



Glacier Bay National Park and Preserve Oceanographic Monitoring Program

2012 Annual Report

Natural Resource Report NPS/SEAN/NRR—2017/1461



ON THE COVER

Winter ocean in Glacier Bay National Park.
NPS photo

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Natural Resource Report NPS/SEAN/NRR—2017/1461

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Abstract

The Southeast Alaska Inventory and Monitoring Network (SEAN) assumed responsibility from the U.S. Geological Survey for long-term oceanographic monitoring of Glacier Bay National Park and Preserve in 2009. This (2012) is the 20th consecutive year of the continuous dataset and is the fourth annual report. As operational conditions allowed, vertical profiles of temperature, salinity, light, turbidity, dissolved oxygen concentration, and chlorophyll fluorescence were obtained for the water column once in late winter and once in mid-summer at 22 permanent stations throughout Glacier Bay; eight of those stations were occupied monthly from March through October (2012 was the first full year in which Station 24 became a “core station” that was sampled during each survey). In general, parameters reflected typical ranges and spatial (both horizontal and vertical) and temporal trends expected for a high-latitude tidewater glacial fjord, with strong seasonal signals and strong length-of-fjord gradients along the glacier-to-bay mouth transects. The water column was well-mixed in winter and strongly stratified in summer. Fluorescence measurements indicated phytoplankton production occurred in surface waters from late spring through fall, presumably fueled by a near-continuous injection of nutrients to the euphotic zone by tidal, wind, and/or internal wave-induced mechanisms. Compared to historical data, the 2012 central bay water column in July was anomalously cool in the upper 30 m, anomalously fresh at 10-75 m, and anomalously low-density at 10-50 m. These anomalies generally resemble anomalies observed in mid-summer at similar depths at GAK1 in the northern Gulf of Alaska, and continue to highlight Glacier Bay’s inherent variability on inter-annual timescales. The 2012 sampling year marked the second with a dedicated survey vessel, as well as the second year of a three-year ocean acidification study that involves water sampling from discrete depths through the water column. It is expected that analyses of these samples (results reported elsewhere) will significantly enhance our understanding of Glacier Bay oceanography.

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Introduction

Oceanography is one of several long-term monitoring “vital signs” identified by the National Park Service (NPS) Southeast Alaska Inventory and Monitoring Network (SEAN) as important for assessing the ecological health of Glacier Bay National Park and Preserve (NPP; Moynahan et al. 2008). A detailed oceanographic monitoring protocol (Danielson et al. 2010) was developed to standardize data collection, analyses, and reporting. This 2012 annual report documents the fourth year of data collection following the development of that protocol. Annual reports summarize the field efforts and resulting data of the previous sampling year. The “oceanographic sampling year” begins with a mid-winter cruise in December or January and ends with an October cruise, after which the measurement instrument receives annual service and sensor calibration. Calibration results allow for final data to be certified, and the annual report is typically generated in January or February. The annual report is intended to be a timely release of summarized data, and it includes a narrative description of field activities, unusual or otherwise noteworthy observations, and graphical and tabular data summaries to place the data in historical context. It is succinct and synoptic in nature, and is aimed at a primary audience of Glacier Bay managers, researchers, and interested stakeholders from the public at large. Care has been taken to assure accuracy of raw data values upon which this report is based; a more analytical interpretation of the data is undertaken in a more comprehensive but less frequent trend report (typically issued on a regular five-year basis). The first of these long-term data analyses covers 1993-2009 (Danielson 2012).

Long-term monitoring of Glacier Bay oceanographic parameters is a key element of informed park management. Glacier Bay’s ocean waters strongly influence ecosystems across the entire park. Together with weather, bathymetry, and glaciers and other terrestrial influences, oceanographic components determine horizontal water movement and vertical stability, thereby driving the spatial and temporal dynamics of energy, and physical, chemical, and biological characteristics of the water column. Marine biological communities and their constituent components—from primary producers to apex predators—are fundamentally controlled in this way. Moreover, because the land/ocean interface is porous to the transfer of energy, materials, and biophysical signals, the Glacier Bay marine system is an important physical and biological driver of adjacent terrestrial systems. Consequently, for park managers to fully understand and protect all park resources, they must include the waters of Glacier Bay itself. In addition to having a basic knowledge of oceanographic components and processes, it is essential to monitor key parameters that are likely to influence the condition of many specific resources—both marine and terrestrial—throughout the park and region.

The Glacier Bay oceanographic monitoring protocol (Danielson et al. 2010) summarizes the purpose, design, and all methods for long-term oceanographic sampling. Oceanographic measurements collected on hydrographic surveys enable a “bottom-up” perspective of ecological relationships. Physical parameters (measured vertically throughout the water column at multiple locations) include water temperature, salinity, light, turbidity, and dissolved oxygen. These measurements characterize the environment that directly impacts both lower trophic (e.g., phytoplankton) and upper trophic (e.g., crabs, fishes, marine mammals, and birds) organisms through their influence on metabolic rates, ability to support carbon fixation through production of chlorophyll, and/or the propensity for

organisms to be retained within or exported from the euphotic layer. Fluorescence measurements of chlorophyll-a provide an index of the phytoplankton standing stock, which in turn forms the food base for primary consumers (zooplankton) and the subsequent cascade of carbon through trophic levels to apex predators (e.g., fishes, marine mammals and birds). Thus, observations made within this monitoring program form a foundation upon which other aspects of the marine ecosystem within Glacier Bay (e.g., habitat, wildlife populations) can be evaluated.

Since 1993, the NPS and the U.S. Geological Survey (USGS) have monitored oceanographic conditions at up to 24 (22 since 2009) standard stations distributed throughout Glacier Bay. Select oceanographic parameters have been measured during periodic visits to those stations each year. The core suite of CTD (Conductivity-Temperature-Depth) vertical profile measurements has been supplemented with additional measurements of turbidity, photosynthetically-active radiation (PAR), and chlorophyll-a concentration. The entire long-term dataset, along with annual reports, peer-reviewed publications, and program evaluations are available from the SEAN oceanography webpage (http://science.nature.nps.gov/im/units/sean/OC_Main.aspx). In 2009, SEAN developed the current revised protocol (also available on the SEAN webpage), largely based on a previous USGS protocol (Hooge et al. 2003).

The objectives for the Glacier Bay oceanographic monitoring program (Danielson et al. 2010) are to:

1. Provide a dataset on physical oceanographic conditions in Glacier Bay (water temperature, salinity, stratification, PAR, and turbidity [optical backscatterance or OBS]) that can be used to better understand seasonal and inter-annual changes in the estuarine dynamics of Glacier Bay and the greater Southeast Alaska oceanographic system.
2. Provide a baseline oceanographic dataset (water temperature, salinity, stratification, PAR, OBS, dissolved oxygen, and chlorophyll-a fluorescence) that can be used by biologists to understand spatial and temporal variation in the abundance patterns of a variety of organisms including phytoplankton, zooplankton, marine invertebrates, fishes, marine mammals, and seabirds of Glacier Bay.

Methods

While detailed field data collection and data processing/management methods are documented in the SEAN oceanography monitoring protocol (Danielson et al. 2010), a brief summary is presented here to enable the rapid dissemination and utilization of annual results

Nine times each year we measure a suite of oceanographic water column parameters at permanent sampling “stations” located mid-channel throughout Glacier Bay (Figure 1). There are 22 standard oceanographic stations, including two just outside the fjord mouth that provide additional information about the water flowing in and out of Glacier Bay proper. Eight stations (including Station 24, added August 2011) are sampled monthly from March through October to describe seasonal variation during times of the strongest physical structure and highest productivity. These are called the “core stations.” Twice a year, in December/January (mid-winter) and in July (mid-summer), we sample the core stations and the remaining 14 stations to detect annual or longer signals. This design achieves a balance between intensive temporal sampling to resolve seasonal signals, and intensive spatial sampling to resolve annual signals and reveal long-term trends.

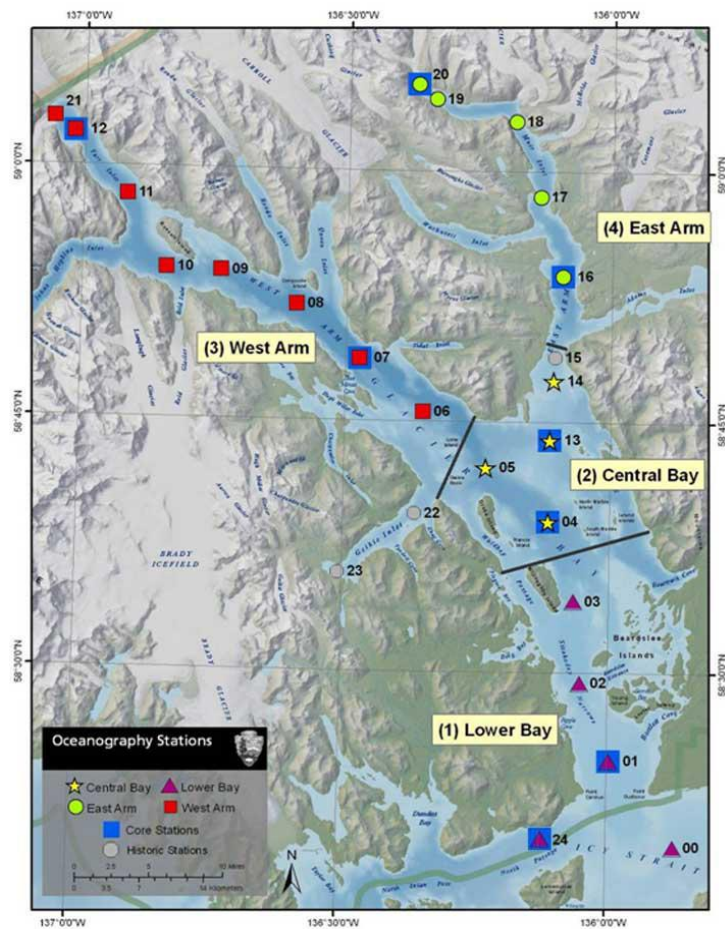


Figure 1. Oceanographic sampling stations in Glacier Bay. Shaded bathymetry indicates relative water depth (darker means deeper). Station depths range from 53 m (Station 00) to 435 m (Station 07).

Measurements are captured by an array of sensors mounted together in an instrument cluster called a CTD (Figure 2) which is lowered through the water column (“cast”) at a rate of 2 m/sec (~1 m/sec through the uppermost 50 m) from the surface to just above the bottom. Parameters are measured twice per second, and the data from each cast are stored within the CTD and downloaded at the end of the survey. Together the measurements yield a vertical profile of important water column characteristics for each station location.



Figure 2. The CTD integrated with the rosette bottle sampler being recovered (bottles closed, containing water samples from known discrete depths) following a cast.

Parameters (and their units of measure) include water temperature ($^{\circ}\text{C}$), salinity (Practical Salinity Units or PSUs), PAR (Photosynthetically-Active Radiation portion of the light spectrum, in $\mu\text{E}/\text{cm}^2\cdot\text{sec}$), chlorophyll-a fluorescence (an index of chlorophyll concentration and thus phytoplankton standing stock, in mg/m^3), OBS (Optical Backscatterance or turbidity, in Nephelometric Turbidity Units or NTUs), and dissolved oxygen concentration (ml/L , starting with the June 2009 survey). A strain gauge continuously records water pressure which is converted to depth in meters. Measurements of temperature and salinity are subsequently analyzed together to calculate density ($\sigma\text{-t}$, kg/m^3) and vertical density gradient ($\text{kg}/\text{m}^3/\text{m} = \text{kg}/\text{m}^4$, a measure of the rate of change in density with depth, which describes stratification relative intensity and indicates the

vertical location of the pycnocline). Raw data for all parameters are processed and verified following each sampling survey (referred to as a “cruise”).

The cycles of phytoplankton bloom and decline are unavoidably aliased with this (monthly) monitoring program. In addition, the phytoplankton assemblage being measured at any given place and time is ephemeral; the same measurement taken a day, a week, or two weeks earlier or later could bear little or no resemblance to the measurements taken on the date of the cruise. Because water column samples of phytoplankton, suspended particulates, and dissolved oxygen are not collected and analyzed, data from these ancillary sensors cannot be quantitatively compared on an inter-cruise or inter-annual basis, nor even at times within the same cruise/survey because many factors, including differing phytoplankton species assemblages and the state of health of the cells also impact the fluorescence response. Nevertheless, with these caveats in mind, we can still recognize coarse patterns and gross trends because (1) high-latitude glacial fjords typically exhibit relatively strong seasonal and inter-annual signals, and (2) expected parameter trends along the length-of-fjord transect are generally well understood (Syvitsky et al. 1987).

Results

Coverage

Table 1 shows the sampling coverage across the 2012 cruise year. All target stations were successfully occupied during all cruises.

Table 1. Sampling coverage of oceanographic stations during the 2012 cruise year. Cells marked with an “X” indicate that there are samples and null fields indicate that there were no samples.

Station	Mid-winter ^a	March	April	May	June ^b	Mid-July	August	September	October
00	X					X			
01 ^c	X	X	X	X	X	X	X	X	X
02	X					X			
03	X					X			
04 ^c	X	X	X	X	X	X	X	X	X
05	X					X			
06	X					X			
07 ^c	X	X	X	X	X	X	X	X	X
08	X					X			
09	X					X			
10	X					X			
11	X					X			
12 ^c	X	X	X	X	X	X	X	X	X
13	X	X	X	X	X	X	X	X	X
14	X					X			
16 ^c	X	X	X	X	X	X	X	X	X
17	X					X			
18	X					X			
19	X					X			
20 ^c	X	X	X	X	X	X	X	X	X
21	X					X			
24 ^c	X	X	X	X	X	X	X	X	X

^aDue to inclement weather as well as vessel and scientific instrument issues, the mid-winter survey, typically conducted during the December-January cruise window prescribed by the data collection protocol, was delayed until early February (February 4-13). See Operations section.

^bThe “June” survey was actually conducted May 31-June 1. See Operations section.

^cIdentifies the eight “core stations” (01, 04, 07, 12, 13, 16, 20, 24) (also in red font).

Operations

2012 was a highly successful survey year in terms of the ability to occupy stations as scheduled. Somewhat surprisingly, the presence of non-navigable pan ice was not a problem during the early-season surveys; this has been a challenge in past years. The mid-winter cruise was slightly delayed until early February by a combination of inclement weather, vessel mechanical breakdowns, and

technical issues with the scientific equipment. None of these problems substantially affected any of the subsequent surveys. During the July cruise some repeat casts were necessary due to weak batteries in the CTD, but the problem was rectified, and good casts were obtained for all stations. As usual, in order to adhere to the seasonal June 1-July 15 non-motorized status of upper Muir Inlet, the “June” cruise actually occurred May 31-June 1. All 2012 deployments were successfully conducted from the same vessel (R/V *Fog Lark*), and the author was able to consistently direct all surveys with the help of assistants.

Starting with the July 2011 cruise, monthly oceanographic surveys became operationally connected to a three-year research project investigating ocean acidification in Glacier Bay. Figure 2 shows how the CTD was incorporated into a steel frame supporting six water sampling bottles that are programmed to close at pre-determined depths at each station, from the surface to near the bottom. These discrete water samples open the way to a powerful suite of observations for better understanding Glacier Bay oceanography. Known-depth water samples collected simultaneously with CTD measurements are analyzed for a variety of metrics important to understanding ocean acidification and the macronutrient chemistry that supports the Glacier Bay food web. Among these discrete samples are several that are useful for field calibration of the monitoring program’s oceanographic sensors, including direct measurements of salinity, dissolved oxygen, and total suspended particulates. These will improve our understanding of how accurately the instruments on the CTD array measure oceanographic parameters (salinity, dissolved oxygen, and turbidity). Water samples also allow for analyses of biologically-important nutrient concentrations, and those metrics will complement this program’s fluorometry (chlorophyll-*a*) measurements to our enhance understanding of primary production and phytoplankton dynamics. These samples were collected on every cast (at every station) and on every cruise through July 2012, and thereafter during the twice-yearly “all-stations” cruises in mid-winter and mid-July through 2014. Results from these water sample analyses will be reported separately.

Overview of Observations

2012 data quality was excellent. Sensor data was complete, and post-season calibrations of all sensors indicated high sensor accuracy. The mid-winter survey, nominally scheduled for December-January, did not occur until February 4 (5 stations) with completion February 11-13 (remaining 17 stations). However, the original January 27 survey that was aborted due to inclement weather and vessel/equipment breakdowns nevertheless collected data from Station 01. This station was subsequently re-sampled during the February survey, and when compared to the late-January measurements, the cast data were not appreciably different. The timing of the 2012 “mid-winter” survey (first half of February) was similar to those for recent years (late March in 2009; early February in 2010; mid-March in 2011). A sampling of those 2012 data (temperature, salinity, density) from the upper 50 m of the water column, as well as from representative “bottom water” depth bands at Stations 01, 04, and 07 were not appreciably different from the 2009-2011 “winter” data. Consequently, we are confident that the February 2012 cruise data describe the “winter” oceanographic condition for Glacier Bay as comparably as the closest-to-winter data collected in 2009-2011. Based on this, we believe that most water column data collected from January, February,

and early March are likely to comparably represent the winter condition throughout most of Glacier Bay, in most years.

2012 was the first full year in which Station 24 became a “core station” that was sampled during each survey.

Appendices A and B summarize the oceanographic parameters by core station and survey month. Appendix A shows values averaged over the upper 0-50 m portion of the water column where the majority of primary production, macronutrient utilization, phytoplankton standing stock, thermal stratification, and low-salinity lenses occur, thus providing an integrated perspective of the most biologically active portion of the water column. Appendix B shows values that are generally descriptive of “bottom water”; these values are averaged across 10-m depth bands centered on a near-bottom depth (for each station) that is well below the pycnocline yet not so deep that data are not consistently captured by casts at that station.

Near-surface Conditions

In the upper 50 m of the eight core stations in 2012, mean water temperatures at all stations steadily increased from early spring minima (February-March, range ~3.5-4.3 °C) to early fall maxima (September-October, range ~6.2-7.8 °C). The most rapid warming occurred in late spring/early summer, between April/May and July. Surface-water temperatures typically warmed ~1.9-3.9 °C (mostly ~3.6 °C) across the season. Throughout the year there was a general trend of increasing mean temperatures along the length-of-fjord gradient from the inlet heads to the mouth of the bay.

Surface-water salinity peaked in spring (April, range ~30.7-30.9 PSU) throughout Glacier Bay, except at Stations 24 and 01 (February/31.6 PSU, and June/31.5 PSU, respectively). Salinity minima occurred in fall (September-October, range ~28.2-30.8 PSU), except at Station 24 (July/30.6 PSU). Salinities were higher throughout the year near the mouth of the bay (Stations 24, 01, 04) and were lowest in summer-fall near the heads of inlets (Stations 12, 20).

Near-surface mean density (*sigma-t*) at all stations was highest in April (range ~24.3-24.5 kg/m³) except at Stations 24 and 01 (February; 25.0 kg/m³ and 24.7 kg/m³, respectively). The most rapid declines generally occurred in late spring- summer (April-July). The former pattern closely tracked that for salinity and reflects the influence of warming (by incoming solar radiation) and freshening (by snowmelt and precipitation) that occurs between spring and fall. Minimum mean densities occurred in fall (October, range ~21.8-23.0 kg/m³), except at Stations 24 and 01 (July; 23.8 kg/m³ and 24.2 kg/m³, respectively). Density was highest throughout the year near the mouth of the bay (Stations 24 and 01). The depth of maximum vertical density gradient is a reasonable proxy for pycnocline depth, where the water density (*sigma-t*) changes most rapidly. At almost all stations in almost all months this depth was in the upper 10 m (exceptions were 14 m at Station 04 in May, and 24 m at Station 24 in July). The deepest (>25 m) generally occurred in winter to spring (February-May) and throughout the length-of-fjord transect, although later-season (September-October) and some of the deeper (43-100 m) maximum depths were observed at Stations 01 and 24.

Mean values for fluorescence (index of chlorophyll-*a* concentration) at most stations peaked in late spring to mid-summer (April-July), but the maxima in the upper West Arm (Station 12) occurred a bit later (in July, August, and September). Peak mean values for fluorescence ranged from ~0.4-5.4 mg/m³ and were variable along the length-of-bay transect, albeit lower at the head of the West Arm (Station 12). Minima (range ~0.09-0.12 mg/m³) occurred in February at all stations. Closely mirroring the pattern of maximum fluorescence values, mean dissolved oxygen concentrations were generally highest in February and in April-July (range ~5.9-6.7 ml/L) at all stations. They were generally lowest in October (range ~4.3-5.4 ml/L); at Station 20 the minimum (~5.5 ml/L) occurred in March. Mean surface-water turbidity values varied throughout the year (range ~1.0-41.3 NTU; generally <2.0 NTU), although the highest values were at the stations closest to the heads of the fjords (Stations 12, 20), and they occurred mid-summer – early fall (July-September) at those stations. As might be expected, mean PAR values through the upper 50 m were highly variable across months and stations, with minimum values approaching 0 $\mu\text{E}/\text{cm}^2\cdot\text{sec}$, and maxima exceeding 62 $\mu\text{E}/\text{cm}^2\cdot\text{sec}$. The lowest values occurred at the head of the East Arm (Station 20) in August-October. Note that PAR values are sensitive to boat shadows, sky cloudiness, and sun elevation, along with water column effects. See Appendix A for data tables.

Near-bottom Conditions

For the near-bottom water at the eight core stations in 2012, mean water temperatures generally increased throughout the year in a pattern similar to that of the surface waters, from early spring minima (March, range ~4.2-4.5 °C) to fall maxima (October, range ~4.9-7.7 °C). Bottom-water temperatures typically warmed ~0.8-3.9 °C across the season. Mean temperatures were not clearly associated with relative position along the length-of-bay gradient, as they were in the surface waters. Bottom-water mean salinity generally peaked (range ~31.1-32.1 PSU) in late spring-summer (May-July) throughout Glacier Bay. Depending on station location, mean bottom-water salinity minima occurred either in February (Stations 04, 07, 16) or October (Stations 01, 12, 13, 20, 24); values ranged from ~30.4–31.4 PSU. Similar to the near-surface (upper 50 m) waters, bottom-water minimum mean density (*sigma-t*) occurred in fall (October) at all stations except Station 16 (February); minima ranged from ~23.8 and ~24.5 kg/m³. Maxima (means) typically occurred in spring (May-June, range ~24.6-24.7 kg/m³). Bottom-water fluorescence (chlorophyll-*a* concentration) measurements were very low (generally <1.0 mg/m³) throughout the year at all stations; the highest value (~1.8 mg/m³ in May) was at Station 01.

Mean dissolved oxygen concentrations were generally highest in winter (January-February, range ~5.8-6.5 ml/L) and lowest in October (range ~4.1-5.4 ml/L). There was no discernible relationship with position along the length-of-bay transect, except that the highest winter maximum occurred at Station 01 near the mouth of Glacier Bay, and similarly the lowest fall minimum occurred at Station 24 outside the mouth of Glacier Bay in September. Patterns of bottom-water mean turbidity were very similar to those in the surface waters. Values varied throughout the year and across stations (range ~0.8-43.9 NTU; generally <2.0 NTU), although the highest values were nearest the heads of the inlets (Stations 12, 20) and occurred mid-summer to fall (July-October). Not surprisingly, near-bottom PAR measurements were very low (0.00-0.18 $\mu\text{E}/\text{cm}^2\cdot\text{sec}$) at all stations in all months. See Appendix B for data tables.

Comparison to the Long-term Historical Mean

Figure 3 provides example vertical profiles of temperature, salinity, and density from a single mid-bay station (Station 04; see Figure 2) during the month of July, 2012, plotted alongside the historical mean values for the same parameters from this station in July for the period of 1993 through 2012. This station and month were identified in the oceanographic monitoring protocol for greater in-depth analysis on a yearly basis.

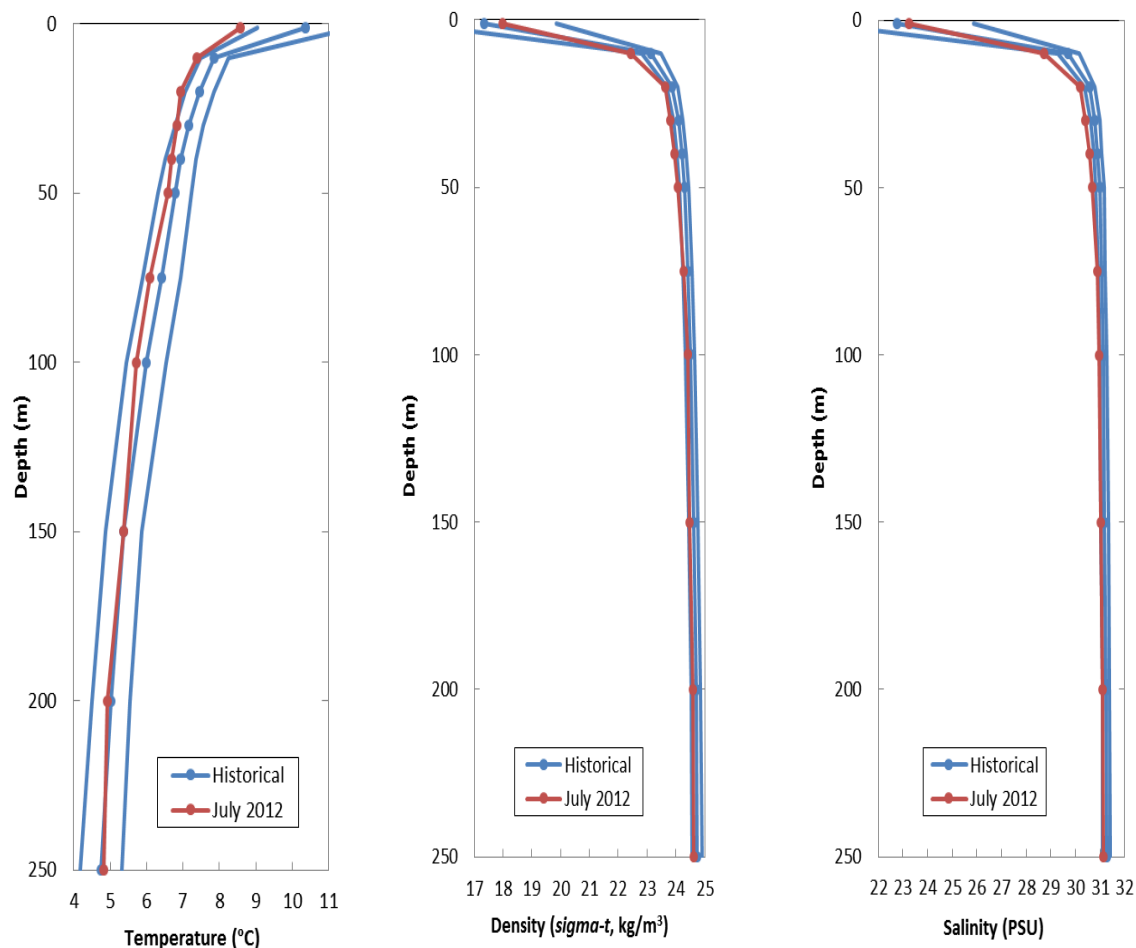


Figure 3. Vertical profiles of temperature (left), salinity (center), and density (σ_t , right) shown along with historical data (means for July 1993-2012, Station 04). 2012 data are shown in red with dots; historical means are blue with dots along with +/- bounds of one standard deviation to either side (blue, without dots). Only a subset of the full vertical profile is shown here, using standard depths of 0, 10, 20, 30, 50, 75, 100, 150, 200, and 250 m.

We describe current-year data as “normal” when the data values fall within one standard deviation of the historical mean (1993-2012) and anomalous otherwise. Figure 3 shows that waters at this station in July of 2012 were anomalously cool in the upper 20 m, anomalously fresh between 10-75 m depth, and anomalously low-density between 20-50 m depth.

Table 2 displays the numerical values plotted in Figure 3.

Table 2. Temperature, salinity, and density measurements from standard depths at Station 04 in July 2012, compared to historical measurements from that station in July, 1993-2012. To help draw attention to anomalous measurements, July 2012 observations lying outside one standard deviation (SD) of the long-term mean are emphasized in ***bold italic type***. (n=sample size)

Depth (m)	Station 04 Temperature (°C)					Station 04 Salinity (PSU)					Station 04 Density (kg/m ³)				
	July 2012	Hist. Mean -1 SD	Hist. July mean	Hist. Mean +1 SD	n	July 2012	Hist. Mean -1 SD	Hist. July mean	Hist. Mean +1 SD	n	July 2012	Hist. mean -1 SD	Hist. July mean	Hist. mean +1 SD	n
1 ^a	8.58	9.04	10.36	11.69	17	23.25	19.63	22.75	25.86	17	17.99	14.84	17.35	19.86	17
10	7.37	7.47	7.86	8.25	17	28.72	29.29	29.72	30.15	17	22.43	22.81	23.15	23.49	17
20	6.95	7.05	7.46	7.87	17	30.18	30.35	30.57	30.79	17	23.63	23.68	23.87	24.05	17
30	6.82	6.78	7.17	7.56	17	30.40	30.61	30.80	30.99	17	23.82	23.93	24.09	24.25	17
40	6.69	6.50	6.93	7.36	17	30.56	30.75	30.91	31.07	17	23.96	24.05	24.20	24.36	17
50	6.58	6.30	6.77	7.24	17	30.68	30.82	30.99	31.15	17	24.07	24.12	24.29	24.45	17
75	6.10	5.88	6.41	6.93	17	30.88	30.93	31.08	31.22	17	24.28	24.25	24.40	24.56	17
100	5.72	5.44	5.99	6.53	16	30.98	30.98	31.13	31.28	16	24.41	24.33	24.50	24.66	16
150	5.37	4.88	5.38	5.88	16	31.03	31.04	31.19	31.33	16	24.49	24.45	24.61	24.77	16
200	4.93	4.50	5.02	5.55	15	31.11	31.10	31.24	31.39	15	24.60	24.54	24.69	24.85	15
250	4.81	4.18	4.75	5.33	9	31.13	31.11	31.26	31.42	9	24.63	24.57	24.74	24.90	9

^aThe standard depth of 0 m has been replaced by 1 m to provide complete and consistent data for analysis. Given the objective of characterizing the surface water, 1 m is a reasonable proxy for 0 m.

Length-of-bay Vertical Profile Visualizations

Horizontal cross-sections provide effective at-a-glance visual depictions of water column parameters as a function of depth and distance along the transect. Figures 4 and 5 show colored contour plots of two length-of-bay transects at two different times of year. These plots incorporate data from all stations along their respective transects. All 22 oceanographic stations were occupied during both surveys; we believe that “mid-winter” cruise conditions are reasonably represented by data from the early February cruise.

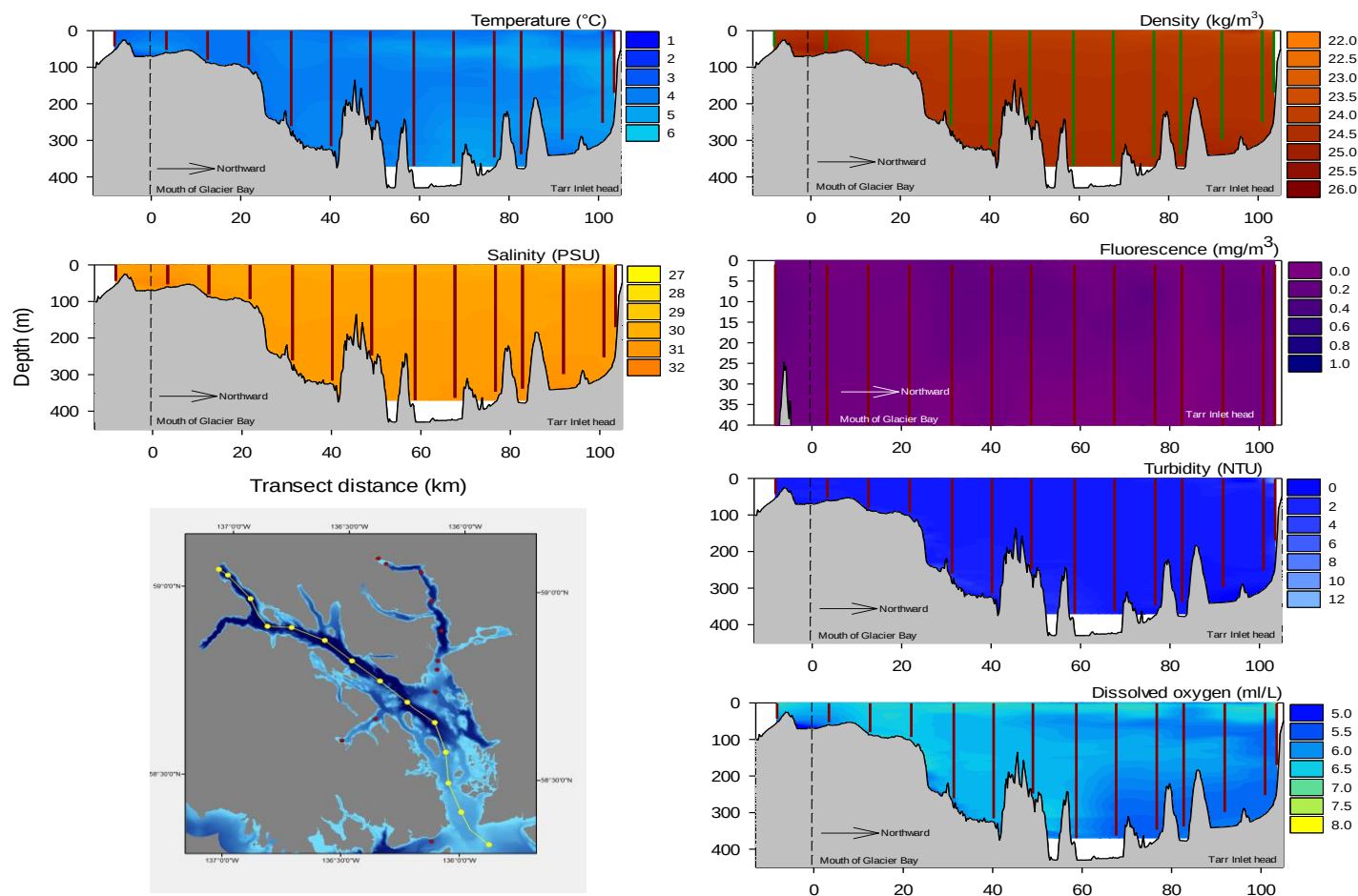


Figure 4a. Length-of-transect cross-sectional contour plots of principal oceanographic parameters for the West Arm transect for February 2012. The depth-shaded maps at bottom-left show station locations (colored dots), and transects are represented by the yellow line and use cast data from the yellow-dotted stations. On the contour plots, note the representation of the bottom (exaggerated by the depth/distance axes) along the transect line. Vertical lines indicate station locations and maximum cast depths. Use caution in interpretation: note that data are interpolated horizontally between adjacent casts, and that there are no data from depths beneath the bottoms of casts (notwithstanding any appearance of color). Also, note the foreshortened depth scale (upper 40 m only) for the Fluorescence parameter.

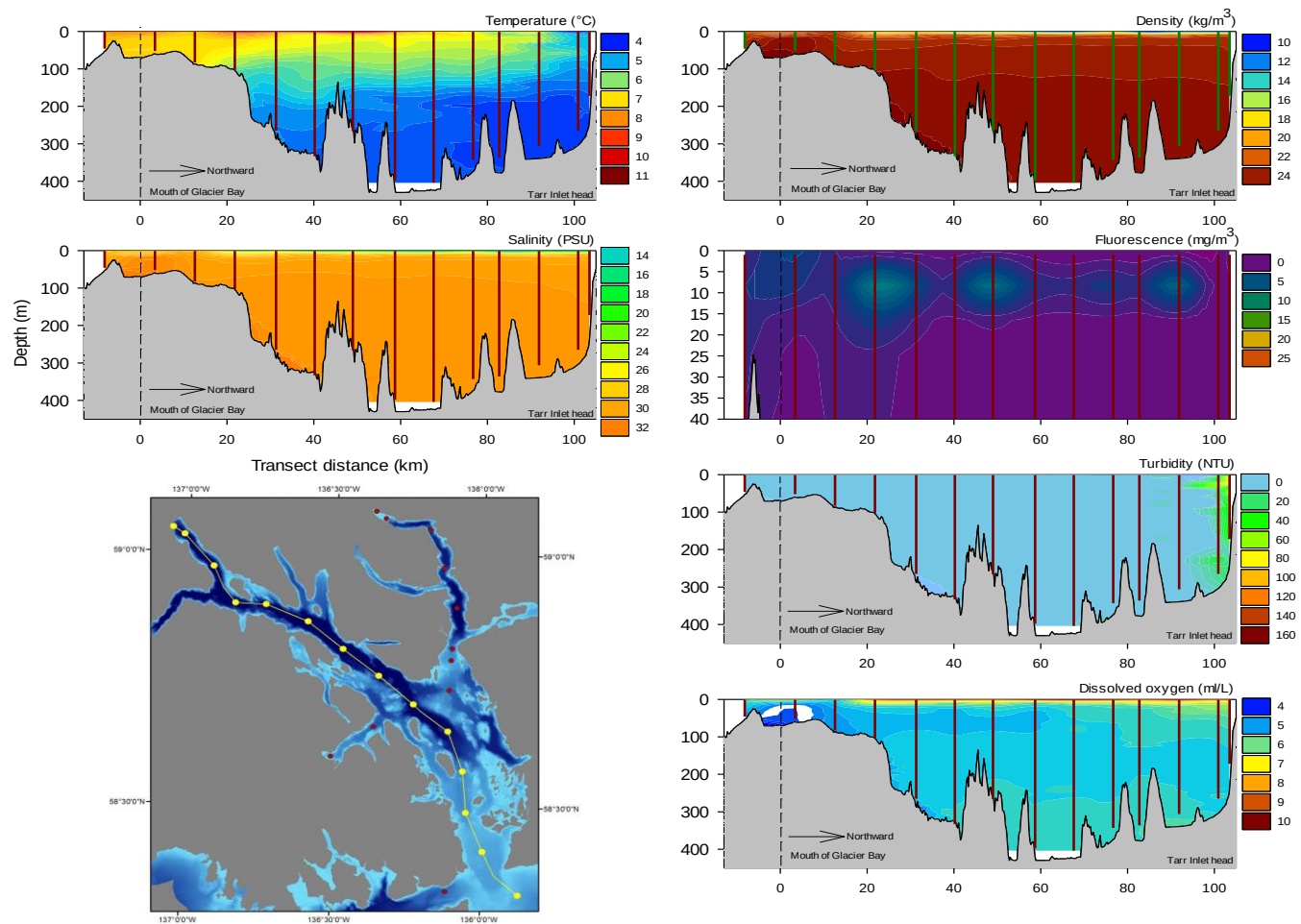


Figure 4b. Length-of-transect cross-sectional contour plots of principal oceanographic parameters for the West Arm transect for July 2012. The depth-shaded maps at bottom-left show station locations (colored dots), and transects are represented by the yellow line and use cast data from the yellow-dotted stations. On the contour plots, note the representation of the bottom (exaggerated by the depth/distance axes) along the transect line. Vertical lines indicate station locations and maximum cast depths. Use caution in interpretation: note that data are interpolated horizontally between adjacent casts, and that there are no data from depths beneath the bottoms of casts (notwithstanding any appearance of color). Also, note the foreshortened depth scale (upper 40 m only) for the Fluorescence parameter.

