National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Glacier Bay National Park and Preserve Oceanographic Monitoring Program

2010 Annual Report

Natural Resource Technical Report NPS/SEAN/NRTR—2013/728

ON THE COVER
Head of Tarr Inlet, Glacier Bay, in winter.
Photo by Chris Sergeant

Glacier Bay National Park and Preserve Oceanographic Monitoring Program

2010 Annual Report

Natural Resource Technical Report NPS/SEAN/NRTR—2013/728

Lewis C. Sharman

National Park Service
Glacier Bay National Park and Preserve
P.O. Box 140
Gustavus, Alaska 99826

April 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available the Southeast Alaska Network (http://science.nature.nps.gov/im/units/sean) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm).

Please cite this publication as:

Sharman, L. C. 2013. Glacier Bay National Park and Preserve oceanographic monitoring program: 2010 annual report. Natural Resource Technical Report NPS/SEAN/NRTR—2013/728. National Park Service, Fort Collins, Colorado.

NPS 132/120488 April 2013

Contents

Figures

Page

Tables

Appendices

Abstract

The Southeast Alaska Inventory and Monitoring Network assumed responsibility from the USGS for long-term oceanographic monitoring of Glacier Bay in 2009. 2010 is the 18th consecutive year of the continuous dataset, and this is the second 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 early spring and once in mid-summer at 22 permanent stations throughout Glacier Bay; seven of those stations were occupied monthly from February through October. Parameters reflected ranges observed in past sampling years, with pronounced seasonal variability and strong length-of-fjord gradients along the glacier-to-baymouth transects. The upper water column was well-mixed by the end of winter to at least 50 m, and strongly stratified in summer. At most stations, chlorophyll fluorescence averaged over the uppermost 50 m of the water column exhibited low values (<0.1 mg/m^3) during the mid-winter cruise and elevated levels (> 0.5 mg/m^3) between late spring and fall, showing that primary productivity is likely sustained well beyond the initial spring bloom. Compared to historical data, a warm, fresh, and low-density anomaly below 40-m depth was observed during July at a central bay station. This anomalous signal appears not to represent a response to large-scale external forcing from the Gulf of Alaska; rather, it was likely a reflection of more local processes. Data quality and quantity for 2011 and future years should be enhanced by improved equipment including a dedicated vessel, and operational improvements such as casts that sample closer to the bottom.

Acknowledgments

For assistance with 2010 field data collection I thank C. Murdoch, D. Decker, B. McDonough, W. Johnson, M. Stachura, W. Bredow, K. Fraley, R. Sharman, and R. Workin. Oceanographic data can be collected only when there are vessels and operators available to deploy instruments at stations. The 2010 data were collected during nine cruises that were logistically supported by the Glacier Bay National Park and Preserve (GLBA) Resource Management, Visitor and Resource Protection, and Maintenance Divisions; special thanks to the Visitor and Resource Protection Division (use of the vessel Rebound) and vessel operator B. McDonough (Maintenance Division). Additionally, I thank the GLBA Maintenance Division, particularly B. McDonough, for ongoing vessel maintenance. Special thanks to W. Johnson for developing routines that automate some data analyses and visualizations and to C. Sergeant for some data summaries. Reviews by S. Danielson and L. Etherington resulted in substantial improvements to this report.

Introduction

Marine conditions comprise one of several long-term monitoring “vital signs” identified by the National Park Service (NPS) Southeast Alaska Inventory and Monitoring Network (SEAN) as important in order to be able to continually assess the ecological health of Glacier Bay National Park and Preserve (GLBA; Moynahan et al. 2008). A detailed oceanographic monitoring protocol (Danielson et al. 2010) was developed to standardize data collection, analyses, and reporting. This 2010 annual data report documents the second 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 GLBA managers, researchers, and interested stakeholders form 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 GLBA. Together with weather, bathymetry, glaciers, and other terrestrial influences, oceanographic components determine horizontal water movement and vertical stability, thereby driving the spatial and temporal dynamics of trophic interactions, 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 start with 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 GLBA 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 fixed stations) 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 context within which other (e.g., habitat, population) aspects of the marine ecosystem within Glacier Bay 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 review 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 GLBA 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, OBS]) that can be used to better understand seasonal and interannual 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

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. Seven stations 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 July (mid-summer) and December/January (mid-winter), we sample the core stations and the remaining 15 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.

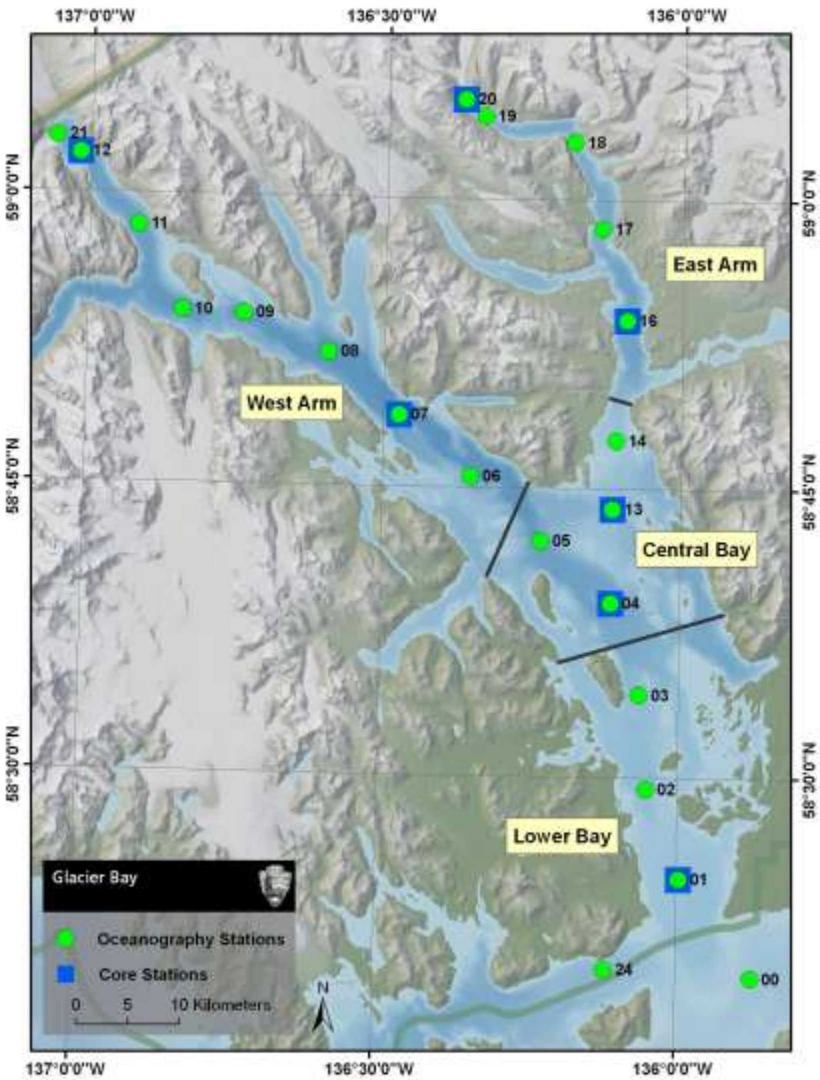


Figure 1. Oceanographic sampling stations in Glacier Bay. Shaded bathymetry indicates relative water depth (darker means deeper). Station depths range from 53 m (Station 00) to 435 m (Station 07).

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 ~1 m/sec 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 ready to be deployed at an oceanographic station.

Parameters (and their units of measure) include water temperature (ºC), salinity (Practical Salinity Units or PSUs), PAR (µE/cm^2*sec), chlorophyll-*a* fluorescence (an index of chlorophyll concentration and thus phytoplankton standing stock or primary production, in mg/m^3), OBS (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-t*, kg/m^3) and the vertical density gradient (kg/m^3/m = kg/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"). Detailed field data collection and data processing/management methods are documented in the SEAN oceanography monitoring protocol (Danielson et al. 2010).

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 2010 cruise year. Nineteen of 22 stations were successfully occupied during the mid-winter cruise; five of the seven core stations were occupied during the March cruise, and six of seven were occupied during the April and June cruises. For all other cruises, all target stations were successfully occupied. See the Operations section directly below for explanations.

Table 1. Sampling coverage of oceanographic stations during the 2010 cruise year. **Red** identifies the seven "core stations" (01, 04, 07, 12, 13, 16, 20).

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

Operations

2010 was a generally successful year in terms of the ability to occupy stations as scheduled. Weather and/or pan ice can occasionally preclude the occupation of some stations, especially early in the year for stations at the extreme heads of inlets. In 2010 the mid-winter and April cruises were incomplete due to the presence of pan ice in the upper inlets (Stations 18, 19, and 20 in mid-winter; Station 20 in April), and rough seas prevented us from occupying Stations 16 and 20 during the March cruise. In June we were unable to occupy Station 20 because the "June" cruise (normally scheduled to occur at the very end of May) was delayed, and upper Muir Inlet is closed to motorized access between June 1 and July 15.

We were successful in securing suitable vessels and operators for the 2010 deployments. The vessel Boomer (operator L. Sharman) was used for all cruises except the mid-winter cruise, for which the vessel Rebound (operator B. McDonough) was used. Starting with the 201 cruise year the SEAN will begin using a dedicated all-seasons vessel suitably outfitted for oceanographic surveys, and multiple personnel will be certified to operate it.

There were no sensor failures during any 2010 cruises. Data quality was excellent. Sensor data was complete, and post-season calibrations of all sensors indicated high sensor accuracy.

Observations

Appendices A and B summarize the oceanographic parameters by core station and survey month, providing a broad overview of the measured components. Appendix A shows values averaged over the near-surface (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. Appendix B shows values that are generally descriptive of "bottom water", averaged across 10-m depth bands centered on a 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.

Appendix A-1 shows that in the upper 50 m of the seven core stations in 2010, mean water temperatures at Stations 04, 07, 13, and 16 increased from ~4.8–5.2 ºC in February to ~7.5-7.8 ºC in mid-late summer (July-August). At the remaining stations (01, 12, and 20), temperatures did not reach their maxima (~6.6 -7.8 ºC) until September-October. Temperatures were generally cooler at stations (12, 20) near the heads of inlets. The near-surface salinities generally peaked in spring (March-May) throughout Glacier Bay, with maximum mean values ranging from ~30.2-31.4 PSU. Salinity minima generally occurred mid-late summer (July-August), with mean values of ~28.2-30.7 PSU. Salinities were lower near the heads of inlets (Stations 12, 20) and higher at the mouth of the bay (Station 01).

Near-surface mean density (*sigma-t*) at all stations was generally higher in the early part of the year (February-May; maxima ~24.1-24.7 kg/m^3) with the most rapid declines in spring-early summer (May-June). This reflects the impact of warming (by incoming solar radiation), freshening (by snowmelt and precipitation) that occurs between spring and fall, and cooling and reduced runoff during winter months. Minimum mean densities generally occurred in mid-late summer (July-August), ranging from ~22.1–23.9 kg/m^3. The depth of the maximum density gradient is a measure of the pycnocline depth, where the density changes most rapidly. At most stations in most months this depth was in the upper 15 m. The deepest occurred in late winter-spring (February-May) and fall (October) at depths reaching 35 m (Station 01).

Appendix A-2 shows that in the upper 50 m of the seven core stations in 2010, fluorescence (index of chlorophyll-*a* concentration) at most stations peaked in late spring – early summer (May–June), but the maximum at Station 16 occurred in September. Peak fluorescence mean values ranged from ~0.7–1.5 mg/m^3 and were variable along the length-of-bay transect. Minima (0.01-0.06 mg/m^3) occurred in winter (February), and values recorded in October, March, and April were usually less than one-half those measured between May and September. Closely mirroring this pattern, mean dissolved oxygen concentrations were generally highest in May-June (~6.3–6.7 ml/L) at all stations, and lowest in October (~4.4-5.3 ml/L). There was no discernible relationship with position along the length-of-bay transect. Mean turbidity values were highest (~1.3-64.9 NTU) from mid-summer to fall (July-October) and lowest (~0.4-1.3

NTU) in spring (April-June). The very highest values were at Stations 12 and 20 (stations close to glacial melt discharge) in August. PAR values through the upper 50 m were highly variable across months and within and among stations, with minimum values approaching 0 μE/cm^2*sec, and maxima exceeding 90 μE/cm^2*sec. Note that PAR values are sensitive to boat shadows, sky cloudiness, and sun elevation, along with water column effects. In general, the highest values (~29.6-90.3 μE/cm^2*sec) occurred in spring-summer (April-July), and the lowest values (0.03-~6.5 μE/cm^2*sec) occurred in late summer-winter (August-February). Stations 12 and 20 (closest to glacial melt discharge) reported the very lowest minimum values (0.03 and 2.26 μE/cm^2*sec, respectively) in August-October.

Appendix B-1 shows that, for the bottom water at the seven core stations in 2010, mean water temperatures increased throughout the year to fall maxima (~5.5-7.8 ºC) in September-October. Minimum temperatures generally occurred in winter-spring (February-May), ranging from ~4.9-5.1ºC. Bottom-water temperatures typically warmed ~0.6-2.7 ºC across the season (~2.7 ºC at Station 01, mouth of Glacier Bay). Temperatures generally increased with distance from the heads of the inlets, toward the mouth of the bay. Bottom-water salinities generally reached their annual maxima (~31.0-31.4 PSU) in spring (April-May) throughout Glacier Bay, but salinity minima (~30.8–31.0 PSU) occurred generally without pattern throughout the year. As with temperature, bottom-water salinity generally increased with distance from the heads of the inlets, toward the mouth of the bay, through which saline Gulf of Alaska waters feed the fjord. Similar to the near-surface (upper 50 m) waters, bottom-water minimum mean density (*sigma-t*) occurred generally from summer through fall (range ~24.1-24.4 kg/m^3), and maxima occurred in spring (April-June, range ~24.5-24.6 kg/m^3).

Bottom-water fluorescence (chlorophyll-*a* concentration) measurements were very low throughout 2010 and at all stations, near the margins of reliable sensor detection. The highest values occurred at Station 01 (1.13 mg/m^3, July). Interestingly, the next highest measurements were at Station 12 (0.14 mg/m^3, June) and at Station 20 (0.11 mg/m^3, July) and may be related to vertical circulation or particle export associated with glacial outflows. The near-bottom sample at Station 01 (40 m depth) may still be within the euphotic zone; all other near-bottom samples shown in Appendix A-2(a), however were at least 100 m deep, so active fluorescence there may represent still-living cells sinking from the surface.

Appendix B-2 shows that, for the bottom water at the seven core stations in 2010, mean dissolved oxygen concentrations were generally highest in May (range ~5.6-6.4 ml/L) and lowest in September-October (range ~4.4-5.1 ml/L). There was no discernible relationship with position along the length-of-bay transect. These patterns are similar to those observed in the surface waters. Bottom-water mean turbidity measurements were variable across the year and across stations, with minimum values ranging from ~0.4-1.3 NTU and maximum values ranging from ~0.7-57.7 NTU. The highest maxima were at Stations 12 (47.06 NTU in July) and 20 (57.66 NTU, also in July), a pattern similar to that for the near-surface waters. The PAR sensor returned values of 0.00 μE/cm^2*sec for bottom-water measurements at all stations and all months.

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, plotted alongside the historical mean values for the same parameters from this station in July for the period of 1993 through 2009. This station and month were identified in the oceanographic monitoring protocol for greater in-depth analysis on a yearly basis.

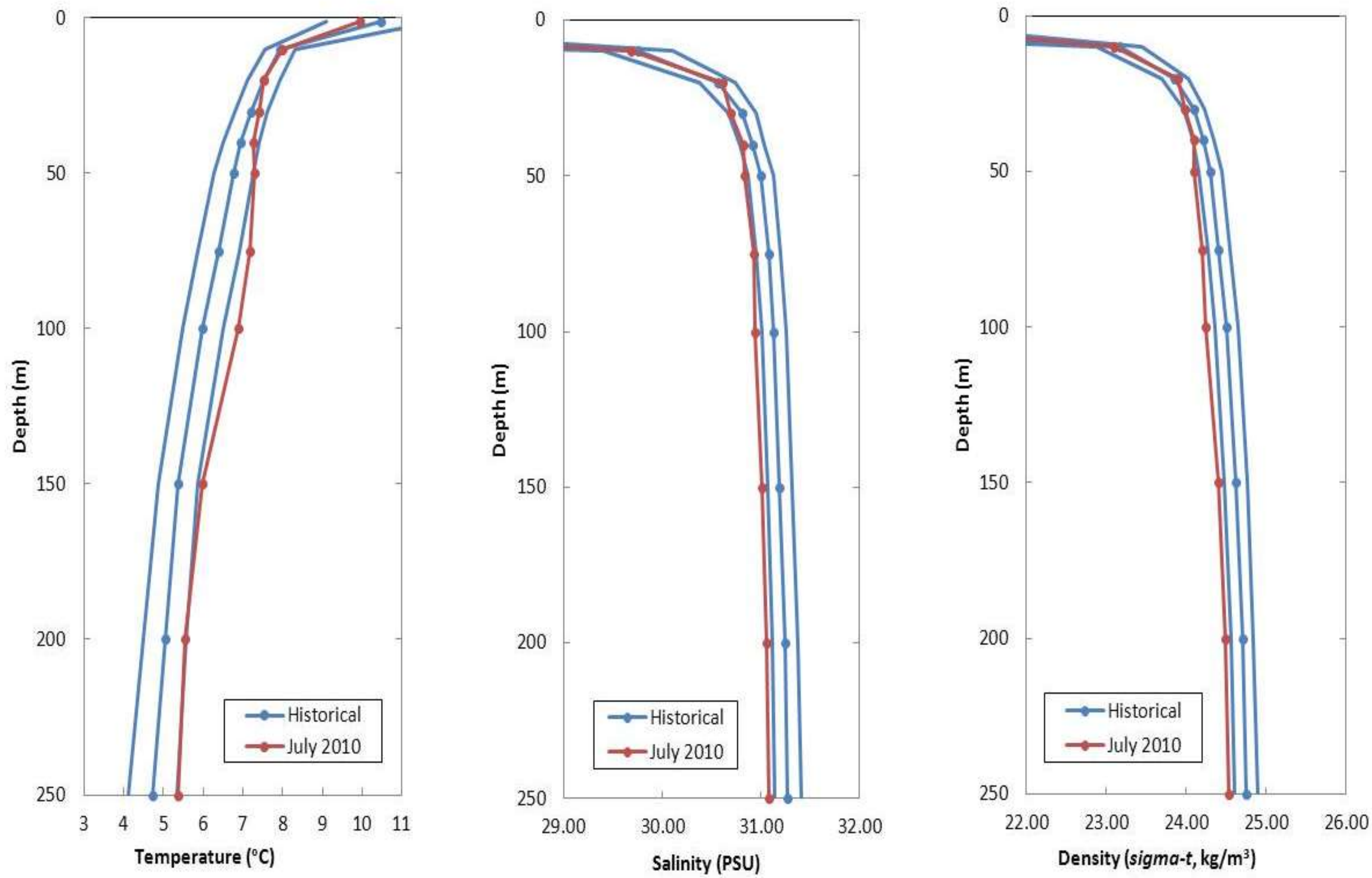


Figure 3. Vertical profiles of temperature (left), salinity (center), and density (sigma-t, right) shown along with historical data (means for July 1993–2009, Station 04). 2010 data are shown in red with dots; historical means are blue with dots along with +/- bounds of one standard deviation to either 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 (1993–2009) and anomalous otherwise. Figure 3 clearly shows that waters at this station in July of 2010 were anomalously warm, fresh, and low-density below the upper 40 m.

Table 2 displays the numerical values plotted in Figure 3.

