Abstract:

Nutrients in salt water play a key role in determining primary productivity in the ocean. The availability of dissolved nutrients in sea water is affected by sources and sinks such as rivers and sediments, and vertical mixing processes. This study examines the distribution of dissolved nutrients (Nitrate, Phosphate, Silicate, and Ammonia) in Clayoquot Sound, BC Canada during the fall season from 2003-2019, and explores nutrient distribution shifts pre and post marine heat wave intrusions. Clayoquot Sound is located off the West Coast of Vancouver Island and consists of five fjord inlets. The distribution of nutrients in these inlets is a function of the physical configuration, season, stratification, and local and coastal circulation. Here, we compare different stations in Clayoquot Sound for the levels of nitrate, silicate, and phosphate as well as ammonia. Inlets that have a shallow sill with a deep inner bay tend to have anoxic bottom waters in the fall, resulting in high bottom phosphate and ammonia levels. Nutrient distributions were mapped using Geographic Information System (GIS), and quartile plots were prepared to compare nutrient levels between years with and without marine heat waves. Results showed that surface nutrient averages decreased over the 16-year sampling period. Overall, the spatial patterns between the years showed no difference due to the marine heat wave, but a consistent pattern of nutrient distribution was evident across all years. The northern inlets, Sydney, Shelter, and Herbert, showed high nutrient deep waters compared to the two southern inlets, Bedwell Inlet which had low nutrients overall, and Tofino Inlet which had a gradual increase in nutrients from the mouth to the head of the inlet. A follow-on study examining the difference in physical configuration and forcing conditions between these two sets of inlets is recommended.

Methods:

• Samples were collected in niskin bottles at different stations across Clayoquot Sound at the Surface, Chlorophyll Max, and Bottom. Addition samples included either one or two middle depths depending on the depth of the station
• Nutrient samples are collected in 60 mL plastic bottles, 2/3 of the way full and frozen on board the research vessel (Figure 1). Nutrients are typically sampled in early September, while in 2006 the samples were collected in early August.
• Frozen samples are sent to the UW Seattle Marine Chemistry Lab to be ran for phosphate, nitrate, nitrite, silicate and ammonia
• Auto analyzer mixes nutrients with reagents to analyze for five different nutrients in one sample (Figure 2). See table 1 below for reporting limits for each nutrient

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Reporting Limits</th>
<th>Method</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₃</td>
<td>0.05 mg/L</td>
<td>UV</td>
<td>mg/L</td>
</tr>
<tr>
<td>PO₄</td>
<td>0.02 mg/L</td>
<td>UV</td>
<td>mg/L</td>
</tr>
<tr>
<td>SiOH₄</td>
<td>0.05 mg/L</td>
<td>UV</td>
<td>mg/L</td>
</tr>
<tr>
<td>NH₄</td>
<td>0.05 mg/L</td>
<td>UV</td>
<td>mg/L</td>
</tr>
</tbody>
</table>


Results:

• Clayoquot Sound is located off the West Coast of Vancouver Island BC Canada and consists of five estuarine fjord inlets (Figure 3).
• The maximum depth of the inlets are 20m with an average sill depth of 10m.
• Physical forcing factors that govern circulation include strong tidal currents associated with large tidal ranges and flushing events are tied to coastal upwelling and downwelling.
• Atmospheric conditions like high precipitation (roughly 130 in/cm), and upwelling and downwelling can influence nutrient levels.
• In 2014, a marine heatwave, also known as "the Blob", intruded warm water into the Pacific Northwest which can influence temperature, salinity, and dissolved oxygen, which can then affect the biological productivity in Clayoquot Sound.
• Figure 4 is a cross section for how the inlets will generally flush from the ocean. Upwelling will push water from the ocean shelf into the inlets over the first sill, and down to the outer basin, and eventually to the inner basin. Flushing typically occurs during the transition from upwelling to downwelling in the early fall.

<table>
<thead>
<tr>
<th>Year</th>
<th>Surface Nutrient</th>
<th>Bottom Nutrient</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>Silicate</td>
<td>phosphate</td>
</tr>
<tr>
<td>2013</td>
<td>Nitrate</td>
<td>Phosphate</td>
</tr>
</tbody>
</table>

Table 1. Reporting Limits for each nutrient

References:

Greengrove, Cheryl. TESC 490 lecture notes.
UNESCO- United Nations Educational, Scientific, and Cultural Organization
University of Washington Marine Chemistry Lab
Cross SF, Byrne A. Net Cage Aquaculture in Clayoquot Sound. :23.

Acknowledgements:

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