CLEAR LAKE ROACH
Lavinia symmetricus ssp.

Status: Moderate Concern. Although apparently in no danger of extinction, isolated populations of Clear Lake roach could decline rapidly and disappear as the result of changes in climate, alterations to streams and water withdrawal for urbanization, rural residences, and agriculture (especially vineyards).

Description: Clear Lake roach are a small (adult size typically 50-100 mm), bronzy cyprinid very similar to the Central California roach in appearance. Clear Lake roach have 8-10 dorsal fin rays (mean 8.6) and 7-9 anal fin rays (mean 8.0) (Hopkirk 1973). The head is large (ca. 3.75 into standard length) and conical. The dorsal fin is positioned behind the insertion point of the pelvic fin. The eyes are small to moderate in size, the snout is short, and the mouth is subterminal, slanting at a downward angle. The pharyngeal teeth (0,5-4,0) have curved tips which overhang grinding surfaces. Roach are usually dark on the upper half of their bodies, ranging from a shadowy gray to a steel blue, while the lower half of the body is much lighter, usually a dull white/silver color. The scales are small, numbering 49-58 (mean 52.7) along the lateral line.

Roach exhibit general (non-nuptial) sexual dimorphism (Snyder 1908a, Murphy 1943). In tributaries to San Francisco Bay, Snyder (1905, 1908a) demonstrated that the sexes could be differentiated by the ratio of pectoral fin length to body length. Males exhibited a ratio of $\geq$.21 while females bore pectoral fins between .16 and .20 the length of their body (standard length). Both sexes exhibit bright orange and red breeding coloration on the operculum, chin and the base of the paired fins. Males may also develop numerous small breeding tubercles (pearl organs) on the head (Murphy 1943).

Taxonomic Relationships: Clear Lake roach were first mentioned by J. O. