cove, ME. Sample sites included the Town Pier, offshore cruise ship anchorages designated Alpha and Bravo, and control site Bell Buoy #7 (Figure 1). During this 7-month time frame, baseline water quality was monitored, twice at the Town Pier when no ships were present, and twelve times in the harbor, when no ships were present. The Bar Harbor harbormaster transported monitors to the offshore anchorages. Water samples were analyzed for phytoplankton, biological oxygen demand, dissolved oxygen, nutrients, salinity, transparency, turbidity, chlorine, and *Enterococcus* bacteria.

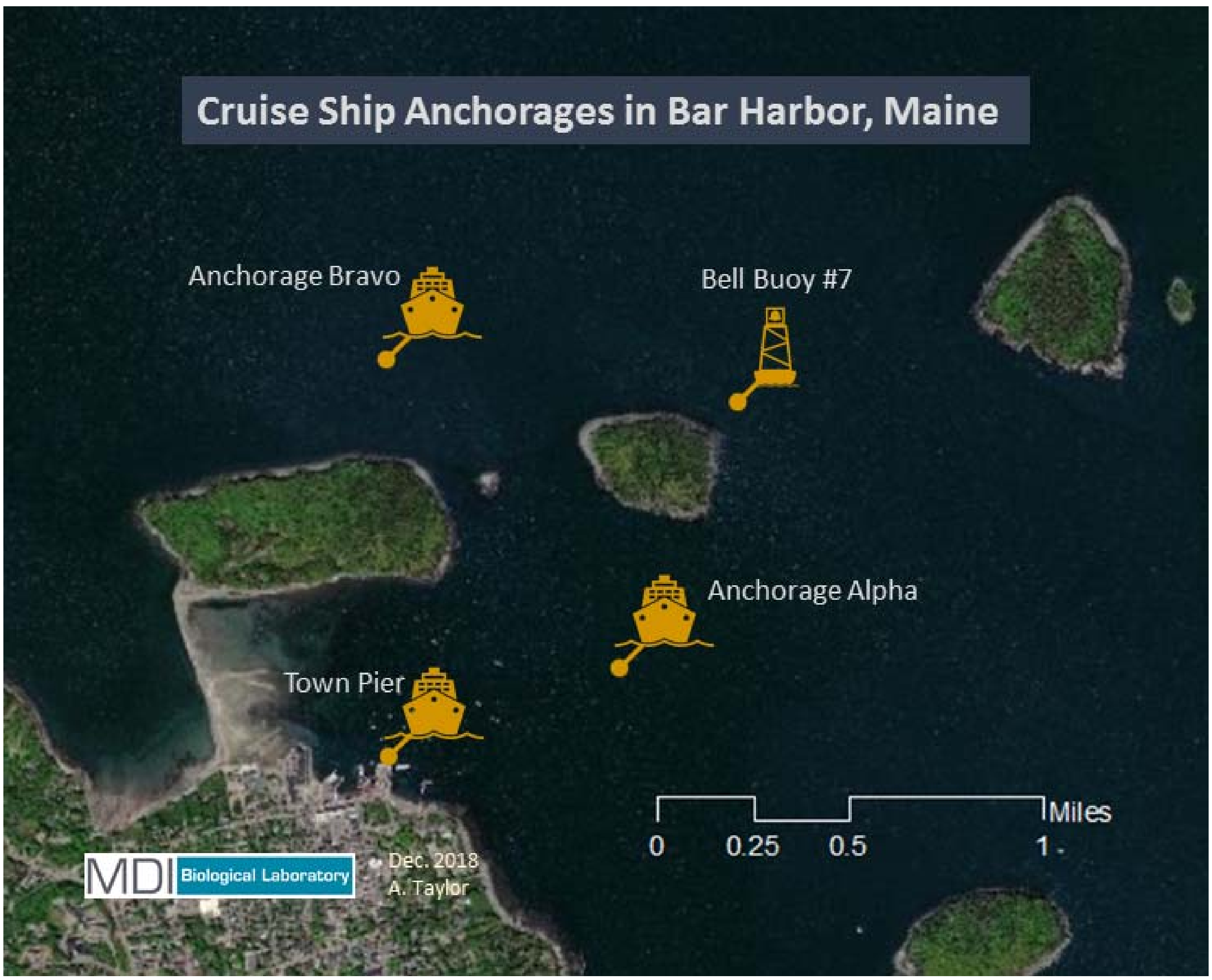

Figure 1. 2018 cruise ship project monitoring sites in Bar Harbor, Maine: Alpha, Bravo, Control Site Bell Buoy #7, and Town Pier.

Introduction

As the world's population expands, there is an increased risk of ocean pollution from a variety of land and marine uses. It is estimated that 80% of ocean pollution comes from land-based activities. However substandard ships or poor shipping practices also contribute to marine pollution (WWF, 2015).

Cruise ships are also a potential source of ocean pollution. A typical cruise ship with 3,000 passengers can generate up to 25,000 gallons of human waste and 143,000 gallons of gray water from showers and sinks each day (Oceana, 2014). There is immense potential for water quality impacts, should an accidental or intentional discharge occur.

Cruise ships are essentially floating cities because they provide all the services that individuals would need and can receive on land (Oceana, 2014). Although land-based sewage treatment systems are strictly regulated by The Clean Water Act (40 CFR 122.3), gray water and black water discharges from cruise ships are only regulated in a couple of states.

Since January 1, 2006, Maine legislation (38 M.R.S.A. §423-D) has required large passenger vessels to have a general permit for the discharge of gray water or a mixture of gray water and black water (DEP Permit #W008222-5Y-A-N). In addition, this legislation requires that large passenger vessels adhere to strict discharge standards that require a certain level of water quality be attained by secondary treatment before discharge within a harbor. Despite this legislation requiring large passenger vessels to obtain a permit before discharging in Maine waters, no ships have applied for a permit in the state of Maine, and there are many boats to which these requirements do not apply. Large commercial passenger vessels are defined in Maine statute as commercial passenger vessels that provide overnight accommodations for 250 or more passengers for hire. The ships that visit the town pier in Bar Harbor are all considered small commercial passenger vessels.

Although small commercial passenger vessels are exempt from the regulations outlined in 38 M.R.S.A. §423-D, there are best management practices recommended by the cruise industry, US EPA, and the US Coast Guard which are outlined in the Town of Bar Harbor Cruise Tourism Destination Management Plan (2007). These include black water discharges being limited to those that meet effluent guidelines and discharges being limited to when the vessel is proceeding at a speed not less than 6 knots where the ship is more than 4 nm from shore. It is also recommended that ships voluntarily prohibit discharge of gray water while in port and that gray water discharges be limited to when the ship is underway and proceeding at a speed not less than 6 knots where the ship is more than 4 nm from shore.

Despite these guidelines, in 2010 and again in 2011, a small passenger cruise ship, *Independence*, discharged wastewater that was visible to passers-by at the town pier in Bar Harbor. Confirmation of these discharges by follow-up water quality monitoring opened lines of communication with the cruise agency and led to apologies and pledges to refrain from these discharges in the future. It also opened discussion about the need for a pump-out station at the town pier.

