Supporting Information for "Tidal mixing maintains regional differences in water properties and nutrient ratios in British Columbia coastal waters"

H.V. Dosser[1], S. Waterman[1], J.M. Jackson[2], C.G. Hannah[3], B.P.V. Hunt[1,4,5]

[1]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4

[2]Hakai Institute, 1010 Langley St, Victoria, BC, V8W 1V8

[3]Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, V8L 4B2

[4]Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, V6T 1Z4

[5]Hakai Institute, Heriot Bay, Quadra Island, BC, V0P 1H0

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Introduction

The following Supporting Information is included herein: S.1 provides additional details regarding regional definitions, S.2 expands on the descriptions of sampling biases in the data from Section 2.2, and S.3 provides additional information about the nutrient concentration data.

Corresponding author: H. V. Dosser, Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada. (hdosser@eoas.ubc.ca)

S.1 Study area: Definitions of regions and evidence of tidal mixing

The boundaries of our study area are chosen based on the availability of DFO, UBC, and Hakai Institute data. Within this area, we define four regions that are located within the generally accepted boundaries of Queen Charlotte Strait (QCSt), Johnstone Strait (JS), the Discovery Islands (DI), and the Strait of Georgia (SoG) (Figure 1). We restrict our focus to eastern QCSt (east of 127.4°W) due to sparse DFO and UBC data and the complete absence of Hakai Institute data in western QCSt. We focus on only the northern SoG (north of 49.8°N) due to its proximity to JS and the DI and the availability of Hakai Institute samples.

A secondary consideration when choosing our regional boundaries are the bathymetric characteristics that influence tidal mixing (Figure 1), since it is anticipated that these factors will have a critical impact on regional differences. As described in Section 3.1, we use buoyancy frequency, $N^2 = -(g/\rho)\ d\rho/dz$, where ρ is the density calculated from each set of T, S profiles and g is the acceleration due to gravity, as a proxy for the direct influence of mixing in each region (Figure 2, Figure S1). In the DI, the shallow, constricted passages are conducive to enhanced tidal mixing, reflected in the absence of significant stratification there. By contrast, the topography in the JS region is smoother and deeper, and weak stratification suggests weaker in-situ tidal mixing. QCSt and the SoG have less complex bathymetry and are more strongly stratified than JS or the DI, with the strong stratification extending to the sills between regions.

Bathymetric features such as sills provide natural boundaries between regions. We define the JS region to include only the deep western basin of Johnstone Strait, and include the shallow, weakly-stratified eastern basin on the other side of the JS/DI sill

(Figure 2) in the DI region. This choice allows the tidal mixing frontal zone to span the boundary between the JS and DI regions. Within the DI, we exclude passages near Bute Inlet, as the high volume of freshwater outflow results in properties that differ from the rest of the region. Lastly, for the SoG region, we include strongly-stratified locations to the east of Quadra Island, terminating at the shallow sills entering the passages between islands in the DI.

S.2 Sampling biases

Both seasonal and spatial sampling biases present in the combined data product reflect the difficulty of sampling in challenging conditions, while interannual and depth biases reflect institutional and technical limitations.

Interannual bias: Temperature and salinity data prior to the mid-1940s are extremely limited. A marked increase in sampling in JS, QCSt, and the DI during the late 1970s was driven in large part by the efforts of a single DFO research program (see e.g. Thomson, 1976; Thomson & Huggett, 1980; Thomson, 1981), which was followed by a decrease in sampling during the 1980s and early 1990s. Few nutrient concentration data exist prior to 1998 in any region (Figure S2). The sharp increase in T, S, and nutrient data after 2014 corresponds to the beginning of the Hakai Institute sampling program. There is a significant interannual bias to recent years in all regions.

Seasonal and spatial biases: Seasonal bias is linked to spatial bias, in that DFO routinely samples repeat stations during particular months of the year (e.g. once in May and once in September), while the Hakai Institute only samples in JS and QCSt from April to July. Sampling is biased towards the summer months in all regions due to the difficulty of accessing remote stations during winter conditions (Figure S3). Since DFO, UBC, and the Hakai Institute all prioritize sampling at repeat stations, data are also biased to these locations. Despite this, T-S profiles are available at locations that span most of each region during all seasons (Figure 3, map). The DI region has the lowest spatial density of sampling locations, while the SoG has the highest. In the DI, the number of sampling locations is lower in channels with extremely strong tidal currents due to the difficulty of making measurements in such conditions. The spatial coverage of nutrient concentration data is even sparser (Figure S4). There are only two Hakai nutrient sampling stations in QCSt, both near the JS sill. In the DI, most of the DFO nutrient samples are taken near Chatham Point and along Nodales Channel, while Hakai nutrient samples are taken along the eastern side of Quadra Island. In the SoG, much of the DFO nutrient data comes from several repeat stations to the south of Discovery Passage, while the Hakai nutrient sampling stations are located near Quadra Island.

Depth bias: During the earliest part of the data record, temperature and salinity samples were collected at discrete and often widely separated depths (e.g. every 50 m in the vertical), rather than as a near-continuous profile as is the case with CTD measurements. Despite this, the vast majority (93%) of T, S data have a vertical resolution of less than 2 m. Nutrient samples are typically closely spaced in the upper 10 m of the water column and more widely spaced below, with 82% of all nutrient data having a vertical resolution of less than 25 m. Since CTD data are unreliable at the surface, and since 30% of T-S profiles begin between 2 m and 10 m, we exclude T, S data in the uppermost 10 m from the analysis. Finally, both T-S and nutrient profiles often terminate well above the seafloor in the deepest passages (particularly in JS), resulting in fewer data points in the deep water column. In the case of JS, the lower portion of the water column is nearly homogeneous (Thomson, 1976, 1981), so that the paucity of full-depth profiles is not expected to significantly bias the results.

S.3 Nutrient concentrations

As described in Section 3.4, distributions of nitrate+nitrite, phosphate, and silicate concentrations (Figures S5, S6, S7) show clear regional differences, with QCSt and JS exhibiting lower median nutrient concentrations compared to the SoG and DI. All three nutrients show occasional depletion near the surface in the SoG, but concentrations are otherwise rarely limiting. Nutrient concentrations are similar in the upper ($<$50 m depth) and lower ($\geq$50 m depth) water column in JS and the DI, likely due to the influence of tidal mixing in those regions. In contrast, nutrient concentrations tend to be higher in the lower water column in QCSt and the SoG. This is likely due to nutrient replenishment by seasonal upwelling and remineralization in the lower water column, as well as nutrient utilization by phytoplankton in the upper water column, as discussed in Section 4.2.

