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Temperature, Harmful Algae, and Summer Shellfish Mortalities in British Columbia*

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Introduction

Pacific oyster growers in British Columbia, and around the world, normally lose between 10 and 40% of their stock in raft-based operations during the summer. Up to 100% of the oysters can be lost in extreme cases. These summer mortalities have been the focus of intensive research, which has resulted in the identification of high temperatures and harmful algal blooms as the main environmental factors involved. While short periods of high temperatures can stress and kill oysters, normal summer temperatures help the oysters grow, as their metabolism increases with the rising temperature. In a similar way, higher abundances of phytoplankton during the spring help the oysters obtain enough nutrition to grow, but blooms of harmful algae during the summer can produce toxicity events, periods of reduced growth, and heavy mortalities. Oysters are normally grown close to the water surface, as both algae and temperature are at their maximum in the first 10 m of the water column during the summer. During this time of the year, a strong thermocline develops at around 8 to 10-m deep, creating a barrier between the warm surface and the colder deep waters. In search for a practical application of the knowledge gathered on summer shellfish mortalities, the Aquaculture Collaborative Research and Development Program (ACRDP) of Fisheries and Oceans Canada (DFO) recently funded a research partnership among UBC (*Dr. Maite Maldonado, David Cassis*), BCSGA (*David McCallum*), DFO (*Dr. Chris Pearce*), Macs Oysters (*Gordy McLellan*), and Taylor Shellfish (*Chris Day*) to carry out a field experiment for the optimization of husbandry techniques to minimize summer mortalities. The main objective of this experiment was to determine the ideal depth at which to grow the oysters during the summer so that maximum survival and growth can be achieved. For this experiment, oysters were grown in trays at depths of 3, 10, and 15 m at four sites within three locations throughout the Strait of

Georgia (Baynes Sound, Okeover Inlet, Hotham Sound). Besides these fixed-depth trays, other sets of trays were kept at 3 m, and lowered to 10 and 15 m when the water temperature at 3 m reached 14, 16, or 18ºC (these lowered trays were brought back to 3 m depth when the temperature dropped below these target temperatures). All experimental oysters were monitored for mortality and growth every four weeks from June to October of 2008. Various environmental variables (such as temperature, salinity, dissolved nutrients, chlorophyll, and abundance and composition of the phytoplankton) were monitored at each site and depth every two weeks for the experimental duration. Results of the experiment are currently being analysed.

Harmful algae may be one of the main causes of summer mortalities, as well as causing other problems (see "*Nuisance Algal Species*" interpretive guide, page 4) for shellfish aquaculture. As a way of helping the shellfish aquaculture community become aware of these harmful algal species, I have prepared the following list of main harmful algae present in the waters of British Columbia and some of their prominent characteristics.

General Characteristics of Phytoplankton

Phytoplankton is the main food for filter-feeding shellfish. It is composed of many different types of unicellular algae. These algae have chlorophyll to carry out photosynthesis, as well as other pigments that give them their unique colours. Some of the main groups of phytoplankton include:

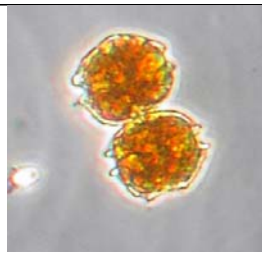
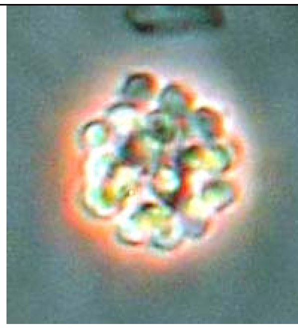
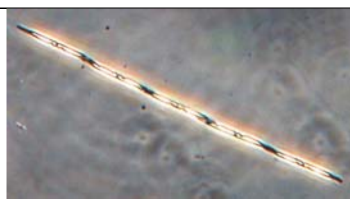
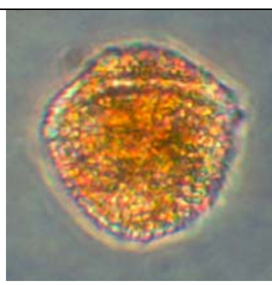
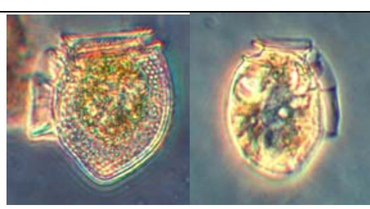
Diatoms: Covered by a glass cell wall. Light to golden brown. Most abundant in spring and fall. No means of propulsion, they rely on the movement of the water to stay close to the water surface. Diatoms are the most abundant group of algae in the modern ocean, and constitute the main food for shellfish.

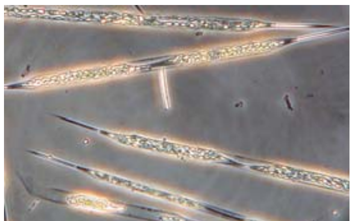
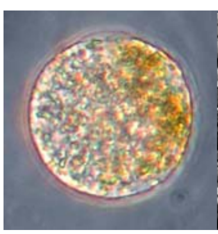
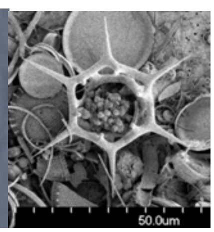
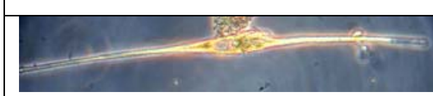
Dinoflagellates: Covered by plates of cellulose (tree bark). Can produce red, black, orange, or brown blooms. Most abundant in summer and early fall. The algae in this group have two flagella (tails) to help them move through the water. Second most abundant group in the modern ocean. Many species form blooms and have toxins. Dinoflagellates are easy to see in Lugol-fixed samples, as they appear darker than the rest of the algae.

Silicoflagellates: Have an internal star-shaped skeleton made up of glass, which they discard sometimes. No information on colour of blooms, but probably golden brown. Sometimes abundant during late spring and summer. Have two flagella for locomotion. This group was abundant before the last glaciation, but only a few species left. Blooms of "skeleton-less" *Dictyocha* have caused farmed salmon mortalities.

"Naked" flagellates: Many different groups included, all without a thick cell cover – only a thin membrane protects the cells. Blooms can be green, bright green, yellow, black, reddish brown (*Heterosigma*), white, or almost any colour. Abundant during late spring and summer. Normally have flagella or other means of locomotion. Normally, blooms of this group do not have toxins and are nutritious for shellfish. Some species have toxins and can produce problems at fish and shellfish farms. Flagellates in general do not fix well in Lugol's solution, with many species shriveling and loosing their normal shape, making them difficult to identify.

Interpretive Guide to the Main Harmful Algae in British Columbia

Main Harmful Algal Species		***Alexandrium* spp. (dinoflagellate, 30-60 µm)** At least two toxic species of *Alexandrium* occur in BC, *A. tamarense* (single cells) and *A. catenella* (chains of cells). Typical "hamburger" shape. Produce saxitoxin, involved in paralytic shellfish poisoning (PSP). Some shellfish (oyster seed) actively reject *Alexandrium* cells instead of eating them. These species can produce large amounts of mucus. Photo: *Alexandrium catenella*.
		***Heterosigma akashiwo* (naked flagellate, 15-20 µm)** *Heterosigma* produces dense, reddish-brown blooms every year during late spring and early summer. This kidney-shaped alga is known to produce an unidentified toxin that can affect most marine life (although not humans), but the trigger for its production is not known. *Heterosigma* is normally rejected by oysters in the form of "pseudo-faeces", long strings of mucus and algae that do not undergo digestion. When *Heterosigma* cells are fixed with Lugol's iodine they acquire a unique "raspberry" or "bunch of grapes" look. Photo: Typical *Heterosigma* cell after fixation with Lugol's.
		***Pseudo-nitzschia* spp. (diatom, 50-140 µm long)** Several species of *Pseudo-nitzschia* can be found throughout the year in BC. Under special conditions they can produce domoic acid, the active compound in amnesic shellfish poison (ASP). The environmental conditions necessary for the production of the toxin are not typically found in the Strait of Georgia. Photo: Chain of cells of *Pseudo-nitzschia*.
Other Toxic Algal Species		***Protoceratium reticulatum* (dinoflagellate, 30-50 µm)** This dinoflagellate is the source of yessotoxin (YTX). Blooms do not usually produce discolouration of the water, but sometimes a reddish colour may occur. It can be a problem to oyster farms as it produces a very strong rejection reaction in the seed, reducing their ability to feed. This species prefers to bloom in warm waters during July and August. Photo: *Protoceratium* cell.
		***Dinophysis* spp. (dinoflagellate, 50-90 µm)** Many species of *Dinophysis* can be observed in BC during the summer. Most are known to produce okadaic acid and other toxins involved in diarrheic shellfish poison (DSP). Photos: *Dinophysis acuta* (left) and *Dinophysis acuminata* (right).

Nuisance Algal Species	 	***Chaetoceros* spp. (200-900 µm long) and *Rhizosolenia setigera* (300-900 µm long)** Blooms of large and spiny *Chaetoceros* and *Rhizosolenia* species are known to occur in BC almost every year during late spring and fall. These algae cannot be eaten by oysters due to their large size and obstructing spines, causing the oysters to reject them by clapping their valves. Blooms of large and/or spiny phytoplankton can affect cultured oysters by preventing them from feeding efficiently, which may lead to periods of reduced growth. Photos: *Chaetoceros convolutus* (top) and *Rhizosolenia setigera* (bottom).
		***Noctiluca scintillans* (dinofagellate, 200-2,000 µm)** The thick bright orange "tomato soup" blooms of this spectacularly bioluminescent giant dinoflagellate are becoming more common in the Strait of Georgia every year. Although very visible, these blooms are normally harmless, unless they become trapped in a small enclosed area. As the cells die and decompose, bacteria can use up most of the oxygen in the water, killing any organisms that cannot escape the area. Photo: *Noctiluca* bloom observed in Coal Harbour.
Potentially Harmful Algal Species	 	***Chattonella* spp. (naked flagellate, 40-60 µm) and *Dictyocha speculum* (silicoflagellate, 15-40 µm)** Some species of "naked" flagellates and silicoflagellates can produce toxins that irritate the gills and other soft tissues of aquatic animals. *Chattonella* and *Dictyocha* blooms have been reported to cause farmed salmon mortalities, but not in BC. Have not been well studied. Photos: *Chattonella* cell (left) and skeleton of *Dictyocha speculum* (right).
		***Ceratium fusus* (dinoflagellate, 200-500 µm long)** Blooms that include *Ceratium fusus* have been observed at the same time as massive mortalities of cultured oysters. *Ceratium fusus* is too large to be eaten by oysters and no toxin has been detected. The bacteria associated with this species could be harmful to oysters. Photo: *Ceratium fusus*.
		***Akashiwo sanguinea* (dinoflagellate, 40-80 µm)** This large dinoflagellate can produce toxins that cause mortalities of marine organisms. It has not, to date, produced large blooms or other problems in BC. Photo: *Akashiwo sanguinea*.

Note: All microalgae were fixed with Lugol's solution and observed under a compound light microscope at magnification of 200 to 400x (1 mm = ~1,000 µm). All photos by *David Cassis*.