Evolution Education with Threespine Stickleback at Swan Lake in B.C.

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Introduction

When educating the public about evolution, educators usually point to the finches in the Galapagos. This gives the public the impression that evolution is only taking place in far off places and in rare situations. If educators pointed to species that are closer to home, the evidence for evolution might be easier for students to see. A species that is common and undergoing many processes of evolution on Vancouver Island is the threespine stickleback (*Gasterosteus aculeatus*). One of the requirements listed by Allmon and Ross (2018) for improving educational success is increasing teachers' familiarity with easily available specimens in the field. This paper reviewsthe literature on threespine stickleback in British Columbia to come to an understanding of this species evolutionary history and the evolutionary concepts that can be discussed using this species as a model.

Morphology and Evolutionary History

The threespine stickleback (*Gasterosteus aculeatus*) is commonly found near the margins of Atlantic and Pacific oceans in the Northern Hemisphere, in fresh and saltwater habitats (McKinnon & Rundle 2002). It is a diminutive fish, being only around 5cm at maturity (Bell & Foster 1994). This fish has no scales, but most members of the species have three easily seen dorsal spines that gives the species its common name (Bell & Foster 1994). This species is morphologically, behaviorally, and physiologically diverse. Depending on the population, the morphological phenotypes (Figure 1) of the threespine stickleback can include bony armour or no bony armour, a variety of different body and eye colours, range in body length by 110 mm, 0 - 8 spines, and much more (Bell & Foster 1994).

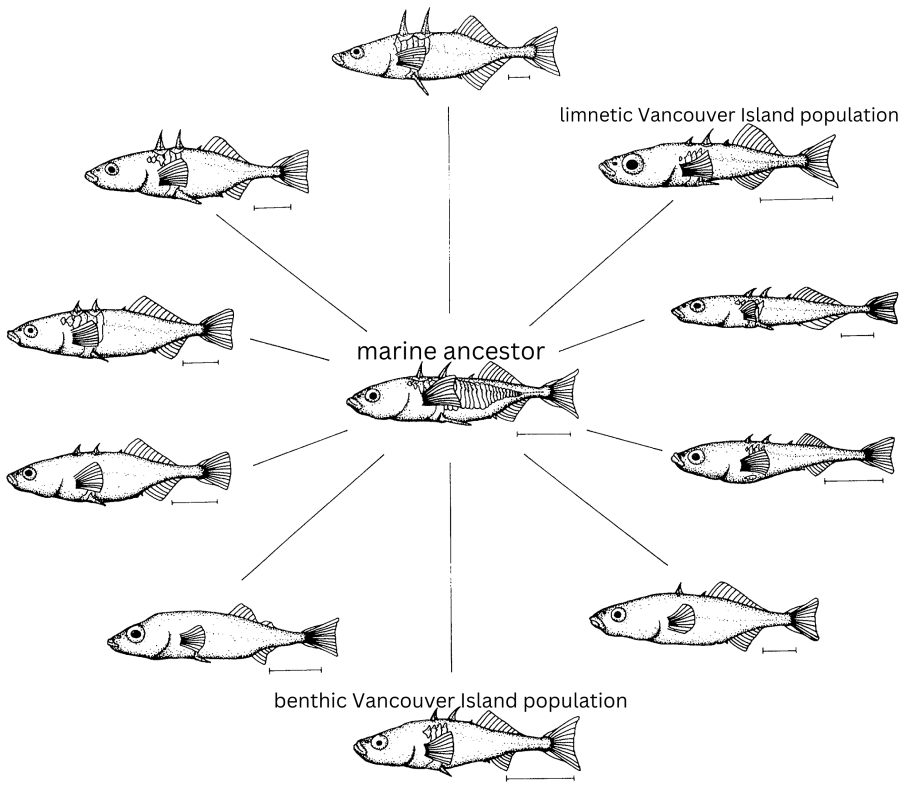

Fig. 1 The diverse morphology of North American populations of threespine stickleback. The fish in the middle represents the ancestral marine stickleback that the surrounding freshwater stickleback have evolved from. The scale bars are all 1 cm. Modified from Bell & Foster (1994).