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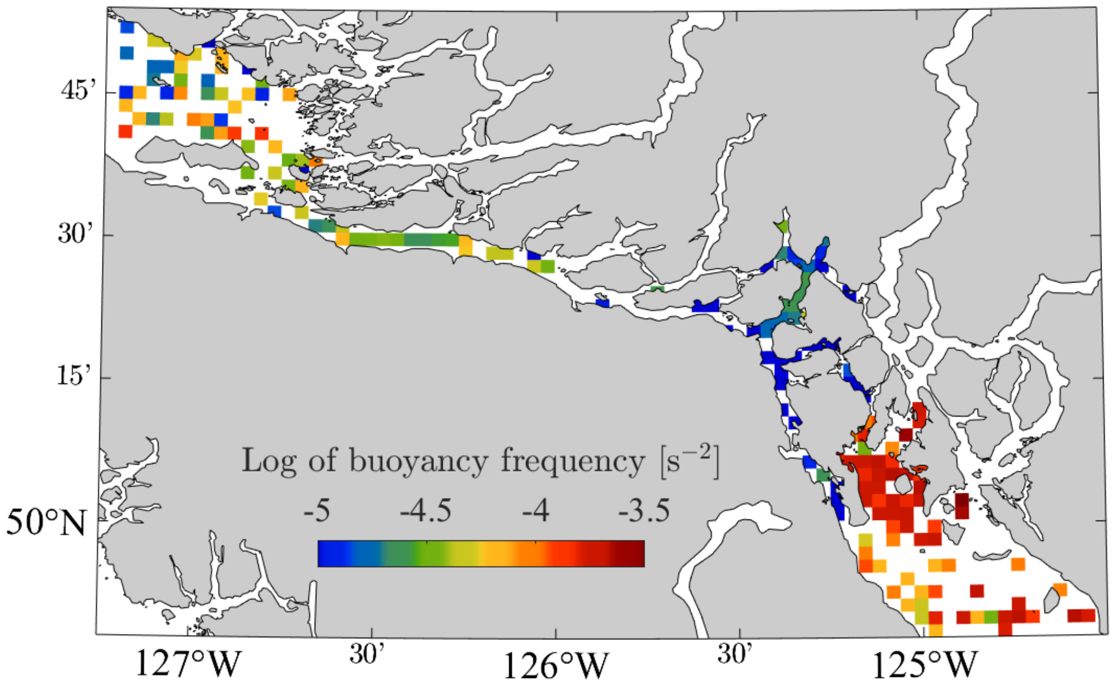

Figure S1. Identical to Figure 2, but for stratification in the winter months (November to April).