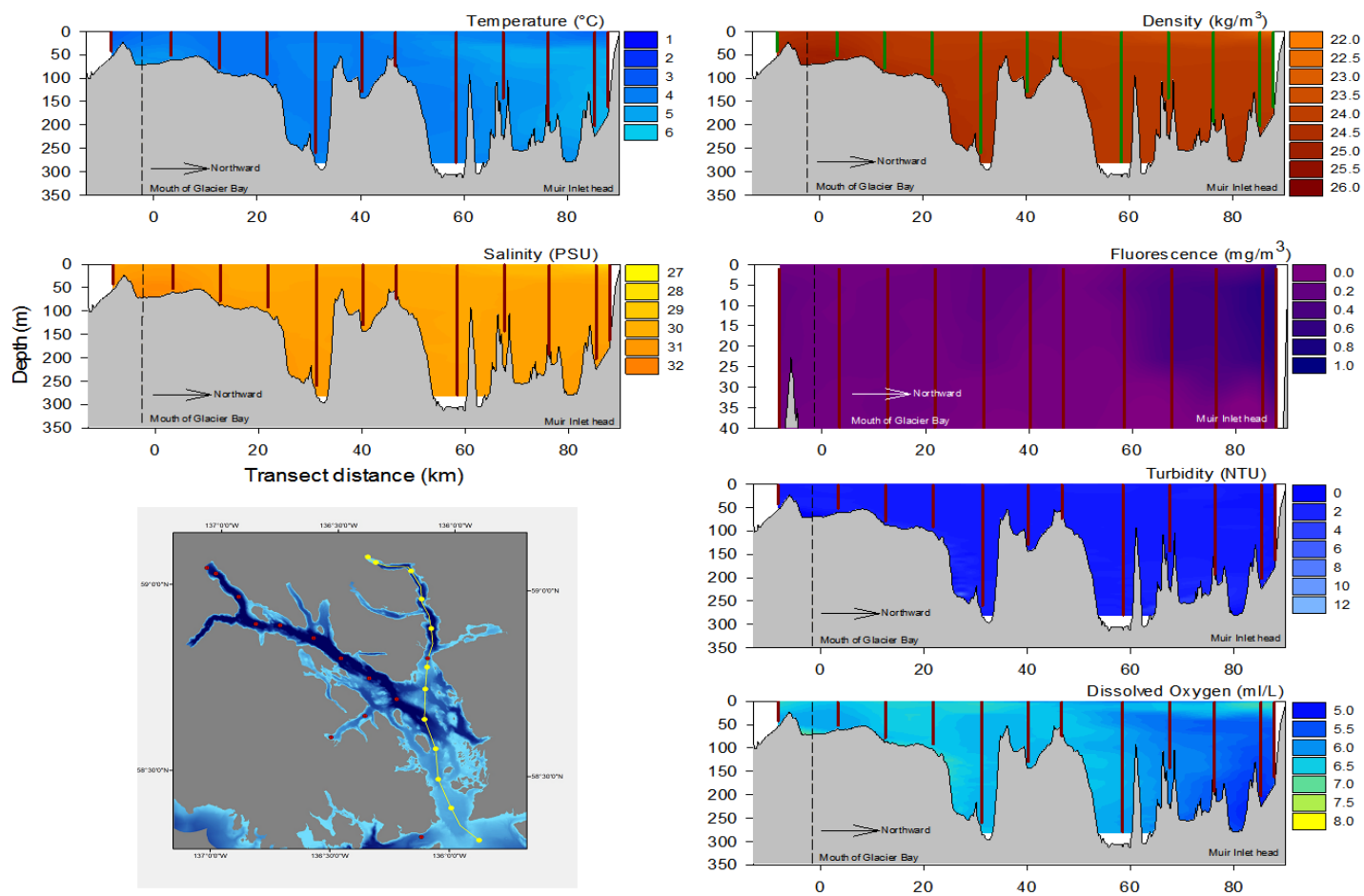


Figure 5a. Length-of-transect cross-sectional contour plots of principal oceanographic parameters for the East Arm transect for February 2012. The depth-shaded maps at bottom-left show station locations (colored dots), and transects are represented by the yellow line and use cast data from the yellow-dotted stations. On the contour plots, note the representation of the bottom (exaggerated by the depth/distance axes) along the transect line. Vertical lines indicate station locations and maximum cast depths. Use caution in interpretation: note that data are interpolated horizontally between adjacent casts, and that there are no data from depths beneath the bottoms of casts (notwithstanding any appearance of color). Also, note the foreshortened depth scale (upper 40 m only) for the Fluorescence parameter.

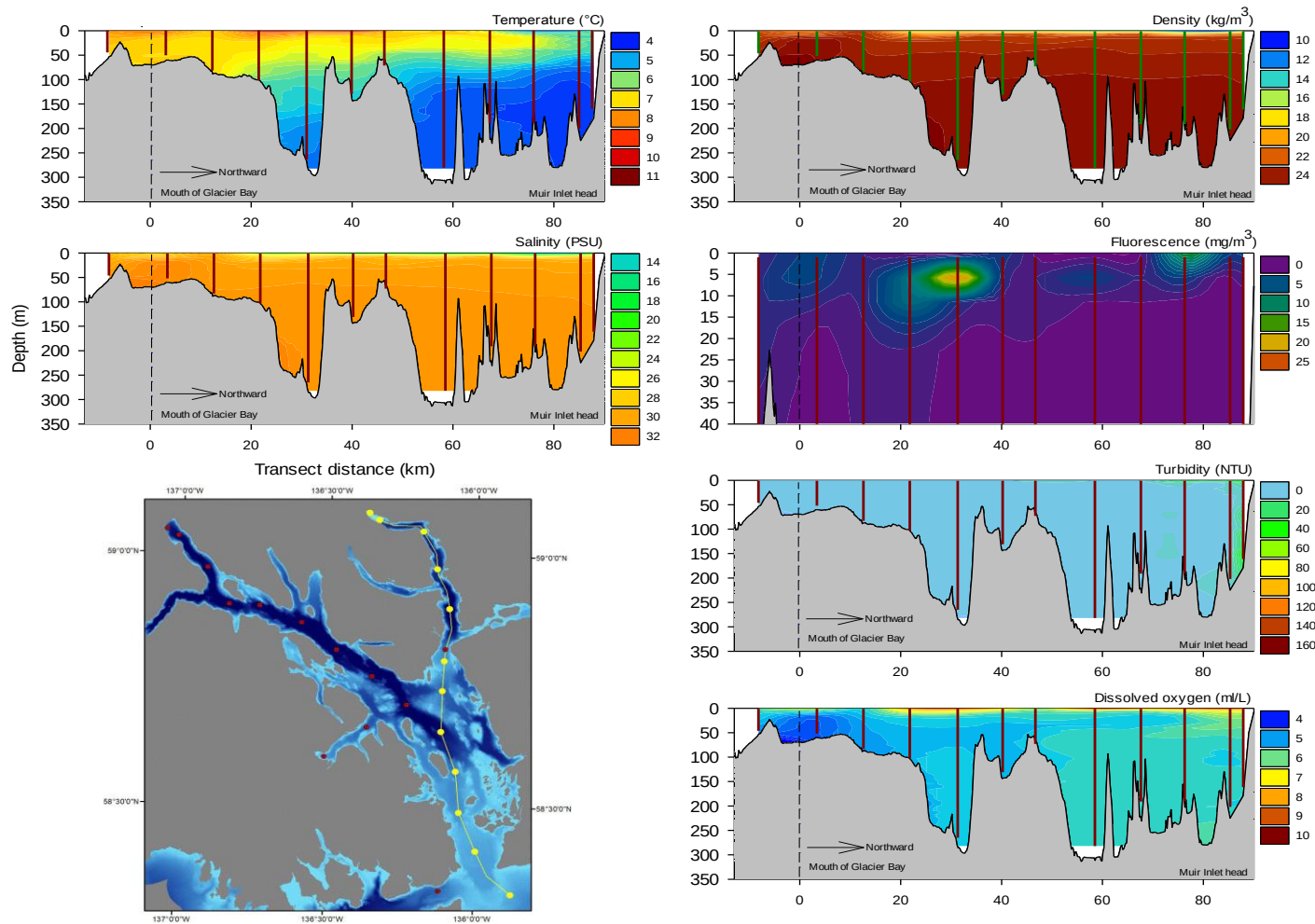


Figure 5b. Length-of-transect cross-sectional contour plots of principal oceanographic parameters for the East Arm transect for July 2012. The depth-shaded maps at bottom-left show station locations (colored dots), and transects are represented by the yellow line and use cast data from the yellow-dotted stations. On the contour plots, note the representation of the bottom (exaggerated by the depth/distance axes) along the transect line. Vertical lines indicate station locations and maximum cast depths. Use caution in interpretation: note that data are interpolated horizontally between adjacent casts, and that there are no data from depths beneath the bottoms of casts (notwithstanding any appearance of color). Also, note the foreshortened depth scale (upper 40 m only) for the Fluorescence parameter.

In an effort to maximize the comparability of the profiles between transects and seasons, the same y-axis data ranges were used for the February contour plots (both transects); similarly, the same data ranges were used for the July contour plots (both transects). Data ranges were defined for each season to encompass the variability observed (both with depth and across the transects). As might be expected, the February ranges for all parameters are considerably narrower than the July ranges because of winter mixing of the water column. The ranges of color shading were selected to proportionately reflect the numerical range breadths, so there is much less color change with depth (or across transects) in the February profiles compared to the July profiles. Again, this represents the relative degree of variability in a parameter in winter due to water column mixing. An important objective was to accurately illustrate the seasonal differences between winter and summer.

Figure 4a (West Arm transect in February 2012) shows cool (generally 3-5 °C) temperatures throughout the water column at all stations, similar to those from the 2010 mid-winter cruise (3.5-5.0 °C; Sharman 2013a), but somewhat warmer and more variable than those from the 2011 mid-winter cruise (3.3-3.6 °C; Sharman 2013b). Slightly warmer mid- to deeper-water regions occurred in upper regions of the West Arm and Tarr Inlet. Salinity and density, like temperature, were more variable in 2012 (30-32 PSU; 22-26 kg/m³) than in 2011 (31-32 PSU; 24.7-25.3 kg/m³; Sharman 2013b). No strong pycnocline was evident, and the water column could be described as quite well mixed. Fluorescence and turbidity were both quite low (generally <0.5 mg/m³; <5.0 NTU) at all stations and depths. Near-surface turbidity was slightly elevated at the extreme head of the fjord. The entire water column was well oxygenated along the entire transect, with dissolved oxygen concentrations above 5.0 ml/L. Fine-scale interpretations of horizontal length-of-transect patterns should be approached cautiously for both this and the East Arm transect and in all seasons, since data are interpolated from a limited number of casts (22) across a long distance (~100 km). Small features associated with local runoff or bathymetric variations are not closely resolved by these data.

By July (Figure 4b), West Arm temperatures were substantially warmer down to at least 100 m depth at most stations, and we observed considerable vertical structure along the entire transect. Increased temperatures and decreased salinities were most noticeable in the surface waters, and a strong near-surface pycnocline had developed in the upper 10-20 m along the entire transect. Bloom conditions were locally established, with moderate (to 10 mg/m³) levels of fluorescence concentrated in near-surface waters (generally 5-15 m; note the change in the vertical depth axis) across all but the northern-most portion of the transect. Turbidity was again quite low except at the extreme head of the inlet (all depths). Dissolved oxygen concentrations remained high across the entire transect (highest in the surface waters), with slightly depressed values in the lower bay; nowhere was there any indication of anoxia at depth.

The East Arm transect in February (Figure 5a) strongly resembles the West Arm transect for that month (Figure 4a). The water column was quite well-mixed. As with the West Arm transect in February, fluorescence and turbidity levels were generally low at all depths and across all stations. Dissolved oxygen concentrations were high.

Figure 5b shows conditions along the East Arm transect in mid-summer (July). As with the mid-summer West Arm transect, compared to February conditions the water temperatures had warmed

considerably, surface salinities had declined, and near-surface stratification was well-developed. Low levels of fluorescence were evident throughout the near-surface waters (upper 15 m), and localized “hotspots” were present in the mid-bay and in upper Muir Inlet. Turbidity levels were higher at the extreme upper inlet than in February. Dissolved oxygen was high across the entire transect, especially near the surface; there were no indications of anoxia at depth.

Discussion

Oceanographic parameters are measured by sensors that are very precise and have very high calibrated accuracy. In cases where sensors do not directly measure parameters of interest (e.g., suspended particulate concentration), they have been shown to measure a closely correlated proxy (e.g., optical backscatterance, or turbidity). However, it is important to understand that because water column samples of phytoplankton, suspended sediment, and dissolved oxygen are not collected and analyzed, data from these ancillary sensors cannot be quantitatively compared with high rigor on an inter-cruise or inter-annual basis, nor even at times within the same cruise/survey because many factors, including differing phytoplankton species assemblages and the state of health of the cells also impact the fluorescence response. The cycles of phytoplankton bloom and decline are unavoidably aliased with this (monthly) monitoring program. In addition, the phytoplankton assemblage being measured at any given place and time is ephemeral; the same measurement taken a day, a week, or two weeks earlier or later could bear little or no resemblance to the measurements taken on the date of the cruise. Nevertheless, with these caveats in mind, we can still recognize coarse patterns and gross trends because (1) high-latitude glacial fjords typically exhibit relatively strong seasonal and inter-annual signals, and (2) expected parameter trends along the length-of-fjord transect are generally well understood (Syvitsky et al. 1987).

A first glance, most measured parameters in 2012 did not appear to exhibit extreme departures from the range of variation observed in Glacier Bay in previous years (Etherington et al. 2007, Sharman 2011, Sharman 2013a, b). The standard data analysis protocol calls for closer inspection of data from the mid-summer (July) cast data from Station 04 in the central bay. In 2012, this analysis showed that waters in that location at that time were anomalously cool above 30 m, fresh between 10 and 75 m, and low-density between 10 and 50 m (Figure 3; Table 2), compared to the 1993-2012 historical mean. By way of recent-year comparison, those waters were anomalously cool, salty, and dense below 10 m in 2011; warm, fresh, and low-density in 2010; and cool, salty, and dense in 2009 (Sharman 2011; 2013a, b). The differences across years are large in terms of changes in heat and fresh water content, with means (from standard depths below 40 m) varying across years by approximately 0.9-1.6 °C for temperature, 0.39-0.62 PSU for salinity, and 0.44-0.56 kg/m³ for density. The 2012 anomalies generally resemble anomalies observed in mid-summer 2012 at similar depths at GAK1 in the northern Gulf of Alaska (<http://www.ims.uaf.edu/gak1/>).

Sharman (2013b) remarked that 2011 was the third consecutive anomalous year for temperature, salinity, and density at this station (Station 04) and time of year (July), compared to the historical means (based on up to 16 years of measurements). Of particular interest was that the anomalies swung from cool/salty/dense to warm/fresh/low density and back to cool/salty/dense across only three years. 2012 adds yet another consecutive anomalous year, this one (albeit at different, generally shallower, depths) cool, fresh, and low density. Clearly there is a high natural variability from year to year in the Glacier Bay physical habitat, and these variations may be important to the greater ecosystem. For example, metabolic rates of phytoplankton and their consumers are sensitive to temperature, and standing stock (and thereby the timing and relative abundance of grazers and subsequent consumers) may be affected in part by water temperatures.

Etherington et al. (2007) and Sharman (2010) have described a generalized model for Glacier Bay oceanography and marine production that is typified by strong seasonality and high productivity. The winter condition is characterized by vertically well-mixed waters that are presumably nutrient rich, but supportive of very low primary productivity rates because of limited light (short day length) and weak physical stratification of the water column. With the onset of spring, warming temperatures, and increasing input of fresh water (primarily from melting snow and glacial ice), a near-surface stratified layer is established, which in the presence of increasing day lengths allows for bloom conditions and the beginning of a sustained period of primary productivity. Stratification further strengthens into the summer, but phytoplankters do not deplete nutrients in the photic zone (and suffer a “bloom crash”) everywhere because Glacier Bay’s strong tidal currents and/or possibly wind-driven upwelling continue to inject nutrients from depth, in at least some “hotspot” locations. This fine balance of maintaining near-surface stratification in the presence of just enough mixing to replenish nutrients for phytoplankton growth is the key to Glacier Bay’s overall productivity. In the fall, a combination of decreasing day length and temperatures, and possibly strong storm activity that may assist with a breakdown of surface stratification, all contribute to a decline in primary productivity that ultimately develops into the dark, well-mixed, biologically constrained winter condition.

This model is well supported by 2012 observations. The 2012 patterns of increasing temperature, salinity, and density with distance from the fjord heads along the length-of-bay transect conforms to expectations, as does the concomitant decrease in turbidity and light penetration from the surface (PAR). One expects the upper fjords to be sources of high freshwater input from melting snow and ice, including tidewater glaciers and turbid outwash streams. The modeled seasonal signal likewise is well supported by 2012 observations. Water temperatures increased from early-spring minima to fall maxima, and salinities/densities were highest in April and lowest in fall. Seasonally driven injections of large volumes of cold, fresh, sediment-laden water should strongly influence the oceanography of the entire fjord even as the lower/central bay is closer and more integrally connected to the warmer, more saline oceanic waters of the Gulf of Alaska. Temperatures and salinities in this coastal fjord were relatively cool and fresh compared to open ocean conditions; they also exhibited larger seasonal variations than oceanic waters (see <http://www.pmel.noaa.gov/ocs/disdeld/disdeld.html> for time series data from Ocean Station P, 50°N, 145°W). Both of these patterns reflect responsiveness to the differences in their respective marine settings and how they respond to the regional weather and climate influences.

In late spring the foregoing physical patterns created near-surface density stratification with a relatively shallow pycnocline depth, generally above 20 m, that persisted well into fall 2012. Fluorometry data show that phytoplankters responded by increasing primary production in a “bloom” that initiated in late spring to mid-summer (April-July) at most stations and was possibly sustained at some places all the way into the fall when physical structure began to break down and the water column became increasingly well mixed. 2012 mean peak fluorescence values ranged from ~0.4-5.4 mg/m³ (somewhat higher than those observed in 2010 and 2011), but were more than an order of magnitude lower than those measured in 2009 (~8-18 mg/m³). Apparently, conditions favorable to phytoplankton growth were again weaker or less common in 2012 than in 2009.

Patterns of dissolved oxygen concentration generally tracked those of fluorometry, with values highest in spring-summer (presumably responding to high rates of primary production and the winter preconditioning) and lowest in October (likely reflecting subsequent bacterial consumption [decomposition] of organic matter). Nevertheless, mean concentration ranges of ~4.1-6.7 ml/L throughout the water column clearly indicate that deep water renewal occurs rapidly enough to prevent anoxic conditions throughout the measured water column. The January-February oxygen concentration peak in the bottom water suggests that 2012 renewal occurred in this timeframe.

Implications for Park Management

Oceanographic parameters are nearly as fundamental to informing ecosystem structure and function as weather. Things like water temperature and salinity are drivers of virtually all other marine ecosystem dynamics, just as air temperature and precipitation are critical drivers of terrestrial systems. A range of critical questions at all levels of detail—from the spatial and temporal patterns of marine primary productivity, to why Glacier Bays hosts such a diversity and abundance of marine mammals and seabirds—can be answered only in the context of oceanography.

Long-term monitoring of core oceanographic parameters is essential to a general understanding of the Glacier Bay marine ecosystem, particularly with respect to how those parameters change in space and time. Park managers embrace the natural variability and general dynamism that characterize Glacier Bay both physically and biologically, and an understanding of the spatial and temporal patterns and magnitudes of those changes is critical to informed decision-making. The measured parameters (with depth) of water temperature, salinity, sunlight penetration from the surface, in situ turbidity, dissolved oxygen concentration, and chlorophyll fluorescence are core water column characteristics that determine and describe water movement, vertical stratification, phytoplankton presence, and other biologically important conditions. This long-term monitoring program quantitatively documents ranges of natural variability as they relate to depth, horizontal distance (the length-of-fjord transect), and time (seasonally and across years). Eventually the long-term dataset will indicate directional trends across time that can be correlated with both natural and anthropogenic changes such as climate change. To the extent that managers can influence or prevent anthropogenic changes to the natural marine environment, they must first detect change that is outside the range of natural variation. This program is designed to do that, as well as to help us better understand how the marine environment controls the distribution and abundance of biological organisms.

The 2012 oceanographic data are reasonably comparable to all data collected previously by the program since its inception in 1993. Statistical anomalies in some measurements (compared to the historical mean) remain common, meaning that the range of variation in some parameters is high. This should be expected in a young, highly dynamic tidewater glacial fjord, and it is believed that long-term trend analyses are likely still premature. Glacier Bay is behaving exactly as we would expect, both spatially (with depth and along the length-of-fjord transect) and temporally (season to season and year to year). Data from this program are a valuable information source for hypothesis testing in a wide variety of process-oriented studies important to informing wise stewardship. The value of the rigorous and robust long-term dataset (now 20 years) should not be underestimated; there are relatively few such datasets anywhere.

Recommendations

The water sampling program initiated in 2011 (associated with an ocean acidification research project) is a very complementary addition to the oceanographic monitoring program. It provides the potential to more directly and accurately measure chlorophyll-a concentrations by collection of water followed by traditional filtering and digestion of phytoplankton cells to release chlorophyll that can then be quantified by regression against the fluorescence profile. Those measurements could be used to calibrate the fluorometer deployed on the CTD. Since improved understanding of Glacier Bay's biological productivity is one of the most important reasons for the oceanographic monitoring program, this opportunity should be considered.

Cast depth continues to be a parameter deserving of additional consideration. On some days at some stations wind and/or current can cause the vessel to drift during the cast. This creates line angle between the surface and the CTD, making for a cast that may be significantly shallower than the target depth (currently based solely on the length of line in the water and presuming a perfectly vertical cast). In some cases this can also mean that the target "standard oceanographic depth" determined to represent "bottom water" for a given station may not be reached by the CTD. In cases where there is significant line angle (e.g., more than thirty degrees from vertical), we should consider increasing the length of line deployed to compensate and assist with approaching the target depth. We recommend that this issue be addressed in the upcoming protocol revision.

Competing priorities and staff workload issues have conspired to create significant challenges to timely generation of annual reports. We feel strongly that some form of annual reporting remains important, and that it be more timely, yet it must be sustainable over the long term. Accordingly, the annual reports must be more easily and quickly generated with less work, and at an admittedly lower level of analyses, interpretation, and discussion. Fortunately, quality-assured raw data from each calendar year are nearly always posted to the Southeast Alaska Network website (https://science.nature.nps.gov/im/units/sean/OC_main.aspx) by the end of the following January. To complement the raw data, we recommend that annual synthetic reporting hereafter take the form of less labor-intensive and more concise Natural Resource Data Series reports.

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Appendix A. 2012 Oceanographic Parameters averaged across the upper 50 m of the Water Column

Table A1. 2012 oceanographic data summary of measured parameters (temperature, salinity, density, and vertical density gradient) at core stations, averaged across the upper 50 m of the water column. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size. Note the absence of standard deviation statistics for vertical density gradient (noisy parameter and dangerous to attempt to read too much into it).

Station	Month	Temperature (°C)					Salinity (PSU)					Density (kg/m ³)					Vertical Density Gradient (kg/m ⁴)			
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	n	Max	Depth of max (m)
01	Feb	4.26	3.95	4.62	0.23	51	31.23	30.86	31.6	0.25	51	24.76	24.50	25.02	0.18	51	0.01	52	0.04	36
	Mar	4.07	3.96	4.13	0.03	51	31.05	30.93	31.14	0.04	51	24.64	24.55	24.70	0.03	51	0.00	53	0.02	2
	Apr	4.25	4.24	4.27	0.01	51	31.09	31.07	31.14	0.02	51	24.65	24.64	24.69	0.02	51	0.00	52	0.00	39
	May	5.66	5.66	5.67	0.00	51	31.31	31.31	31.32	0.00	51	24.68	24.68	24.68	0.00	51	0.00	51	0.00	47
	Jun ^a	6.65	6.64	6.68	0.01	51	31.50	31.45	31.56	0.04	51	24.71	24.67	24.75	0.03	51	0.00	57	0.01	24
	Jul	7.37	7.19	8.03	0.28	51	30.94	27.97	31.64	1.19	51	24.17	21.75	24.74	0.97	51	0.06	49	0.39	8
	Aug	7.59	7.58	7.64	0.01	51	31.32	31.11	31.38	0.06	51	24.45	24.27	24.49	0.05	51	0.00	51	0.07	2
	Sep	7.74	7.73	7.77	0.02	51	31.03	30.62	31.51	0.26	51	24.19	23.87	24.57	0.20	51	0.01	51	0.04	43
	Oct	7.58	7.54	7.62	0.02	51	30.29	29.71	30.52	0.20	51	23.64	23.19	23.81	0.16	51	0.01	51	0.08	2
04	Feb	4.20	4.02	4.38	0.16	51	30.52	30.39	30.67	0.12	51	24.20	24.12	24.31	0.08	51	0.00	260	0.03	25
	Mar	3.91	3.34	4.22	0.31	51	30.62	30.21	30.80	0.17	51	24.31	24.03	24.43	0.11	51	0.00	262	0.05	2
	Apr	4.24	4.18	4.26	0.02	51	30.86	30.81	30.91	0.03	51	24.47	24.43	24.52	0.03	51	0.00	265	0.01	45
	May	5.01	4.68	5.79	0.40	51	30.62	29.56	31.14	0.59	51	24.21	23.28	24.62	0.51	51	0.01	250	0.17	14
	Jun ^a	6.06	5.63	6.76	0.29	51	30.39	27.39	31.05	1.01	51	23.90	21.46	24.48	0.83	51	0.02	215	0.36	4
	Jul	7.05	6.53	8.58	0.56	51	29.41	23.25	30.68	1.98	51	23.01	17.99	24.07	1.62	51	0.03	264	0.83	3
	Aug	7.47	7.25	8.44	0.31	51	29.83	23.72	30.77	1.93	51	23.29	18.38	24.05	1.55	51	0.02	253	1.45	5
	Sep	7.45	7.34	7.74	0.12	51	29.94	27.35	30.63	0.96	51	23.37	21.31	23.94	0.77	51	0.01	258	0.38	6
	Oct	7.41	6.96	7.59	0.15	51	28.95	23.99	30.54	1.98	51	22.60	18.76	23.86	1.54	51	0.02	261	0.52	4
07	Feb	4.42	4.09	4.85	0.32	51	30.48	30.33	30.68	0.14	51	24.15	24.06	24.27	0.08	51	0.00	366	0.02	26
	Mar	3.55	3.02	4.24	0.36	51	30.32	29.71	30.66	0.21	51	24.11	23.67	24.31	0.14	51	0.00	392	0.12	2
	Apr	4.35	4.25	4.41	0.04	51	30.86	30.72	30.94	0.10	51	24.46	24.35	24.53	0.07	51	0.00	410	0.04	17

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Table A1 (continued). 2012 oceanographic data summary of measured parameters (temperature, salinity, density, and vertical density gradient) at core stations, averaged across the upper 50 m of the water column. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size. Note the absence of standard deviation statistics for vertical density gradient (noisy parameter and dangerous to attempt to read too much into it).

