HIGHLIGHTS

- In the summer, strong inshore-offshore gradients in salinity are established by freshwater runoff from mainland rivers.
- Oceanography changes dramatically at the onset of fall storms.
- Tidally-forced internal waves are a prevalent oceanographic feature in the fjord system.

METHODS

In the summers of 2014 and 2015, oceanographic surveys were conducted aboard the RV Bangarang, a 12m motorsailer, with a team of three researchers. Circuits of the Kitimat Fjord System were completed within a target duration of 20 days, during which we visited a grid of 24 oceanographic stations, between which we conducted systematic transect surveys.

During transects, surface water temperature (SST) and salinity (SSS) were sampled at 0.3m depth every two seconds with a Seabird Electronics 45 thermostalinograph (TSG, calibrated annually). Sound-scattering objects in the water column were surveyed with a Syvquest Hydrobox echosounder. Backscatter was recorded from 0 to 300 m depth on two frequencies: 200 kHz, which reflects zooplankton such as krill, and 33 kHz, which reflects fish and some jellies.

At each station we performed Secchi disk readings of water turbidity (8 replicate casts from the same observer) and a water column sample (down to 250m, seafloor permitting) with a SBE25plus CTD. The Secchi disk was equipped with a 5 lb. diving weight to combat the effects of strong tidal currents and vessel windage. The Secchi depth was defined as the exact depth at which the black and white quadrants cannot be discerned (as in Smith 2001).

The CTD measured temperature, salinity, density, chlorophyll-a (an indicator of phytoplankton activity), dissolved oxygen concentration, and sound velocity. From these measurements the following variables were calculated: Mixed layer depth, which indicates the degree of near-surface mixing due to waves and runoff, was calculated as SST - 0.8C (Fiedler 2010); thermocline, which is the temperature gradient that occurs below the mixed layer is an important control of primary production, was calculated using the differencing technique used in Reilly & Fiedler (1994) and Fiedler & Talley (2006) and outlined in Fiedler (2010); stratification was calculated as the density difference between the surface and a standard depth (Behrenfield et al., 2006), in our case 50m due to regions of shallow seafloor within the study area. For temperature and salinity, mean values were calculated for the “upper” water column (depths above the thermocline) and the “bottom” water column (depths below thermocline).

To visually ground-truth the objects causing krill-like backscatter from our echosounder data, I used the KISS, a weight-balanced deepwater imaging towfish apparatus with mounted Go-Pro and 2,000-lumen LED spotlight in pressure-rated housing (Group B Inc.). KISS casts were conducted regularly throughout the season in various backscatter conditions (Fig. 1). The KISS was deployed on 250 meters of line marked every 25m so that KISS depth could be recorded throughout a cast. Recorded video was retrieved and frames were assigned depths using timestamp matching with data entry software output.
SUMMARY

Sea surface
Freshwater runoff from snowmelt and rains enter the Kitimat Fjord System primarily from Douglas Channel and Gardner Canal. As this freshwater flows out into Gil Basin and meets waters from Hecate Strait, strong offshore-inshore gradients in water properties are established. The strength of these gradients depends on many factors, including the amount of snow-melt and rain as well as storm energy. The salinity gradient is often more dramatic than the temperature gradient, which is more affected by local heating. In 2015, the offshore-inshore salinity gradient was strongest in August and June, but relatively weak in July and September (Fig. 2).

The most homogenous surface conditions occurred in September, perhaps due to mixing by the early onset of autumn storms. September was also the month of the coldest (mean 12.37 °C, min 10.48 °C) and most saline measurements (mean 26.92 ppt, max. 31.73 ppt). Waters were warmest in July (mean 14.67°C, max 19.05°C), with hotspots in Squally Channel, Wright Sound and McKay Reach. The widest range of measurements were taken in July for temperature (11.41 – 19.05°C) and in August for salinity (11.59 – 31.36 ppt).

In 2015, water clarity was poorest in June and best in July, particularly in Squally Channel. In general, the interior channels (Whale, McKay, Ursula and Verney) were the most turbid.

Chlorophyll-a
The amount of chlorophyll-a declined throughout the 2015 season (Fig. 3). June concentrations were much higher in the southwest channels (max. 28.5 µg l⁻¹). After June, high chlorophyll totals only persisted in isolated hotspots occurring increasingly inland. The largest hotspots were in north Squally in June (above value) and in Douglas Channel in September (27.02 µg ml⁻¹).

Acoustic backscatter
Echosounder data suggest that zooplankton biomass peaks in the outer channels (Squally, Estevan and Caamano) in June, then declines throughout the summer while dispersing into the fjord system (Fig. 3). A similar pattern was found in the 33 kHz backscatter, which was processed to be indicative of small schooling fish. In early summer, the most schooling fish was found in Estevan Sound. By late summer, the most schooling fish was found in North Ursula Channel.