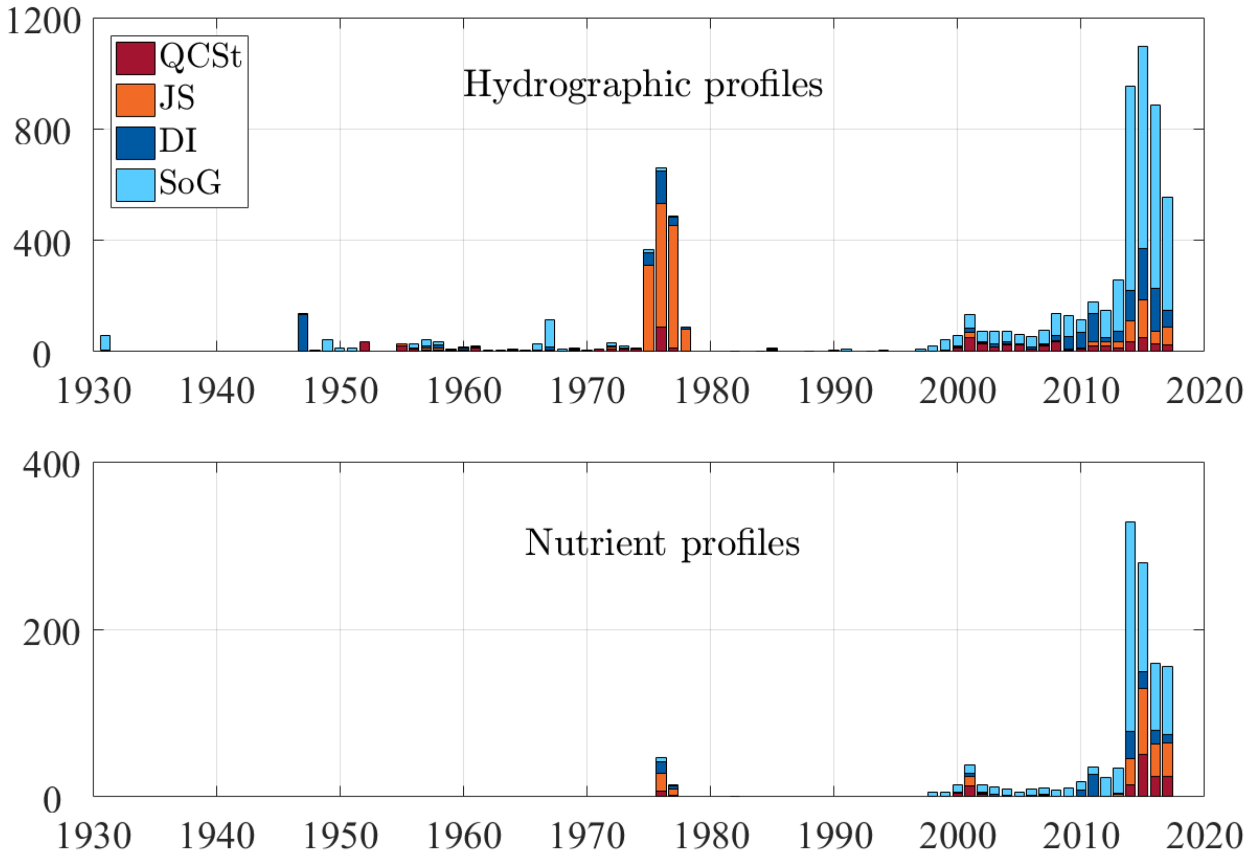

Figure S2. (Top) Number of T-S profiles collected by DFO, UBC, and the Hakai Institute each year from 1932-2018. Colours correspond to each of the four regions in Figure 1. (Bottom) As above, but for nutrient profiles, where each 'profile' includes samples of nitrate, phosphate, and silicate.

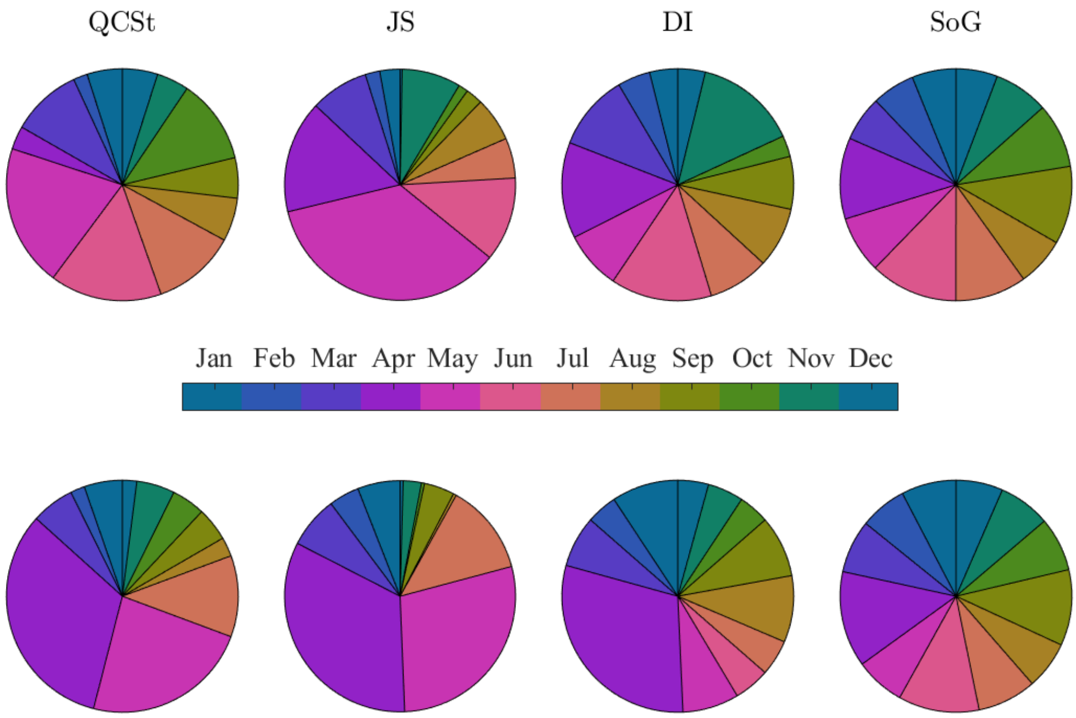

Figure S3. Fraction of total T-S profiles (top row) and nutrient sample profiles (bottom row) collected each month in each region (columns as indicated). Warmer colours indicate the summer months.

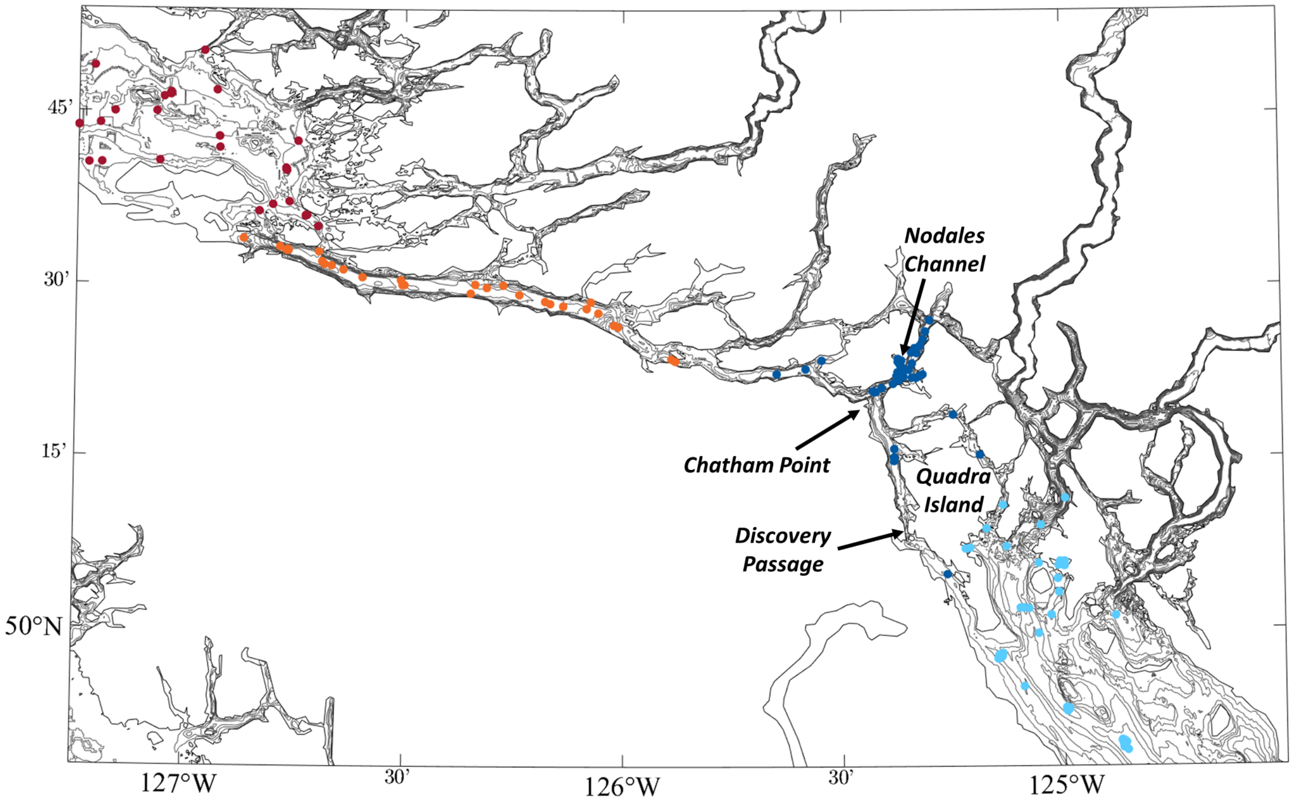

Figure S4. Bathymetric map with locations of nutrient sampling shown by the coloured dots, with QCSt in red, JS in orange, the DI in dark blue and the SoG in light blue. Locations of interest (as discussed in the text) are indicated.

