

THREESPINE STICKLEBACK

Gasterosteus aculeatus Linnaeus, 1758
(Gasterosteidae)

Global rank G5 (20Sep1996)
State rank S5 (24Jun1996, reviewed
16May2006)

State rank reasons

Abundant and widespread in coastal areas. The Cook Inlet area contains some rare and evolutionarily divergent populations; genetic research is currently underway to differentiate these groups. Most habitat is pristine and threats are likely minimal, but certain rare populations face substantial threat of eradication by introduced northern pike. Stocking or other introduction of non-native predatory fishes is the primary threat to local populations.

Taxonomy

Complex patterns of variation make taxonomic treatment difficult. May be considered a species complex with many unique and reproductively isolated populations, subspecies or species.

Populations exist that are strictly marine, anadromous and freshwater resident. The marine and anadromous forms give rise to diverse resident phenotypes. Subspecies have been recognized in the past, but current scientific discussion of this species complex recognizes multiple distinct species within evolutionary radiations; current genetic research is underway to determine relationships between evolutionary groups and species before names can be assigned (Hatfield 2001a, 2001b). Lateral plate morphs of resident freshwater forms are recognized as lows (i.e. lateral plates on anterior parts of the fish only), partials (i.e. lateral plates on anterior and posterior ends of the fish with a gap between) and completes (i.e. lateral plates in a continuous row anterior to posterior). In a rare form, plates are entirely absent; *G. a. williamsoni* is an endangered plateless form exhibiting reduction in pelvic structure, and only occurs in drainages in southern California. Lows from the Pacific coast of North America have been called *G. a. microcephalus*, Pacific coast completes are *G. a. aculeatus*, and Penczak (1964 in Wootton 1976) designated lows from Iceland *G. a. islandicus*. A plateless form occurring in Shay Creek, San Bernardino County, CA has been identified as *G. a. santaeannae* (or *santa-annae*), but is currently recognized as synonymous with *G. a. williamsoni* (Ross 1973, Moyle et al. 1989).



Studies of allozyme variation (Haglund et al. 1992) and mitochondrial DNA sequences (Orti et al. 1994) in Asian, North American, and European populations recognized two primary clades: (1) European, North American, and some Japanese samples, which could be divided into an (1a) Atlantic basin clade comprising the eastern North American and European populations, and a (1b) basal Pacific basin assemblage comprising western North American and some Japanese populations; and (2) a divergent group of Japanese populations. The divergent Japanese clade deserves further study and possible taxonomic recognition.

Sympatric species pairs bearing "limnetic" and "benthic" life histories and distinct morphologies have evolved in several British Columbian lake systems, some populations of which are endangered or already extinct (Wood 2003). Several low-lying lakes and streams in the Cook Inlet area contain rare and evolutionarily divergent populations of *G. aculeatus* including three populations polymorphic for lateral plate morphs, several populations polymorphic for pelvic armor morphs, one lake containing 2 freshwater morphs of the species (a benthic and a limnetic feeder), and one lake containing both anadromous and resident freshwater forms of the species (von Hippel pers. comm.). Bell and Orti (1994) viewed divergent populations in freshwater habitats around Cook Inlet as parts of an endemic radiation warranting special consideration for conservation as a unit.

General description

A small (to 10 cm), laterally compressed, scaleless fish with large eyes and a narrow caudal peduncle, 3 (rarely 2 or 4) dorsal spines (the last very short) followed by a soft dorsal fin with 10-14 rays. Pelvic fin reduced to a single spine and a small ray; bony keel along each side of caudal peduncle in the fully plated form; 0-30 bony plates on each side (resident freshwater

populations usually have fewer plates than marine populations). Silver-green to brown above, sides silver, often with dark mottling; breeding males typically have blue sides, bright red belly and lower sides, and bright blue or green eyes; (Moyle 1976a, Page and Burr 1991).

Diagnostic characteristics

Differs from other sticklebacks in having fewer dorsal spines (3 vs. 4 or more for other sticklebacks). Spines and bony plates serve as defense against predators; spines may be erected and then “locked” in an upright position making it difficult for predatory birds or fish to swallow (Wootton 1976).

Length (cm) 10 (maximum)

Reproduction

Spawns in spring and summer. In most populations, adults spawn at 1-2 years old, do not live beyond 4 years, and presumably die at the end of their first breeding season. Reimchen (1992) described a population in Drizzle Lake, Queen Charlotte Islands, British Columbia, in which individuals lived up to 8 years. Male acquires a territory and constructs a nest of sand grains and algae or other vegetation glued together with a substance secreted from his kidneys. Males entice gravid females to lay eggs in their nest, then fertilize and guard eggs, fan them day and night to aerate developing embryos, and later actively guard fry (Morrow 1980). Eggs hatch in approximately 6-10 days. Nest may contain eggs of several females. Female fecundity reportedly ranges from 30 to >1,000 eggs, but entire mature clutch usually consists of 200-300 eggs, which are deposited at once.

Sexual maturity generally attained at 2 years (Morrow 1980, von Hippel pers. comm.). Among limnetic-benthic species pairs in freshwater lakes of B.C., limnetic forms reach sexual maturity earlier (around 1 year) and rarely live longer than 2 years; benthic forms mature around 2 years of age and may live to 7 years (Hatfield 2001a, 2001b, Hatfield and Ptolemy 2001).

Ecology

Found in marine, brackish and fresh waters; exists in strictly marine, anadromous and resident freshwater forms. Host to a large number of parasites, including the tapeworm *Schistocephalus*; a host species for the freshwater mussel *Anodonta beringiana*, an obligate parasite of Alaska streams (Hart and

Fuller 1974). A possible competitor with sockeye salmon (*Oncorhynchus nerka*) fry (Narver 1969), but Hale (1981) reports competition to the detriment of salmon fry is rare. An important prey species for predaceous marine, anadromous and freshwater fish including Arctic char (*Salvelinus alpinus*), Dolly Varden (*Salvelinus malma*), salmon and trout (*Oncorhynchus* and *Salmo* spp.), sculpins (*Cottus* spp.), and northern pike (*Esox lucius*; Greenbank and Nelson 1959, Morrow 1980, Hale 1981). Forms loose schools except when spawning (Moyle 1976a). Lifespan is usually 2-4 years (Morrow 1980).

Economic comments: Sticklebacks are emerging as an important model species in environmental contaminant studies, as well as in genomics and developmental genetics studies with human health implications; has also been used in carcinogenesis testing (Metcalfe 1989).

Migration

Anadromous populations migrate into freshwater for spawning (Moyle 1976a). Harvey et al. (1997) reports large stickleback migrations upstream from Chignik Bay to Black Lake, Alaska, in May, and sparse downstream movements from June through September.

Food

Eats various invertebrates and fish eggs and fry. Freshwater stream populations feed primarily on bottom organisms or organisms living on aquatic plants, limnetic form also feeds on plankton. Anadromous populations feed more on free-swimming crustaceans, also bottom organisms.

Phenology

Diurnal but migrations are mostly nocturnal (Harvey et al. 1997).

Habitat

Marine, brackish and fresh waters, normally low elevation and slow-flowing waters. Benthic; typically occurs in quiet weedy pools and lakes, or among emergent plants at stream edges, over bottoms of sand and mud. Marine populations apparently pelagic, usually stays close to shore but recorded near surface up to 800 km offshore (Mecklenburg et al. 2002). Many unique populations exist in lakes with no inlet or outlet, hence no native salmonid predators (ADFG 2005).

Eggs usually deposited in shallow fresh water in a nest of sand and plant material made by the

male on the bottom (Greenbank and Nelson 1959, Wootton 1976). Some populations breed in marine water. Dense aquatic vegetation may be a habitat requirement for some populations.

Among limnetic-benthic species pairs in freshwater lakes of B.C., limnetics feed in the pelagic zone and choose nest sites in shallow (often <1 m), unvegetated habitat with gravel/rock, submerged log or firm muddy substrate; benthic populations feed over open mud bottoms or submerged vegetation and choose nest sites in deeper (1-2 m), densely vegetated habitat where nests can be concealed (Hatfield 2001a, 2001b, Hatfield and Ptolemy 2001).

Global range

Coastal waters of Eurasia, Iceland, Greenland, eastern Asia, and North America. In North America, from Alaska to Baja California on west coast, from Baffin Island and west side of Hudson Bay to Chesapeake Bay, Virginia, along east coast; also in inland areas (including Lake Ontario) along both coasts. Sometimes occurs in open ocean. Introduced and established in certain areas of California, Massachusetts, and the Great Lakes (lakes Huron, Michigan, Erie, and Superior) (Fuller et al. 1999, Stephenson and Momot 2000).

State range

Simpson Lagoon, Beaufort Sea; Point Lay and Cape Thompson, Chukchi Sea; Bering Sea and Gulf of Alaska including Cook Inlet, south along coast to Canada (Craig 1984, Morrow 1980, Mecklenburg et al. 2002). Rarely found north of Bristol Bay region or far inland (Mecklenburg et al. 2002).

Global abundance

Total population size unknown, but relatively abundant throughout range. However, several unique populations have declined to very low levels of abundance including *G. a. williamsoni*, the unarmored form from southern California, and 4 species pairs in British Columbia, one of which is now extinct (Hadley Lake, Lasqueti Island, B.C.; Hatfield 2001a, Wood 2003). Available density estimates include 7-28 fish/m² in suitable habitat in Wales, 24-63 fish/m² in northwestern England, 2 fish/m² in Kamchatka, Russia, and 4-21 fish/m² in British Columbia (see sources in Wootton and Smith 2000).

State abundance

Abundant in lowland lakes and streams as well as marine and brackish waters.

Global trend

Unknown. Apparently still abundant throughout range, but some unique, isolated populations have declined to very low levels requiring protection (e.g., *G. a. williamsoni* and species pairs in B.C.). Other populations have increased or were created as the result of accidental or purposeful introductions to habitats where this species was not native; increasing population size and distribution in the upper Great Lakes area is an example of growing non-indigenous populations in the U.S. (Moyle 1976b, Fuller 2005). Several studies report evidence of considerable fluctuation in population size from year to year (Greenbank and Nelson 1959, Wootton and Smith 2000). A 26-year study (1972-1998) of a Wales population showed cyclic changes in abundance with a period of about 6 years, around a generally declining trend (Wootton and Smith 2000).

State trend

Unknown, although some unique populations in Southcentral Alaska are likely declining or possibly extinct (ADFG 2005).

Global protection

No formal protection at species level, although certain populations with divergent phenotypes are recognized and protected (Reimchen 1984). The unarmored form known as *G. a. williamsoni*, which occurs in southern California, is a U.S. federally-listed endangered species (Moyle 1976b, USFWS 2005), although critical habitat has yet to be designated for protection of this form (Federal Register 17 September 2002). Several other populations exhibiting similar rare and divergent characteristics (e.g., loss of spines and plates, pelvic reduction) have been identified in the Queen Charlotte Islands, B.C., in Scotland, Norway, and in the Cook Inlet region of Alaska; these populations may be threatened by habitat change and the introduction of predatory fish, and require protection (Reimchen 1984, Bell and Orti 1994, Wood 2003, Foster et al. 2003, von Hippel pers. comm.). Populations of limnetic-benthic species pairs from Vancouver and Texada Islands, B.C. have been designated Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2005) and some are now extinct (Hatfield 2001a, Foster et al. 2003, Wood 2003). Lake populations on the

Queen Charlotte Islands were assigned Special Concern status by COSEWIC in the 1980s, which promotes awareness of the species' status but affords no formal protection (Reimchen 1984, COSEWIC 2005).

State protection

No formal protection except where habitat is protected in state or federal parks, refuges and reserves.

Global threats

Threats include human impacts on spawning habitat and water quality, stocking or other introduction of non-native, predatory fishes, including introductions of certain forms of *G. aculeatus* itself.

Craig (1984) noted that large-scale industrial and petroleum extraction development in the Beaufort Sea could cause direct mortality as a result of intake of juvenile fishes with seawater and indirectly harm populations by altering coastal habitat, including water circulation patterns. The California Department of Fish and Game (CDFG) recognized that increasing development along and recreational uses of the Santa Clara River were threats to the existence of the endangered *G. a. williamsoni* population (CDFG 1974). In British Columbia, beaver activity has resulted in fluctuating water levels that have reduced access to some spawning sites used by the giant stickleback (currently recognized as *G. aculeatus*, but considered by some scientists to be a separate species, this fish is black in color and more than twice as long as threespine stickleback; occurs only in Mayer Lake, Queen Charlotte Islands; see sources in Rubidge 2000, Species at Risk Canada 2004); increasing human recreational use of lake habitat also threatens this population (Species at Risk Canada 2004).

In Alaska and elsewhere, non-native species such as the northern pike (*Esox lucius*) and stocked salmonids may threaten sticklebacks through predation and competition for juvenile food resources (Hatfield 2001a, Hatfield and Ptolemy 2001, Foster et al. 2003, Wood 2003). Hybridization between different forms of *G. aculeatus* threatens the unique genetic characteristics of specific populations recognized as rare or divergent; extensive hybridization between the native *G. a. williamsoni* (unarmored) and introduced *G. a. microcephalus* (armored) forms in California contributed to declines in the

now endangered *G. a. williamsoni* form (CDFG 1974, Moyle 1976b, Fuller 2005).

State threats

Introduction of non-native species such as northern pike and stocked salmonids may threaten sticklebacks with predation and competition for juvenile food resources (Foster et al. 2003). Introduction of anadromous, armored forms of this species into lakes in the Cook Inlet region could potentially threaten the genetic uniqueness of divergent populations in this area.

In the Cook Inlet area, a unique threat to the stickleback polymorphic population present in Loberg Lake is the falling lake level. This reduction in water level is likely caused by pumping water from the lake for nearby highway construction and loss of input from a spring, the discharge from which was redirected due to highway construction (von Hippel pers. comm.)

Although most habitats are in relatively pristine condition, human impacts on water quality in developed areas are of concern. The effects of increasing water temperatures caused by global climate change are unknown, but are of potential concern; Rogers (1973) found a significant positive correlation between water temperature and mortality rate for age I threespines in Lake Aleknagik, near Bristol Bay.

Global research needs

Continue studies of systematics and clarification of taxonomy for this species; identification of distribution and characteristics of rare/unique populations will contribute to this work. Investigate threats posed by habitat degradation and introduction of non-native species, especially to unique populations.

State research needs

See Global research needs. Study habitat requirements of unique Cook Inlet populations. Investigate threats posed by development, oil pollution and introduction of non-native species.

Global inventory needs

Map and survey divergent populations throughout range. See State inventory needs.

State inventory needs

Map, survey and monitor population trends in unique Cook Inlet populations and other key habitats. Monitor distinct populations at index locations to better assess statewide trends and

natural population variability over longer periods of time.

State conservation and management needs

Prevent introduction of predatory and competitive fish species as well as different forms of *G. aculeatus* by developing a lake and stream stocking policy that includes special protections for rare and divergent stickleback populations, such as those found in certain lakes and streams in the Cook Inlet area. Eradicate northern pike from lakes which are habitat for unique stickleback populations. Monitor habitat and water quality, especially in locations with unique populations; use preventative measures to avoid sedimentation from road construction and logging operations. Insure sufficient quantity of water for unique populations. Manage for viable population sizes, based on regular monitoring of distribution and population trends throughout the state.

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