Station	Month	Temperature (°C)					Salinity (PSU)					Density (kg/m ³)					Vertical Density Gradient (kg/m ⁴)			
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	n	Max	Depth of max (m)
7 (continued)	May	4.61	4.22	6.00	0.50	51	30.66	28.87	31.01	0.59	51	24.28	22.71	24.59	0.52	51	0.01	404	0.41	5
	Jun ^a	5.46	4.97	6.16	0.24	51	30.39	22.98	31.08	1.75	51	23.98	18.06	24.52	1.40	51	0.02	403	2.35	2
	Jul	6.84	6.45	8.31	0.46	51	29.43	16.99	30.72	2.93	51	23.06	13.15	24.12	2.35	51	0.03	397	3.43	2
	Aug	6.81	5.85	7.31	0.25	51	29.27	16.07	30.64	3.21	51	22.93	12.58	24.02	2.52	51	0.03	364	3.50	2
	Sep	7.28	6.77	8.22	0.42	51	29.52	26.08	30.49	1.34	51	23.07	20.26	23.90	1.11	51	0.01	421	0.54	7
	Oct	7.18	5.89	7.47	0.31	51	29.27	18.87	30.48	2.63	51	22.88	14.84	23.83	2.04	51	0.02	398	1.99	2
12	Feb	4.08	3.68	4.67	0.29	51	30.23	29.96	30.59	0.20	51	23.98	23.80	24.22	0.13	51	0.00	251	0.04	22
	Mar	3.52	2.54	4.37	0.47	51	30.22	29.77	30.67	0.23	51	24.03	23.75	24.31	0.15	51	0.00	254	0.06	5
	Apr	4.21	3.74	4.39	0.20	51	30.82	30.37	30.95	0.19	51	24.45	24.13	24.53	0.13	51	0.00	252	0.08	10
	May	4.59	4.22	5.83	0.46	51	30.07	24.83	31.02	1.77	51	23.81	19.62	24.60	1.44	51	0.02	265	0.80	8
	Jun ^a	4.31	2.64	4.73	0.42	51	29.73	16.83	30.96	3.22	51	23.57	13.42	24.54	2.53	51	0.05	215	3.86	3
	Jul	5.25	4.19	5.50	0.28	51	28.99	14.62	30.61	3.41	51	22.89	11.61	24.15	2.68	51	0.05	264	3.81	2
	Aug	5.69	2.96	6.40	0.57	51	28.86	7.07	30.52	4.33	51	22.73	5.62	24.06	3.39	51	0.06	265	4.77	1
	Sep	6.33	5.66	7.09	0.36	51	29.10	16.27	30.40	3.01	51	22.85	12.82	23.94	2.37	51	0.04	264	3.28	2
	Oct	6.37	3.18	6.71	0.48	51	28.59	4.13	30.32	3.91	51	22.44	3.35	23.82	3.06	51	0.05	263	8.03	1
13	Feb	4.14	4.04	4.18	0.03	51	30.54	30.33	30.66	0.10	51	24.23	24.07	24.32	0.08	51	0.00	129	0.02	4
	Mar	3.74	3.44	4.18	0.21	51	30.47	30.07	30.72	0.13	51	24.21	23.91	24.37	0.09	51	0.00	131	0.09	2
	Apr	4.34	4.20	4.53	0.08	51	30.79	30.59	30.95	0.12	51	24.41	24.23	24.55	0.10	51	0.00	127	0.02	26
	May	4.92	4.70	5.64	0.30	51	30.72	29.48	31.10	0.54	51	24.29	23.24	24.61	0.46	51	0.01	118	0.20	8
	Jun ^a	6.11	5.94	6.27	0.09	51	30.56	28.66	31.09	0.78	51	24.03	22.52	24.47	0.62	51	0.02	125	0.21	6
	Jul	7.13	6.64	8.99	0.54	51	29.60	20.04	30.63	2.22	51	23.16	15.43	24.02	1.80	51	0.07	130	2.82	2
	Sep	7.33	7.13	8.02	0.25	51	29.86	25.94	30.56	1.24	51	23.33	20.17	23.90	1.00	51	0.03	131	0.63	5
	Oct	7.22	6.64	7.40	0.14	51	29.37	22.17	30.53	2.02	51	22.96	17.37	23.87	1.57	51	0.05	130	1.28	2

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Table A1 (continued). 2012 oceanographic data summary of measured parameters (temperature, salinity, density, and vertical density gradient) at core stations, averaged across the upper 50 m of the water column. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size. Note the absence of standard deviation statistics for vertical density gradient (noisy parameter and dangerous to attempt to read too much into it).

Station	Month	Temperature (°C)					Salinity (PSU)					Density (kg/m ³)					Vertical Density Gradient (kg/m ⁴)			
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	n	Max	Depth of max (m)
16	Feb	4.64	4.29	4.88	0.21	51	30.36	29.98	30.55	0.18	51	24.03	23.77	24.17	0.12	51	0.00	280	0.04	6
	Mar	4.23	3.37	4.50	0.27	51	30.42	29.77	30.63	0.21	51	24.12	23.68	24.26	0.15	51	0.00	286	0.09	3
	Apr	4.33	4.15	5.01	0.23	51	30.72	30.22	30.85	0.15	51	24.36	23.88	24.47	0.15	51	0.00	276	0.11	3
	May	4.56	4.24	5.97	0.45	51	30.40	27.26	30.92	0.90	51	24.08	21.44	24.52	0.76	51	0.01	284	0.79	3
	Jun ^a	5.37	4.81	7.76	0.61	51	30.14	21.01	31.02	2.15	51	23.79	16.34	24.52	1.76	51	0.03	288	2.34	2
	Jul	6.70	5.97	7.71	0.41	51	29.42	19.10	30.68	2.59	51	23.07	14.91	24.13	2.07	51	0.03	281	2.35	2
	Aug	6.72	6.47	7.37	0.23	51	29.56	20.00	30.69	2.37	51	23.17	15.59	24.09	1.88	51	0.03	282	2.27	2
	Sep	6.99	6.76	7.43	0.21	51	29.56	25.83	30.52	1.50	51	23.14	20.15	23.92	1.20	51	0.02	273	0.63	7
	Oct	6.99	5.63	7.19	0.31	51	28.99	14.10	30.45	3.39	51	22.69	11.11	23.84	2.64	51	0.05	282	4.42	2
20	Feb	4.32	3.34	5.41	0.67	51	29.87	28.37	30.63	0.68	51	23.68	22.57	24.17	0.48	51	0.01	162	0.20	6
	Mar	4.87	4.20	5.16	0.24	51	30.47	29.85	30.69	0.21	51	24.10	23.67	24.26	0.14	51	0.00	164	0.10	2
	Apr	4.39	4.18	5.93	0.44	51	30.72	29.81	30.83	0.22	51	24.34	23.46	24.45	0.22	51	0.01	161	0.27	2
	May	4.73	4.14	6.62	0.76	51	30.08	22.75	30.95	1.75	51	23.81	17.86	24.55	1.44	51	0.04	163	1.90	2
	Jun ^a	4.60	4.15	6.90	0.75	51	30.43	27.28	30.91	0.87	51	24.10	21.35	24.52	0.77	51	0.02	160	0.57	2
	Jul	5.70	5.42	6.06	0.13	51	29.13	19.34	30.50	2.82	51	22.95	15.21	24.06	2.24	51	0.06	160	1.53	4
	Aug	5.75	5.18	6.18	0.21	51	29.08	16.98	30.49	3.30	51	22.90	13.41	24.04	2.60	51	0.07	158	2.16	2
	Sep	6.18	3.92	6.61	0.50	51	28.66	14.25	30.33	3.62	51	22.52	11.33	23.86	2.82	51	0.08	167	3.10	2
	Oct	6.18	3.79	6.61	0.67	51	27.76	8.89	30.27	5.38	51	21.81	7.07	23.80	4.19	51	0.11	161	3.04	3

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Table A2. 2012 oceanographic data summary of measured parameters (fluorescence, dissolved oxygen, OBS, and PAR) at core stations, averaged across the upper 50 m of the water column. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size. Note the absence of standard deviation statistics for PAR (decreases exponentially from the surface, so SD has little meaning).

Station	Month	Fluorescence (mg/m ³)					Dissolved Oxygen (mg/L)					OBS (NTU)					PAR (μE/cm ² * s)		
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
07	Feb	0.09	0.00	0.20	0.07	51	6.34	6.00	6.64	0.23	51	1.19	1.09	1.35	0.06	51	14.22	0.00	144.46
	Mar	0.50	0.17	0.84	0.21	51	5.90	5.24	6.21	0.24	51	1.17	1.09	1.25	0.04	51	35.66	0.14	271.79
	Apr	0.76	0.11	3.01	0.89	51	5.94	5.69	6.53	0.33	51	0.99	0.94	1.08	0.03	51	20.40	0.10	120.33
	May	2.78	0.09	13.45	3.22	51	6.16	5.69	8.35	0.73	51	1.27	0.96	2.09	0.30	51	18.45	0.00	275.41
	Jun ^a	1.06	0.10	12.17	2.52	51	6.51	6.07	9.20	0.80	51	1.10	0.85	2.64	0.47	51	33.50	0.04	459.59
	Jul	1.14	0.17	13.70	2.49	51	5.86	5.29	9.53	1.07	51	1.34	1.03	3.96	0.71	51	22.52	0.00	187.71
	Aug	1.67	0.23	17.45	3.07	51	5.67	5.04	9.84	1.16	51	1.36	0.97	4.49	0.86	51	4.82	0.00	81.10
	Sep	1.19	0.04	5.03	1.43	51	5.20	4.72	6.82	0.63	51	1.04	0.94	1.24	0.09	51	16.10	0.00	177.51
12	Oct	0.20	0.01	0.92	0.23	51	4.83	4.50	6.84	0.57	51	1.36	0.88	3.78	0.78	51	12.80	0.00	150.72
	Feb	0.10	0.00	0.18	0.05	51	6.53	6.18	6.73	0.17	51	2.47	1.54	4.54	0.84	51	5.35	0.00	85.01
	Mar	0.31	0.04	0.58	0.15	51	5.97	5.39	7.48	0.54	51	1.72	1.37	3.72	0.58	51	22.77	0.00	337.18
	Apr	0.35	0.06	1.37	0.39	51	5.78	5.62	6.27	0.20	51	1.43	1.14	2.32	0.38	51	51.30	0.00	720.80
	May	2.85	0.13	8.92	3.11	51	6.26	5.64	8.57	1.01	51	2.79	1.40	9.26	2.01	51	13.83	0.00	272.38
	Jun ^a	0.27	0.05	0.82	0.23	51	5.87	5.30	7.93	0.83	51	2.88	1.64	7.79	1.84	51	11.21	0.00	209.36
	Jul	0.41	0.00	1.53	0.32	51	6.38	5.86	8.39	0.57	51	41.34	6.09	88.46	24.96	51	33.33	0.00	678.90
	Aug	0.49	0.00	1.93	0.49	51	6.09	5.66	8.38	0.66	51	23.99	5.12	198.78	41.44	51	6.38	0.00	197.74
13	Sep	0.79	0.00	5.82	1.58	51	5.55	5.24	7.46	0.51	51	3.80	2.12	16.57	3.11	51	7.53	0.00	162.03
	Oct	0.10	0.00	0.50	0.14	51	5.37	5.04	9.55	0.71	51	5.89	0.00	29.63	7.44	51	15.80	0.00	259.23
	Feb	0.09	0.02	0.23	0.06	51	6.40	5.79	6.59	0.14	51	1.38	1.26	1.50	0.06	51	7.83	0.00	69.97
	Mar	0.49	0.13	0.74	0.17	51	5.87	5.25	6.05	0.19	51	1.26	1.17	1.35	0.04	51	27.26	0.07	212.65
	Apr	1.10	0.11	2.24	0.72	51	6.04	5.74	6.37	0.22	51	1.02	0.92	1.22	0.07	51	12.72	0.00	85.91
	May	2.80	0.33	10.62	3.25	51	6.46	6.07	7.71	0.49	51	1.38	1.10	2.46	0.29	51	10.51	0.00	161.15
	Jun ^a	1.38	0.35	5.99	1.54	51	6.56	6.06	7.72	0.58	51	1.19	0.97	2.35	0.39	51	22.50	0.00	313.72

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Table A2 (continued). 2012 oceanographic data summary of measured parameters (fluorescence, dissolved oxygen, OBS, and PAR) at core stations, averaged across the upper 50 m of the water column. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size. Note the absence of standard deviation statistics for PAR (decreases exponentially from the surface, so SD has little meaning).

Station	Month	Fluorescence (mg/m ³)					Dissolved Oxygen (mg/L)					OBS (NTU)					PAR (μE/cm ² * s)		
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
13 (continued)	Jul	1.18	0.18	5.63	1.27	51	5.65	5.27	7.43	0.54	51	1.40	1.01	3.22	0.55	51	20.11	0.00	269.05
	Aug	0.90	0.34	4.88	1.01	51	5.25	4.98	6.80	0.40	51	1.27	1.04	2.86	0.40	51	9.28	0.00	114.26
	Sep	1.14	0.22	5.18	1.30	51	4.99	4.65	6.77	0.55	51	1.06	0.90	1.64	0.16	51	20.93	0.00	224.43
	Oct	0.22	0.02	1.14	0.29	51	4.84	4.53	6.25	0.42	51	1.30	0.78	3.07	0.68	51	15.17	0.00	199.80
16	Feb	0.10	0.00	0.28	0.09	51	6.05	5.49	6.37	0.21	51	1.45	1.20	1.87	0.21	51	14.52	0.00	140.53
	Mar	0.46	0.09	0.85	0.23	51	5.81	5.57	6.22	0.14	51	1.25	1.15	1.32	0.04	51	13.98	0.00	110.66
	Apr	0.74	0.10	2.73	0.87	51	5.95	5.80	6.85	0.21	51	1.05	0.97	1.19	0.06	51	14.63	0.00	116.82
	May	5.36	0.54	22.92	6.60	51	6.54	5.92	9.87	0.96	51	1.87	1.25	3.63	0.73	51	3.83	0.00	71.53
	Jun ^a	1.71	0.12	13.21	3.14	51	6.68	5.95	10.33	1.11	51	1.46	0.93	5.00	1.05	51	7.49	0.00	126.79
	Jul	0.99	0.00	12.80	2.16	51	5.86	5.37	9.30	0.81	51	1.46	1.03	3.66	0.72	51	22.60	0.00	355.15
	Aug	1.05	0.19	5.16	1.42	51	5.55	5.14	7.42	0.61	51	1.19	0.92	3.02	0.52	51	11.51	0.00	143.94
	Sep	0.94	0.02	4.06	1.20	51	5.25	4.79	6.75	0.61	51	1.02	0.78	1.87	0.27	51	18.64	0.00	210.97
	Oct	0.14	0.02	0.60	0.16	51	4.99	4.67	7.18	0.54	51	1.44	0.94	4.03	0.83	51	32.59	0.00	506.16
20	Feb	0.45	0.00	0.75	0.29	51	6.24	5.62	6.86	0.40	51	1.22	0.79	1.67	0.24	51	4.51	0.00	39.99
	Mar	0.42	0.02	0.87	0.24	51	5.40	5.14	5.86	0.21	51	1.12	1.01	1.23	0.05	51	18.68	0.11	129.22
	Apr	4.40	0.12	70.08	12.77	51	6.35	5.92	11.69	1.26	51	1.39	1.16	4.18	0.55	51	10.36	0.00	116.08
	May	4.14	0.29	12.15	3.56	51	7.40	5.60	12.25	2.30	51	2.43	1.28	7.01	1.36	51	8.95	0.00	161.17
	Jun ^a	0.28	0.02	2.88	0.63	51	6.18	5.24	11.40	1.63	51	3.42	1.49	16.15	3.20	51	4.45	0.00	100.11
	Jul	0.60	0.05	4.81	1.29	51	6.38	5.87	8.81	0.64	51	10.83	4.75	38.69	7.92	51	5.04	0.00	121.01
	Aug	0.24	0.06	1.30	0.31	51	5.99	5.77	7.16	0.36	51	22.79	13.35	103.50	18.59	51	0.18	0.00	4.56
	Sep	0.28	0.00	1.61	0.51	51	5.75	5.45	8.14	0.59	51	14.63	3.63	128.06	27.65	51	0.11	0.00	2.69
	Oct	0.15	0.00	1.00	0.24	51	5.56	5.22	8.06	0.67	51	7.63	4.67	21.48	3.76	51	1.00	0.00	23.34

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Appendix B. 2012 Oceanographic Parameters averaged across a 10-m Vertical Depth Band representing “Bottom Water”

Table B1. 2012 oceanographic data summary of measured parameters (temperature, salinity, density, and fluorescence) at core stations, averaged across a 10-m vertical depth band centered on a representative “bottom water” depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size.

Station	Depth	Month	Temperature (°C)					Salinity (PSU)					Density (kg/m ³)					Fluorescence (mg/m ³)				
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n
01	40	Feb	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Mar	4.08	4.08	4.08	0.00	10	31.06	31.06	31.07	0.00	10	24.65	24.64	24.65	0.00	10	0.29	0.27	0.31	0.01	10
		Apr	4.26	4.26	4.27	0.00	10	31.11	31.09	31.13	0.02	10	24.67	24.65	24.69	0.01	10	1.13	1.06	1.23	0.07	10
		May	5.66	5.66	5.66	0.00	10	31.31	31.31	31.31	0.00	10	24.68	24.68	24.68	0.00	10	1.81	1.75	1.94	0.06	10
		Jun ^a	6.65	6.65	6.65	0.00	10	31.55	31.54	31.55	0.01	10	24.75	24.74	24.75	0.00	10	1.12	1.09	1.14	0.02	10
		Jul	7.20	7.20	7.20	0.00	10	31.63	31.63	31.63	0.00	10	24.74	24.74	24.74	0.00	10	0.77	0.75	0.80	0.02	10
		Aug	7.58	7.58	7.58	0.00	10	31.37	31.37	31.38	0.00	10	24.49	24.48	24.49	0.00	10	1.07	1.05	1.10	0.02	10
		Sep	7.76	7.76	7.77	0.01	10	31.30	31.24	31.46	0.08	10	24.40	24.35	24.53	0.06	10	0.70	0.60	0.77	0.05	10
04	200	Oct	7.60	7.60	7.61	0.00	10	30.44	30.42	30.46	0.02	10	23.75	23.74	23.77	0.01	10	0.34	0.32	0.38	0.02	10
		Feb	4.17	4.17	4.17	0.00	10	30.85	30.84	30.85	0.00	10	24.47	24.47	24.47	0.00	10	0.08	0.06	0.10	0.02	10
		Mar	4.22	4.21	4.22	0.00	10	30.92	30.92	30.92	0.00	10	24.52	24.52	24.52	0.00	10	0.13	0.11	0.14	0.01	10
		Apr	4.10	4.10	4.10	0.00	10	31.04	31.03	31.04	0.00	10	24.63	24.62	24.63	0.00	10	0.31	0.28	0.36	0.02	10
		May	5.16	5.14	5.19	0.02	10	31.27	31.26	31.27	0.00	10	24.70	24.70	24.70	0.00	10	0.52	0.50	0.54	0.02	10
		Jun ^a	4.96	4.94	4.97	0.01	10	31.23	31.23	31.24	0.00	10	24.69	24.69	24.70	0.00	10	0.09	0.07	0.11	0.01	10
		Jul	4.93	4.91	4.94	0.01	10	31.11	31.10	31.11	0.00	10	24.60	24.59	24.60	0.00	10	0.04	0.02	0.05	0.01	10
		Aug	5.07	5.07	5.08	0.01	10	31.06	31.06	31.06	0.00	10	24.55	24.54	24.55	0.00	10	0.31	0.29	0.33	0.01	10
07	200	Sep	5.62	5.61	5.62	0.00	10	30.94	30.94	30.94	0.00	10	24.39	24.39	24.39	0.00	10	0.08	0.06	0.10	0.02	10
		Oct	5.95	5.93	5.97	0.01	10	30.90	30.90	30.90	0.00	10	24.32	24.32	24.32	0.00	10	0.34	0.32	0.37	0.02	10
		Feb	4.19	4.18	4.19	0.01	10	30.84	30.83	30.84	0.00	10	24.46	24.46	24.46	0.00	10	0.07	0.06	0.09	0.01	10
		Mar	4.30	4.28	4.30	0.01	10	30.94	30.94	30.95	0.00	10	24.53	24.53	24.54	0.00	10	0.07	0.04	0.11	0.02	10
		Apr	4.10	4.10	4.11	0.00	10	31.03	31.03	31.04	0.00	10	24.62	24.62	24.62	0.00	10	0.21	0.20	0.23	0.01	10

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Table B1 (continued). 2012 oceanographic data summary of measured parameters (temperature, salinity, density, and fluorescence) at core stations, averaged across a 10-m vertical depth band centered on a representative “bottom water” depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size.

Station	Depth	Month	Temperature (°C)					Salinity (PSU)					Density (kg/m ³)					Fluorescence (mg/m ³)				
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n
07 (continued)	200	May	4.50	4.50	4.51	0.01	10	31.17	31.17	31.18	0.00	10	24.70	24.69	24.70	0.00	10	0.12	0.11	0.14	0.01	10
		Jun ^a	4.38	4.36	4.38	0.01	10	31.14	31.14	31.14	0.00	10	24.68	24.68	24.68	0.00	10	0.17	0.13	0.20	0.02	10
		Jul	4.82	4.81	4.82	0.00	10	31.08	31.08	31.09	0.00	10	24.59	24.59	24.60	0.00	10	0.05	0.04	0.08	0.01	10
		Aug	4.99	4.98	5.01	0.01	10	31.02	31.01	31.03	0.01	10	24.52	24.51	24.53	0.01	10	0.00	0.00	0.00	0.00	10
		Sep	5.40	5.35	5.46	0.04	10	30.91	30.90	30.92	0.01	10	24.39	24.38	24.41	0.01	10	0.00	0.00	0.00	0.00	10
		Oct	5.72	5.68	5.78	0.04	10	30.89	30.88	30.89	0.00	10	24.34	24.33	24.34	0.00	10	0.00	0.00	0.00	0.00	10
12	200	Feb	4.92	4.86	4.96	0.04	10	30.91	30.90	30.91	0.01	10	24.44	24.44	24.44	0.00	10	0.00	0.00	0.00	0.00	10
		Mar	4.50	4.48	4.52	0.02	10	30.96	30.96	30.96	0.00	10	24.52	24.52	24.53	0.00	10	0.00	0.00	0.00	0.00	10
		Apr	4.17	4.16	4.17	0.00	10	31.05	31.05	31.05	0.00	10	24.63	24.63	24.63	0.00	10	0.18	0.16	0.20	0.02	10
		May	4.26	4.26	4.27	0.00	10	31.13	31.13	31.14	0.00	10	24.69	24.69	24.69	0.00	10	0.06	0.04	0.08	0.02	10
		Jun ^a	4.27	4.27	4.28	0.00	10	31.13	31.13	31.13	0.00	10	24.68	24.68	24.68	0.00	10	0.25	0.24	0.26	0.01	10
		Jul	4.39	4.39	4.40	0.00	10	31.00	30.99	31.01	0.01	10	24.57	24.56	24.57	0.00	10	0.10	0.08	0.12	0.01	10
		Aug	4.59	4.57	4.61	0.02	10	30.92	30.91	30.93	0.01	10	24.49	24.48	24.50	0.01	10	0.34	0.31	0.37	0.02	10
		Sep	4.85	4.83	4.87	0.02	10	30.84	30.83	30.85	0.01	10	24.39	24.38	24.40	0.01	10	0.07	0.04	0.09	0.02	10
		Oct	5.04	5.03	5.04	0.00	10	30.79	30.79	30.79	0.00	10	24.34	24.34	24.34	0.00	10	0.30	0.27	0.33	0.02	10
13	200	Feb	4.15	4.15	4.15	0.00	10	30.74	30.74	30.74	0.00	10	24.39	24.39	24.39	0.00	10	0.03	0.02	0.06	0.02	10
		Mar	4.26	4.26	4.26	0.00	10	30.91	30.91	30.91	0.00	10	24.51	24.51	24.51	0.00	10	0.06	0.04	0.08	0.01	10
		Apr	4.07	4.07	4.08	0.00	10	30.99	30.99	31.00	0.00	10	24.59	24.59	24.60	0.00	10	0.20	0.20	0.21	0.01	10
		May	4.77	4.70	4.79	0.03	10	31.16	31.14	31.17	0.01	10	24.66	24.65	24.66	0.01	10	0.22	0.20	0.26	0.02	10
		Jun ^a	5.27	5.25	5.29	0.02	10	31.16	31.16	31.17	0.00	10	24.61	24.60	24.61	0.00	10	0.12	0.12	0.14	0.01	10
		Jul	5.77	5.74	5.82	0.03	10	30.99	30.97	30.99	0.01	10	24.41	24.39	24.42	0.01	10	0.02	0.00	0.04	0.01	10
		Aug	6.23	6.15	6.31	0.05	10	30.85	30.83	30.88	0.01	10	24.25	24.22	24.28	0.02	10	0.34	0.33	0.37	0.01	10
		Sep	6.43	6.39	6.49	0.04	10	30.79	30.78	30.79	0.01	10	24.17	24.16	24.18	0.01	10	0.30	0.28	0.32	0.01	10
		Oct	6.77	6.70	6.82	0.04	10	30.72	30.71	30.74	0.02	10	24.08	24.06	24.11	0.02	10	0.04	0.03	0.06	0.01	10

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Table B1 (continued). 2012 oceanographic data summary of measured parameters (temperature, salinity, density, and fluorescence) at core stations, averaged across a 10-m vertical depth band centered on a representative “bottom water” depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size.

