RIFFLE SCULPIN
Cottus gulosus (Girard)

Status: Moderate Concern. The riffle sculpin has a fragmented distribution and faces numerous threats that, in combination with climate change, could conceivably cause extinction of genetically distinct populations, leading to reduced diversity and further isolation. The taxon here appears to represent several species or subspecies.

Description: Riffle sculpins are 'generic' sculpins with no single definitive identifying external characteristics, although quite distinct genetically. According to Moyle (2002) they "are defined by the following combination of characteristics: four pelvic elements (1 spine and 3–4 rays); 7–8 soft spines on the first dorsal fin; 16–19 rays in the second dorsal fin; 15–16 rays in each pectoral fin, some of which may be branched; 12–16 rays (usually 13–15) in the anal fin; palatine teeth that are usually present; prickles that are present only behind the pectoral fin (axillary patch); 2–3 preopercular spines; a lateral line that is complete or incomplete with 22–36 pores; and dorsal fins that are usually joined. The mouth is large, so the maxillary may reach as far as the rear edge of the eye. The pelvic fins usually do not reach the vent when depressed. There is usually one median chin pore. They have the typical sculpin mottled body color, with a large black blotch on the rear of the first dorsal fin. Spawning males are dark, often with an orangish edge to the first dorsal fin (p. 350)."

Taxonomic Relationships: As Moyle (2002) states "Riffle sculpin were originally described by Charles Girard in 1854, from San Mateo Creek, San Mateo County, as *Cottopsis gulosus.* The identity of local populations has been in a state of confusion ever since (p. 351)." Fortunately, Baumsteiger et al. (2012) and Baumsteiger (2013) have used molecular phylogenetics to resolve many aspects of riffle sculpin systematics, using both mitochondrial and nuclear DNA. These studies show the following:

1. The anomalous populations in Oregon and Washington, long considered part of *C. gulosus* (Moyle 2002), belong to a quite different, distantly related species. This makes riffle sculpin a species endemic to California.

2. Riffle sculpins in streams tributary to the San Joaquin River are distinct from other riffle sculpin populations. They also show considerable genetic differences (structure) among populations, indicating that each stream contains an isolated population with little historic gene flow to other populations.

3. Riffle sculpins in the Sacramento River and tributaries are distinct from San Joaquin riffle sculpins, reflecting an undefined relationship (e.g., ancient hybridization, shared ancestry) with Pit sculpin (*C. pitensis*).

4. Coastal populations of riffle sculpin are separate lineages from sculpins in Central Valley tributaries and seem to be more closely related to prickly sculpin (*C. asper*) than to other riffle sculpins. The populations from the Russian River also appear to be distinct from other coastal populations. Because the original description of riffle sculpin was

based on a coastal population, future taxonomy may designate these populations as *C. gulosus,* and other populations as separate species.

The evidence presented by Baumsteiger et al. (2012) and Baumsteiger (2013) indicates that California populations of riffle sculpin potentially represent four species or subspecies (associated with San Joaquin, Sacramento, Pajaro-Salinas, and Russian river watersheds). The presence of such cryptic taxa has been found within other "species" of *Cottus* as well (Kinzinger et al. 2005, Lemoine et al. 2014). However, further work is needed to define taxon boundaries and to look for morphological and meristic differences as well. Until such work is completed, all populations in California should continue to be treated as part of one species, while excluding the Oregon and Washington populations, which are widely separated geographically from the other populations.

Life History: The sculpins grouped together here as riffle sculpins are found exclusively in permanent cold-water streams. Despite genetic differences, we assume the habitat similarities among disparate populations indicate similar life history adaptations, following the general pattern described in Moyle (2002).

The disjunct distribution pattern of riffle sculpins reflects their narrow habitat requirements and the poor dispersal abilities of both adults and young. Following a severe drought, it took over 18 months for sculpins in the Pajaro River to recolonize a riffle that went dry only 500 m downstream from a large permanent population (Smith 1982). The fact that their larvae are benthic (rather than planktonic) and do not move far after hatching greatly reduces their ability to quickly recolonize areas from which they have been extirpated, especially if there are barriers that restrict recolonization.

Riffle sculpins eat mainly benthic invertebrates, primarily active insect larvae such as those of caddisflies, stoneflies, and mayflies (Moyle 2002). However, they will consume other prey that is readily available, such as amphipods and small fish, including other sculpins. They appear to feed mainly at night, although their stomachs can contain food at any time of the day.

Age and growth of riffle sculpin has not been well studied and is based mainly on length-frequency distributions (Moyle 2002). Most adults are 60–80 mm long (standard length) and are assumed to be 2-3 years old. Older fish, probably 3-4 year old males, measure 75–100 mm. Larger fish are rare but, when food is abundant, they can reach 100–160 mm TL and 4+ years old. The maximum age for the species is not known.

Riffle sculpins are thought to mature at the end of their second year, spawning in February, March, and April (Moyle 2002). Spawning takes place under rocks in swift riffles or inside cavities in submerged logs. Males choose nesting sites and will spawn with multiple females. Embryo counts range from 462 to more than 1,000 per nest; embryos may be in different stages of development, the result of multiple spawnings. Males stay in the nest to guard embryos and fry, often becoming emaciated in the process. Embryos hatch in 11 (at 15°C) to 24 (at 10°C) days. After absorbing the yolk sac, at about 6 mm TL, fry assume their benthic existence and remain close to the nest.

Habitat Requirements: Riffle sculpins live in permanent, cool, headwater streams where riffles and rocky substrates predominate (Moyle 2002, Leidy 2007). Such streams are clear and shaded, with moderate gradients. In Deer Creek (Tehama County), they occupy areas in fairly shallow (mean depth of 38–39 cm), fast-flowing water (mean water column velocity of 42–44 cm/sec), typical of rocky riffles. However, they live in areas sheltered from strong currents, under rocks or logs (mean water velocity of 8–9 cm/sec). Consequently, they also live in small pools that contain undercut banks, rubble, or other complex cover. They are most abundant in water that does not exceed 25–26°C for extended periods of time; temperatures over 30°C are usually lethal. Dissolved oxygen levels must be at or near saturation, a requirement that also restricts them to areas with flowing water. In most streams, they occur with 3-6 species of other native fishes, most typically with rainbow trout (*Oncorhynchus mykiss*).

Distribution: Riffle sculpin are found in many increasingly isolated watersheds in the Central Valley drainage and the central coast. In tributaries to the San Joaquin River, they are present from the Mokelumne River south to the Kaweah River. They are mostly present in mid-elevation reaches, although they are present below dams with coldwater releases (e.g. Kings and Tuolumne rivers, Moyle 2002). They are absent from the Cosumnes River (Moyle et al. 2010). In the Sacramento River drainage, they are present in Putah Creek on the west side and most tributaries on the east side, from the American River north to the upper Sacramento and McCloud rivers. However, the exact boundaries between riffle and Pit sculpin (*Cottus pitensis*) distributions still need to be determined. In the San Francisco Bay region, they are still found in about a quarter of the watersheds, including Coyote Creek, the Guadalupe River, the Napa River, Sonoma Creek, Corte Madera Creek, and Green Valley Creek (Leidy 2007, Leidy et al. 2011). They are absent today from San Mateo Creek, from which they were originally described (Leidy 2007). They are found in coastal streams that have had historical connections to the Central Valley drainage, including the Pajaro and Salinas rivers and Salmon and Redwood creeks (Marin County). They are also present in Russian River tributaries. Although they have been identified in the Navarro River, recent surveys have failed to locate riffle sculpin (Moyle 2002), indicating past records represent misidentification of other sculpin species. The absence of riffle sculpins from many tributary streams in which they might be expected within their known range demonstrates the difficulties this species has in re-colonizing a stream, once a population has been lost.

Trends in Abundance: Most fish surveys in California do not identify sculpins to species so trend data is largely absent. However, the studies of Leidy (2007) and others (Moyle 2002) indicate they were more widely distributed in the past. They are absent from the South Fork Yuba watershed, in which they were presumably once present. Populations are present below dams on a number of rivers and creeks (e.g., Kings, Mokelumne, Tuolumne and Yuba rivers, Putah Creek), which suggests they can persist if there are adequate cold water flows. The large population in the upper Sacramento River below Dunsmuir was wiped out by the 1991 Cantara toxic fungicide spill, but showed apparent complete recovery by 1998. Presumably, the reach was recolonized by fish from upstream or from tributaries. Likewise, the population in the North Fork Feather River was able to survive repeated piscicide treatments that were supposed to eradicate "nongame" fish species.

Nature and Degree of Threats: Riffle sculpins are abundant and widely distributed in many streams, although each genetic group has more limited distribution and, consequently, a higher vulnerability to the threats noted here. Most populations are increasingly isolated from other populations and are thus vulnerable to local extinction, with limited potential for recovery. Physiologically, they are exceptionally vulnerable to habitat changes that reduce flows or increase temperatures.

	Rating	Explanation
Major dams	Medium	Dams fragment populations; however, some populations likely benefit from cold water releases below dams
Agriculture	Medium	Agricultural runoff and diversions pollute water and contribute to fragmentation
Grazing	Medium	Grazing can reduce riparian vegetation and negatively affect habitat quality in some streams
Rural residential	Low	Localized effects; impacts largely unknown
Urbanization	Medium	Urban runoff is a source of nutrients and pesticides
Instream mining	Medium	Dredging, currently banned, particularly affects benthic fishes such as sculpin and their habitats
Mining	Medium	Legacy effects of gold mining still impair habitats in many streams within historic distribution
Transportation	Low	Roads can channelize streams and contribute pollutants and sediment
Logging	Medium	Erosion from timber harvest have likely increased the amount of fine sediments in streams, reducing habitat suitability for sculpins
Fire	Low	Wild and human-induced fires can increase sediment delivery to streams and reduce canopy cover and associated shading, often leading to increased stream temperatures
Estuary alteration	n/a	
Recreation	Low	Off-road vehicles and other activities can negatively affect streams but impacts are generally localized
Harvest	n/a	
Hatcheries	n/a	
Alien species	Medium	Absent from waters where alien species are abundant

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of riffle sculpin. Factors were rated on a five-level ordinal scale where a factor rated “critical” could push a species to extinction in 3 generations or 10 years, whichever is less; a factor rated “high” could push the species to extinction in 10 generations or 50 years whichever is less; a factor rated “medium” is unlikely to drive a species to extinction by itself but contributes to increased extinction risk; a factor rated “low” may reduce populations but extinction unlikely as a result; and a factor rated “n/a” has no known impact to the taxon under consideration. Certainty of these judgments is moderate. See methods section for descriptions of the factors and explanation of the rating protocol.

Major dams. Dams occur in virtually every watershed inhabited by riffle sculpins. Because these sculpins cannot use fish ladders designed for salmonids, nor survive in reservoirs, dams effectively isolate populations, preventing recolonization if local populations are extirpated. While cold-water releases below dams create refuges for riffle sculpins, potential cessation of such flows during severe drought may lead to loss of these populations, indicating that their dependence upon such artificially maintained habitats is tenuous. Baumsteiger and Aquilar (2014) found that where riffle sculpins are found below dams, their presence in the river predates dam construction, so each below-dam population represents a further isolation event.

Agriculture. Agricultural diversions and polluted, warm return water make large sections of rivers (e.g., San Joaquin) uninhabitable for riffle sculpins. A growing threat is diversion of water for production of marijuana in many areas throughout their historic range, although direct impacts to fishes and other aquatic organisms need further study.

Grazing. Most headwater streams inhabited by sculpins flow through livestock grazing lands. Cattle reduce riparian shade, trample banks, increase local sedimentation, and generally reduce habitat quality for riffle sculpins.

Rural residential. Many streams are affected by suburban or rural development, resulting in degradation of riparian habitat, effluent from septic tanks, diversions, and other localized, yet cumulative, impacts.

Urbanization. Streams in urban areas are often highly altered for flood control, and many are channelized and polluted from storm water and surface runoff, although protected reaches (especially with coldwater sources) can act as refuges (Leidy et al. 2011). However, most populations in urban areas are isolated in limited areas of suitable habitat.

Mining. Instream mining is largely detrimental to sculpins, given their benthic habitat occupation across all life history stages, as Harvey (1986) demonstrated for gold dredging, a practice currently banned in California. Other effects from mining are mainly legacy effects of hydraulic mining (e.g., elimination of riffle sculpin from the South Yuba River) and polluted drain water from abandoned hardrock mines.

Transportation. Roads and railroads often run along one or both sides of riffle sculpin streams and bridges and/or unimproved roads with culverts cross them. Impacts may include channelization, habitat fragmentation, narrowing of stream channels, increased sedimentation, and increased likelihood of contaminant delivery; the latter was dramatically demonstrated by the 1991 fungicide spill in the Sacramento River, when a train derailed at the Cantara Loop and fell into the river, killing most aquatic organisms in the river for many miles downstream of the spill.

Logging. Timber harvest and associated road development and erosion are common in the riffle sculpin's range, especially in the Sierra Nevada. Such land use increases the likelihood of local extinctions of already fragmented populations.

Alien species. Riffle sculpins are generally absent from stream reaches in which alien fishes, such as smallmouth bass, redeye bass, and brown trout, are common, or even present. This is largely a reflection of habitat quality, because cool water streams tend to favor native species. But it also indicates vulnerability to predation by alien predators.

Effects of Climate Change: Riffle sculpin require cool water habitats that will become increasingly restricted to higher elevations and northern latitudes as stream temperatures increase and summer base flows decrease. During periods of extended severe drought, cold water releases below most dams may disappear, with severe consequences to sculpin populations. As a result, Moyle et al. (2013) rated the riffle sculpin as "critically vulnerable" to climate change.

Status Determination Score = 3.0 - Moderate Concern (see Methods section Table 2). The riffle sculpin has a fragmented distribution and faces many threats that, in combination, could eventually cause extinction of one or more of the genetically distinct population segments (Baumsteiger 2013).

Metric	Score	Justification
Area occupied	5	Riffle sculpin are present in multiple watersheds in four distinct geographical regions
Estimated adult abundance	4	Current abundance is not known but assumed to be locally abundant in a number of streams
Intervention dependence	3	Many stressors threaten the viability and health of riffle sculpin; different for each population
Tolerance	2	Requires high quality cold water environments
Genetic risk	3	Values range from 1 to 4 depending on populations
Climate change	1	All populations exceptionally vulnerable
Anthropogenic threats	3	See Table 1
Average	3.0	21/7
Certainty (1-4)	3	Reasonable knowledge of many populations

Table 2. Metrics for determining the status of riffle sculpin, where 1 is a major negative factor contributing to status, 5 is a factor with no or positive effects on status, and 2-4 are intermediate values. See Methods section for further explanation.

Management Recommendations: A major step toward protecting riffle sculpin would include a more extensive study of the genetics, morphometrics, and meristics of sculpins from diverse populations, to determine the identity of cryptic species or subspecies indicated by the work of Baumsteiger et al. (2012) and Baumsteiger (2013). Genetically distinct population segments occupying four geographical areas (San Joaquin drainage, Sacramento drainage, central coast watersheds, and Russian River; Figure 1) have varying levels of vulnerability to extinction although all are threatened, especially by climate change.

A comprehensive assessment and monitoring program should be developed across all four regions to assess abundance and distribution of riffle sculpin and to identify threats to all local populations. Potential refuge watersheds or stream reaches should be evaluated, along with identification of coldwater sources that can sustain populations during severe drought and in the face of climate change. Environmental flows should be provided, including during drought periods, which would protect a viable portion of the population below major dams; such flows would also benefit other native fishes and aquatic organisms.

Figure 1: Genetically distinct populations of riffle sculpin (*Cottus gulosus*, Girard) in California (based on Baumsteiger 2013). There are four distinct genotypes: (1) San Joaquin basin and lower Sacramento River (2) upper Sacramento River basin, (3) Pajaro-Salinas basin, and (4) Russian River basin.