It is Bar Harbor's policy that visiting ships hold all waste while in the harbor. This is based on best practice recommendations from a variety of federal and state entities. There are no federal or state mandates that support this policy where small cruise passenger vessels are concerned; therefore, there is no outside entity that will check for compliance of Bar Harbor's policy if Bar Harbor does not do so.

Checking for compliance with harbor policy regarding discharge of waste water sends a message to visiting ships that water quality is important to citizens of Bar Harbor. Water quality monitoring may serve as a deterrent to discharging of wastewater by all types of vessels visiting Bar Harbor. Not only can wastewater discharges affect the health of the ecosystem, but they can also affect human health. One type of bacteria that is used as an indicator of sewage pollution is *Enterococcus*, which is found in the intestinal tract of warm-blooded animals. *Enterococcus* indicates that other pathogenic organisms may be present. Discharge of untreated wastewater from visiting ships may result in outbreaks of recreational water illnesses, or RWIs, since people use the town beach near where small cruise ships and other vessels dock, and local kayaking companies launch from the nearby boat ramp. RWIs may include a wide variety of illnesses, including infections of the skin, eye, ear, and gastrointestinal system.

A monitoring program that includes open communication with the cruise industry has helped to address two questions: Are cruise ships aware of and complying with Bar Harbor's "No Discharge" policy? The second question is: How can we use water quality data to open lines of communication with the cruise industry and others and affect positive change that ensures that Bar Harbor remains a sustainable cruise destination?

Dr. Jane Disney, director of the Community Lab at MDI Biological Laboratory, and project manager for the 2018 Cruise Ship Monitoring Program in Bar Harbor, has been engaging citizens in monitoring water quality in Frenchman Bay since 1997 as part of the Maine Shore Stewards program, the Maine Phytoplankton Monitoring Program, and most recently the Maine Healthy Beaches program. In 2004, as director of the non-profit MDI Water Quality Coalition, she was involved in a series of four "Community Conversations on Cruise Ships" in Bar Harbor. Due to citizen concern about the potential for cruise ship impacts on water quality, she designed a water quality monitoring regime to look at water quality at cruise ship anchorages and at the Town Pier in Bar Harbor. Working with citizen volunteers, water quality data were collected in the vicinity of 31 large and small passenger vessels between May and November of 2004. The final report was cited in *From Ship to Shore: Sustainable Stewardship in Cruise Destinations,* published in 2006 by Conservation International. This publication acknowledged that "because of their unique skills and expertise on conservation and community development issues, civil society organizations have an opportunity to work with other stakeholders, including the cruise lines, to develop and implement solutions for addressing their key concerns and increasing the sustainability of cruise tourism."

After a purported wastewater discharge incident by a small passenger vessel at the town pier in 2010, staff scientists at the Community Lab received a request from the harbormaster to take water samples to assess the health of the surrounding water. In 2011, Community Lab staff followed up on this incident by implementing a second cruise ship monitoring project, this time focused in the vicinity of small passenger vessels at the town pier. Water quality was monitored on eight different occasions and a report was prepared for the Town of Bar Harbor. The authors of the report recommended that communications with visiting cruise ships include expectations that ships hold all wastewater until out of port (May & Disney, 2011).

In 2014, the Community Lab staff monitored in the vicinity of 19 large and small cruise ships; monitoring revealed elevated bacteria levels three times during the season (Disney, Charabati, & Farrell, 2015). Two of the instances were at the town pier. On one of these occasions, American Glory had just docked, on the other occasion there was no cruise vessel at the pier. On both occasions, the registered herring carrier from Columbia, ME, F/V Reliance was docked; observers noted discharge coming from Reliance on the first of these two occasions and reported the event to the harbormaster. Elevated bacteria levels were also found at anchorage Alpha when the large passenger vessel, Summit, was visiting. The visit corresponded with heavy rainfall and runoff in Bar Harbor, which probably led to the high bacteria levels.

In 2018 Community Lab staff monitored the water quality around 27 ships that visited Bar Harbor. Results showed that *Enterococcus* remained at consistently low levels.

The 2004, 2011, 2014, and 2015 cruise ship monitoring projects helped to open lines of communication between ship captains and the harbormaster, provide clarity on wastewater treatment and management practices on-board visiting ships, and allay concerns of Bar Harbor citizens about the potential impact of cruise ships on marine water quality along the Bar Harbor shorefront (Disney & Farrell, 2015). As this current report reveals, the 2018 cruise ship monitoring project accomplished the same goals.

The expertise and experience of Community Lab staff with water quality monitoring in Bar Harbor, as participants in state-level initiatives, as well as local cruise ship monitoring projects, were brought to bear on the 2018 cruise ship monitoring project, the results of which are presented in this report.

Methods

What we tested for:

The water quality monitoring protocol is like the one described in the MDI Water Quality Coalition Cruise Ship Water Quality Report (2005) and detailed in the 2016 Quality Assurance Project Plan (QAPP) that guides all field and lab testing at the Community Lab. Variables assessed in water samples taken from the town pier or in cruise ship anchorages include water temperature, *Enterococcus* bacteria, dissolved oxygen (DO), biological oxygen demand (BOD), nutrients (nitrate and nitrite (NO_3+NO_2), silica ($Si(OH)_4$) and phosphorus (PO_4)), chlorine, transparency, turbidity, salinity, and dominant phytoplankton species.

Why we monitored for these variables:

The presence of *Enterococcus* indicates that pathogenic organisms may be present in the water. Since *Enterococcus* is found in the gut of warm-blooded animals, it can be found in both black water (from sewage) and gray water (from sinks and showers) from boats. Discharges from boats can impact more than human health. The nutrients and organic matter in discharges can affect DO levels, which must be above 4-6 ppm for a healthy marine ecosystem. Measuring BOD helps to determine if there is excessive organic matter in the water column. In metabolizing organic matter, bacteria can quickly multiply and consume dissolved oxygen, leading to high (>2 ppm) BOD results. The nutrients in both black water and gray water can spur phytoplankton blooms, which in turn, can also affect DO levels in the water. Water temperature can also affect DO levels. Concentrations of nutrients can vary in different locations in bays and estuaries. On-going monitoring when ships are in port or when no ships are present helps to establish baseline readings of what is normal or expected in particular marine systems.

How samples were collected and analyses were conducted:

Samples for bacterial analysis were collected using sterile Whirl-Pak sample bags and then tested using the Enterolert® protocol from IDEXX; this method is currently being used in the Maine Healthy Beaches Program. As part of that program, we have data on the Bar Harbor town beach for comparison with offshore samples. US-EPA recommends *Enterococcus* as the best fecal indicator in marine waters from a public health perspective. It is recommended that *Enterococcus* tests be run as soon as possible, but not later than 6 hours after sampling. The Community Lab is near the sampling sites and we ran the tests well below the 6-hour holding time limit. The Maine Healthy Beaches Program supplied all field equipment and sample bags as well as lab supplies related to running *Enterococcus* tests (dilution jars, multi-well plates for Most Probable Number (MPN) determination, pipets, and media) at no cost to the town, as the data generated may help to inform beach management in Bar Harbor in the future.

DO samples were collected in duplicate and fixed using a LaMotte DO test kit. Water samples for BOD determination were collected in duplicate in bottles covered with aluminum foil and then kept in the dark for 5 days using a method described in Mitchell and Stapp (2000). Both same-day DO and 5-day DO levels were determined using the Winkler Titration Method. BOD was calculated by subtracting the 5-day DO levels from the original DO levels.

Water samples were collected for phosphorus, nitrite and nitrate analysis by filtering through a syringe filter containing a Millipore 0.45 µm filter into sterile vials. These were transported in a seawater ice-bath to the Community Lab, where they were stored in a -20°C freezer. The samples were transported to the University of Maine-Orono to be analyzed with an Autoanalyzer II by Maura Thomas in Dr. David Townsend's Laboratory.

Transparency was documented by using an oceanographic Secchi disk to determine descending and ascending transparencies; these values were then averaged. Secchi disks measurements (in meters) revealed the clarity of the water. Turbidity samples were analyzed in triplicate using the 2020 e LaMotte turbidity meter; these values were then averaged. Readouts from the turbidimeter provided a relative measure of turbidity in nephelometer turbidity units (NTU). Samples for phytoplankton analysis were collected by filtering 10 liters of seawater through 20-micron netting. Phytoplankton samples were analyzed using a Sedgewick Rafter slide; dominant phytoplankton types were scored, and slides were scanned for the presence of non-native species. Salinity was measured in ppt using a refractometer and pH and water temperature were measured using a hand-held multiparameter meter. The meter also recorded DO levels which we used to compare to our samples tested with the LaMotte DO test kit.

Additional data regarding environmental characteristics were also recorded, including air temperature, tide stage, times of high and low tide, wind speed, weather, and observations of all boats and yachts at the pier and moored in the harbor. Air Temperatures were taken with a digital thermometer. Times of low and high tides were determined using an online Bar Harbor tide chart. Wind speed and direction were measured with a compass and a Beaufort scale. Control samples were collected at Bell Buoy #7 when ships were present at one or more of the anchorages and compared with water from around the ships. Baseline samples were collected when no ships were in the harbor to determine water quality in the absence of ships. Weather was determined by conditions in the field at the time of sampling. The amount of precipitation in the 48 hours preceding sampling was determined using data from noaa.gov and accuweather.com. All data collected in the field were recorded on paper data sheets, which were then entered into Microsoft Access. At the end of the season, the entire dataset was uploaded to the citizen science platform Anecdata.org, developed at the MDI Biological Laboratory. This platform helps individuals collect, report, and share their scientific observations. All of the Bar Harbor Cruise Ship Monitoring Project data are available to the public through Anecdata.org under the "Bar Harbor Cruise Ship Monitoring" project: https://www.anecdata.org/projects/view/205

Results and Discussion

Scope of Monitoring:

We obtained samples in the vicinity of 27 ships on 18 separate occasions this year, with 10 control samples collected for comparison. Anchorage Alpha was sampled 16 times when ships were in anchorage and 3 times when ships were not. Anchorage Bravo was sampled 9 times when ships were in anchorage, and 3 times when ships were not. Control Site Bell Buoy #7 was sampled 7 times as a control, and the Town Pier site was sampled once when ships were in anchorage and five times when ships were not. While the town pier was sampled every week as part of our sampling for the Maine Volunteer Phytoplankton Monitoring Program, this did not always include water quality testing for the Cruise Ship Monitoring Project.

Bacteria and Oxygen:

For the purposes of this monitoring program, fecal bacteria and oxygen were the most important indicators of healthy water, as bacteria relates to public health and oxygen levels relate to overall ecosystem health.

Enterococcus is recommended by the US EPA as the best fecal indicator in marine waters from a public health perspective. The highest bacteria concentration during the 2018 cruise monitoring season was 10 MPN on July 18, 2018 at our control site Bell Buoy #7; as a comparison, the highest bacteria concentration during the 2015 sampling season was 41 MPN on August 17, 2015 when Grand Caribe was docked at the town pier. All other samples around cruise ships and our control site were 5 MPN. No samples at any site reached the EPA exceedance level for water contact (104 MPN/100 mL).

Many species, including fish, invertebrates, and plants require oxygen to carry out their life cycles. Atmospheric oxygen dissolves readily in water until the water is saturated. Distribution depends on movement of the water. Photosynthetic species, such as marine plants, algae, and phytoplankton also produce oxygen in the water. Different species at different life stages require varying amounts of oxygen, but in general, dissolved oxygen levels below 3 ppm are stressful to most marine organisms and levels below 2 or 1 ppm will not support fish. Levels at or above 5 ppm are required for most life processes (LaMotte, 2001). Average dissolved oxygen over the 2018 monitoring season was 8.6 ppm. Each test was run in duplicate; the lowest average dissolved oxygen at any site was 7.3 ppm (Figure 2).

Biological Oxygen Demand (BOD), as we measured it, reflects the amount of dissolved oxygen that organisms consume to carry out life processes over a specific amount of time. There are natural sources of organic materials (swamps, bogs, vegetation, animal waste), and human sources (wastewater). When BOD levels are high, it means microorganisms are consuming much of the available dissolved oxygen, leaving little oxygen for other organisms (Mitchell and Stapp, 2000). Average actual biochemical oxygen demand (DO-BOD) over the 2018 monitoring season was very low (1.1 ppm).

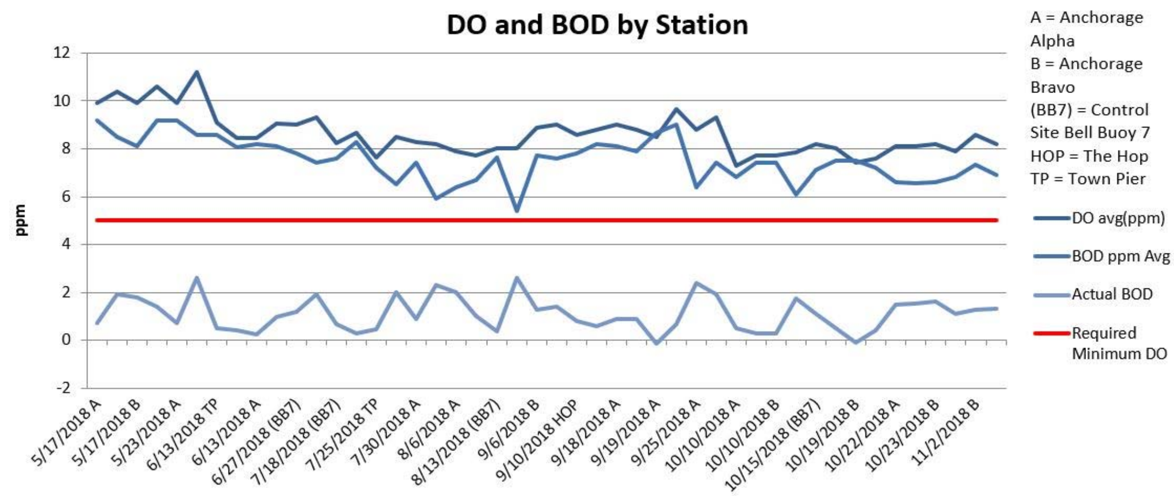

Figure 2. Dissolved oxygen (DO), DO after a five-day hold (5-Day DO), and biochemical oxygen demand (BOD) over the sampling time period.

Chlorine:

Chlorine is used to treat wastewater in some ships using Marine Sanitation Devices (MSDs). Chlorine can be damaging to the environment when discharged, even at low levels. According to the US EPA, the recommended maximum for all fish and aquatic life is 0.01 ppm (2015). Most marine plankton species are killed when levels reach 0.1 ppm. During the 2018 monitoring season, the average total residual chlorine level across all sites was 0.006 ppm.

Nutrients:

Elevated nutrient levels in the water column may be indicative of pollution events. The breakdown of organic material, which could result from a pollution event, releases nutrients into the water, particularly nitrogen and phosphorus (Mitchell and Stapp, 2000). Excess nutrients can cause algal blooms, leading to a decrease in light and oxygen in the water. We sampled for nitrate and nitrite (NO_3+NO_2), silicate ($Si(OH)_4$) and phosphorus (PO_4). Silicate levels appeared elevated on four different occasions: 10/10/18 next to Fram (8.63 uM), 10/10/18 next to the Norwegian Escape (21.07 uM), 10/15/18 control site Bell Buoy #7 (18.48 uM), and 10/19/18 next to Zuiderdam (9.46 uM). On the days when elevated silica was recorded, nitrogen levels were higher than usual as well (see Figure 3a and 3b). These levels are still within typical ranges for these nutrients in Frenchman Bay. Nutrient levels can vary from site to site and season to season in the bay. However, we do not see an overall difference from year to year. Examination of nutrient levels in 2015 as compared to 2018 revealed no difference between years as determined by a t-test, which is used to determine whether the difference between two means is statistically significant. The difference is significant when the P-value is less than 0.05. The t-tests for each of the nutrients we examined resulted in the following P-values, none of which were less than 0.05: combined nitrate and nitrite, *P-value*: 0.09456, phosphorous, *P-value*: 0.07967, silicate, *P-value*: 0.32426. Also, there is no consistent pattern of elevated nutrients at a cruise ship with concomitant low nutrients at the control site (Bell Buoy #7), although samples could not always be collected from the control site due to occasional large swells leading to an unsafe sampling environment. It should be noted that Dr. Townsend's lab was not able to analyze samples for ammonium this sampling season which means we have no Dissolved Inorganic Nitrogen (ammonium plus nitrate plus nitrite, DIN) to report as a comparison with 2015. Instead, we report just the combined nitrate plus nitrite results. Town pier samples have not been analyzed for nutrients at the time of this report, as our collaborator who supports these analyses is currently waiting to identify a lab that can provide ammonium results in addition to nitrate and nitrite.

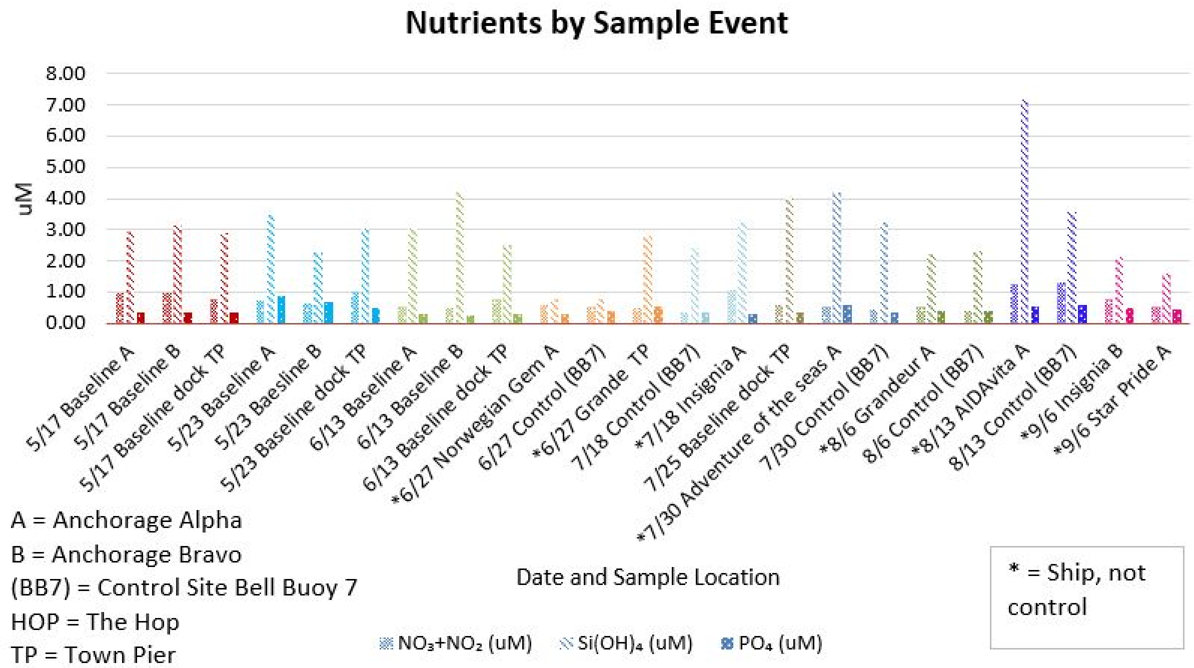

Figure 3a. Nitrate and nitrite, silica, and phosphorus levels over the sampling period (5/17/18-9/6/18). Different colors represent individual days. Nutrients are represented by checks (NO_3 +NO_2), hatch marks ($Si(OH)_4$) and solid with dots (PO_4), not by color.

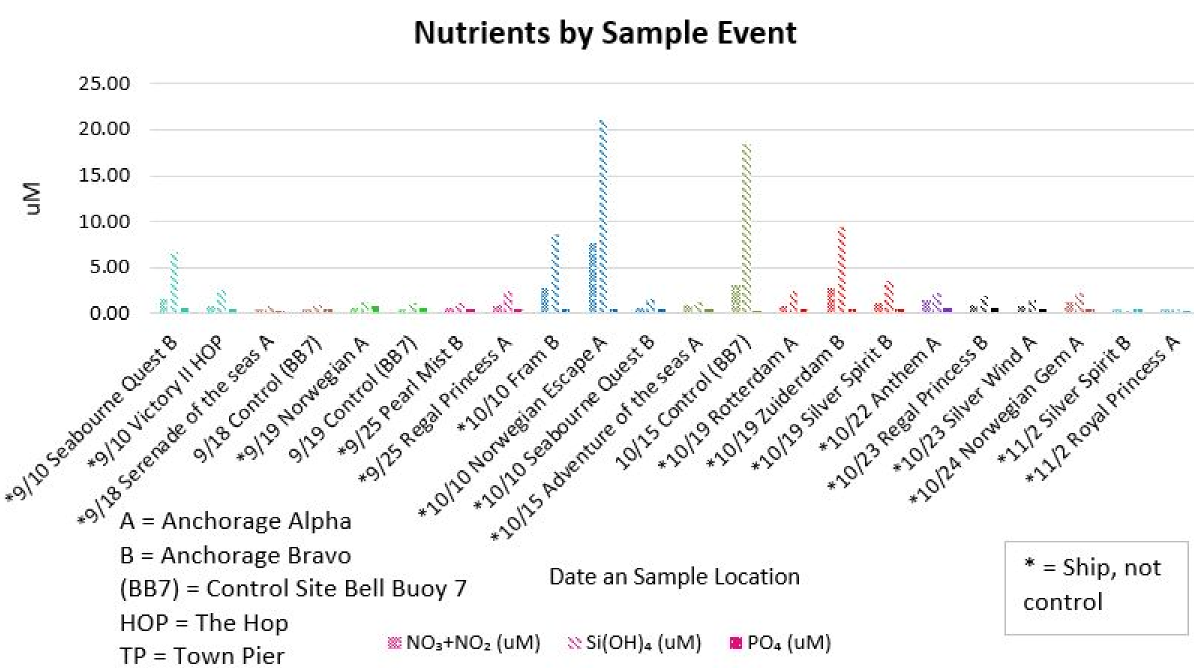

Figure 3b. Nitrate and nitrite, silica, and phosphorus levels over the sampling period (9/10/18-11/2/18). Different colors represent individual days. Nutrients are represented by checks (NO_3 +NO_2), hatch marks ($Si(OH)_4$) and solid with dots (PO_4), not by color.

Other Water Quality Variables:

In addition to collecting information on bacteria and nutrients, we looked at a host of associated water quality variables (Appendix 2). In addition to rainfall, water temperature, dissolved oxygen, and biochemical oxygen demand, the transparency and turbidity of the water were assessed at each site on each sampling day. Transparency and turbidity are different measures of water clarity. Both measure the passage of light through particles suspended in the water but use different techniques (see Methods section). Turbidity increases and transparency decreases, as a result of suspended solids in the water. These solids may be natural, i.e. clay, silt, and plankton, or human induced, i.e. industrial wastes and sewage. When water clarity decreases, temperatures may rise, causing oxygen levels to fall. In addition, photosynthesis decreases because less light penetrates the water. A combination of these things makes it very difficult for some species to survive (Mitchell and Stapp, 2000). Our transparency and turbidity measurements show that Bar Harbor has exceedingly clear water, often with a transparency above three meters, at times as high as six or eight meters. Turbidity measurements also indicated clear water: numbers were usually below 1.0 NTU. This result remains the same as in the 2015 sampling season. When transparency is high, turbidity tends to be low (Figure 4).

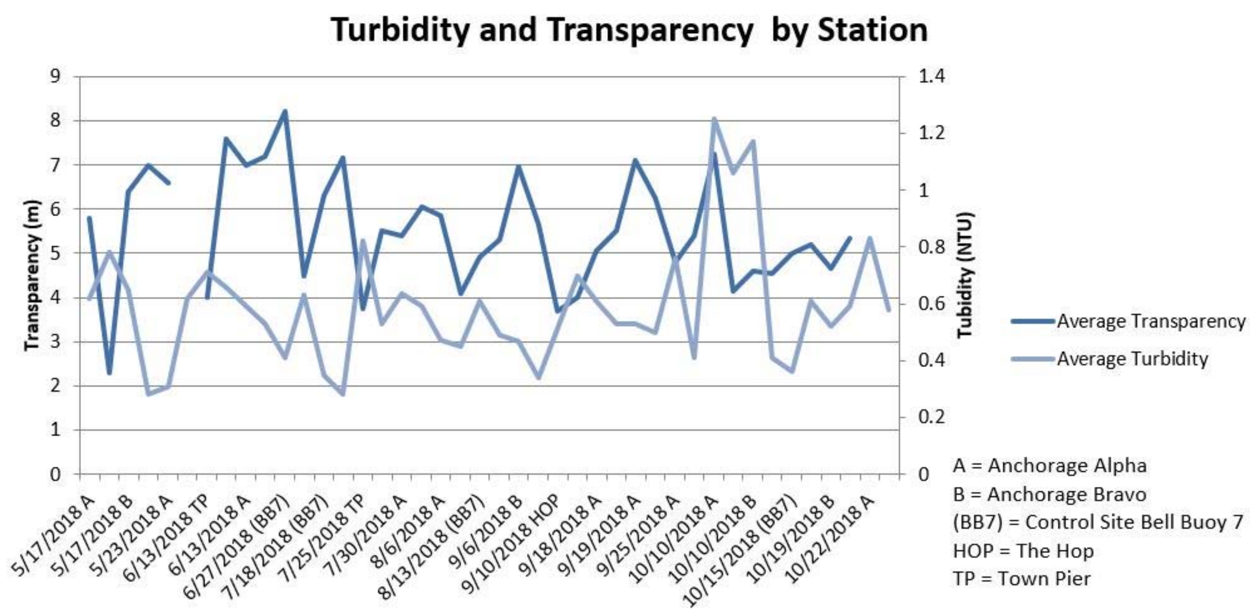

Figure 4. Transparency and turbidity are inversely related at all stations throughout the 2018 cruise season.

Phytoplankton:

Phytoplankton populations were also tracked during the cruise season (Appendix 3). The array of phytoplankton species observed in samples taken in the vicinity of visiting cruise ships mirrored those seen at Department of Marine Resources (DMR) phytoplankton monitoring locations in Frenchman Bay. *Chaetoceros spp*. was most frequently the dominant species in water samples, followed by *Guinardia* and a mix of other species (Figure 5). *Chaetoceros* has remained the most dominant species since 2015, but the following most dominant species have shifted. *Chaetoceros*, *Guinardia*, *Thalassionema*, *Coscinodiscus*, and *Leptocylindrus* are non-toxic phytoplankton common in the Gulf of Maine. However, *Pseudo-nitzschia* and *Dinophysis* are considered toxic phytoplankton as under certain environmental conditions they produce toxins that can accumulate in shellfish and lead to clamflat closures. Fortunately, while these two species were present in our collected samples, numbers were low and not a cause for concern. We did not see any phytoplankton species that were atypical for Gulf of Maine; in other words, there were no apparent non-native (foreign) phytoplankton species that would be indicative of a ballast water exchange.

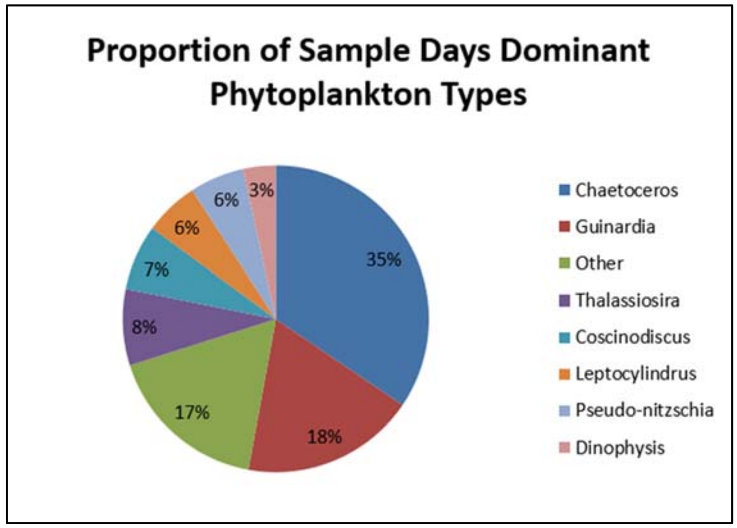

Figure 5. Phytoplankton types in vicinity of visiting cruise ships in Bar Harbor, 2018.

Increase in Ship Visits:

Each year, there is a greater number of cruise ships that visit Bar Harbor, resulting in a dramatic increase of passengers as well as foreign ships (Figure 6). As these numbers increase, monitoring the health of our water becomes even more crucial as the potential for ocean pollution increases.

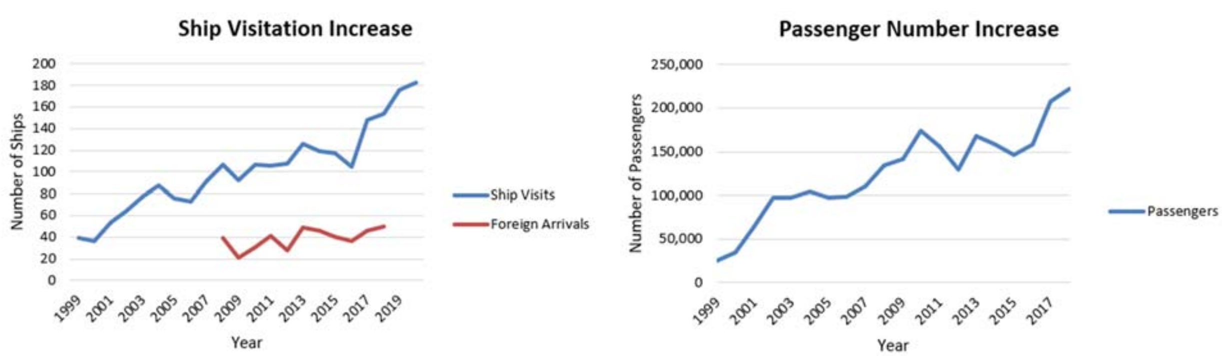

Figure 6. Increased numbers in ships and passengers over the years.

Conclusions:

Bar Harbor has excellent water quality. Based on sample results, visiting cruise ships and other vessels are adhering to harbor policy and holding all waste. There are also pollution sources on land which threaten the quality of water in Bar Harbor, particularly after heavy rain. Sources of bacteria on land include malfunctioning septic systems, broken sewer lines, pet waste, and waste from farm animals, as well as wildlife. Runoff from the land can confound the results of harbor monitoring. Nonetheless, water quality monitoring in the harbor provides a baseline for future reference, reveals trends, provides incentive for visiting ships to comply with harbor policy, and allays the concerns of citizens with regard to water quality in the harbor.

Recommendations:

1. We recommend that Bar Harbor continue to invest in a healthy future for the harbor by supporting water quality monitoring. In our opinion, the focus of a monitoring program does not need to be on cruise ships. A broader-based monitoring program will help to address behaviors by operators of all types of vessels, may help pinpoint land-based pollution sources, and provide on-going baseline data so that we understand changes that may occur over time. We also recommend that the monitoring program be focused on the most informative water quality variables, including bacteria and associated environmental variables such as water temperature, DO, BOD, transparency, turbidity, salinity, and rainfall. We propose that establishing sampling sites along the shoreline in Bar Harbor, with a focus near the bar, the town pier, and one-two offshore sites, on a routine basis, may suffice to follow emerging trends in our coastal waters.

2. We recommend that the Harbor Committee review harbor policies and discuss ways to ensure that all boat owners who visit Bar Harbor understand and acknowledge their understanding of harbor policies. The current standard operating procedure for Bar Harbor expands on existing federal and state requirements regarding discharges of black water and specifically states that "All cruise ships calling in Bar Harbor, whether in anchorage A or B or laying alongside the town pier floats are expected to hold all waste water including gray water while in port." We recommend that the SOP be modified to include all boats that visit Bar Harbor. We suggest that there should be repercussions for boat owners who do not comply with harbor policy. In the case of intentional discharge of bacteria-laden water into the harbor, those repercussions should be designed to ensure public health.

3. There are numerous resources available to help Bar Harbor with boater education. Adapting one of these resources to meet the needs of Bar Harbor, for example, the "Pump it Don't Dump It" flyer developed by the Maine Healthy Beaches program (http://mainehealthybeaches.org/documents/UseYourHead.pdf), may be one avenue to help address boater behavior and helping to ensure good water quality in the future.

Acknowledgements:

This project was made possible with cruise passenger fees and the support of the Maine Healthy Beaches Program, which provided field monitoring equipment and supplies (valued at $1023) for bacteria analysis, at no cost to the town of Bar Harbor. We appreciate the input of the Maine Healthy Beaches coordinator, Meagan Sims, on project design. Bar Harbor Harbormaster, Charlie Phippen, provided transportation to offshore vessels and was helpful with creation of a reasonable monitoring schedule. We appreciate the assistance of a myriad of citizen volunteers as well as the Community Lab student intern, Jade Lee, who helped us with sampling, lab tests, and data management.

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Appendix 1: Cruise Ship Data

Date	Berth	Cruise Ship Name	Enterococcus /100ml	Assoc. Chlorine	NO_3+NO_2 (uM)	$Si(OH)_4$ (uM)	PO_4 (uM)
5/17/2018	Alpha	Baseline	5	0.04	0.99	2.94	0.36
5/17/2018	Bravo	Baseline	5	0.05	0.97	3.12	0.35
5/17/2018	Bar Harbor Town Pier	Baseline	5	0.05	0.77	2.89	0.34
5/23/2018	Alpha	Baseline	5	0.06	0.71	3.47	0.88
5/23/2018	Bravo	Baseline	5	0.05	0.64	2.26	0.68
5/23/2018	Bar Harbor Town Pier	Baseline	5	0.05	1.04	3.03	0.49
6/13/2018	Alpha	Baseline	5	0.04	0.55	3.02	0.32
6/13/2018	Bar Harbor Town Pier	Baseline	5	0.2	0.78	2.51	0.28
6/13/2018	Bar Harbor Town Pier	Baseline	5	0.2	0.78	2.51	0.28
6/13/2018	Bravo	Baseline	5	0.05	0.51	4.17	0.26
6/27/2018	Bell Buoy 7	Control	5	0	0.55	0.79	0.41
6/27/2018	Alpha	Norwegian Gem	5	-0.01	0.59	0.78	0.32
7/16/2018	Bar Harbor Town Pier	Grande Mariner	5	0	0.51	2.81	0.53
7/18/2018	Control	Control	10	-0.01	0.37	2.4	0.35
7/18/2018	Alpha	Insignia	0	-0.01	1.09	3.23	0.28
7/25/2018	Bar Harbor Town Pier	Control	5	-0.01	0.6	4.01	0.33
7/30/2018	Alpha	Adventures of the Sea	5	-0.02	0.52	4.18	0.58
7/30/2018	Bell Buoy 7	Control	5	-0.02	0.46	3.21	0.35
8/6/2018	Bell Buoy 7	Control	5	0.01	0.53	2.24	0.39
8/6/2018	Alpha	Grandeur of the Seas	5	-0.01	0.4	2.3	0.38
8/7/2018	Bar Harbor Town Pier	Control	5	-0.01	--	--	--
8/13/2018	Alpha	AIDAvita	5	0	1.25	7.18	0.52
8/13/2018	Bell Buoy 7	Control	5	0	1.3	3.56	0.59
9/6/2018	Bravo	Insignia	5	-0.02	0.78	2.11	0.51
9/6/2018	Alpha	Star Pride	5	-0.01	0.53	1.58	0.44
9/10/2018	Bravo	Seabourn Quest	5	0	1.68	6.61	0.7
9/10/2018	The Hop	Victory II	5	-0.01	0.72	2.67	0.49
9/18/2018	Alpha	Serenade of the Seas	5	0.01	0.53	0.72	0.37
9/18/2018	Bell Buoy 7	Control	5	0.01	0.52	0.95	0.42
9/19/2018	Bell Buoy 7	Control	5	0.02	0.48	1.08	0.6
9/19/2018	Alpha	Norwegian Escape	5	0.01	0.61	1.32	0.73
9/25/2018	Alpha	Regal Princess	5	0.02	0.96	2.35	0.55

9/25/2018	Bravo	Pearl Mist	5	-0.01	0.56	1.15	0.44
10/10/2018	Bravo	Fram	5	-0.01	2.79	8.63	0.48
10/10/2018	Alpha	Norwegian Escape	5	-0.05	7.65	21.07	0.44
10/10/2018	Bravo	Seabourn Quest	5	-0.02	0.62	1.61	0.4
10/15/2018	Alpha	Adventures of the Sea	5	0.01	0.89	1.36	0.48
10/15/2018	Bell Buoy 7	Control	5	0	3.13	18.48	0.34
10/19/2018	Bravo	Silver Spirit	5	0	1.06	3.63	0.53
10/19/2018	Bravo	Zuiderdam	5	0.01	2.71	9.46	0.52
10/19/2018	Alpha	Rotterdam	5	0	0.72	2.46	0.54
10/22/2018	Alpha	Anthem of the Seas	5	-0.02	1.51	2.23	0.58
10/23/2018	Bravo	Regal Princess	5	0	0.9	1.92	0.63
10/23/2018	Alpha	Silver Wind	5	0.01	0.76	1.41	0.51
10/24/2018	Alpha	Norwegian Gem	5	0.02	1.3	2.25	0.49
11/2/2018	Alpha	Royal Princess	5	0	0.43	0.41	0.35
11/2/2018	Bravo	Silver Spirit	5	-0.01	0.45	0.31	0.4

Appendix 2: Environmental Data

Date	Berth	Cruise Ship Name	H2O Temp (°C)	Transparency Avg. (m)	Avg. DO (ppm)	Salinity (ppt)	Act. BOD (ppm)	NTU Avg.
5/17/2018	Alpha	Baseline	8.1	5.8	9.9	32	0.7	0.62
5/17/2018	Bar Harbor Town Pier	Baseline	8.3	2.3	10.4	32	1.9	0.78
5/17/2018	Bravo	Baseline	8.1	6.4	9.9	33	1.8	0.65
5/23/2018	Bravo	Baseline	11	7	10.6	31	1.4	0.28
5/23/2018	Alpha	Baseline	9.5	6.6	9.9	32	0.7	0.31
5/23/2018	Bar Harbor Town Pier	Baseline	10.9		11.2	32	2.6	0.62
6/13/2018	Bar Harbor Town Pier	Baseline	11	4	9.1	32	0.5	0.71
6/13/2018	Bravo	Baseline	11.7	7.6	8.45	31	0.4	0.66
6/13/2018	Alpha	Baseline	11.6	7	8.45	30	0.25	0.59
6/27/2018	Alpha	Norwegian Gem	12.3	7.2	9.05	31	0.95	0.53
6/27/2018	Bell Buoy 7	Control	12.4	8.2	9	31	1.2	0.41
7/16/2018	Bar Harbor Town Pier	Grande Mariner	15	4.5	9.3	31	1.9	0.63
7/18/2018	Control	Control	15.5	6.3	8.25	30	0.65	0.35
7/18/2018	Alpha	Insignia	13.4	7.17	8.65	30	0.3	0.28
7/25/2018	Bar Harbor Town Pier	Control	14.6	3.75	7.65	31	0.45	0.82
7/30/2018	Bell Buoy 7	Control	17.4	5.5	8.5	31	2	0.53
7/30/2018	Alpha	Adventures of the Sea	17.3	5.4	8.3	32	0.9	0.636
8/6/2018	Bell Buoy 7	Control	18.6	6.05	8.2	31	2.3	0.59
8/6/2018	Alpha	Grandeur of the Seas	18.1	5.85	7.9	30	2	0.473
8/8/2018	Bar Harbor Town Pier	Control	18.7	4.1	7.7	30	1	0.45
8/13/2018	Bell Buoy 7	Control	14.5	4.9	8	31	0.35	0.61
8/13/2018	Alpha	AIDAvita	14.6	5.3	8	31	2.6	0.49
9/6/2018	Bravo	Insignia	17.3	6.95	8.9	31	1.25	0.47
9/6/2018	Alpha	Star Pride	16.7	5.65	9	31	1.4	0.34
9/10/2018	The Hop	Victory II	14.5	3.7	8.6	33	0.8	0.51
9/10/2018	Bravo	Seabourn Quest	13.6	4	8.8	33	0.6	0.7
9/18/2018	Alpha	Serenade of the Seas	15.6	5.05	9	31	0.9	0.61
9/18/2018	Bell Buoy 7	Control	15.7	5.5	8.8	32	0.9	13.9
9/19/2018	Alpha	Norwegian Escape	14.9	7.1	8.5	31	-0.15	0.53
9/19/2018	Bell Buoy 7	Control	15	6.25	9.65	32	0.65	0.5
9/25/2018	Alpha	Regal Princess	13.7	4.8	8.8	31	2.4	0.76
9/25/2018	Bravo	Pearl Mist	13.9	5.4	9.3	32	1.9	0.41
10/10/2018	Alpha	Norwegian Escape	13.4	7.25	7.3	33	0.5	13.6

10/10/2018	Bravo	Seabourn Quest	13.5	4.15	7.7	32	0.3	1.06
10/10/2018	Bravo	Fram	13.4	4.6	7.7	32	0.3	1.17
10/15/2018	Alpha	Adventures of the Sea	13	4.55	7.85	32	1.75	0.41
10/15/2018	Bell Buoy 7	Control	12.9	5	8.2	32	1.1	13.767
10/19/2018	Alpha	Rotterdam	12.1	5.2	8	33	0.5	0.61
10/19/2018	Bravo	Silver Spirit	12.2	4.65	7.4	34	-0.1	0.52
10/19/2018	Bravo	Zuiderdam	12.2	5.35	7.6	33	0.4	0.59
10/22/2018	Alpha	Anthem of the Seas	11.9		8.1	33	1.5	0.83
10/23/2018	Alpha	Silver Wind	11.7	5.15	8.1	32	1.55	0.58
10/23/2018	Bravo	Regal Princess	11.6	4.15	8.2	32	1.6	0.92
10/24/2018	Alpha	Norwegian Gem	11.7	3.2	7.9	33	1.1	0.95
11/2/2018	Bravo	Silver Spirit	10	4.1	8.6	33	1.25	0.64
11/2/2018	Alpha	Royal Princess	10	4.35	8.2	33	1.3	0.7

Appendix 3: Dominant Phytoplankton Types

Date	Berth	Cruise Ship Name	Phytoplankton Dominant 1	Phytoplankton Dominant 2
5/17/2018	Alpha	Baseline	*Chaetoceros spp.*	*Pleurosigma spp.*
5/17/2018	Bar Harbor Town Pier	Baseline	*Chaetoceros spp.*	*Pleurosigma spp.*
5/17/2018	Bravo	Baseline	*Chaetoceros spp.*	*Thalassionema spp.*
5/23/2018	Bravo	Baseline	*Chaetoceros spp.*	
5/23/2018	Alpha	Baseline	*Chaetoceros spp.*	
5/23/2018	Bar Harbor Town Pier	Baseline	*Chaetoceros spp.*	*Fragillaria spp.*
6/13/2018	Bar Harbor Town Pier	Baseline	*Leptocylindrus spp.*	
6/13/2018	Bravo	Baseline	*Thalassionema spp.*	
6/13/2018	Alpha	Baseline	*Thalassionema spp.*	*Leptocylindrus spp.*
6/27/2018	Alpha	Norwegian Gem	*Chaetoceros socialis*	*Leptocylindrus spp.*
6/27/2018	Bell Buoy 7	Control	*Chaetoceros socialis*	*Leptocylindrus spp.*
7/16/2018	Bar Harbor Town Pier	Grande Mariner	*Guinardia spp.*	*Dinophysis spp.*
7/18/2018	Control	Control	*Dactyliosolen*	
7/18/2018	Alpha	Insignia	*Dinophysis spp.*	*Dactyliosolen*
7/25/2018	Bar Harbor Town Pier	Control	*Protoperidinium spp.*	*Other*
7/30/2018	Bell Buoy 7	Control	*Pleurosigma spp.*	*Chaetoceros socialis*
7/30/2018	Alpha	Adventures of the Sea	*Chaetoceros socialis*	*Thalassiosira spp.*
8/6/2018	Bell Buoy 7	Control	*Thalassiosira spp.*	*Pseudonitzschia spp.*
8/6/2018	Alpha	Grandeur of the Seas	*Pseudonitzschia spp.*	*Thalassiosira spp.*
8/8/2018	Bar Harbor Town Pier	Control	*Pseudonitzschia spp.*	*Coscinodiscus spp.*
8/13/2018	Bell Buoy 7	Control	*Rhizoselenia spp.*	*Guinardia spp.*
8/13/2018	Alpha	AIDAvita	*Guinardia spp.*	*Thalassiosira spp.*
9/6/2018	Bravo	Insignia	*Guinardia spp.*	*Coscinodiscus spp.*
9/6/2018	Alpha	Star Pride	*Guinardia spp.*	*Rhizoselenia spp.*
9/10/2018	The Hop	Victory II	*Guinardia spp.*	*Ceratium lineatum*
9/10/2018	Bravo	Seabourn Quest	*Guinardia spp.*	*Rhizoselenia spp.*
9/18/2018	Alpha	Serenade of the Seas	*Guinardia spp.*	*Chaetoceros socialis*
9/18/2018	Bell Buoy 7	Control	*Guinardia spp.*	*Pseudonitzschia spp.*
9/19/2018	Alpha	Norwegian Escape	*Guinardia spp.*	*Chaetoceros socialis*
9/19/2018	Bell Buoy 7	Control	*Guinardia spp.*	*Chaetoceros socialis*
9/25/2018	Alpha	Regal Princess	*Guinardia spp.*	*Phaeocystis spp.*
9/25/2018	Bravo	Pearl Mist	*Guinardia spp.*	*Pseudonitzschia spp.*
10/10/2018	Alpha	Norwegian Escape	*Chaetoceros socialis*	*Guinardia spp.*
10/10/2018	Bravo	Seabourn Quest	*Chaetoceros socialis*	*Guinardia spp.*
10/10/2018	Bravo	Fram	*Chaetoceros socialis*	*Guinardia spp.*

10/15/2018	Alpha	Adventures of the Sea	*Chaetoceros socialis*	*Coscinodiscus spp.*
10/15/2018	Bell Buoy 7	Control	*Chaetoceros socialis*	*Detonula spp.*
10/19/2018	Alpha	Rotterdam	*Chaetoceros socialis*	*Chaetoceros spp.*
10/19/2018	Bravo	Silver Spirit	*Chaetoceros socialis*	*Coscinodiscus spp.*
10/19/2018	Bravo	Zuiderdam	*Chaetoceros socialis*	*Pleurosigma spp.*
10/22/2018	Alpha	Anthem of the Seas	*Chaetoceros socialis*	*Coscinodiscus spp.*
10/23/2018	Alpha	Silver Wind	*Chaetoceros socialis*	*Chaetoceros spp.*
10/23/2018	Bravo	Regal Princess	*Chaetoceros socialis*	*Coscinodiscus spp.*
10/24/2018	Alpha	Norwegian Gem	*Chaetoceros socialis*	*Leptocylindrus spp.*
11/2/2018	Bravo	Silver Spirit	*Chaetoceros socialis*	*Chaetoceros spp.*
11/2/2018	Alpha	Royal Princess	*Chaetoceros socialis*	*Dinophysis spp.*