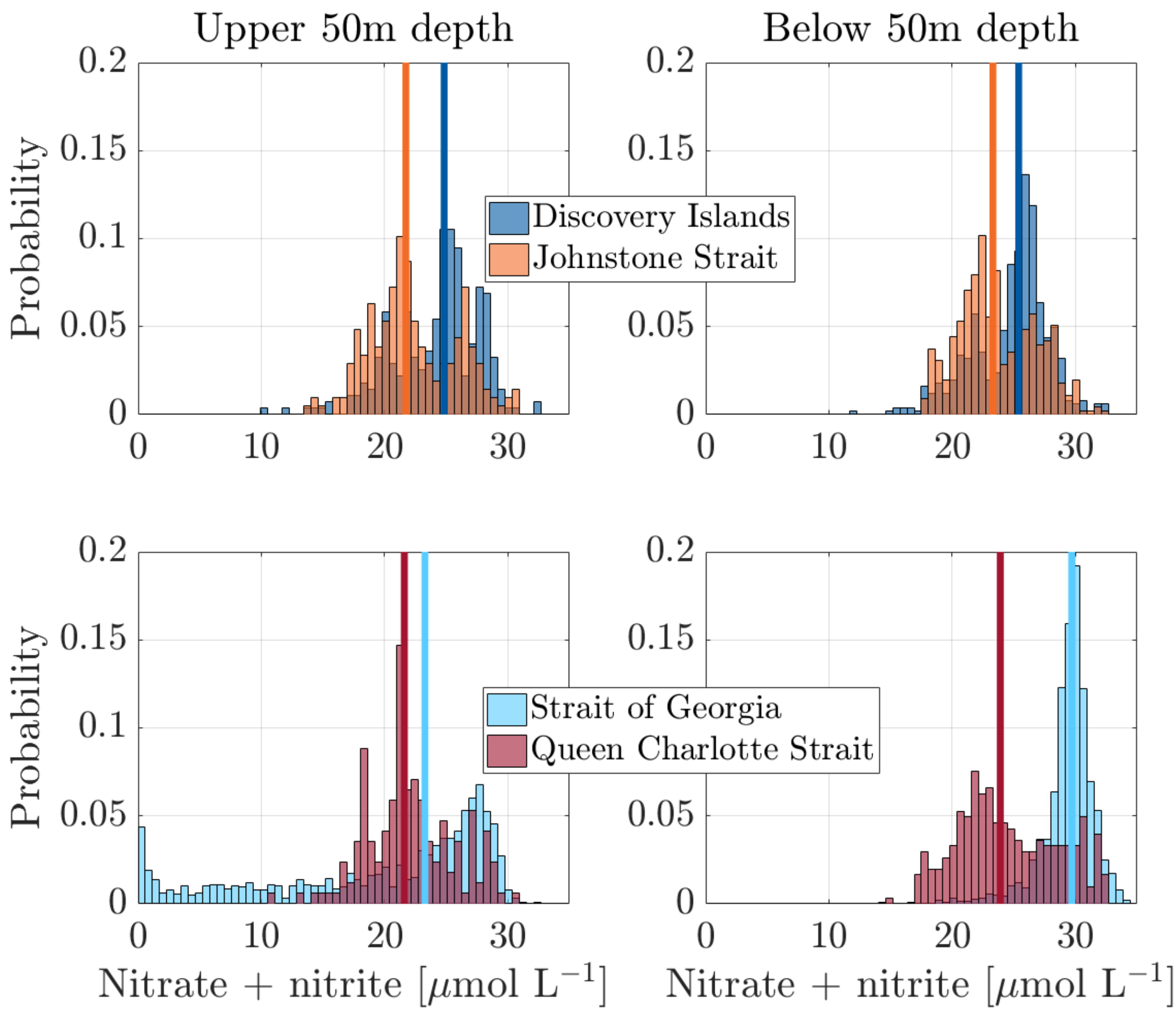

Figure S5. Distributions of nitrate+nitrite concentration, calculated using the full nutrient dataset, binned every 25 m in the vertical, and coloured by region, for the upper 50 m of the water column (left) and below 50 m depth (right). Vertical lines give the median value for each distribution.

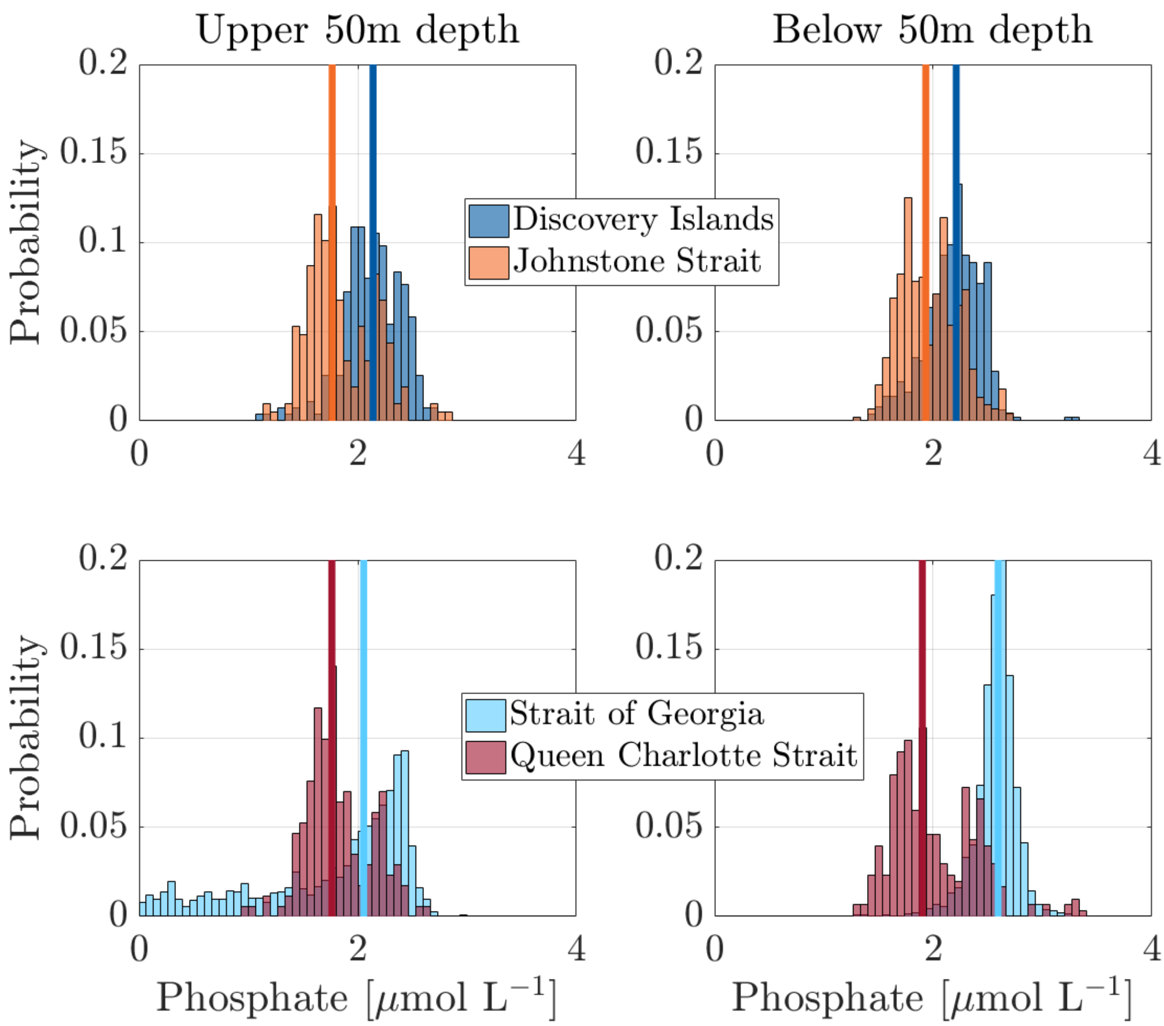

Figure S6. As in Figure S5, but for the distributions of phosphate concentration.

