Museum Society Guest Speaker for March 1976

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Evolution of the Queen Charlotte Stickleback Fish

The study of evolutionary genetics deals with the causative factors responsible for adaptation in natural populations. It deals with the relationship beyween the genotype and the environment and how these two factors interact through the process of natural selection. The research being carried out on the three-spined stickleback on the Charlottes is attempting to provide some understanding of these processes.

From extensive sampling on the Queen Charlottes, it has become apparent that the stickleback show an unparralleled degree of morphological differentiation between some of the fresh water lakes. Where one would have to travel 2000km in Europe to get slight differences in adult size of the fish, a distance of 2km on the Charlottes shows populations which are not only extremely different in adult size, but also in spine size, spine number, lateral armour, and pigmentation patterns. For example, at Mayer Lake, 5km south of Port Clements, the stickleback are among the largest known in its world distribution reaching lengths of up to 120mm (4.8in) while less than 2km away at Loon Lake, individuals seldom exceed 50mm (2in). Many of these populations on the Islands are undisturbed ecologically and thus allow an ideal opportunity to understand natural species interactions and their evolutionary consequences.

Dr. G. E. Moodie, working at Mayer Lake between 1966 and 1969, found the cutthroat trout to be one of the major predators on the stickleback, and was able to show that the large adult size of the stickleback in this lake, as well as the large spines, are an anti-predator response to the cutthroat.

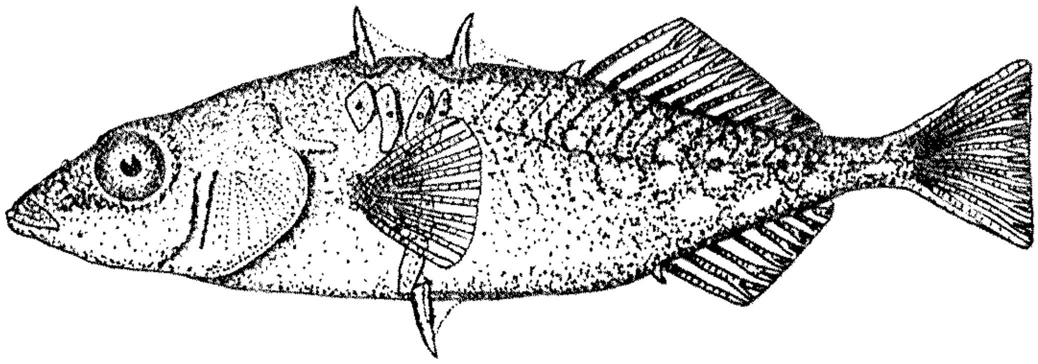
I have examined a number of other lakes on the islands and found that in addition to the cutthroat, numerous other predators also occur. These include the common and red-throated loons, the red-necked grebe, the kingfisher, the common merganser, and various invertebrate species including predacious diving beetles, dragonfly larvae, and leeches. Since each of these predators hunts in a different manner and utilizes different structures for capturing prey, the stickleback have undergone adaptation in a number of different ways to reduce the probability of capture. For example, compare the hunting strategy of the common loon to that of the kingfisher. The former pursues its prey in a horizontal plane under the surface while the latter hovers above the water and performs a vertical dive when its prey is seen. The adaptation of the stickleback to these predators is quite different. With the loon as predator, there is strong selection favouring distinct counter shading (dark back and white belly) for camouflage in addition to rapid swimming speed. With the kingfisher as predator, the best colouration for camouflage is a disruptive pattern (alternating transverse bands of light and dark) in addition to an escape response favouring hiding characteristics rather than "flight" as in response to the loon. It appears that many of the differences in the stickleback between the lakes can be attributed to subtle changes in the abundance of these predators since no two lakes on the island have exactly the same kinds or proportions of the various predators. In contrast, the European stickleback show little differentiation between lakes owing in part to the continual disturbance of natural species interactions. The long history of introducing popular game species into almost every watershed as well as the elimination of many of the fish-eating birds has tended to a uniformity and simplification of what were previously diverse and unique habitats. The evolutionary response of the European stickleback has been towards more and more similarity between watersheds since the selective pressures have become more uniform.

Within each lake on the Charlottes, there is morphological variation in the stickleback such that some individuals have shorter or fewer spines than the average, some have disruptive colouration as opposed to countershading, or in other words, no two individuals within a population are identical. This characteristic is not unique to the stickleback but has been found in every species of plant or animal that has been studied. The reasons for this variation within populations is one of the major problems in evolutionary genetics. It is generally believed that most of the variation observed is either detrimental or irrelevant to the population. In evolutionary terminology, the individuals possessing the average characteristics have the highest fitness while those which deviate from these characteristics have a progressively lower fitness.

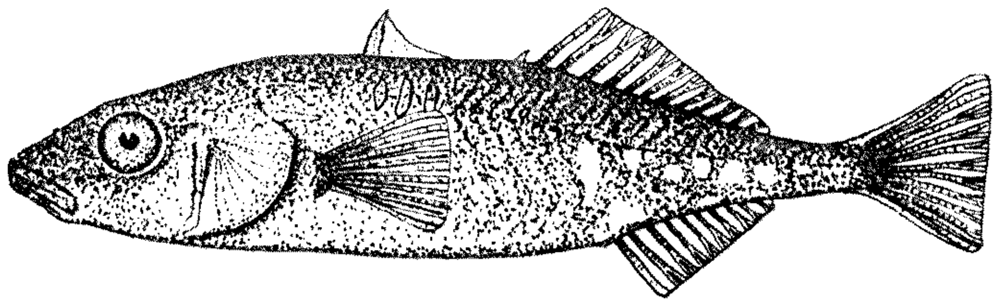
Evolution of the Queen Charlotte Stickleback (Cont'd)

The studies now being undertaken at Boulton Lake and Drizzle Lake are for the purpose of determining whether all individuals within the population, both the average and the variant, have the same fitness, and whether this variation is advantageous to the population. The conclusions to date have suggested that this is indeed the case and that the variation is an adaptive evolutionary strategy. The principle reasons for this are that each individual has a unique life history and therefore slightly different adaptations. For example, in Drizzle Lake, some stickleback feed predominantly on bottom fauna, while others feed on plankton near the surface. Still others utilize food sources near to shore in very shallow water. Each of these three feeding strategies result in different predator interactions. The bottom feeder is exposed to invertebrate predators, the planktonic feeder to the common loon and cutthroat, and the shallow water feeder to the red-necked grebe and the kingfisher. Just as the stickleback have adapted between lakes to differences in predators, so they have adapted within lakes. When examining the colouration of the stickleback, I have found that besides considering the type of predator, it was also important to consider the time of day at which the predator hunts, in addition to the amount of transmitted and reflected light in the water. These factors influence the background that a predator perceives and this in turn alters the selective pressures acting on the pigmentation patterns of the stickleback. All of the variation observed appears to be the result of an exceedingly complex pattern of species interactions and that even the most variable individual within the population is adapted to its special life history.

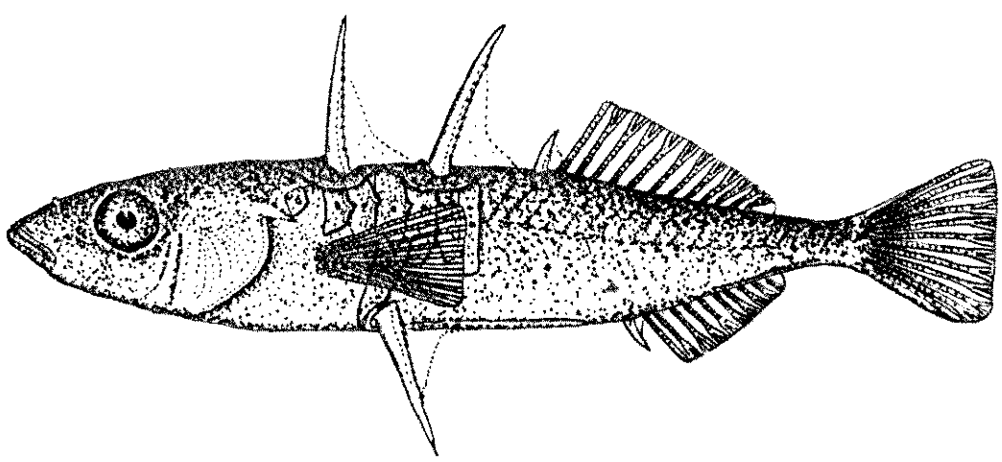
It is unfortunate that so many of the ecosystems remaining on earth's surface, both terrestial and aquatic, no longer resemble what they were less than 100 years ago. In these it is no longer possible to satisfactorily understand any natural species interaction since the total species composition have been dramatically altered. We have barely begun to understand the natural history of such an obscure fish as the stickleback and have barely realized the number of species dependent upon it. Looking at lumbering practices and industry, it is apparent that we have not understood the ecological or evolutionary consequences of environmental deterioration to the life histories of almost all plant and animal species. Much of this is due to the fact that very few studies have attempted to look at the total biology for each species except for those which are economically relevant. The evolutionary studies of the stickleback on the Charlottes in relatively undisturbed habitats has provided some understanding of the causes of variation in animal populations and hopefully will increase the appreciation of the complexity of species interactions in biological systems.



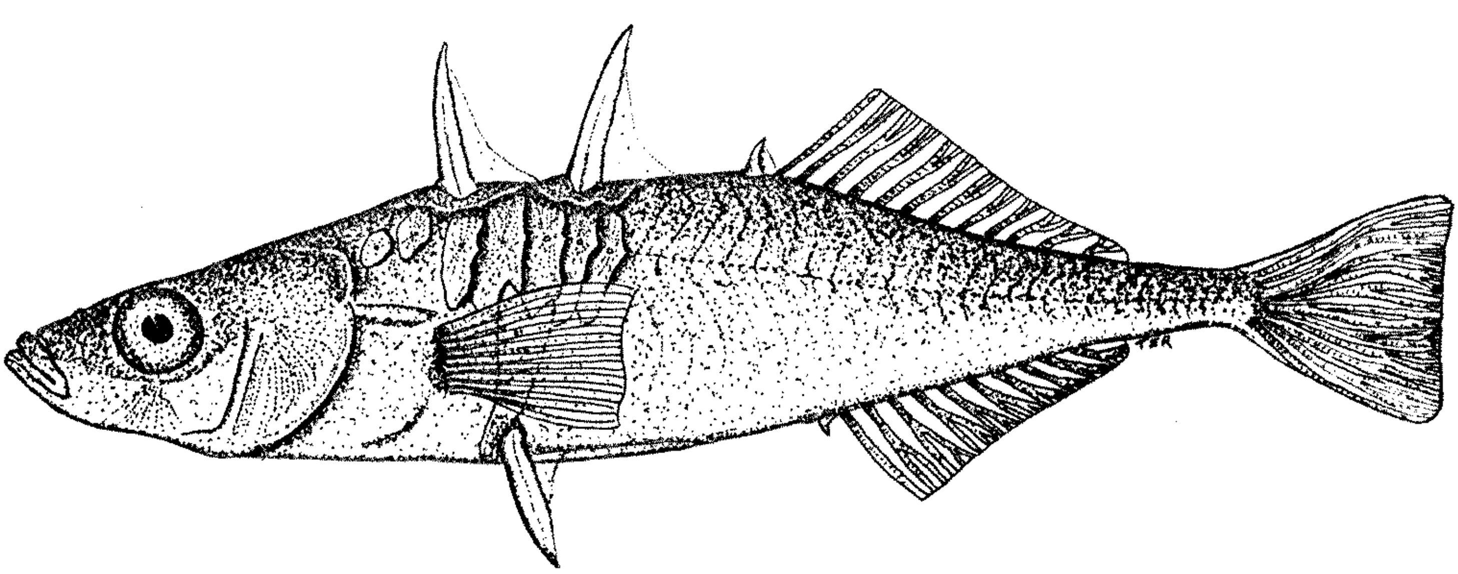
Gold Creek (European type)



Boulton Lake



Yakoun Lake



Mayer Lake, Drizzle Lake

STICKLEBACK FISH

Captions to Figures

Figure 1. Boulton Lake showing depth contours (m), floating vegetation (circles) and generalized distribution of submergent grasses(vertical lines). Depth measurements made at 50 m intervals on transects A-B, C-D, E-F, etc. Seining position indicated by dotted line.

Figure 2. Variation in dorsal and pelvic skeletal elements.

A. Dorsal spine phenotypes and associated support bones. 1st dorsal(D-1) and 2nd dorsal (D-2) shown in common positional relationship to specific vertebra. Categories referred to in text include D-II(upper figure) and D-IO(lower figure).

B. Pelvic girdle and spine phenotypes. Categories include P-OO(left), P-IO(center) and P-II (right). vp- ventral plate; ap-ascending or vertical process. Representative individuals we drawn but skeletal material was highly variable.

Figure 3. Percentage of males among individuals according to total spine number, including dorsals, pelvics, and anal positions. Comparison based on combined samples for all fish greater than 30mm.

Figure 4. Percentage of males in relation to length class and habitat. Shoreline positions (square), central lake positions (diamond). Dotted line shows an equal sex ratio. All samples from 1977. Vertical line- one standard deviation.

Figure 5. Percentage of adult males (> 50mm) for month and habitat. Shoreline positions(square), central lake (diamond). Dotted line shows equal sex ratio.

Figure 6. Frequencies of pelvic variation separated for sex and length class. Full pelvis(solid), half pelvis(dotted), no pelvis (open). One percent equals 3.6 degrees of arc. Smaller circles indicate samples with less than 30 individuals. All collections from 1977 between February and November.

Figure 7. Summary of habitat associations between phenotypes. Vertical axis represents percentage of a specific phenotype in central lake positions in comparison to total numbers of that phenotype captured (shoreline + central lake). Horizontal dashed line at 50% indicates an equal distribution between habitats. A- 15-20mm fish; B- 20-40mm fish; C- 40-60mm fish. For statsical analysis refer to Table 3.

Figure 8. General distribution of some predators. G. immer (dashed line) and M. alcyon (narrow continuous line) show positions in which diving was observed. Relative abundance of Aeshna, assessed from minnow traps, seine, and benthic trawls, shown as common (solid square), occasional (triangle) and absent (open square). Observations summarized from all years. Refer to Figure 1 for depth contours.

Table 4

Occurence of predators on G. aculeatus in Boulton Lake. Data summarized from all years of observation. (1) In 1976 and 1977, these species were absent in December and January due to ice cover.

Species	J	F	M	A	M	J	J	A	S	O	N	D	Daily occurr. /month	No. /day.	Hourly occur. /day
Gavia immer				x	x	x	x	x	x				30	1-3	24
Podiceps grisegena[1]	x	x	x						x	x	x	x	5-15	1-2	1-10
P. auritus		x	x							x	x		3-10	2	4-10
Mergus serrator[1]		x								x	x	x	3-5	2-5	1-5
Megaceryle serrator			x	x	x	x	x	x	x				30	1-2	4-8
Aeshna (larvae)	x	x	x	x	x	x	x	x	x	x	x	x	30	common	24
Dytiscus (adult)						x	x	x					?	?	?

Table 5

Summarized results of predation experiments with <u>Aeshna</u> and different size classes of fish. Submerged pieces of wood collected from the lake were placed in the tanks providing a substratum for the larva. The experiment was carried out for a period of 25 days, and all fish replaced every 6 days with new groups(10 fish per length class).

Tank		Numbers eaten	
	15-25mm	30-40mm	50-60mm
A	30	1	1
B	28	3	0
C	30	0	0
% of total	97.8	4.4	1.1