Water Column
The depth of the mixed layer and its underlying thermocline was fairly constant in all months except for September 2015, when it substantially deepened (Fig. 4). Again, this may have been due to the early onset of autumn storms. In all months, the mixed layer extended deeper in outer channels (where winds were generally stronger) than in interior channels.

Water column temperatures above the thermocline mirrored sea surface temperatures in 2015: isolated hotspots with overall temperature peaking in July (Fig. 5). Bottom water temperatures, however, increased throughout summer 2015 to peak in September. This warming was most dramatic in the outer channels of Caamano and Campania Sounds (Fig. 6).
Annual differences: 2014 vs. 2015
The three substantial differences between years were: 1) surface property gradients were relatively weak in 2014; 2) deep water temperatures were warmer in 2015; and 3) oxygen levels were higher in 2014 than they were in 2015. Due to limited sampling in 2014, further comparisons between survey years cannot be made meaningfully. However, it is interesting that conditions in August and September 2014 were generally quite different from the same months in 2015; to the extent that a “typical” oceanographic pattern exists for this fjord system, the timing of the pattern, or perhaps the pattern itself, was different for those two years.

Internal waves
Steep seafloor sills occur at the intersections of channels within the Kitimat Fjord System. These sills can be very shallow; the sill at Amy Point at the north tip of Gribbell Island is less than 30m deep. Flooding and ebbing tides pump water over these sills, creating underwater turbulence that often sorts into “internal waves”, in which two layers of water oscillate up and down. Internal waves are impressive oceanographic features; when dramatic enough they can create bands of disrupted waters on the surface (Fig. 11). Gitga’at waters have particularly excellent examples of internal wave processes. These features are of great interest to oceanographers because they contribute to mixing that brings nutrients to the surface, thus driving productivity, and aggregate algae and zooplankton for predators.

MANAGEMENT CONSIDERATIONS

Importance of consistent long-term monitoring
The oceanography of the Kitimat Fjord System is fundamental to every other aspect of its environment. A long-term program of regular oceanographic surveys would be of enormous value. This brief report demonstrates the need for and potential of regular surveys in all seasons over many years. Surveys would be most effective if they occurred monthly, quarterly at the least.

Investing “upstream”: forestry and climate
Patterns in the summertime oceanography of Gitga’at waters are closely linked to patterns in climate, including storm energy, ocean temperatures, summer rainfall and wintertime snow accumulation. These processes coincide to establish the inshore-offshore gradients and month-to-month trends that are the habitat for important cultural keystones such as salmon and whales, as well as their prey. These processes are also directly impacted by issues that are much larger than the fjord system itself: forestry and damming activities upstream influence the amount, timing and chemistry of freshwater runoff, as do patterns in global climate. Positioned at a complex interface between the land and the sea, Gitga’at waters are susceptible to environmental disturbances from all directions. It is therefore important for the First Nation to remain involved and invested in upstream issues that have the potential to indirectly alter the fundamental oceanographic processes that moderate the marine ecosystem in Gitga’at waters.
REFERENCES


FIGURES

Figure 1. A) Acoustic backscatter collected during a focal follow of 3 fin whales on 29 July 2015. Y-axis is depth (m), X-axis is chronological order of echosounder pings geo-rectified into 6m horizontal bins. Greyed-out sections are periods of high engine RPM that compromised 33 kHz readings and were manually removed. B) Still-frame of Go-Pro video taken during same focal follow using the Bangarang Krill Imaging and Scrambling System (KISS), displaying dense aggregations of euphausiids at approximately 170m. Black bracketed line in panel A displays the time window in which KISS cast descended from 150m to 200m. For the full video: http://www.rvbangarang.wordpress.com/moments.
Figure 2. Sea surface properties in each monthly survey. 1% light depth is a way of describing the clarity of water; it is the depth at which only 1% of surface light levels remain (deeper = clearer).
Figure 3. Measurements of marine algae (Chl-a sum, top), krill (inferred from 200 kHz backscatter, middle), and small schooling fish (inferred from 33 kHz backscatter, bottom).

Figure 4. The depth of the thermocline and mixed layer in each monthly survey.
Figure 5. Differences between upper and bottom portions of the water column in each survey month.
Figures 6 – 10. The following pages present patterns in water properties from inshore waters to offshore waters along the transect shown below. Each page pertains to a single variable, such as temperature. The transect begins in Caamano Sound (left side of page) and travels through the fjord system to north Verney Pass (right side of page). Each row is a single survey month, displaying a cross-section of the water column from the sea surface to 150m. Plots were made by interpolating CTD measurements taken at 12 stations along the transect.
Figure 6.
Figure 7.
Figure 8.
Figure 9.
Figure 10.
Figure 11. A) Surface signatures of internal waves on an otherwise calm day within the Kitimat Fjord System at Amy Point (K.B. Watson for scale). B and C) Acoustic backscatter (200 kHz) detections of internal waves from same seafloor sill (large red bands at bottom of each pane are seafloor reflections).