Station	Month	Depth	Temperature (°C)					Salinity (PSU)					Density (kg/m ³)					Fluorescence (mg/m ³)				
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n
16	Feb	200	4.22	4.22	4.22	0.00	10	30.60	30.60	30.60	0.00	10	24.26	24.26	24.26	0.00	10	0.04	0.02	0.06	0.01	10
	Mar	200	4.24	4.24	4.24	0.00	10	30.75	30.75	30.75	0.00	10	24.39	24.39	24.39	0.00	10	0.04	0.02	0.06	0.01	10
	Apr	200	4.14	4.14	4.14	0.00	10	30.91	30.91	30.91	0.00	10	24.52	24.52	24.52	0.00	10	0.30	0.28	0.32	0.01	10
	May	200	4.39	4.38	4.40	0.01	10	31.05	31.05	31.05	0.00	10	24.61	24.61	24.61	0.00	10	0.06	0.02	0.08	0.02	10
	Jun ^a	200	4.62	4.60	4.63	0.01	10	31.08	31.08	31.08	0.00	10	24.61	24.61	24.61	0.00	10	0.03	0.01	0.05	0.02	10
	Jul	200	4.52	4.51	4.52	0.00	10	31.03	31.03	31.03	0.00	10	24.58	24.58	24.58	0.00	10	0.08	0.06	0.08	0.01	10
	Aug	200	4.53	4.53	4.53	0.00	10	30.99	30.98	30.99	0.00	10	24.54	24.54	24.55	0.00	10	0.24	0.23	0.28	0.02	10
	Sep	200	4.74	4.73	4.74	0.00	10	30.94	30.94	30.94	0.00	10	24.48	24.48	24.49	0.00	10	0.25	0.24	0.27	0.01	10
	Oct	200	4.87	4.86	4.88	0.01	10	30.90	30.90	30.90	0.00	10	24.44	24.44	24.44	0.00	10	0.00	0.00	0.02	0.01	10
20	Feb	125	5.36	5.35	5.37	0.01	10	30.72	30.72	30.73	0.00	10	24.25	24.24	24.25	0.00	10	0.00	0.00	0.00	0.00	10
	Mar	125	4.39	4.37	4.44	0.02	10	30.72	30.71	30.72	0.00	10	24.35	24.34	24.35	0.00	10	0.01	0.00	0.02	0.01	10
	Apr	125	4.17	4.17	4.17	0.00	10	30.85	30.85	30.85	0.00	10	24.47	24.47	24.47	0.00	10	0.23	0.21	0.24	0.01	10
	May	125	4.23	4.23	4.24	0.00	10	31.00	31.00	31.00	0.00	10	24.59	24.59	24.59	0.00	10	0.16	0.12	0.23	0.04	10
	Jun ^a	125	4.26	4.26	4.26	0.00	10	31.01	31.01	31.01	0.00	10	24.59	24.59	24.59	0.00	10	0.06	0.04	0.08	0.02	10
	Jul	125	4.39	4.39	4.40	0.00	10	30.87	30.84	30.88	0.01	10	24.46	24.44	24.47	0.01	10	0.13	0.11	0.15	0.01	10
	Aug	125	4.65	4.56	4.72	0.05	10	30.76	30.74	30.79	0.02	10	24.35	24.33	24.39	0.02	10	0.36	0.32	0.38	0.02	10
	Sep	125	4.86	4.81	4.96	0.06	10	30.72	30.69	30.75	0.02	10	24.30	24.26	24.33	0.02	10	0.25	0.20	0.27	0.02	10
	Oct	125	5.10	5.06	5.20	0.05	10	30.66	30.63	30.68	0.02	10	24.23	24.19	24.24	0.02	10	0.13	0.10	0.17	0.03	10

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Table B2. 2012 oceanographic data summary of measured parameters (dissolved oxygen, OBS, and PAR) at core stations, averaged across a 10-m vertical depth band centered on a representative “bottom water” depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size. Note the absence of the SD statistic for PAR (decreases exponentially from the surface, so SD has little meaning).

Station	Depth	Month	Dissolved Oxygen (mg/L)					OBS (NTU)					PAR (µE/cm2 * s)		
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
01	40	Feb	6.10	6.04	6.21	0.05	30	1.64	1.54	1.73	0.04	30	0.00	0.00	0.02
		Mar	5.74	5.73	5.74	0.00	10	1.51	1.45	1.59	0.05	10	0.00	0.00	0.01
		Apr	6.24	6.23	6.26	0.01	10	1.21	1.11	1.39	0.10	10	0.00	0.00	0.00
		May	6.26	6.25	6.26	0.00	10	2.68	2.54	2.95	0.13	10	0.00	0.00	0.00
		Jun ^a	5.71	5.70	5.72	0.01	10	1.22	1.20	1.25	0.02	10	0.18	0.02	0.44
		Jul	4.56	4.56	4.57	0.00	10	1.42	0.83	1.85	0.37	10	0.00	0.00	0.00
		Aug	4.30	4.29	4.30	0.00	10	2.43	2.35	2.54	0.06	10	0.00	0.00	0.00
		Sep	4.30	4.23	4.35	0.05	10	1.68	1.61	1.78	0.06	10	0.01	0.00	0.04
04	200	Oct	4.70	4.68	4.71	0.01	10	1.79	1.72	1.85	0.04	10	0.00	0.00	0.00
		Feb	6.37	6.36	6.38	0.00	10	1.61	1.59	1.67	0.03	10	0.00	0.00	0.00
		Mar	5.70	5.69	5.71	0.00	10	1.42	1.34	1.48	0.04	10	0.00	0.00	0.00
		Apr	6.04	6.03	6.05	0.01	10	1.03	0.97	1.11	0.04	10	0.00	0.00	0.00
		May	6.19	6.18	6.20	0.00	10	1.25	1.17	1.33	0.04	10	0.00	0.00	0.00
		Jun ^a	5.96	5.96	5.97	0.01	10	0.88	0.82	0.91	0.03	10	0.00	0.00	0.00
		Jul	5.53	5.53	5.54	0.01	10	1.22	1.18	1.30	0.04	10	0.00	0.00	0.00
		Aug	5.42	5.41	5.43	0.00	10	1.40	1.35	1.47	0.04	10	0.00	0.00	0.00
07	200	Sep	5.10	5.09	5.11	0.01	10	1.22	1.19	1.30	0.04	10	0.00	0.00	0.00
		Oct	4.81	4.80	4.81	0.01	10	1.77	1.68	1.89	0.08	10	0.00	0.00	0.00
		Feb	6.30	6.28	6.31	0.01	10	1.47	1.38	1.53	0.04	10	0.00	0.00	0.00
		Mar	5.64	5.61	5.66	0.02	10	1.34	1.30	1.40	0.04	10	0.00	0.00	0.00
		Apr	5.94	5.94	5.95	0.00	10	1.07	1.00	1.11	0.04	10	0.00	0.00	0.00
		May	5.98	5.97	5.98	0.00	10	0.89	0.87	0.95	0.03	10	0.00	0.00	0.00
		Jun ^a	5.86	5.85	5.87	0.01	10	0.91	0.88	0.98	0.04	10	0.00	0.00	0.00
		Jul	5.56	5.55	5.57	0.01	10	1.01	0.97	1.06	0.03	10	0.00	0.00	0.00

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Table B2 (continued). 2012 oceanographic data summary of measured parameters (dissolved oxygen, OBS, and PAR) at core stations, averaged across a 10-m vertical depth band centered on a representative “bottom water” depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size. Note the absence of the SD statistic for PAR (decreases exponentially from the surface, so SD has little meaning).

Station	Depth	Month	Dissolved Oxygen (mg/L)					OBS (NTU)					PAR ($\mu\text{E}/\text{cm}^2 \cdot \text{s}$)		
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
07 (continued)	200	Aug	5.46	5.45	5.47	0.01	10	1.17	1.15	1.21	0.02	10	0.00	0.00	0.00
		Sep	5.32	5.31	5.34	0.01	10	1.01	0.95	1.03	0.03	10	0.00	0.00	0.00
		Oct	4.99	4.94	5.02	0.03	10	1.30	1.27	1.37	0.03	10	0.00	0.00	0.00
12	200	Feb	5.81	5.78	5.83	0.02	10	1.39	1.29	1.45	0.06	10	0.00	0.00	0.00
		Mar	5.24	5.21	5.26	0.02	10	1.64	1.51	1.85	0.13	10	0.00	0.00	0.00
		Apr	5.80	5.78	5.81	0.01	10	1.30	1.26	1.35	0.03	10	0.00	0.00	0.00
		May	5.79	5.76	5.81	0.02	10	1.22	1.05	1.73	0.18	10	0.00	0.00	0.00
		Jun ^a	5.70	5.69	5.70	0.00	10	1.55	1.49	1.61	0.04	10	0.00	0.00	0.00
		Jul	5.55	5.54	5.56	0.01	10	7.90	6.01	8.83	0.89	10	0.00	0.00	0.00
		Aug	5.55	5.54	5.56	0.01	10	43.92	41.07	45.83	1.81	10	0.00	0.00	0.00
		Sep	5.45	5.45	5.45	0.00	10	6.08	5.58	6.58	0.42	10	0.00	0.00	0.00
		Oct	5.37	5.37	5.38	0.00	10	26.33	25.00	28.19	1.18	10	0.00	0.00	0.00
13	100	Feb	6.39	6.38	6.39	0.01	10	1.46	1.37	1.53	0.05	10	0.00	0.00	0.00
		Mar	5.66	5.65	5.67	0.01	10	1.49	1.42	1.53	0.04	10	0.00	0.00	0.00
		Apr	6.00	6.00	6.01	0.00	10	0.97	0.95	1.01	0.02	10	0.00	0.00	0.00
		May	6.05	6.03	6.06	0.01	10	1.20	1.17	1.27	0.04	10	0.00	0.00	0.00
		Jun ^a	5.97	5.96	5.99	0.01	10	1.08	1.02	1.17	0.05	10	0.00	0.00	0.00
		Jul	5.32	5.30	5.33	0.01	10	1.37	1.29	1.42	0.04	10	0.00	0.00	0.00
		Aug	5.07	5.05	5.08	0.01	10	1.23	1.18	1.32	0.05	10	0.00	0.00	0.00
		Sep	4.78	4.76	4.80	0.02	10	1.29	1.24	1.35	0.04	10	0.00	0.00	0.00
		Oct	4.54	4.53	4.55	0.01	10	1.25	1.16	1.33	0.06	10	0.00	0.00	0.00
16	200	Feb	6.30	6.29	6.31	0.01	10	1.60	1.54	1.66	0.04	10	0.00	0.00	0.00
		Mar	5.77	5.77	5.78	0.00	10	1.47	1.43	1.52	0.04	10	0.00	0.00	0.00
		Apr	5.94	5.94	5.95	0.00	10	1.14	1.10	1.19	0.03	10	0.00	0.00	0.00

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

Table B2 (continued). 2012 oceanographic data summary of measured parameters (dissolved oxygen, OBS, and PAR) at core stations, averaged across a 10-m vertical depth band centered on a representative “bottom water” depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; SD=standard deviation; n=sample size. Note the absence of the SD statistic for PAR (decreases exponentially from the surface, so SD has little meaning).

Station	Depth	Month	Dissolved Oxygen (mg/L)					OBS (NTU)					PAR (µE/cm2 * s)		
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
16 (continued)	200	May	5.95	5.94	5.96	0.01	10	1.16	1.12	1.22	0.03	10	0.00	0.00	0.00
		Jun ^a	5.94	5.92	5.95	0.01	10	0.88	0.81	0.92	0.04	10	0.00	0.00	0.00
		Jul	5.71	5.70	5.72	0.01	10	1.00	0.97	1.05	0.03	10	0.00	0.00	0.00
		Aug	5.67	5.67	5.68	0.00	10	1.01	0.98	1.04	0.02	10	0.00	0.00	0.00
		Sep	5.52	5.51	5.53	0.00	10	1.01	0.97	1.04	0.02	10	0.00	0.00	0.00
		Oct	5.37	5.36	5.37	0.01	10	1.02	0.99	1.04	0.02	10	0.00	0.00	0.00
20	125	Feb	5.52	5.51	5.54	0.01	10	0.91	0.88	0.97	0.02	10	0.00	0.00	0.00
		Mar	5.58	5.55	5.60	0.02	10	1.61	1.56	1.67	0.03	10	0.00	0.00	0.00
		Apr	5.91	5.90	5.92	0.01	10	1.27	1.25	1.33	0.03	10	0.00	0.00	0.00
		May	5.86	5.85	5.87	0.00	10	1.82	1.70	2.03	0.11	10	0.00	0.00	0.00
		Jun ^a	5.80	5.78	5.82	0.01	10	1.73	1.54	1.87	0.11	10	0.00	0.00	0.00
		Jul	5.61	5.60	5.62	0.01	10	23.13	22.69	23.77	0.31	10	0.00	0.00	0.00
		Aug	5.58	5.57	5.60	0.01	10	28.84	25.73	30.89	1.72	10	0.00	0.00	0.00
		Sep	5.51	5.49	5.52	0.01	10	9.50	8.06	10.73	0.96	10	0.00	0.00	0.00
		Oct	5.43	5.42	5.44	0.01	10	24.67	19.86	31.64	4.89	10	0.00	0.00	0.00

^aTo avoid conflicting with the June 1-July 15 closure of upper Muir Inlet to motorized access, the “June” survey actually occurred May 31-June 1.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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