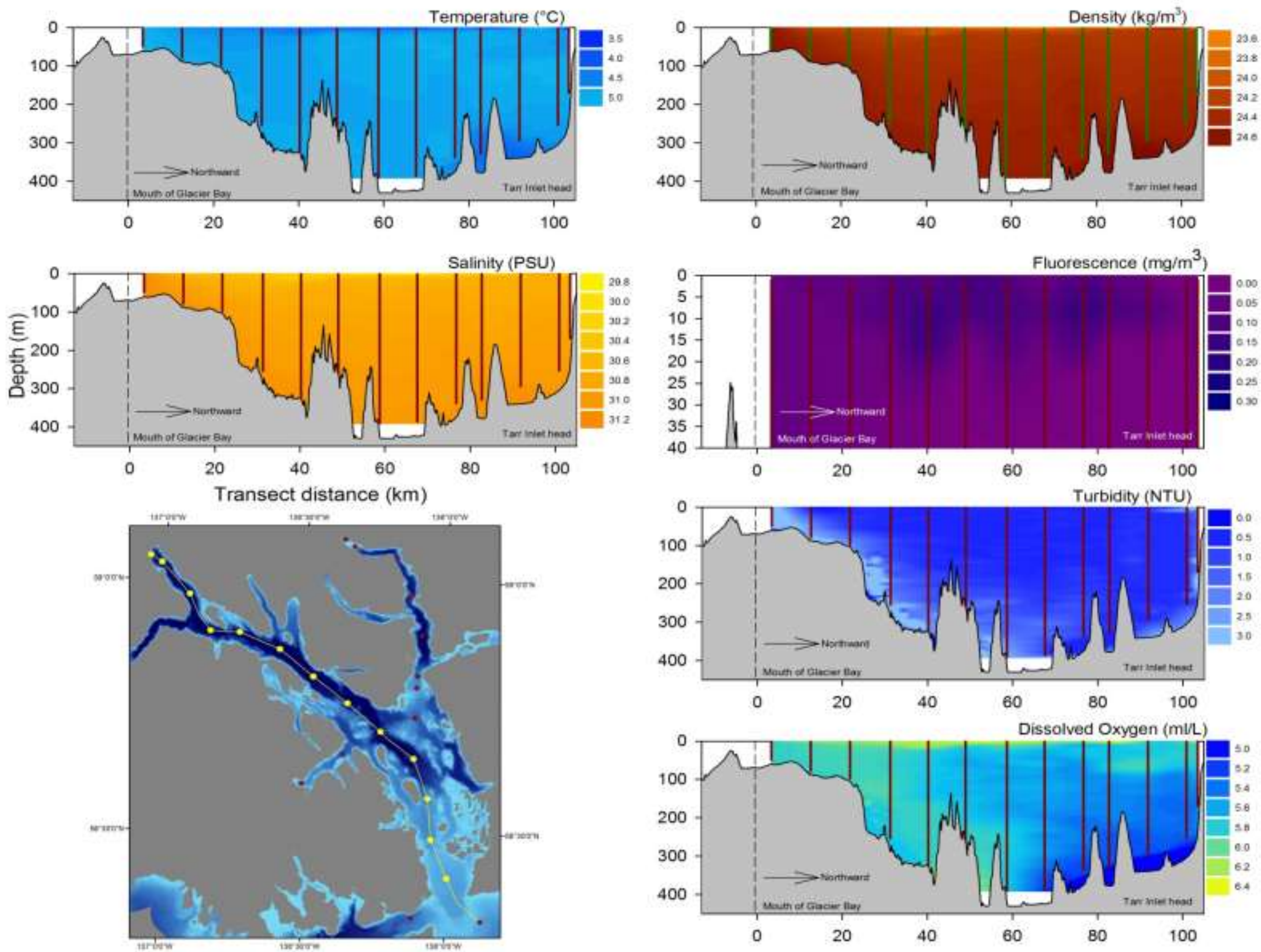
Table 2. Temperature, salinity, and density measurements from standard depths at Station 04 in July 2010, compared to historical measurements from that station in July, 1993–2009. To help draw attention to anomalous measurements, July 2010 observations lying outside one standard deviation (SD) of the 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 2010	Historic July mean	Historic mean -1 SD	Historic mean +1 SD	n	July 2010	Historic July mean	Historic mean -1 SD	Historic mean +1 SD	n	July 2010	Historic July mean	Historic mean -1 SD	Historic mean +1 SD	n
1[1]	9.93	10.47	9.11	11.84	14	25.25	22.40	19.07	25.72	14	19.36	17.06	14.38	19.74	14
10	7.99	7.92	7.54	8.31	14	29.69	29.75	29.40	30.10	14	23.10	23.16	22.88	23.45	14
20	7.53	7.53	7.13	7.93	14	30.61	30.56	30.38	30.75	14	23.89	23.86	23.70	24.02	14
30	7.42	7.20	6.79	7.60	14	30.70	30.81	30.67	30.95	14	23.98	24.09	23.96	24.22	14
40	7.28	6.96	6.51	7.40	14	30.82	30.92	30.79	31.04	14	24.09	24.21	24.08	24.34	14
50	***7.29***	6.78	6.29	7.26	14	***30.83***	31.00	30.87	31.13	14	***24.10***	24.29	24.15	24.44	14
75	***7.19***	6.40	5.88	6.92	14	***30.94***	31.08	30.96	31.21	14	***24.19***	24.41	24.27	24.55	14
100	***6.89***	5.99	5.49	6.50	13	***30.94***	31.14	31.01	31.26	13	***24.24***	24.50	24.36	24.64	13
150	***5.99***	5.38	4.88	5.88	13	***31.02***	31.19	31.07	31.32	13	***24.41***	24.62	24.47	24.76	13
200	5.55	5.04	4.50	5.58	12	***31.06***	31.25	31.12	31.38	12	***24.49***	24.70	24.56	24.84	12
250	***5.37***	4.73	4.11	5.36	6	***31.09***	31.28	31.14	31.41	6	***24.53***	24.75	24.61	24.90	6

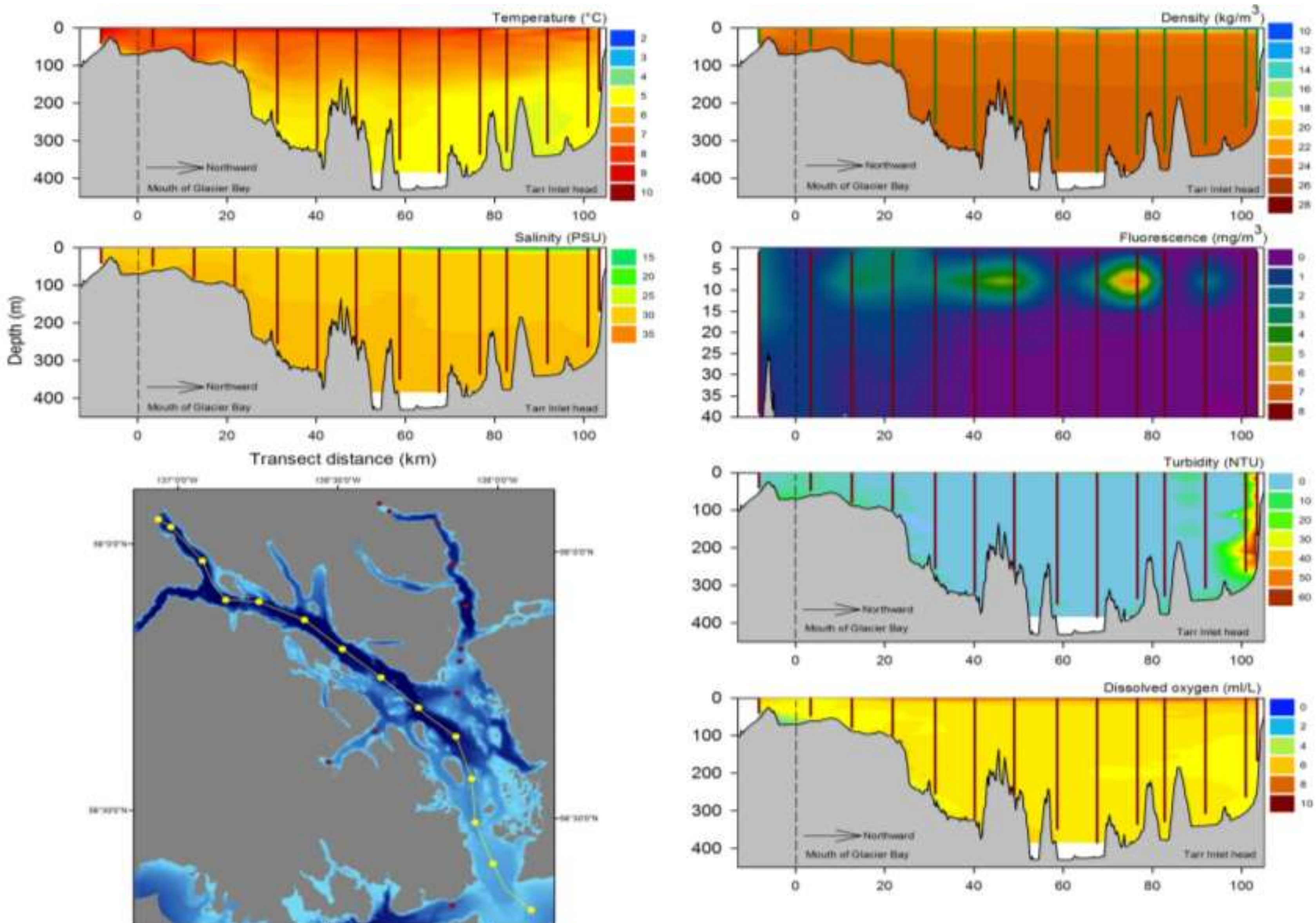
[1]The standard depth of 0 m has been replaced by 1 m to provide complete and consistent data for analysis. Given the objective of characterizing the surface water, 1 m is a reasonable proxy for 0 m.

Horizontal cross-sections provide effective at-a-glance visual depictions of water column parameters as a function of depth and distance along the transect. Figure 4 shows 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 the mid-summer (July)cruise, and all but Stations 18, 19, and 20 were occupied during the mid-winter (February) cruise.

Figure 4 (next two pages). Length-of-transect cross-sectional contour plots of principal oceanographic parameters for the West Arm transect for (a) February 2010, and (b) July 2010. 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 the appearance of color). Also, note the foreshortened depth scale (upper 40 m only) for the Fluorescence parameter for both February and July.