Since the stickleback population's morphology varies so much, this paper focuses on one local variation found at Swan Lake, in Saanich, BC. This location is well suited for stickleback to be seen and studied by the local community. It is within walking distance of many schools.

The history of stickleback at Swan Lake is fairly recent. The last glaciation ended about 10,000 years ago (Yorath 2005). Swan Lake was carved out of the landscape during this glaciation and revealed once the glaciers had receded (Yorath 2005). The only native species of fish that is currently known to be in the lake is the threespine stickleback. The other species, bullhead catfish (*Ictalurus nebulosus*) and pumpkinseed sunfish (*Lepomis gibbosus*), are invasives that have been in the lake since 1912 (Zaccarelli 1975). During the last glaciation, the stickleback would have been restricted to their oceanic habitat (Foster 1995). As the glaciers receded, stickleback started to independently colonize freshwater habitats (Paccard et al 2019). This is likely how stickleback came to call Swan Lake home.

Oceanic VS Freshwater Stickleback

This move from the ocean to freshwater is a potential example of adaptive radiation, rapidly evolved organisms that diversified from a common ancestor (Gillespie et al 2020). In this case, the common ancestor is the oceanic form of the threespine stickleback. This same process has been observed throughout the Pacific Northwest (Fang 2020), therefore sticklebacks are also an example of parallel evolution. Parallel evolution can be defined as a process where similar traits are independently evolved in response to similar pressures. Students can observe this by taking and comparing pictures of threespine sticklebacks from a variety of local freshwater sources.

The most notable change in phenotypic traits observed in stickleback in lakes compared to oceans are the number of lateral plates. Oceanic sticklebacks have about 36 plates on each lateral side that act as an antipredator armour (Bell & Aguirre 2013, Bell & Foster 1994). The freshwater morphs have far fewer, zero to nine per side (Bell & Foster 1994). It turns out that this wide variation comes mostly from the expression of a single gene (Ferchaud 2016, Colosimo et al 2005). Depending in which environment a population is undergoing evolutionary change, different alleles (varieties of the gene) are expressed (Ferchaud 2016). This change in gene expression is able to happen repeatedly because the oceanic population maintains this genetic variation over years of glacial expansion (Schluter & Conte 2009). In other words, if a lake population goes extinct, the gene that was used to express fewer lateral plates is available to the species. It is still in the ancestral oceanic populations.

Swan Lake is a freshwater lake connected to a marine bay 3.8 km away by two creeks (Townsend 2010). Based on the freshwater environment and research by Planidin (2021) at Swan Lake, the estimated average number of lateral plates is five per side. This evolutionary pressure to go from 36 plates in the ocean to five plates in lakes comes from the difference in predator populations and refuge availability. In the ocean, there are less places to hide from the stickleback’s main predators, other fish. The increased anti-predator armor, lateral plates, increases an individual's chances of escape after capture. In a lake, birds are a dominant predator and there are more places for refuge. This situation favors being able to outmaneuver predators with a body that isn't hindered by lateral plates (Bell at al 2004).

Differences in Lake Type

On top of exhibiting physical differences between the ocean and lake habitats, Threespine stickleback have repeatedly shown evolved physical and behavioral differences in small, shallow lakes compared to large, steep sided lakes (Foster 1995). Small lakes often have stickleback populations that specialize in foraging for large invertebrates on substrates at the bottom of the lake (Schluter & McPhail 1992). This ecotype, typically called benthic, has deeper heads and bodies, larger mouths, molariform teeth, and smaller eyes (Foster 1995, Willacker 2010). Together these morphologies facilitate maneuvering among vegetation and crushing hard bodied prey like snails and clams (Willacker 2010). Large lakes often have stickleback populations that specialize in foraging for plankton in the open water of a lake (Schluter & McPhail 1992). This ecotype, typically called limnetic, has narrower bodies, long snouts for fast jaw movements, and larger eyes (Foster 1995).

Benthic populations display similar behaviour to their oceanic ancestors (Baker et al 2008). Benthic populations forage together in large groups. Whenever a stickleback nest is detected, the group cannibalizes the nest (Foster 1995). Males defend their nests against cannibalistic attacks by performing "diversionary displays", so that the group does not notice the nest (Baker et al 2008). Limnetic populations form foraging groups, but are not observed to be cannibalistic (Foster 1995).

The 68% failure of nests due to cannibalism in benthic populations has resulted in large differences in courtship behaviour between the two ecotypes (Foster 1995). In benthic populations, the drab coloured males try to be inconspicuous while courting, so that they don't draw attention to their nest location (Baker 2008, Foster 1995). Dorsal pricking (Fig. 2) is a major part of courtship (Foster 1995). The female usually initiates and performs the pricking behaviour (Foster 1995). A short zig-zag dance is sometimes performed by the male before he leads her to the nest (Foster 1995).

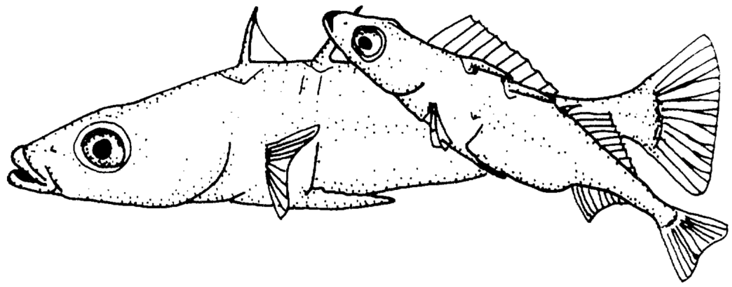

Figure 2: Dorsal pricking seen in benthic populations. The females (smaller) are the ones that prick the males. Modified from Bell & Foster (1994).

Sexual selection is a lot more pronounced in limnetic populations. During courtship, males are able to focus more on females without risking the location of their nests (Foster 1994). In these populations, more elaborate displays by males are rewarded (Foster 1994). The male will initiate the courtship by performing the zig-zag dance towards the female, even over several meters (Foster 1994). Dorsal pricking may also occur, but it occurs less frequently (Foster 1994).

Willacker et al (2010) found more benthic populations of threespine stickleback in shallow lakes with a mean depth below 3.05 m. Swan Lake has a maximum depth of 6 meters, but its mean depth is 2.4 m (Bowen 2021b, Townsend 2009). Based on this, it can be assumed that the stickleback at Swan Lake have mostly benthic phenotypes: smaller eyes, cannibalistic behavior, prominent dorsal pricking, dull colouration, and molariform teeth.

Evolution Discussions

Threespine stickleback are frequently brought up in discussions of a species that is currently experiencing adaptive radiation (McKinnon & Rundle 2002, Gillespie et al 2020, Paccard et al 2019). The term adaptive radiation is usually used to describe the process of multiple species rapidly evolving from a single species. This is exciting for stickleback researchers because it could mean we are able to watch speciation happen in real time, an example of contemporary evolution. Much of the change seen in these fish is simply the result of phenotypic plasticity, the change in a genotype that occurs due to a difference in the environment (Bell & Aguirre 2013). Therefore, all this change is not always an example of speciation. Luckily, there are populations that show evolving phenotypic plasticity as a result of natural selection and sexual selection (McKinnon & Rundle 2002). Over time we may be able to confidently say that threespine sticklebacks are no longer one species.

This real debate over the speciation of threespine stickleback is an engaging way to involve students in a discussion of what a species is and why distinguishing species is important for conservation. There are at least 3 populations endemic to BC that are considered distinct species of stickleback by some scientists. There was a 4th, in Hadley Lake, but this species went extinct in the 1900's due to the introduction of non-native brown bullhead catfish (*Ameirus nebulosus*) (Hatfield 2001). What protection would be possible if these individual populations were named unique species? How has the introduction of brown bullheads affected the evolution of sticklebacks in Swan Lake? What role has the eutrophication of Swan Lake had on the evolution of sticklebacks? These questions can start to guide students to open inquiry of evolution

The threespine stickleback population at Swan Lake has the opportunity to be used to communicate evolutionary concepts with the public. The community can easily walk to the lake and engage in a discussion about evolutionary dynamics: adaptive variation, contemporary evolution, adaptive radiation, morphological diversity, rapid speciation, parallel evolution, and sympatric speciation. The exciting news is that this information can be learned and observed in their own backyard, not only in the Galapagos.

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