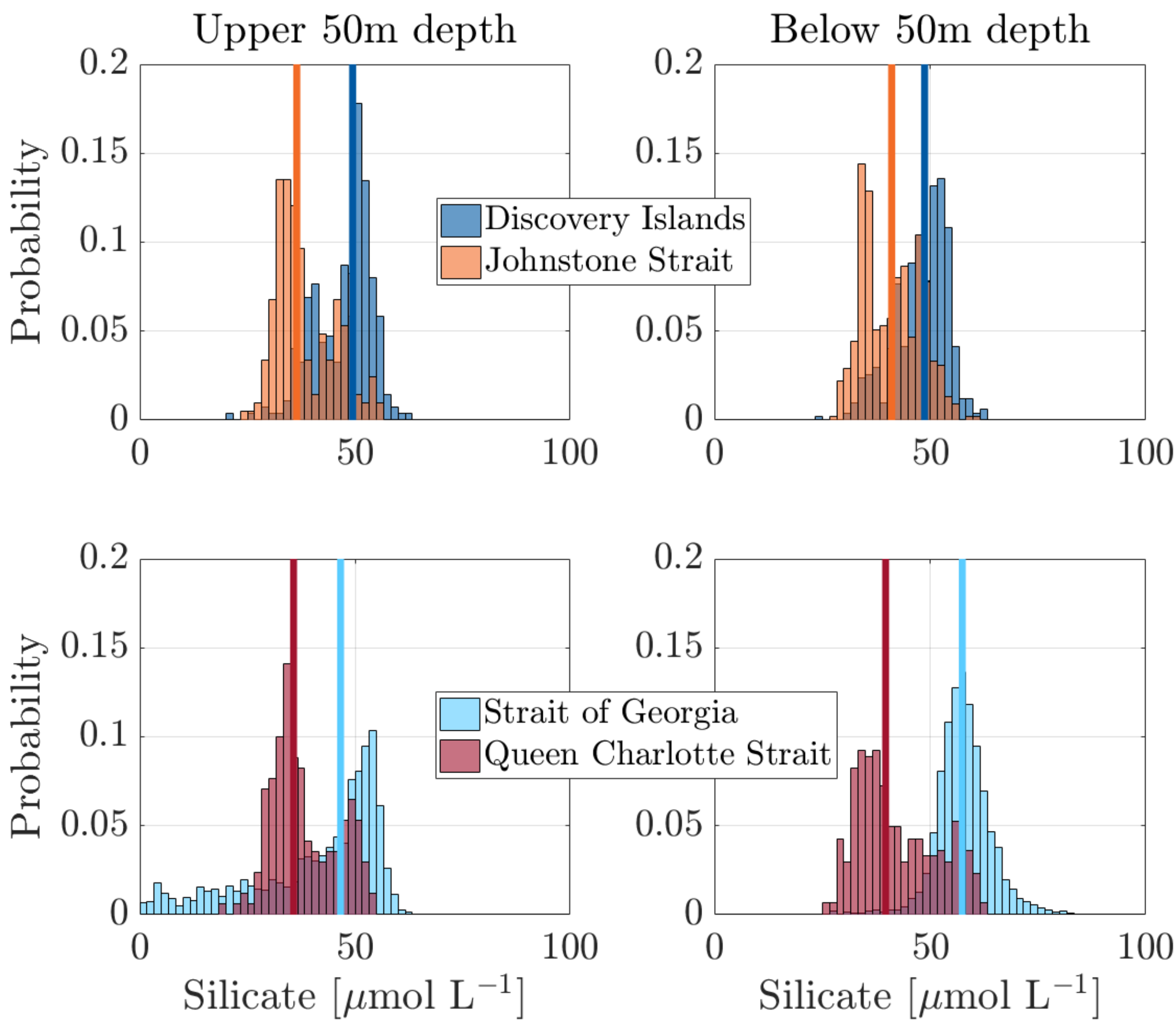

Figure S7. As in Figure S5, but for the distributions of silicate concentration.