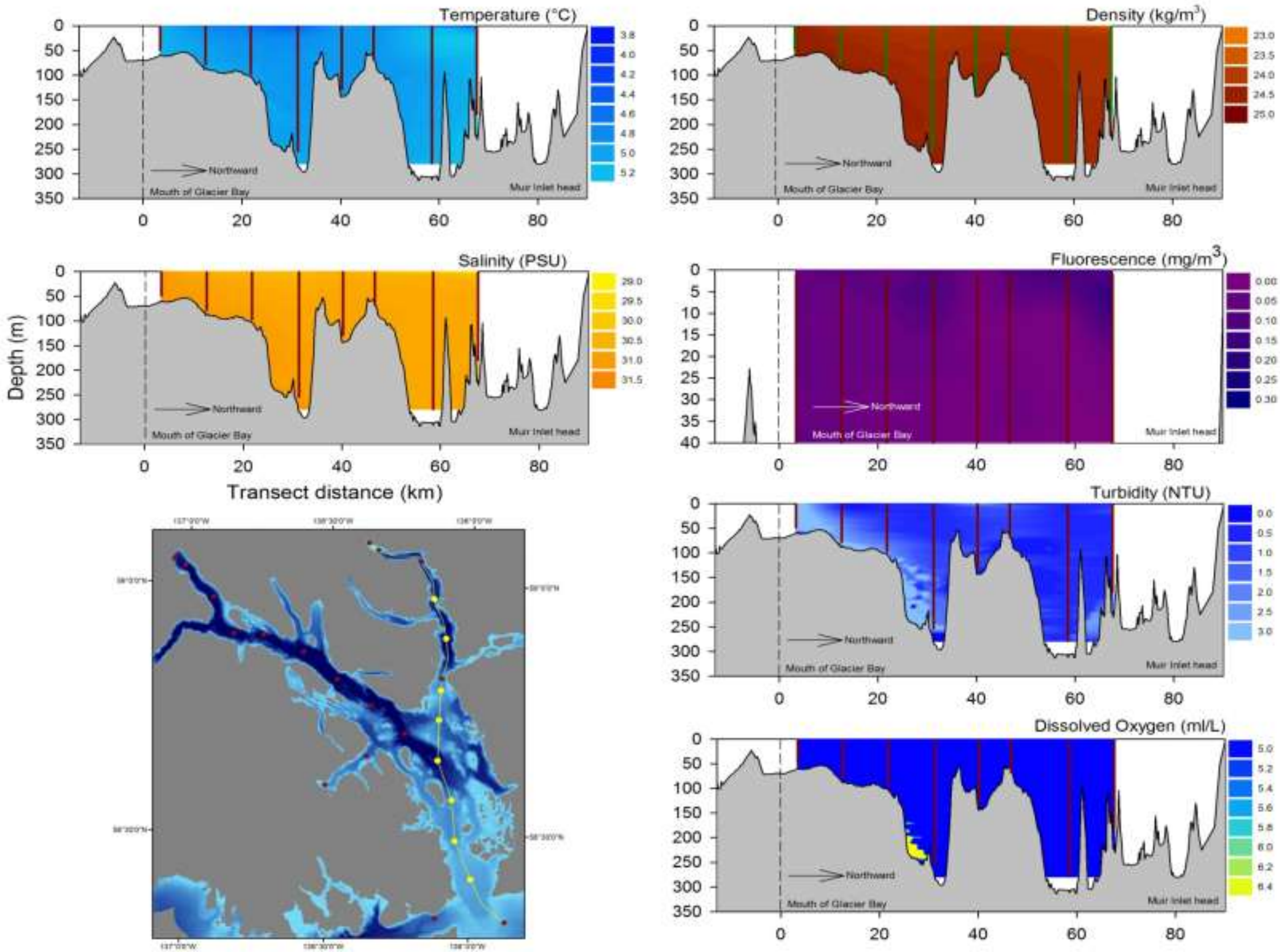


(a) February 2010 West Arm

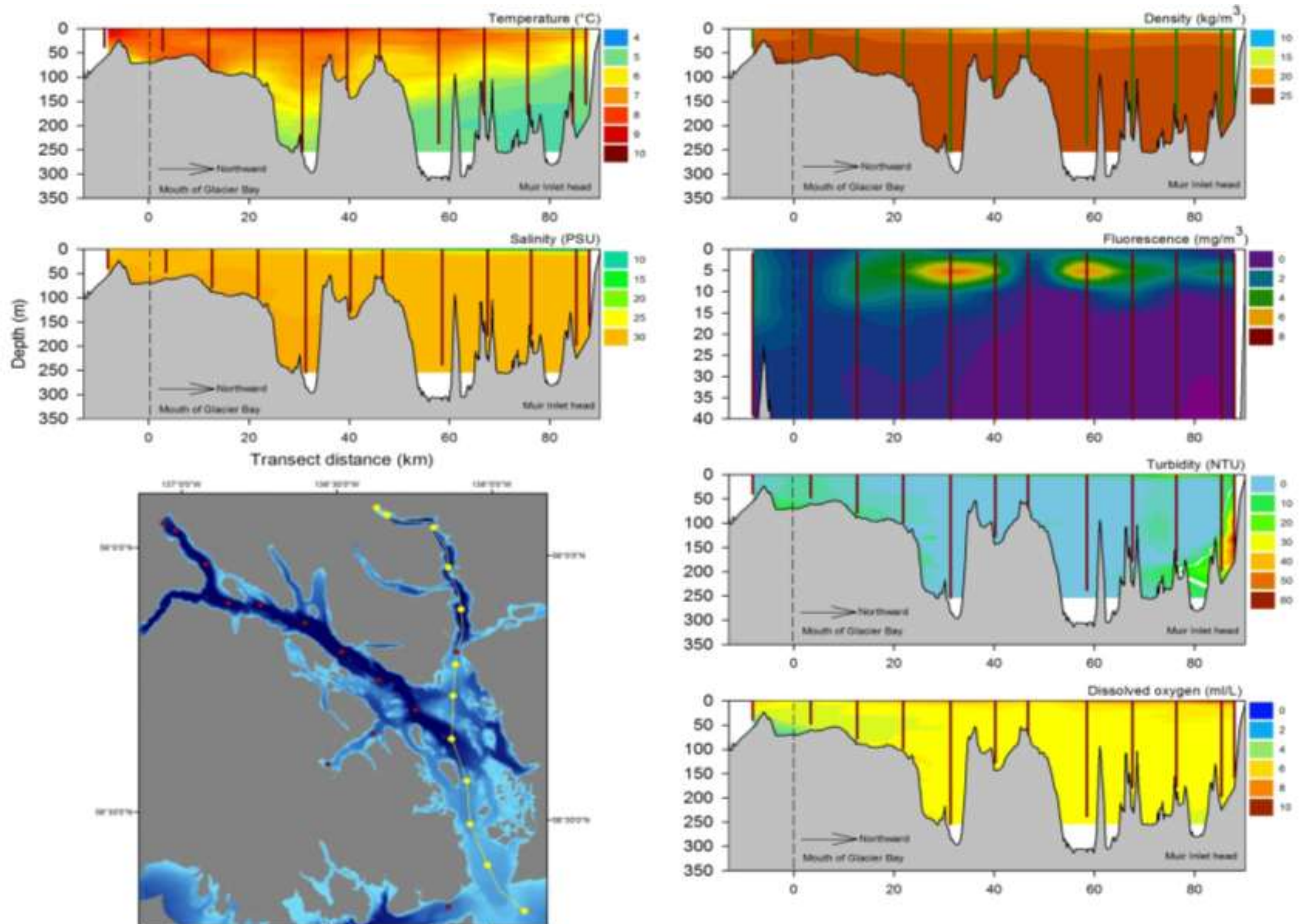


(b) July 2010 West Arm

Figure 5 (next two pages). Length-of-transect cross-sectional contour plots of principal oceanographic parameters for the East Arm transect for (a) February 2010, and (b) July 2010. 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 the appearance of color). Also, note the foreshortened depth scale (upper 40 m only) for the Fluorescence parameter for both February and July.



(a) February 2010 East Arm



(b) July 2010 East Arm

Figure 4a (West Arm transect in February, 2010) shows moderate temperatures (~3.5-5.0 °C) throughout the water column at all stations, especially when compared to the mid-winter (March) visualization of the same transect in 2009 (~3.5-4.0 °C) (Sharman 2011). Some areas of cooler water appear in the upper 100 m in the central part of the transect, as well as at depth in the upper bay. Salinity and density showed a pattern of slight increase with depth across the entire transect, although both, compared to other times of year, were relatively high and uniform (~29.5-31.0 PSU and ~23.0-24.5 kg/m^3, respectively) across both depth and distance. There was no strong near-surface pycnocline evident, and in general the water column can be described as well mixed. Fluorescence was uniformly very low (<0.3 mg/m^3), with slightly elevated values in the upper 20 m across much of the transect. Turbidity was quite low (<3.0 NTU) at all depths and across all stations, with slightly elevated levels near the bottom in the lower bay, and in the extreme upper fjord near the glaciers. Dissolved oxygen concentration was relatively high (>5.0 ml/L) across depth and distance, especially near the surface and throughout the lower bay waters; readers should ignore the apparently low concentrations indicated below the bottoms of casts in the upper bay, since they are not supported by any actual data.
In mid-summer (July), the West Arm transect looks dramatically different (Figure 4b). Temperatures were substantially warmer (~5-9 °C) throughout the water column, and there was considerable vertical structure along the entire transect. Increased temperatures and decreased salinities (to <20 PSU) were most noticeable in the surface waters, and a strong near-surface pycnocline had developed across the entire transect, generally at a depth of 10-20 m. Apparent phytoplankton bloom conditions were established, with moderate levels (to 7.0 mg/m^3) of fluorescence in the near-surface waters (generally the upper 15 m; note the change in the vertical depth axis), especially in the central bay and a "hotspot" about midway up the West Arm. Turbidity also was considerably higher (to 60 NTU) compared to February, especially at the extreme head of the fjord.(all depths). Dissolved oxygen concentration was high (generally >5 ml/l) across the entire transect with no indication of anoxia at depth. Higher concentrations (approaching 10 ml/L) were evident in the near-surface waters, and this region tended to thicken toward the head of the fjord.

The East Arm transect in February (Figure 5a) looks much like the West Arm for that month (Figure 4a). Across the entire transect the water column was generally well-mixed, with little vertical stratification. As with the West Arm transect in February, fluorescence and turbidity levels were generally low at all depths and across all stations, with indications of slightly elevated turbidity levels near the bottom in the lower bay. Dissolved oxygen concentrations were uniform across depth and distance, with no indications of anoxia anywhere.

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 (approaching 10 °C in some surface waters) , surface salinities had declined (to <20 PSU), and vertical stratification was well-developed. Moderate fluorescence levels occurred near the surface (upper 10-15 m), with "hotspots" (to 7.0 mg/m^3) in the central bay and in lower Muir Inlet. Turbidity levels were higher (to $\geq$10 NTU) than in February, especially near the head of the fjord. Dissolved oxygen concentrations were high (generally >5 ml/L) at all depths across the entire transect. Higher concentrations were evident in the near-surface waters, and this region of slightly increased oxygen tended to thicken toward the head of the fjord

Discussion

In 2010, measured parameters mostly conformed to the range of variation previously observed in Glacier Bay (Etherington et al. 2007, Sharman 2011). However, waters in the central bay (Station 04) were anomalously warm, fresh, and low-density below the upper 40 m in mid-summer (Figure 3; Table 2), compared to the 1993–2009 historical mean. This contrasts with the July 2009 observation at Station 04 which was at that time anomalously cold, salty, and dense (Sharman 2011). The means from 2009 and 2010 differed by approximately 1-1.3ºC for temperature, 0.35 PSU for salinity, and 0.40-0.45 kg/m^3 for density. The 2009 anomaly was interpreted as an influence of external forcing from outside Glacier Bay proper and/or the impact of water column homogenization during the course of the previous winter (Sharman 2011). This was based partly on a similar cold anomaly (2006-2009) reported from oceanographic station GAK1(located at the mouth of Resurrection Bay, near Seward, AK) in the northern Gulf of Alaska. Updated observations show that the GAK1 cold anomaly also abated in 2010 (http://www.ims.uaf.edu/gak1/), and that the water column mid-depths experienced a slight warming, consistent with the signal observed in Glacier Bay. It is especially interesting that the anomaly was generally restricted to the water column below 40 m. Such a large swing to opposite sides of the 17-year historical mean in a single year is remarkable and clearly illustrates the potential for extremely high natural variability in Glacier Bay.

Etherington et al. (2007) and Sharman (2010) described a generalized model for Glacier Bay oceanography and marine production that is typified by strong seasonality and high productivity. Winter condition is are characterized by weakly stratified waters that are presumably nutrient-rich but supportive of very low primary productivity because of limited light (short day length) and weak to non-existent water column density stratification . 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 elevated 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.

The 2010 patterns of increasing temperature and salinity with distance along transect from the heads of the inlets conforms to prior expectations. One expects the upper fjords to be sources of high freshwater input from melting snow and ice, including tidewater glaciers and turbid outwash streams. At the same time, the lower/central bay is closer and more integrally connected to the warmer, more saline oceanic waters of the Gulf of Alaska. The decline in salinity in the upper water column after spring/early summer reflects the influence of increasing freshwater input as air temperatures warm and snowmelt proceeds. The ranges of both temperature and salinity values were relatively cool and fresh, respectively, compared to open ocean conditions; they also varied seasonally more than oceanic waters (see http://www.pmel.noaa.gov/ocs/disdel/disdel.html for time series data from Ocean Station P, 50ºN, 145ºW). Both of these patterns reflect responsiveness to local coastal conditions, spatially buffered from the open ocean by the fjord's surrounding topography.

The shallow pycnocline depth, generally 2–35 m, provides a physical discontinuity within the photic zone at most stations for much of the year. This density stratification helps keep phytoplankters in the sunlit surface portion of the water column where they can grow and reproduce rapidly. Strong pycnoclines can also hamper nutrient renewal from depth, which is required for phytoplankton blooms to be sustained as the plants strip out available nutrients from surrounding surface waters. However, in Glacier Bay it is apparent that physical forces (perhaps tidal mixing, especially, acting across a bathymetry that features several relatively shallow sills) or other forces provide for nutrient replenishment throughout the spring and summer (Etherington et al. 2007).

This was somewhat evident in the 2010 fluorescence patterns across the seasons, although mean fluorescence values (~0.7-1.5 mg/m^3 in 2010) were more than an order of magnitude lower than those measured in 2009 (~8-18 mg/m^3). While we lacked field calibrations of the fluorometer with water filtrations, this apparent change in standing stock is notable and likely reflects a real alteration in the plankton community. These differences may reflect variations in phytoplankton production, differences in phytoplankton consumption by micro- or macrozooplankton, or, more probably, some combination of these factors.

Patterns of dissolved oxygen concentration generally agree with what should be expected given the patterns of biological productivity. Near-surface peaks in May-June followed by slight declines suggest initial plant growth (production via photosynthesis) followed by consumption (decomposition of organic matter). Nevertheless, mean concentration ranges of ~4.5–6.5 ml/L throughout the water column clearly indicate that deep water renewal occurs, preventing anoxic conditions throughout the measured water column. The May oxygen concentration peak in the bottom water suggests renewal in this timeframe.

The maximum mean turbidity values observed from mid-summer into the fall reasonably aligns with the pattern of turbid freshwater discharge into the upper inlets, along with higher phytoplankton densities through the summer. As expected, the highest turbidity measurements (and lowest PAR measurements) were generally observed at the extreme heads of the inlets and near the bottoms of the profiles (a reflection of bottom sediment re-suspension).

Perhaps the most biologically important parameter currently measured in the oceanographic monitoring program is fluorescence, a proxy for phytoplankton standing stock. In order to properly calibrate the fluorometer, water samples must be collected, filtered, and then regressed against the fluorescence profile. Lack of data on nutrient availability remains an important constraint to improving our understanding of the proposed generalized model for Glacier Bay oceanography and marine productivity. This parameter, too, requires analyses of field water samples. Both of these—direct chlorophyll and nutrient measures—are elements in a GLBA/SEAN ocean acidification study that will begin in July 2011 and run for three years.

Recommendations

Water sampling—scheduled to begin in 2011—will be a notable and positive addition to the monitoring program. In addition to direct chlorophyll and nutrient measures, it may be possible to better interpret OBS (turbidity) sensor data by acquiring direct measurements of total suspended particulates.

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 cast over the side). 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 over the side to compensate and assist with approaching the target depth.

Procurement in 2010 of the dedicated SEAN vessel (R/V Fog Lark) will significantly enhance the amount and quality of data collected starting with 2011. This vessel is designed to accommodate oceanographic monitoring, it will reliably be available on a priority basis for surveys, and it is intended to be operated by multiple personnel.

Literature Cited

Danielson, S.L. 2012. Glacier Bay oceanographic monitoring program analysis of observations, 1993-2009. Natural Resource Technical Report NPS/SEAN/NRTR—2012/527. National Park Service, Fort Collins, Colorado.

Danielson, S., W. Johnson, L. Sharman, G. Eckert, and B. Moynahan. 2010. Glacier Bay National Park and Preserve oceanographic monitoring protocol: Version OC-2010.1. Natural Resource Report NPS/SEAN/NRR—2010/265. National Park Service, Fort Collins, Colorado, USA.

Etherington L. L., P. N. Hooge, E. R. Hooge, and D. F. Hill. 2007. Oceanography of Glacier Bay, Alaska: Implications for biological patterns in a glacial fjord estuary. Estuaries and Oceans 30(6):927–944.

Hooge, P. N., E. R. Hooge, E. K. Solomon, C. L. Dezan, C. A. Dick, J. Mondragon, H. Rieden, and L. Etherington. 2003. Fjord oceanography monitoring handbook: Glacier Bay, AK. U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska, USA.

Moynahan, B. J., W. F. Johnson, D. W. Schirokauer, L. C. Sharman, G. Smith, and S. M. Gende. 2008. Vital signs monitoring plan: Southeast Alaska Network. National Park Service, Fort Collins, Colorado, USA.

Sharman, L. 2010. Driving the marine ecosystem: Oceanography as a key long-term monitoring vital sign at Glacier Bay National Park and Preserve. Alaska Park Science 9(1):36–39.

Sharman, L. C. 2011. Glacier Bay National Park and Preserve oceanographic monitoring program: 2009 annual report. Natural Resource Technical Report NPS/SEAN/NRTR-2011/508. National Park Service, Fort Collins, Colorado.

Syvitski, J. P. M., D. C. Burrell, and J. M. Skel. 1987. Fjords: processes and products. Springer-Verlag, Inc., New York, New York, USA.

Appendix A: 2010 oceanographic data summary of measured parameters at core stations, averaged across the upper 50 m of the water column.

Table A-1. 2010 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). Data absences are due to inability to occupy stations because of rough seas, non-navigable pan ice, or motorized area closure; see Operations section for details.

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[1]	5.13	5.13	5.14	0.00	50	31.16	31.15	31.16	0.00	50	24.61	24.61	24.62	0.00	50	0.00	48	0.00	35
	Mar	5.19	5.18	5.19	0.00	45	31.24	31.24	31.24	0.00	45	24.67	24.67	24.67	0.00	45	0.00	43	0.00	26
	Apr	5.30	5.28	5.30	0.01	46	31.34	31.33	31.34	0.00	46	24.74	24.74	24.74	0.00	46	0.00	44	0.00	26
	May	6.04	6.00	6.06	0.01	49	31.37	31.33	31.40	0.02	49	24.68	24.66	24.70	0.01	49	0.00	47	0.01	5
	June	7.75	7.54	8.32	0.23	49	30.97	29.98	31.14	0.28	49	24.14	23.29	24.29	0.25	49	0.02	47	0.20	2
	Jul	7.63	7.62	7.66	0.01	48	30.85	30.79	30.86	0.02	48	24.06	24.02	24.07	0.01	48	0.00	46	0.02	3
	Aug	7.71	7.53	8.45	0.20	49	30.69	28.87	31.06	0.47	49	23.93	22.40	24.25	0.39	49	0.04	47	0.52	2
	Sep	7.74	7.74	7.74	0.00	49	30.91	30.89	30.93	0.01	49	24.10	24.08	24.12	0.01	49	0.00	47	0.01	15
	Oct	7.80	7.79	7.80	0.00	49	31.09	31.09	31.09	0.00	49	24.23	24.23	24.23	0.00	49	0.00	47	0.00	32
04	Feb[1]	4.76	4.42	4.90	0.14	51	30.59	30.33	30.72	0.11	51	24.20	24.03	24.29	0.07	51	0.00	253	0.02	2
	Mar	4.94	4.72	5.00	0.09	51	30.83	30.59	30.92	0.11	51	24.38	24.21	24.44	0.08	51	0.00	236	0.03	7
	Apr	4.80	4.51	4.90	0.12	51	30.74	30.26	30.93	0.20	51	24.32	23.97	24.46	0.15	51	0.00	256	0.07	5
	May	5.56	5.33	6.31	0.26	51	30.81	29.50	31.06	0.40	51	24.29	23.17	24.49	0.34	51	0.01	258	0.23	3
	June	7.28	6.09	10.20	1.07	51	30.07	24.70	31.15	1.75	51	23.50	18.89	24.44	1.51	51	0.03	205	0.70	2
	Jul	7.73	7.28	9.93	0.69	51	30.06	25.25	30.83	1.42	51	23.43	19.36	24.10	1.21	51	0.02	253	0.71	4
	Aug	7.77	7.28	11.05	0.89	51	29.85	21.56	30.83	2.12	51	23.27	16.33	24.09	1.78	51	0.04	231	2.01	3
	Sep	7.69	7.23	9.38	0.57	51	29.87	25.89	30.78	1.35	51	23.29	19.94	24.06	1.13	51	0.02	255	0.49	2
	Oct	7.40	7.26	7.49	0.08	51	30.25	28.63	30.88	0.75	51	23.63	22.37	24.13	0.58	51	0.01	178	0.20	7
07	Feb[1]	4.86	4.10	5.09	0.27	51	30.58	29.88	30.75	0.21	51	24.19	23.71	24.30	0.14	51	0.00	390	0.12	3
	Mar	4.86	4.77	4.98	0.09	51	30.71	30.62	30.87	0.10	51	24.29	24.23	24.40	0.07	51	0.00	160	0.02	27
	Apr	4.79	4.41	4.91	0.14	51	30.69	29.97	30.95	0.30	51	24.28	23.75	24.48	0.22	51	0.00	367	0.09	9
	May	5.38	5.03	7.38	0.67	51	30.54	27.91	30.96	0.76	51	24.10	21.79	24.47	0.68	51	0.01	393	0.46	3
	June	6.66	5.81	8.82	0.65	51	29.98	16.61	31.11	3.09	51	23.51	12.82	24.41	2.48	51	0.05	254	4.12	2
	Jul	7.80	7.27	9.54	0.59	51	29.41	20.03	30.74	2.68	51	22.92	15.35	24.03	2.17	51	0.03	348	1.54	3
	Aug	7.67	7.13	10.07	0.73	51	29.09	15.05	30.72	3.84	51	22.69	11.50	24.04	3.08	51	0.03	390	3.29	3
	Sep	7.60	7.11	9.14	0.55	51	29.76	21.44	30.70	1.94	51	23.22	16.53	24.02	1.58	51	0.02	379	2.32	2
	Oct	7.13	6.71	7.20	0.13	51	29.45	25.24	30.73	1.63	51	23.03	19.77	24.03	1.27	51	0.03	144	0.52	5
12	Feb[1]	4.84	4.43	4.96	0.15	51	30.70	30.47	30.76	0.09	51	24.28	24.15	24.33	0.05	51	0.00	252	0.03	7
	Mar	4.22	2.95	5.06	0.67	51	29.86	28.17	30.90	0.82	51	23.68	22.44	24.42	0.59	51	0.01	211	0.22	5
	Apr	4.61	3.81	4.95	0.36	51	30.57	29.50	30.96	0.42	51	24.21	23.43	24.48	0.30	51	0.00	259	0.13	3
	May	4.93	4.89	4.98	0.03	51	30.76	30.35	30.97	0.20	51	24.32	23.99	24.49	0.16	51	0.00	153	0.04	14
	June	5.14	3.95	5.43	0.31	51	30.04	21.77	30.87	2.02	51	23.73	17.29	24.40	1.57	51	0.03	254	2.04	2
	Jul	6.78	6.25	7.61	0.36	51	28.28	11.06	30.63	4.95	51	22.16	8.57	24.06	3.90	51	0.06	261	2.63	3
	Aug	6.64	3.84	7.22	0.68	51	29.14	13.04	30.62	3.84	51	22.84	10.37	24.04	2.98	51	0.05	257	4.11	2
	Sep	6.90	6.28	7.91	0.39	51	29.64	21.46	30.62	2.13	51	23.21	16.85	24.04	1.68	51	0.03	251	1.37	2
	Oct	6.74	4.74	7.04	0.46	51	28.90	21.03	30.61	2.25	51	22.65	16.64	24.01	1.74	51	0.03	225	1.77	2

[1]The 2010 “mid-winter” cruise (normally conducted between December 1 and February 28) was delayed until early February.

Table A-1 (continued). 2010 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). Data absences are due to inability to occupy stations because of rough seas, non-navigable pan ice, or motorized area closure; see Operations section for details.

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)
13	Feb[1]	4.93	4.91	4.94	0.01	51	30.71	30.61	30.77	0.04	51	24.28	24.21	24.33	0.03	51	0.00	128	0.01	2
	Mar	4.91	4.55	5.01	0.13	51	30.76	30.32	30.89	0.17	51	24.33	24.01	24.42	0.12	51	0.01	89	0.04	7
	Apr	4.95	4.88	5.32	0.10	51	30.83	30.54	30.98	0.16	51	24.38	24.11	24.50	0.13	51	0.00	127	0.03	13.5[2]
	May	5.48	5.35	5.95	0.14	51	30.92	30.47	31.04	0.15	51	24.39	23.98	24.50	0.13	51	0.00	126	0.07	5
	June	7.42	6.79	10.28	0.70	51	30.29	21.95	31.07	1.92	51	23.66	16.75	24.36	1.60	51	0.07	112	2.50	2
	Jul	7.46	7.02	8.74	0.48	51	29.53	21.18	30.79	2.48	51	23.05	16.35	24.10	2.00	51	0.06	126	1.18	5
	Aug	7.82	7.16	10.65	1.04	51	29.33	18.27	30.75	3.06	51	22.85	13.88	24.05	2.52	51	0.08	126	1.96	3
	Sep	7.49	7.19	8.36	0.28	51	30.31	27.65	30.80	0.71	51	23.66	21.46	24.09	0.60	51	0.02	126	0.57	2
	Oct	7.25	6.93	7.36	0.13	51	30.04	27.11	30.87	1.23	51	23.48	21.22	24.12	0.95	51	0.03	91	0.44	12
16	Feb[1]	5.17	4.39	5.27	0.20	51	30.57	29.60	30.71	0.27	51	24.15	23.45	24.26	0.19	51	0.00	278	0.14	2
	Mar																			
	Apr	5.03	4.98	5.17	0.05	51	30.48	29.35	30.86	0.53	51	24.09	23.18	24.40	0.42	51	0.00	289	0.15	11
	May	5.32	4.97	7.37	0.59	51	30.20	23.25	30.89	1.59	51	23.84	18.14	24.42	1.32	51	0.03	255	2.25	2
	June	6.68	5.89	9.17	0.74	51	30.05	18.26	30.97	2.63	51	23.57	14.02	24.38	2.14	51	0.04	234	3.49	2
	Jul	7.50	7.04	8.71	0.35	51	29.31	16.51	30.73	3.37	51	22.88	12.72	24.05	2.67	51	0.05	237	2.77	3
	Aug	7.50	6.92	9.60	0.66	51	29.06	15.26	30.71	3.65	51	22.69	11.64	24.05	2.94	51	0.05	261	2.51	2
	Sep	7.37	6.66	8.22	0.45	51	29.73	24.45	30.68	1.59	51	23.22	19.01	24.06	1.29	51	0.02	276	0.76	2
	Oct	6.79	6.41	7.02	0.14	51	29.29	24.27	30.78	1.75	51	22.95	19.04	24.12	1.37	51	0.02	269	0.57	2
20	Feb[1]																			
	Mar																			
	Apr																			
	May	5.23	4.96	6.41	0.43	51	30.15	23.32	30.92	1.61	51	23.81	18.33	24.45	1.31	51	0.04	155	2.01	2
	June																			
	Jul	6.03	4.47	6.89	0.49	51	28.17	8.94	30.56	5.56	51	22.15	7.08	24.08	4.36	51	0.11	156	3.42	4
	Aug	6.40	2.88	7.15	0.81	51	28.54	9.49	30.50	4.76	51	22.40	7.58	23.97	3.72	51	0.11	150	4.38	2
	Sep	6.53	5.89	7.14	0.29	51	29.35	19.74	30.61	2.75	51	23.03	15.53	24.06	2.16	51	0.06	152	1.42	2
	Oct	6.60	6.11	6.87	0.23	51	29.23	23.94	30.65	1.62	51	22.93	18.81	24.08	1.28	51	0.04	156	0.90	2

[1]The 2010 “mid-winter” cruise (normally conducted between December 1 and February 28) was delayed until early February.

[2]This fractional value arises from the rare event in which the maximum density gradient for this cast (station and month) occurred identically at two depths (12 m and 15 m); the depth value reported is thus halfway between.

Table A-2. 2010 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 standard deviation has little meaning). Data absences are due to inability to occupy stations because of rough seas, non-navigable pan ice, or motorized area closure; see Operations section for details.

Station	Month	Fluorescence (mg/m^3)					Dissolved Oxygen (mg/L)					OBS (NTU)					PAR ($\mu E/cm^2 * s$)		
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
01	Feb[1]	0.06	0.04	0.08	0.01	50	5.86	5.85	5.87	0.01	50	4.07	3.41	4.83	0.27	50	3.30	0.00	46.14
	Mar	0.16	0.11	0.17	0.01	45	5.92	5.91	5.93	0.01	43	4.69	3.76	5.19	0.31	45	3.01	0.00	37.30
	Apr	0.20	0.16	0.25	0.01	46	6.13	6.11	6.14	0.01	44	1.29	1.04	1.48	0.11	46	5.93	0.00	50.86
	May	0.49	0.28	0.54	0.06	49	6.40	6.38	6.46	0.02	44	1.70	1.30	2.09	0.22	49	23.68	0.00	281.90
	June	0.80	0.59	1.32	0.22	49	6.01	5.90	6.49	0.13	49	1.05	0.72	1.28	0.14	49	11.36	0.00	69.30
	Jul	1.09	0.63	1.22	0.14	48	5.15	5.13	5.17	0.01	48	4.71	3.62	5.24	0.37	48	29.57	0.00	418.85
	Aug	0.82	0.66	1.38	0.17	49	4.80	4.57	5.19	0.17	48	1.58	1.32	1.83	0.10	49	0.52	0.00	6.01
	Sep	0.53	0.47	0.58	0.02	49	4.44	4.41	4.46	0.01	49	3.54	3.16	4.06	0.23	49	3.56	0.00	48.54
	Oct	0.16	0.14	0.20	0.01	49	4.68	4.67	4.69	0.00	49	5.45	5.18	6.21	0.22	49	1.78	0.00	28.64
04	Feb[1]	0.04	0.01	0.11	0.03	51	5.96	5.86	6.25	0.11	51	0.60	0.55	0.66	0.02	51	13.99	0.00	107.10
	Mar	0.11	0.07	0.20	0.04	51	5.92	5.85	6.15	0.08	51	0.70	0.31	0.87	0.17	51	6.94	0.00	50.34
	Apr	0.19	0.10	0.29	0.05	51	6.19	6.11	6.53	0.11	51	0.49	0.27	0.67	0.13	51	18.73	0.04	139.53
	May	1.15	0.14	7.21	1.81	51	6.63	6.40	9.03	0.59	51	0.76	0.54	1.56	0.25	51	33.13	0.00	502.95
	June	1.42	0.05	7.68	2.47	51	6.67	5.89	9.57	1.16	51	0.95	0.32	2.68	0.77	51	8.66	0.00	79.15
	Jul	1.23	0.40	7.50	1.46	51	5.66	5.23	8.25	0.69	51	1.28	0.88	2.36	0.38	51	37.50	0.00	588.19
	Aug	0.59	0.07	3.18	0.76	51	5.32	4.81	9.05	0.94	51	0.77	0.37	2.10	0.40	51	6.52	0.00	78.84
	Sep	1.10	0.01	4.62	1.48	51	5.27	4.55	7.89	1.07	51	0.74	0.36	1.59	0.32	51	6.55	0.00	87.82
	Oct	0.11	0.01	0.32	0.10	51	4.84	4.44	5.84	0.41	51	0.81	0.57	1.11	0.15	51	8.03	0.00	67.63
07	Feb[1]	0.05	0.00	0.14	0.05	51	5.85	5.68	6.33	0.18	51	0.53	0.29	0.67	0.10	51	17.43	0.10	124.74
	Mar	0.08	0.01	0.14	0.05	51	5.84	5.59	5.99	0.14	51	0.59	0.45	0.70	0.04	51	15.68	0.04	114.44
	Apr	0.19	0.00	0.29	0.09	51	6.07	5.72	6.68	0.27	51	0.37	0.25	0.65	0.08	51	33.49	0.21	249.86
	May	1.31	0.13	11.36	2.49	51	6.47	5.95	9.97	0.99	51	0.80	0.36	1.84	0.42	51	38.55	0.00	562.31
	June	0.47	0.04	5.68	1.09	51	6.37	6.01	10.60	0.93	51	0.97	0.29	5.49	1.35	51	21.05	0.00	220.41
	Jul	0.49	0.05	3.93	0.89	51	5.84	5.36	8.36	0.72	51	0.91	0.34	4.36	0.99	51	19.07	0.00	298.63
	Aug	0.69	0.00	4.28	1.15	51	5.64	5.09	9.94	1.17	51	0.97	0.31	3.46	0.98	51	3.45	0.00	51.36
	Sep	1.04	0.01	5.92	1.58	51	5.40	4.80	9.16	1.10	51	0.78	0.32	3.09	0.64	51	9.17	0.00	119.20
	Oct	0.09	0.00	0.32	0.10	51	4.97	4.41	6.20	0.59	51	1.43	0.46	4.30	1.14	51	9.08	0.00	84.50
12	Feb[1]	0.01	0.00	0.05	0.01	51	5.85	5.79	6.01	0.06	51	1.11	0.64	2.42	0.57	51	9.63	0.00	115.40
	Mar	0.30	0.00	0.85	0.23	51	6.27	5.38	7.22	0.63	51	1.11	0.58	3.29	0.75	51	18.15	0.00	206.13
	Apr	0.23	0.00	0.55	0.20	51	5.78	5.38	6.71	0.43	51	0.88	0.54	2.50	0.53	51	31.99	0.00	351.03
	May	1.42	0.04	4.24	1.41	51	5.62	5.30	6.37	0.37	51	1.91	0.82	3.17	0.77	51	18.97	0.00	305.74
	June	0.63	0.13	1.85	0.53	51	5.43	5.09	7.57	0.52	51	9.06	1.37	34.51	9.58	51	9.25	0.00	179.51
	Jul	0.18	0.00	2.33	0.43	51	6.21	5.46	9.22	0.97	51	9.96	6.96	23.70	3.70	51	25.07	0.00	449.35
	Aug	0.18	0.00	0.96	0.23	51	5.62	5.22	8.54	0.72	51	34.81	12.23	88.99	13.36	51	10.93	0.00	249.71
	Sep	1.29	0.00	20.58	4.19	51	5.51	5.04	8.89	1.11	51	5.88	3.62	12.78	2.65	51	9.68	0.00	212.58
	Oct	0.09	0.00	0.48	0.11	51	5.28	4.87	6.80	0.51	51	5.68	2.98	14.51	3.15	51	2.26	0.00	43.49

[1]The 2010 “mid-winter” cruise (normally conducted between December 1 and February 28) was delayed until early February.

Table A-2 (continued). 2010 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 standard deviation has little meaning). Data absences are due to inability to occupy stations because of rough seas, non-navigable pan ice, or motorized area closure; see Operations section for details.

Station	Month	Fluorescence (mg/m^3)					Dissolved Oxygen (mg/L)					OBS (NTU)					PAR ($\mu E/cm^2 * s$)		
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
13	Feb[1]	0.01	0.00	0.04	0.01	51	5.80	5.79	5.82	0.01	51	1.04	0.78	2.30	0.34	51	6.48	0.00	58.85
	Mar	0.09	0.04	0.25	0.06	51	5.94	5.84	6.36	0.14	51	0.91	0.56	1.32	0.17	51	13.96	0.00	103.52
	Apr	0.13	0.00	0.23	0.05	51	6.12	6.03	6.18	0.04	51	0.63	0.51	0.88	0.09	51	32.44	0.07	240.13
	May	0.81	0.13	4.36	0.98	51	6.50	6.24	8.16	0.40	51	0.78	0.58	1.14	0.16	51	58.97	0.00	657.32
	June	0.53	0.00	4.76	0.86	51	6.48	6.06	9.86	0.84	51	0.91	0.35	2.98	0.73	51	90.33	0.00	1297.50
	Jul	0.80	0.07	5.21	1.20	51	5.67	5.36	8.00	0.58	51	1.61	0.57	5.92	1.59	51	17.43	0.00	302.37
	Aug	0.73	0.01	3.38	0.96	51	5.49	4.95	8.50	0.91	51	0.95	0.37	3.76	0.80	51	16.40	0.00	237.89
	Sep	0.55	0.02	2.89	0.81	51	4.86	4.49	6.32	0.48	51	0.75	0.47	1.90	0.34	51	11.39	0.00	138.69
	Oct	0.06	0.00	0.26	0.09	51	4.69	4.37	5.67	0.45	51	1.30	0.36	4.53	1.34	51	8.91	0.00	132.70
16	Feb[1]	0.02	0.00	0.13	0.04	51	5.48	5.43	5.82	0.08	51	0.58	0.38	0.65	0.04	51	3.68	0.00	29.13
	Mar																		
	Apr	0.20	0.01	0.40	0.12	51	5.80	5.63	6.40	0.24	51	0.42	0.28	0.61	0.10	51	24.60	0.13	177.71
	May	1.39	0.18	6.76	1.85	51	6.40	5.78	9.89	1.00	51	0.86	0.29	2.45	0.63	51	60.10	0.00	973.07
	June	0.30	0.00	1.06	0.31	51	6.55	6.07	10.24	0.85	51	1.01	0.34	3.77	0.85	51	75.83	0.00	1011.30
	Jul	0.71	0.03	7.57	1.51	51	5.77	5.43	9.06	0.75	51	1.51	0.54	6.19	1.72	51	11.76	0.00	211.53
	Aug	0.71	0.02	5.87	1.08	51	5.51	5.17	7.74	0.62	51	1.65	0.44	6.35	1.70	51	30.43	0.00	489.10
	Sep	1.54	0.00	11.54	2.57	51	5.54	4.80	10.45	1.48	51	0.97	0.32	3.02	0.83	51	6.66	0.00	106.16
	Oct	0.07	0.00	0.30	0.08	51	5.04	4.45	6.16	0.50	51	2.30	0.84	4.93	1.26	51	7.41	0.00	77.83
20	Feb[1]																		
	Mar																		
	Apr																		
	May	0.72	0.10	3.84	0.83	51	6.55	5.53	11.49	1.86	51	1.28	0.32	7.31	1.66	51	46.19	0.00	719.72
	June																		
	Jul	0.39	0.04	3.53	0.68	51	6.20	5.50	10.55	1.16	51	15.88	8.92	41.56	6.30	51	18.40	0.00	377.27
	Aug	0.22	0.07	0.80	0.20	51	5.93	5.39	10.73	1.17	51	64.93	28.72	234.39	46.61	51	0.03	0.00	0.86
	Sep	0.31	0.00	3.93	0.87	51	5.64	5.21	8.82	1.07	51	5.81	2.68	24.39	5.36	51	0.52	0.00	12.87
	Oct	0.11	0.00	0.31	0.09	51	5.21	4.94	6.14	0.29	51	27.91	10.18	63.42	15.73	51	1.43	0.00	34.97

[1]The 2010 "mid-winter" cruise (normally conducted between December 1 and February 28) was delayed until early February.

Appendix B: 2010 oceanographic data summary of measured parameters at core stations, averaged across a 10-m vertical depth band centered on a representative bottom water depth for each station.

Table B-1. 2010 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. Data absences are due to inability to occupy stations because of rough seas, non-navigable pan ice, or motorized area closure; see Operations section for details.

Station	Month	Depth (m)	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
	Feb[1]		5.14	5.14	5.14	0.00	10	31.16	31.16	31.16	0.00	10	24.62	24.62	24.62	0.00	10	0.07	0.04	0.08	0.01	10
	Mar		5.19	5.19	5.19	0.00	9	31.24	31.24	31.24	0.00	9	24.67	24.67	24.67	0.00	9	0.17	0.16	0.17	0.00	9
	Apr		5.30	5.30	5.30	0.00	10	31.34	31.34	31.34	0.00	10	24.74	24.74	24.74	0.00	10	0.18	0.16	0.20	0.02	10
	May		6.05	6.05	6.05	0.00	10	31.39	31.38	31.40	0.00	10	24.70	24.69	24.70	0.00	10	0.50	0.49	0.52	0.02	10
01	June	40	7.63	7.63	7.64	0.00	10	31.13	31.11	31.14	0.01	10	24.29	24.27	24.29	0.01	10	0.64	0.59	0.66	0.02	10
	Jul		7.63	7.63	7.63	0.00	10	30.85	30.84	30.85	0.00	10	24.06	24.06	24.07	0.00	10	1.13	1.10	1.17	0.02	10
	Aug		7.56	7.54	7.58	0.01	10	31.01	30.97	31.05	0.03	10	24.20	24.17	24.24	0.02	10	0.70	0.68	0.74	0.02	10
	Sep		7.74	7.74	7.74	0.00	10	30.92	30.92	30.93	0.01	10	24.11	24.10	24.12	0.01	10	0.50	0.47	0.52	0.02	10
	Oct		7.80	7.80	7.80	0.00	10	31.09	31.09	31.09	0.00	10	24.23	24.23	24.23	0.00	10	0.16	0.14	0.18	0.01	10
	Feb[1]		4.98	4.98	4.98	0.00	10	30.96	30.96	30.97	0.00	10	24.48	24.48	24.48	0.00	10	0.05	0.03	0.06	0.01	10
	Mar		5.12	5.12	5.12	0.00	10	31.10	31.10	31.10	0.00	10	24.57	24.57	24.57	0.00	10	0.11	0.10	0.13	0.01	10
	Apr		4.97	4.97	4.97	0.00	10	31.06	31.06	31.06	0.00	10	24.56	24.56	24.56	0.00	10	0.04	0.04	0.05	0.01	10
	May		5.64	5.62	5.66	0.02	10	31.17	31.17	31.18	0.01	10	24.57	24.57	24.58	0.00	10	0.22	0.20	0.24	0.01	10
04	June	200	5.38	5.37	5.39	0.01	10	31.11	31.11	31.11	0.00	10	24.55	24.55	24.55	0.00	10	0.00	0.00	0.00	0.00	10
	Jul		5.55	5.53	5.57	0.01	10	31.06	31.05	31.06	0.00	10	24.49	24.49	24.49	0.00	10	0.00	0.00	0.00	0.00	10
	Aug		5.68	5.67	5.69	0.01	10	31.04	31.04	31.04	0.00	10	24.46	24.46	24.47	0.00	10	0.00	0.00	0.00	0.00	10
	Sep		6.15	6.07	6.23	0.06	10	31.04	31.04	31.04	0.00	10	24.40	24.40	24.41	0.01	10	0.00	0.00	0.00	0.00	10
	Oct																					
	Feb[1]		4.97	4.96	4.97	0.00	10	30.92	30.92	30.92	0.00	10	24.44	24.44	24.45	0.00	10	0.00	0.00	0.00	0.00	10
	Mar																					
	Apr		5.03	5.03	5.04	0.00	10	31.09	31.09	31.09	0.00	10	24.57	24.57	24.57	0.00	10	0.00	0.00	0.00	0.00	10
	May		5.14	5.14	5.15	0.00	10	31.10	31.09	31.10	0.00	10	24.57	24.57	24.57	0.00	10	0.01	0.00	0.02	0.01	10
07	June	200	5.01	5.01	5.01	0.00	10	31.06	31.05	31.06	0.00	10	24.55	24.55	24.55	0.00	10	0.00	0.00	0.00	0.00	10
	Jul		5.43	5.42	5.44	0.01	10	31.04	31.04	31.04	0.00	10	24.49	24.49	24.49	0.00	10	0.00	0.00	0.00	0.00	10
	Aug		5.58	5.57	5.59	0.01	10	31.01	31.01	31.01	0.00	10	24.45	24.45	24.45	0.00	10	0.00	0.00	0.00	0.00	10
	Sep		6.02	5.94	6.06	0.04	10	31.00	31.00	31.00	0.00	10	24.39	24.39	24.40	0.00	10	0.00	0.00	0.00	0.00	10
	Oct																					
	Feb[1]		4.99	4.98	4.99	0.00	10	30.93	30.93	30.93	0.00	10	24.45	24.45	24.46	0.00	10	0.00	0.00	0.00	0.00	10
	Mar		4.92	4.92	4.92	0.00	10	31.00	31.00	31.00	0.00	10	24.51	24.51	24.51	0.00	10	0.00	0.00	0.00	0.00	10
	Apr		4.98	4.98	4.99	0.00	10	31.07	31.07	31.07	0.00	10	24.56	24.56	24.56	0.00	10	0.00	0.00	0.00	0.00	10
	May																					
12	June	200	4.99	4.98	4.99	0.00	10	31.05	31.04	31.05	0.00	10	24.55	24.54	24.55	0.00	10	0.14	0.11	0.16	0.01	10
	Jul		5.15	5.14	5.16	0.01	10	30.94	30.94	30.95	0.00	10	24.44	24.44	24.45	0.00	10	0.07	0.05	0.08	0.01	10
	Aug		5.29	5.28	5.32	0.02	10	30.92	30.91	30.92	0.01	10	24.41	24.40	24.42	0.01	10	0.07	0.05	0.08	0.01	10
	Sep		5.43	5.41	5.45	0.02	10	30.90	30.90	30.91	0.00	10	24.38	24.38	24.39	0.00	10	0.00	0.00	0.00	0.00	10
	Oct		5.56	5.52	5.62	0.03	10	30.90	30.89	30.90	0.00	10	24.36	24.35	24.37	0.01	10	0.00	0.00	0.00	0.00	10

[1]The 2010 “mid-winter” cruise (normally conducted between December 1 and February 28) was delayed until early February.

Table B-1 (continued). 2010 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. Data absences are due to inability to occupy stations because of rough seas, non-navigable pan ice, or motorized area closure; see Operations section for details.

Station	Month	Depth (m)	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
	Feb[1]		4.94	4.94	4.94	0.00	10	30.88	30.88	30.88	0.00	10	24.42	24.42	24.42	0.00	10	0.01	0.00	0.03	0.01	10
	Mar																					
	Apr		4.94	4.94	4.94	0.00	10	31.03	31.03	31.04	0.00	10	24.54	24.54	24.54	0.00	10	0.04	0.04	0.05	0.01	10
	May		5.31	5.30	5.31	0.00	10	31.08	31.07	31.08	0.00	10	24.53	24.53	24.53	0.00	10	0.05	0.04	0.07	0.01	10
13	June	100	6.10	6.06	6.13	0.02	10	31.12	31.11	31.13	0.00	10	24.47	24.47	24.48	0.01	10	0.02	0.02	0.02	0.00	10
	Jul		6.48	6.46	6.50	0.01	10	30.97	30.96	30.98	0.01	10	24.31	24.31	24.32	0.00	10	0.03	0.01	0.05	0.02	10
	Aug		6.65	6.61	6.68	0.03	10	30.92	30.91	30.93	0.01	10	24.25	24.24	24.27	0.01	10	0.00	0.00	0.00	0.00	10
	Sep		6.92	6.87	6.96	0.03	10	30.93	30.92	30.93	0.00	10	24.22	24.21	24.23	0.01	10	0.01	0.00	0.02	0.01	10
	Oct																					
	Feb[1]		5.04	5.03	5.05	0.01	10	30.76	30.76	30.76	0.00	10	24.31	24.31	24.31	0.00	10	0.00	0.00	0.00	0.00	10
	Mar																					
	Apr		4.90	4.90	4.90	0.00	10	30.95	30.95	30.95	0.00	10	24.47	24.47	24.47	0.00	10	0.00	0.00	0.00	0.00	10
	May		5.01	5.01	5.01	0.00	10	30.99	30.99	30.99	0.00	10	24.50	24.50	24.50	0.00	10	0.03	0.01	0.05	0.01	10
16	June	200	5.10	5.08	5.14	0.02	10	31.00	30.99	31.00	0.00	10	24.49	24.49	24.49	0.00	10	0.00	0.00	0.00	0.00	10
	Jul		5.07	5.06	5.09	0.01	10	30.96	30.96	30.96	0.00	10	24.47	24.47	24.47	0.00	10	0.00	0.00	0.00	0.00	10
	Aug		5.17	5.16	5.17	0.00	10	30.95	30.95	30.95	0.00	10	24.45	24.45	24.45	0.00	10	0.00	0.00	0.00	0.00	10
	Sep		5.30	5.28	5.31	0.01	10	30.92	30.91	30.92	0.00	10	24.41	24.40	24.41	0.00	10	0.00	0.00	0.00	0.00	10
	Oct		5.49	5.47	5.52	0.02	10	30.89	30.89	30.90	0.00	10	24.37	24.36	24.37	0.00	10	0.00	0.00	0.00	0.00	10
	Feb[1]																					
	Mar																					
	Apr																					
	May		4.91	4.91	4.91	0.00	10	30.96	30.96	30.96	0.00	10	24.48	24.48	24.48	0.00	10	0.03	0.01	0.05	0.01	10
20	June	125																				
	Jul		5.16	5.15	5.17	0.01	10	30.79	30.79	30.79	0.00	10	24.32	24.32	24.33	0.00	10	0.11	0.07	0.14	0.02	10
	Aug		5.27	5.24	5.29	0.02	10	30.79	30.78	30.80	0.01	10	24.31	24.30	24.32	0.01	10	0.06	0.03	0.08	0.02	10
	Sep		5.36	5.31	5.41	0.03	10	30.78	30.77	30.79	0.01	10	24.29	24.28	24.31	0.01	10	0.00	0.00	0.00	0.00	10
	Oct		5.47	5.46	5.48	0.01	10	30.79	30.78	30.79	0.00	10	24.29	24.28	24.29	0.00	10	0.01	0.00	0.02	0.01	10

[1]The 2010 "mid-winter" cruise (normally conducted between December 1 and February 28) was delayed until early February.

Table B-2. 2010 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). Data absences are due to inability to occupy stations because of rough seas, non-navigable pan ice, or motorized area closure; see Operations section for details.

Station	Month	Depth (m)	Dissolved Oxygen (mg/L)					OBS (NTU)					PAR (μE/cm² * s)		
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
01	Feb[1]	40	5.86	5.85	5.87	0.01	10	4.02	3.90	4.13	0.09	10	0.00	0.00	0.00
	Mar		5.92	5.91	5.92	0.00	7	4.82	4.58	5.07	0.20	9	0.00	0.00	0.00
	Apr		6.12	6.11	6.14	0.01	8	1.32	1.23	1.40	0.05	10	0.00	0.00	0.00
	May		6.39	6.38	6.39	0.01	8	1.93	1.78	2.08	0.11	10	0.00	0.00	0.00
	June		5.92	5.90	5.93	0.01	10	1.08	0.88	1.17	0.10	10	0.00	0.00	0.00
	Jul		5.15	5.15	5.16	0.00	10	4.97	4.81	5.22	0.16	10	0.00	0.00	0.00
	Aug		4.61	4.57	4.67	0.03	10	1.60	1.47	1.78	0.08	10	0.00	0.00	0.00
	Sep		4.42	4.41	4.43	0.01	10	3.72	3.39	4.02	0.20	10	0.00	0.00	0.00
	Oct		4.68	4.67	4.69	0.00	10	5.32	5.20	5.54	0.12	10	0.00	0.00	0.00
04	Feb[1]	200	5.83	5.81	5.84	0.01	10	1.83	1.64	2.04	0.13	10	0.00	0.00	0.00
	Mar		5.87	5.87	5.88	0.00	10	1.37	1.27	1.52	0.07	10	0.00	0.00	0.00
	Apr		6.09	6.08	6.10	0.01	10	0.65	0.55	1.00	0.14	10	0.00	0.00	0.00
	May		6.30	6.29	6.31	0.01	10	1.17	1.08	1.34	0.10	10	0.00	0.00	0.00
	June		5.78	5.78	5.79	0.00	9	0.36	0.33	0.45	0.03	10	0.00	0.00	0.00
	Jul		5.43	5.43	5.44	0.00	10	0.78	0.60	0.93	0.10	10	0.00	0.00	0.00
	Aug		5.25	5.24	5.26	0.01	10	1.00	0.81	1.16	0.12	10	0.00	0.00	0.00
	Sep		4.81	4.77	4.86	0.03	10	0.96	0.83	1.12	0.11	10	0.00	0.00	0.00
	Oct														
07	Feb[1]	200	5.65	5.64	5.66	0.01	10	0.80	0.64	0.93	0.10	10	0.00	0.00	0.00
	Mar														
	Apr		5.84	5.82	5.86	0.01	10	0.45	0.30	0.60	0.10	10	0.00	0.00	0.00
	May		5.95	5.94	5.96	0.00	10	0.59	0.55	0.65	0.03	10	0.00	0.00	0.00
	June		5.50	5.49	5.52	0.01	10	0.46	0.38	0.58	0.08	10	0.00	0.00	0.00
	Jul		5.44	5.44	5.45	0.00	10	0.54	0.38	0.65	0.10	10	0.00	0.00	0.00
	Aug		5.28	5.27	5.29	0.01	10	0.48	0.36	0.66	0.11	10	0.00	0.00	0.00
	Sep		4.98	4.96	5.00	0.01	10	0.41	0.33	0.54	0.07	10	0.00	0.00	0.00
	Oct														
12	Feb[1]	200	5.39	5.38	5.41	0.01	10	0.59	0.56	0.62	0.02	10	0.00	0.00	0.00
	Mar		5.48	5.47	5.49	0.01	10	0.71	0.59	0.85	0.08	10	0.00	0.00	0.00
	Apr		5.59	5.58	5.59	0.01	10	0.60	0.57	0.64	0.03	10	0.00	0.00	0.00
	May														
	June		5.36	5.36	5.37	0.01	10	6.76	6.56	7.06	0.17	10	0.00	0.00	0.00
	Jul		5.13	5.12	5.14	0.00	10	47.06	41.65	49.80	2.87	10	0.00	0.00	0.00
	Aug		5.10	5.09	5.11	0.01	10	45.61	43.13	48.32	2.19	10	0.00	0.00	0.00
	Sep		5.01	5.00	5.02	0.01	10	9.43	8.62	9.89	0.40	10	0.00	0.00	0.00
	Oct		4.96	4.95	4.96	0.00	10	3.21	3.05	3.39	0.11	10	0.00	0.00	0.00

[1]The 2010 "mid-winter" cruise (normally conducted between December 1 and February 28) was delayed until early February.

Table B-2 (continued). 2010 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). Data absences are due to inability to occupy stations because of rough seas, non-navigable pan ice, or motorized area closure; see Operations section for details.

Station	Month	Depth (m)	Dissolved Oxygen (mg/L)					OBS (NTU)					PAR (μE/cm^2 * s)		
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
	Feb[1]		5.83	5.81	5.84	0.01	10	1.01	0.83	1.13	0.10	10	0.00	0.00	0.00
	Mar														
	Apr		6.04	6.02	6.05	0.01	10	0.70	0.55	0.93	0.12	10	0.00	0.00	0.00
	May		6.12	6.11	6.12	0.00	10	0.84	0.80	0.89	0.03	10	0.00	0.00	0.00
13	June	100	5.91	5.90	5.94	0.01	10	0.52	0.34	0.65	0.11	10	0.00	0.00	0.00
	Jul		5.32	5.30	5.34	0.02	10	0.88	0.80	1.11	0.09	10	0.00	0.00	0.00
	Aug		5.00	4.99	5.02	0.01	10	0.85	0.80	0.91	0.03	10	0.00	0.00	0.00
	Sep		4.52	4.50	4.54	0.01	10	0.86	0.82	0.91	0.03	10	0.00	0.00	0.00
	Oct														
	Feb[1]		5.64	5.62	5.66	0.02	10	0.66	0.59	0.81	0.08	10	0.00	0.00	0.00
	Mar														
	Apr		5.88	5.87	5.89	0.01	10	0.57	0.47	0.69	0.08	10	0.00	0.00	0.00
	May		5.94	5.94	5.95	0.00	10	0.62	0.55	0.65	0.03	10	0.00	0.00	0.00
16	June	200	5.86	5.85	5.87	0.01	10	0.38	0.37	0.40	0.01	10	0.00	0.00	0.00
	Jul		5.54	5.54	5.55	0.00	10	0.54	0.35	0.62	0.09	10	0.00	0.00	0.00
	Aug		5.49	5.49	5.50	0.00	10	0.42	0.28	0.65	0.11	10	0.00	0.00	0.00
	Sep		5.30	5.29	5.31	0.01	10	0.37	0.31	0.42	0.04	10	0.00	0.00	0.00
	Oct		5.07	5.06	5.08	0.01	10	0.71	0.59	0.84	0.09	10	0.00	0.00	0.00
	Feb[1]														
	Mar														
	Apr														
	May		5.81	5.79	5.81	0.01	10	1.09	0.95	1.33	0.11	10	0.00	0.00	0.00
20	June	125													
	Jul		5.34	5.32	5.34	0.01	10	57.66	50.09	65.27	5.38	10	0.00	0.00	0.00
	Aug		5.32	5.31	5.33	0.01	10	40.43	37.85	42.48	1.66	10	0.00	0.00	0.00
	Sep		5.20	5.19	5.23	0.01	10	2.38	2.22	2.59	0.11	10	0.00	0.00	0.00
	Oct		5.05	5.03	5.07	0.02	10	13.83	11.97	16.52	1.69	10	0.00	0.00	0.00

[1]The 2010 "mid-winter" cruise (normally conducted between December 1 and February 28) was delayed until early February.

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.

NPS 132/120488 April 2013

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA ™