Plankton – What do we know about the bottom of the aquatic food chain?

What’s happening with plankton?

Chances are with other changes occurring in Howe Sound, plankton, the tiny organisms at the base of the food chain, may be changing too. The problem is we don’t know what’s happening because no one is currently doing any research in this area. The last time any extensive plankton surveys were undertaken in Howe Sound was in the 1970s, so we currently have no data to tell us if there have been any changes in plankton biomass and the timing of their cycles. We can observe phytoplankton blooms remotely by sensing water colour using a satellite sensor such as MERIS (Figure 1), with its 300 meter spatial resolution, but this sensor is no longer in operation. Early in 2016, the European Space Agency launched the OLCI sensor onboard the Sentinel-3 satellite, which has the same resolution and data will be available soon.

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Figure 1. Full resolution (300 m) MERIS images of Howe Sound. The true colour image (left) shows high sediment levels at the head of the Sound and at the mouth of the Fraser River, while the fluorescence signal (right) gives an indication of different levels of chlorophyll (Chl) in Howe Sound. Red indicates high Chl, blue indicates very low Chl, while orange and green indicate intermediate values. The apparent high levels of Chl at the head of the Sound and near the mouth of the Fraser River are a false signal caused by high suspended sediment. (Image data provided by the European Space Agency and processed by S. King, Sea This Consulting.)
What are plankton and why are they important?

Phytoplankton (i.e., plant plankton) are microalgae and they are the main primary producers of food in the sea (the ‘grass of the sea’). They combine carbon dioxide, nutrients, and sunlight via the process of photosynthesis to produce organic carbon and provide food for the animals in the food chain. They can ‘bloom’ and increase their biomass by 1,000-fold during spring, when conditions are just right (high nutrients, good light and little wind). Zooplankton (i.e., animal plankton) range in size from microscopic to a few millimetres. They are the ‘insects of the sea’ and are the main grazers of phytoplankton, and then small fish and invertebrates feed on the zooplankton and so on up the food chain. Without plankton, the food web of Howe Sound would collapse. Forage fish such as herring, sandlance and smelt would disappear, as would the salmon, dolphins and humpback whales that eat the great schools of these small fish.

Are there any known cultural connections by First Nations to plankton?

Phytoplankton are very small and cannot be seen with the naked eye unless they are in a colonial stage, form surface blooms (e.g., red tides) or produce bioluminescence. Therefore, it is less likely that cultural connections were made to these organisms, unlike with several larger iconic animals. However there is no doubt about First Nations’ very strong connections to eelgrass, Enteromorpha (seaweed, sea lettuce), Rhizoclonium (green alga – a cladophora), kelp and other macrophytes located within the shallower waters of the Squamish River estuary.²
What is the current state of plankton health?

The current state of the health of plankton is unknown. In the 1970s, John Stockner, Colin Levings, and others from Department of Fisheries and Oceans (DFO) West Vancouver Laboratory began a three-year extensive bio-oceanographic survey to provide a better understanding of plankton and their distribution and production at multiple stations throughout Howe Sound (Figure 2). Their studies revealed information on the dominant species of phytoplankton, timing and production levels of the spring phytoplankton bloom, and some data on zooplankton. Changes in the timing of this spring phytoplankton bloom due to warmer surface waters (earlier bloom) or too much wind (later bloom) could produce a timing mismatch and may impact the growth and survival of zooplankton if they arrive before the phytoplankton bloom (too early) or well after the bloom (too late).

A bloom of phytoplankton in Howe Sound can be seen in satellite images, provided the area is not cloud covered and the bloom is near the surface. The timing of the spring bloom in the mid- to outer sectors of the Sound varies from year to year, usually between April and early May and is mainly dependent upon sunlight and very light winds to produce a calm surface layer that provides sufficient light for phytoplankton growth. The inner sector (Zone 1) blooms later due to turbidity from the river. This is similar to the Strait of Georgia where the onset of the spring bloom is dependent on sunny calm weather for several days and not dependent on surface water temperature nor the Fraser River discharge.4,5,6

Figure 2. Map of Howe Sound with 1970s plankton sampling stations 1-10, and three major zones (circled numbers): Zone 1 — inner true fjord portion — inner sill to river; Zone 2 — mid-section; Zone 3 — seaward boundary with Strait of Georgia.4
At the head of the inlet (Zone 1), because of snowmelt in the mountains, the high flows of the Squamish River from April to June strongly affects both the production and distribution of phytoplankton owing to fine sediment in the outflow, which limits sunlight penetration, and increases flow and mixing within the surface layer. Once phytoplankton “bloom,” they move with the currents, so understanding the dynamics of currents and tides is particularly important. In the upper portion of the Sound, a prominent “sill” or shallow topographic barrier/boundary prevents complete mixing of deeper waters of this zone with the lower Howe Sound waters and hence is likely of paramount importance to the biological activities (Figure 3).7

Based on surveys in the 1970s, peak primary production occurred in June with values of 3,000–5,000 milligrams of carbon per square metre per day adjacent to the Strait of Georgia (Zone 3, boundary waters). Peak primary production levels at the head of the inlet adjacent to the Squamish River estuary (Zone 1) were almost 100 times less productive, at 40–50 milligrams of carbon per square metres per day, and they occurred in July.3 Turbid waters and low light penetration during spring with high river flows are responsible for the large difference in primary production between Zones 1 and 3.8

Figure 3. Vertical section along the main channel of Howe Sound showing the depth profile with the prominence and the shallowness of the "sill" at 50 metres depth. (The main channel was cut by glaciers during the Ice Ages, and the sill is a moraine that was left at the toe of a glacier during a short-lived advance at the end of the last Ice Age.) The head of the inlet is on the left. The sill is also marked near Station 6 in Figure 2.9
What did we learn in the 1970s?

The studies in the 1970s found five major classes of phytoplankton within Howe Sound:

1. Bacillariophyceae  
   (diatoms)

2. Dinophyceae  
   (dinoflagellates)

3. Chrysophyceae  
   (coccilithophores, silico–flagellates)

4. Cryptophyceae  
   (cryptomonad flagellates)

5. Chlorophyceae  
   (green flagellates, euglenophytes)

The dominant species were the diatoms *Thalassiosira aestivalis*, *T. nordenskioldii*, *T. pacifica*, *Skeletonema costatum*, and *Chaetoceros* spp. (Figure 4). *S. costatum* and *T. pacifica* are the dominant species during the spring bloom and are common through much of the summer in most regions of Howe Sound. These three diatoms are also dominant in the Strait of Georgia. In addition, large inflows of freshwater from the Squamish River to surface layers in the fjord portion (Zone 1) contain mainly freshwater diatoms of lake or river origin: *Asterionella*, *Hannaea*, *Meridion*, *Eunotia* and *Tabellaria*. The focus of the initial studies of Howe Sound in the 70s was on phytoplankton and hence zooplankton populations were sampled infrequently and only at a few key stations. Identified zooplankton included both crustacean (shrimp-like mysids, euphausiids, calanoid and cyclopoid copepods) and jellyfish (*Cyanea* or stinging jelly fish and, *Aurelia* or moon jellies). Some common examples appear in Figure 5. Usually there was a distinct annual lag of approximately two to three weeks between the peak phytoplankton bloom and peak zooplankton numbers. More recent work has shown that there is a higher proportion of crustaceans (the preferred food source of salmon and herring, especially the smaller cyclopoid copepods that are preferred food for both juvenile salmon and herring) and fewer jellyfish in Howe Sound compared to Indian Arm.
Current and emerging threats to healthy phytoplankton

Some current threats to healthy phytoplankton production include climate change with the dual impacts of increasing CO2 (ocean acidification), and the warming of surface waters (global warming). Organisms that produce calcium carbonate structures, including many plankton species and bivalves, are impacted by the lower pH levels. Over time there will likely be a shift towards species that are more tolerant of warmer waters as average temperatures begin to rise. Some may be new invasive species that move up from the south and could possibly be toxic to shellfish or carry new viruses that might affect starfish, mussels, crab, shrimp and crustacean zooplankton.

In addition, proposals for new developments, such as gravel extraction and transport of sediment from McNabb Creek, could threaten plankton production if proposed activities reduce light penetration.

What is being done?

Currently, there is little or no research on plankton in Howe Sound. In the 1970s, an important component of the research by DFO was to understand connections between disturbance in the Sound, including pulp mills, foreshore log booms, gravel washing operations and dissolved metal inputs from Britannia mine and Squamish terminals, and primary production of phytoplankton. These disturbances and industrial activities were thought to be responsible for a marked decline in fisheries production, notably herring, salmon and ground fish stocks.
Among the anthropogenic stressors in the 1970s, discharge from two pulp mills (Woodfibre, Port Mellon; Figure 2, Station 4) with associated toxicity to plankton were the most significant pollutants.\textsuperscript{16,17,18} Copper and other metals from mine tailing effluent from Britannia Mine (Figure 2, Station 7) delivered to the Sound via Britannia Creek destroyed all shoreline vegetation, both macrophytes and epiphytes, for several kilometers from the river discharge point during the 1970s and 1980s.\textsuperscript{19,20} Gravel washing discharge from tributaries on the west side of the Sound and extensive log-boom storage along the shorelines of Gambier and Anvil Islands impacted and shaded the intertidal zone and affected algal and marine plant production. Collectively these point-source anthropogenic industrial activities strongly influenced populations of marine resources, such as oysters, clams, crabs, shrimp and prawns and seaweeds. The identification of these stressors and their effects on food webs within the Sound, e.g. populations of plankton, herring, salmon, ground fish, and shellfish fisheries, eventually led to new strict regulations that over several decades have restored many fisheries and seem to have improved the health of the Sound.

Assessing potential trends in plankton health is difficult because little or no scientific studies were conducted before 1970 and very few after the 1980s. There have been only a few brief surveys for identification of the presence or absence of major species. There have also been several identifications requested by curious residents of possible deleterious or toxic phytoplankton blooms, or red tides, that still occur in summer in Howe Sound and are most common in the southern sectors (Zones 2 and 3).

For example, there was an unusual coccolithophore bloom in the Sound and Strait in mid-August 2016 that turned the surface waters a green/turquoise color\textsuperscript{21} due to the calcium carbonate scales on the surface of the cell (a similar optical effect to glacial flour in lakes) (Figure 6). Coccolithophore blooms often occur on the west coast of Vancouver Island, but this is the first large-scale occurrence of such a visible bloom in the Strait and the Sound. They are not toxic and the reason for their sudden appearance in these inland waters is not known, but unlikely to be related to global warming.

However, we can surmise that current plankton production is relatively healthy, when we consider anecdotal indications of recovery from the 1970s and 1980s stressors. We have seen the return of significant numbers of herring and along with them the return of marine mammals; dolphins and whales now occur in the inner waters of the Sound along with increasing numbers of harbor seals.
Figure 6. The Landsat-8 true colour image of Howe Sound on Aug. 19, 2016 at 30 m spatial resolution. The bright water covering most of the Sound is from the unusual coccolithophore bloom observed in the Sound and the Strait of Georgia in August 2016. The very bright water at the head of the Sound is from high-suspended sediment. The image was downloaded from USGS Earth Explorer using The Development Seed’s Libra Browser for Landsat-8 and processed by S. King, Sea This Consulting.
What can you do?

SOME ACTIONS CONTRIBUTED BY CORI

Individual and Organization Actions:

• Keep an eye out for unusual blooms and continue to ask what they are and why are they occurring in the Sound.

• True colour satellite imagery, useful for monitoring coccolithophore blooms and turbidity, can be viewed in near real time on NASA’s Worldview (worldview.earthdata.nasa.gov). The satellite images will be the “web-cam” for active citizen science groups that are interested in on-going plankton events in the Sound.

Government Actions and Policy:

• Conduct a survey, preferably utilizing the same DFO stations in the 1970s (Figure 2), so valid comparisons of decadal changes can be made. This survey should include standard physical, chemical (nutrients, oxygen) and biological (dominant species, phytoplankton and zooplankton biomass, and primary productivity) parameters. What species are being lost or gained (i.e., changes in biodiversity) due to climate change and what are the changes in plankton/ecosystem productivity?

• Information on zooplankton, an important food source for many small fish, is lacking and should be conducted similar to an on-going study on zooplankton seasonal succession in another fjord, Rivers Inlet, up the B.C. coast.

• Continue the practice of testing water quality in front of the Port Mellon pulp mill (Station 4, Figure 2) to determine if the present mill is meeting provincial and federal marine foreshore water standards.

• Similarly, if an LNG terminal at the old Woodfibre site (Station 8, Figure 2) is approved, then an extensive survey will be needed to determine the “before” or baseline inventory and continued monitoring if it begins operations.

• Make baseline inventory and regular monitoring of plankton (the key food resource for all higher trophic levels) a requirement for coastal development projects, so that any changes in production, diversity, or timing can be assessed.

• Collect important historical data on the Sound (before scientists and other groups retire) and archive the data in a government data centre.
Footnotes

1 J. Gower and S. King, personal communication with the authors, June 2, 2016.
10 Stockner et al. 1977.
14 Harrison and Mackas. 2014.
15 For references to this early research see: