Inquiry-based Ecological Explorations in the Bras d'Or Lake Biosphere

Adapting to watery habitats in the Bras d'Or estuary: An Integrated, Multidisciplinary, Inter-Cultural Curriculum Resource for Elementary Classrooms

Bras d'Or Lake Biosphere Reserve Association
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Background:

The Bras d'Or Lake Biosphere is nestled in the heart of Unama'ki, one of the seven traditional districts of the Mi'kmaw nation. This territory is covered by the "Treaties of Peace and Friendship" which Mi'kmaq and Wolastoqiyik (Maliseet) people first signed with the British Crown in 1726. The treaties did not deal with surrender of lands and resources but, recognized Mi'kmaq and Wolastoqiyik (Maliseet) title and established the rules for what was to be an ongoing relationship between nations. The indigenous Mi'kmaq have been joined by settlers from all over the world in this ancestral territory. Those who live in Unama'ki (Cape Breton) have lives intertwined with the plants, animals and spirit of the Bras d'Or Lake (which is actually an estuary). The Mi'kmaq name for Bras d'Or reflects this long history. Pitupa'k means 'rivers flowing into oneness' and Mi'kmaq Elder Albert Marshall points out that this refers to a time when sea level was lower and the lake was much smaller and fresh. According to geological evidence, that was between four and nine thousand years ago. The animals before that time lived in a different habitat. This is an important point and should be emphasized.

Animals and their habitats change over time and what we are observing in our time is merely a snapshot of a much larger and longer cycle.

Biodiversity of Bras d'Or plankton is a function of density and buoyancy!

The geological formations cradling the Bras d'Or estuary allow the persistence of pockets of cold, salty water overlain by warmer, brackish water. It is this persistent patchwork of water masses with different characteristics that supports plankton from the arctic and the sub-tropics to co-exist in the same estuary. The incredible **biodiversity** of plankton is a function of their structural **adaptations** to control **density** and the resulting **buoyancy** which enables them to maintain position in a water mass that is suitable to satisfy their physiological requirements. Thus, in the Bras d'Or estuary, **adaptations** allow plankton to control their **density** which leads to impressive **biodiversity**!

Plankton are plants and animals that float in water (fresh, salt and brackish). Some are large (jellyfish) but most are microscopic. Plankton that photosynthesize are called phytoplankton. Zooplankton are tiny animals that feed on other plankton. Some animals and plants are planktonic only during the early part of their life cycle and then they settle and grow on the bottom. Some plankton remain in the water column for their whole existence. Plankton must avoid sinking. Phytoplankton must stay in the upper water column to get enough sunlight to power their photosynthesis.. Zooplankton need to stay near their food source (phytoplankton and smaller zooplankton). Plankton diversity in the Bras d'Or estuary is due, in part, to the ability of arctic and sub-tropical species that have lived here through many severe climatic changes to maintain their positions in isolated water masses that suit their physiological requirements. These water masses within the estuary are isolated because of the geological formations which form sills and deep channels.

Biodiversity of plankton is a result of adaptations of individual species. Plankton avoid sinking by developing an increased surface area. Adaptations such as flattened bodies and body projections slow sinking rates by adding surface area without increasing density. Other adaptations are the formation of long chains and the production of stored oil droplets.

This learning experience is designed to introduce the concept of buoyancy, density and adaptation by experimenting with structural changes that change density. Reproductive tissues change the density and buoyancy of the plankton and that impairs their ability to adapt to the environment. Students can design their own adaptations to allow their model plankton to maintain buoyancy in spite of having increased density due to reproductive parts. The persistence of these arctic species so far from the environment that they originated in is one of the remarkable characteristics of this unique estuary!

The Bras d'Or estuary: Biodiversity reflects past climates

Nova Scotia's climatic regime is boreal. The boreal ecosystem has a subarctic climate in the Northern Hemisphere, (approx. 45° to 65°N). There are basically two groups of animals that usually inhabit the boreal region. The first group can only tolerate the range of summer to winter temperatures that are characteristic of the region. The second can tolerate a much wider range of temperatures and has a broad geographic distribution (Lambert, 2002). In contrast to the rest of Nova Scotia, the Bras d'Or estuary has two additional groups of animals which were isolated from their main distribution in the geological past. Interestingly, one group is adapted to warm waters and the other to Arctic waters. Their movement into the Bras d'Or Lakes can be traced to two past periods when sea levels and temperatures were markedly different than they are today.

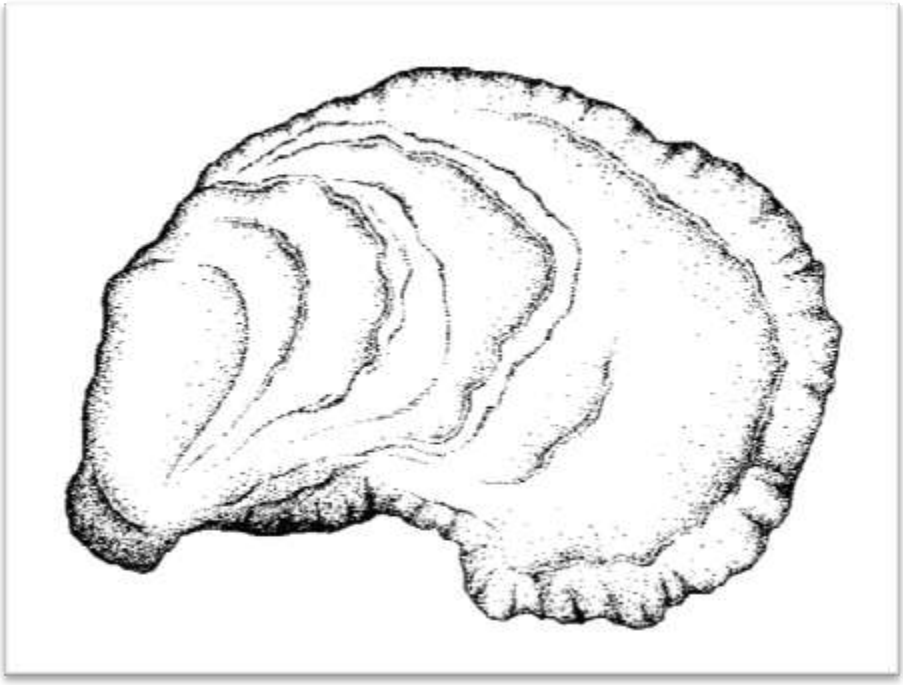

Figure 1: The Bras d'Or oyster (Crassostrea virginica). Adults are around 10 cm in length.

The warm water group is more commonly found off the coast of Virginia and is called the 'Virginian enclave'. This group of settlers moved into the Bras d'Or estuary about 6,000 years ago when the ocean flooded into the Lake and average ocean temperatures were about 2.0^{o}C. warmer than they are today. Examples of the Virginian enclave that have persisted in the warmer parts of the Bras d'Or estuary include the oyster, (*Crassostrea virginica*) (Lambert, 2002). The eastern oyster (in Mi'kmaq: mntmu'k) is native to the eastern seaboard and Gulf of Mexico coast of North America. This species thrives in estuaries, but also lives in marine coastal environments. This species has been extensively cultured in the Bras d'Or Lake in the past, although it is at the northern limit of its' range.

The arctic relict group moved into the Bras d'Or estuary long before this time, about 10,000 years ago, as the glaciers retreated and melted. This group is composed of species that are now largely centred in the Arctic and they continue to exist in the deep, cold parts of the Bras d'Or estuary.

The arctic relics

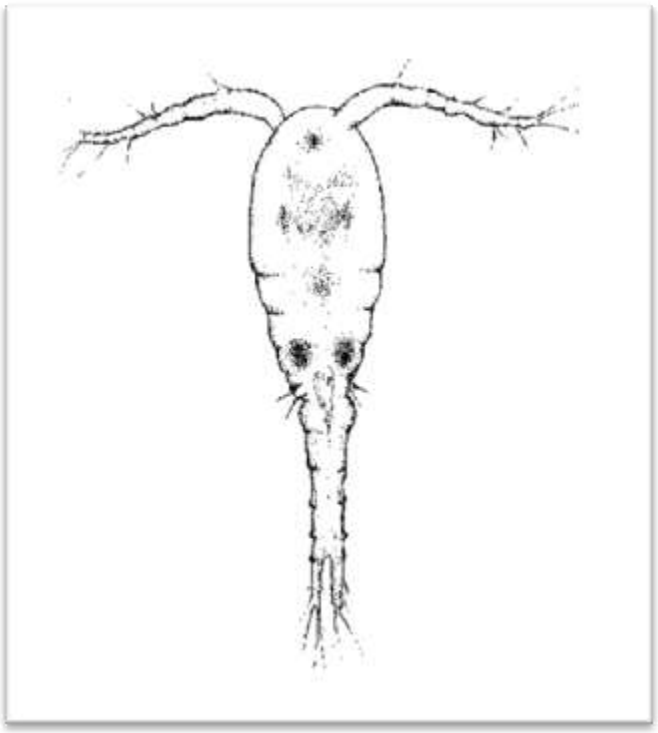

Figure 2: A typical copepod (adult size approximately 2 mm long)

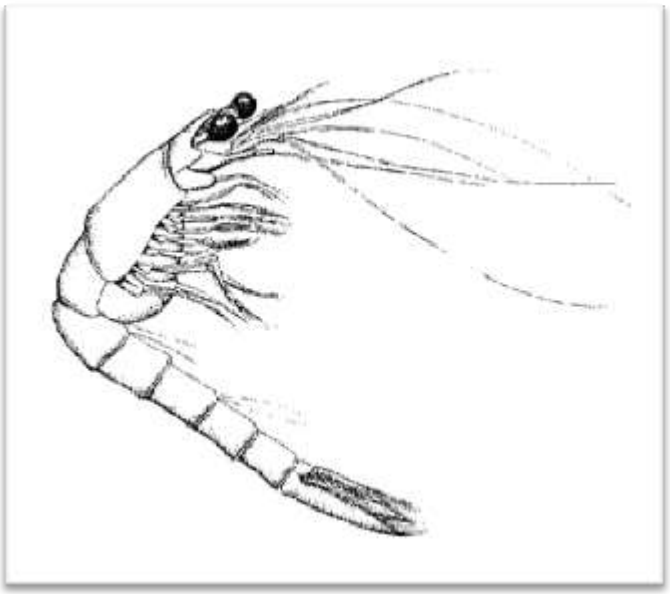

Figure 3: A typical mysid shrimp (adult size 5 to 25 mm long)

Several taxonomic groups compose the suite of Arctic relict species. They are all small animals that live in the water column or on the surface of the sediment. These include two crustaceans; a copepod (*Microcalanus pusillus*) and a mysid shrimp (*Mysis oculata*). Crustaceans are a large group of animals which have an external chitinous (made of chitin) or calcareous (made of calcium carbonate) skeleton with a mandible jaw, a pair of modified appendages on each segment and two pairs of antennae. 'Crustacea' is derived from the Latin meaning "having a crust or shell" (https://www.etymonline.com/word/crustacea). Well known crustacea include the lobsters, shrimp, crabs and wood lice. Copepods (from the Greek; meaning "oar-feet") such as *M. pusillus* are a subclass of very small crustaceans which are abundant in most aquatic habitats https://www.merriam-webster.com/dictionary/copepod. Mysids such as *M. oculata* are an order of other very small, shrimp-like crustacea. Their larvae are raised in a brood pouch rather than free-swimming as other crustacea. Perhaps the first mysid colonizers of the Bras d'Or estuary came as families.

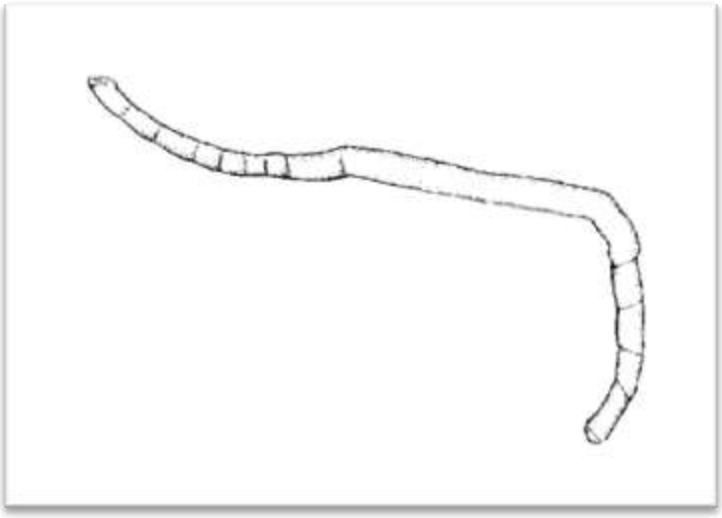

Figure 4: The polychaete Clymenura polaris, a resident of the Bras d'Or estuary. Adults are approximately 2 cm long.

Other arctic relicts include three species of polychaete worms (*Clymenura polaris, Sabellides borealis and Lysippe labiata*) (Lambert, 2002). Polychaete (from Latin meaning 'much hair') worms are segmented and are often referred to as bristle worms because each segment carries bristles made of chitin. They live on or just under the sediment surface and are often free-swimming.

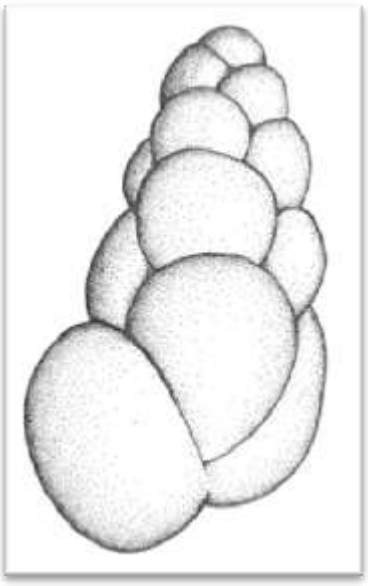

Figure 8: Eggerella advena, a species of foraminifera that inhabits the Bras d'Or Lake. Adults are less than 0.5 mm in length.

Other arctic relicts include two species of foraminifera, *Eggerella advena* and *Rheophax arctic*a (Lambert, 2002). Foraminifera (from Latin meaning hole bearers) are single-celled organisms characterized by an external shell and streaming ectoplasm for catching food.

As mobile species for at least part of their life, these crustacea, polychaetes and forams maintain a suitable habitat by adjusting their density to stay in the colder, denser parts of the Bras d'Or estuary.

Building a plankton model

Students are now familiar with plankton **biodiversity** and the role that **adaptation** plays in that. Adaptations are a way for plankton to maintain position in their ideal water mass. The students can now come to a deeper understanding of these relationships by building models of the plankton and observing how their designed adaptations change **density** and **buoyancy**.

Buoyancy is defined as the vertical upward pressure of a liquid on a floating body which is equal to the weight of the displaced liquid. Density is defined as weight per volume.

https://en.oxforddictionaries.com/. Students make plankton models and manipulate buoyancy by changing density. They use 'found' materials to change surface area and density of their models. This mimics adaptation by living plankton and is precisely the mechanism by which some relict arctic species can maintain their positions in the deeper cold water of the Bras d'Or estuary, allowing them to persist in this environment.

The elaborate structures of plankton help maintain position in the water column, and allow the tiny plants and animals to control their buoyancy. Many body parts of plankton are denser than seawater, so elaborate systems have evolved to slow sinking rates or to make the assembled body the same density as seawater. In this activity, students will use metal washers to represent dense reproductive body parts and more buoyant materials such as Styrofoam to help their models maintain neutral density. In nature this represents a balancing act. To carry their genes to the next generation, plankton have to develop reproductive organs. The added mass can change density which might cause the plankton to drift into a water mass that is too warm or contains too much fresh water for their continued existence. Through adaptation the plankton balance the mass of reproductive tissue with their ability to maintain position in cold, salty water.

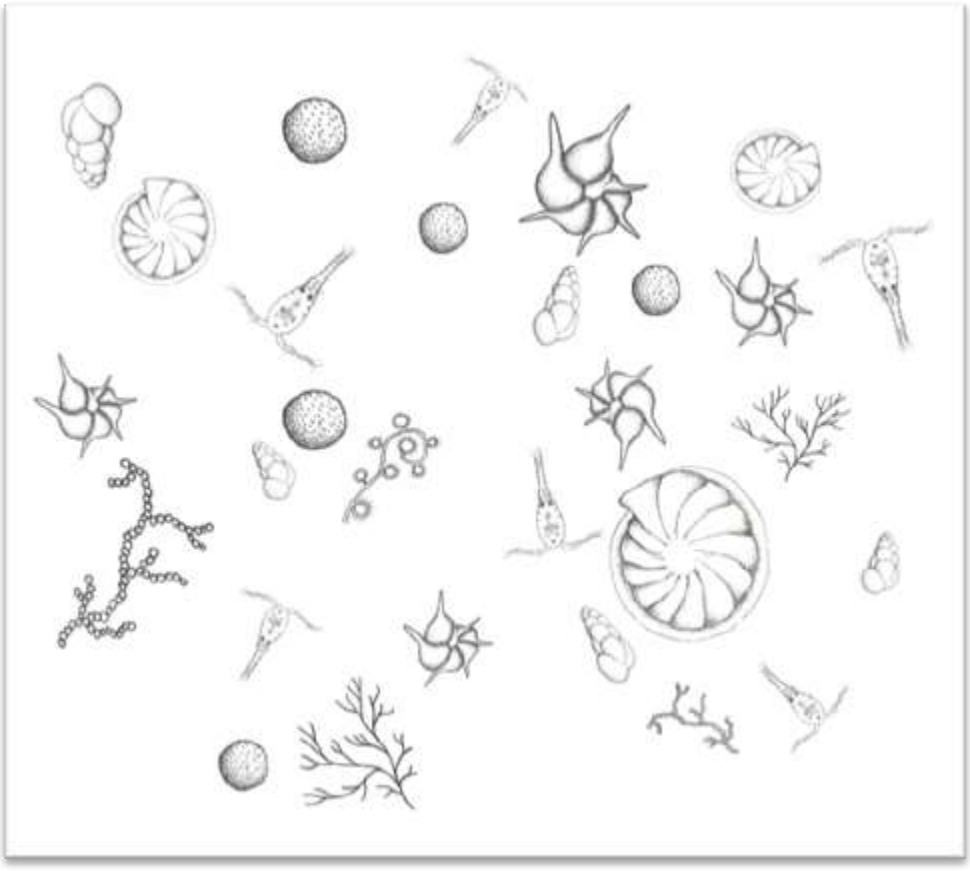

Figure 9: The plankton community in the Bras d'Or estuary is very diverse.

Instructions: Plankton buoyancy

This lesson plan was developed by Bob Chen (Plankton Races) at Centers for Ocean Sciences Education Excellence Ocean (www.cosee.net). All of the resources needed for this activity are available on the WW Web. Teachers can choose those most appropriate for their class.

http://www.cesn.org/cosee_CD/web/activity/The_Great_Plankton_Race.pdf

Materials:

- Assortment of sizes of metal washers and other 'found' materials such as small pieces of Styrofoam, wood etc.
- Cloth
- Pipe cleaners
- Water (large bin or pool?)

Pre-planning

1. The classroom should be decorated with images of plankton, emphasizing the diversity of shape and function

2. The student should be prepared before this activity with knowledge of how diverse plankton structures are in nature. There are many good books available with pictures of plankton structures. It would be useful to have the student pre-plan his or her construction on a whiteboard or sheet of paper. It is also important to expose the student to the concept of density in a more general context. Density is the amount of 'stuff' crammed into a space. There are many resources on the web. For example:http://www.youtube.com/watch?v=B3kodeQnQvU

Procedure:

Students will use their creativity and imagination and the basic principles of buoyancy, density and surface area to create their own plankton. They will use provided materials or materials that they have brought in. The only rules are that their plankton must fit in the container of water and contain some reproductive parts (washers).

1. Have the students start by designing plankton using pipe cleaners.
2. The plankton can then be embellished with washers (representing reproductive parts).
3. The student can then experiment by adding other materials to their phytoplankton model to maintain neutral density when it is introduced to the water basin.

4. This activity can be set up as a race. So, two students can place their (named) plankton in two identical water containers to see which one will sink first. The plankton that sinks more slowly advances to the next round. If they both sink at the same rate, the one with the most reproductive parts wins.
    a. *Note: The plankton that sink more slowly with the same amount of reproductive tissue will definitely win the race in the estuary as it will be more likely to hold position in the water mass which has most suitable environmental conditions.*
5. There are many variations that can be employed. Students could vote for the best looking, or graph the sinking rates.
6. Students may be asked about whether certain objects will float or sink and give their reasons for that conclusion.
7. Students may be asked to replicate real plankton. They should understand their rationale for choosing certain materials.
8. Encourage students to discuss how they designed their plankton (ie: increased surface area, balance of dense and buoyant materials).
9. Students may wish to try to replicate the body design of the Bras d'Or arctic relics.

Resources

http://www.marine.usf.edu/pjocean/packets/f01/f01u6p2.pdf

https://sites.google.com/a/avonworth.k12.pa.us/sci8/unit-d---properties-of-matter/the-great-plankton-race

http://sites.udel.edu/mast821-f2012/2012/09/17/making-plankton-exciting-to-those-outside-marine-science/

https://yonasmarinescience.weebly.com/the-great-plankton-race-lab.html

Bigelow Lab: Phytopia CD (order at: http://www.bigelow.org/phytopia/)

Cerullo, Mary M. and Bill Curtsinger (1999) Sea Soup I, Phytoplankton. Tilbury House Publishers, Gulf of Maine Research Institute. 40 pp.

Cerullo, Mary M. and Bill Curtsinger (2001) Sea Soup II, Zooplankton. Tilbury House Publishers, Gulf of Maine Research Institute. 40 pp.

Sheean T. Haley and Sonya T. Dyhrman (2009) The Artistic Oceanographer Program—Enhancing ocean science literacy through multidisciplinary learning. Science and Children, 46: 31–35

Stevens, Betsy T. (1999) Sea Soup Teachers Guide. Tilbury House Publishers, Gulf of Maine Research Institute. 128 pp.

References

Lambert, T., 2002. Overview of the Ecology of the Bras d'Or Lakes with emphasis on the fish. N.S. Inst. Of Sci., 42(1), pages 65-98.

After this activity the students will be able to:

1. Compare the external features, and structural adaptations for an animal to survive in a particular habitat.
2. Understand the relationship between density and buoyancy
3. Understand how adaptations may change density in plankton
4. Appreciate that the natural diversity in an ecosystem like the Bras d'Or estuary may have assembled in an earlier time when environmental conditions were different.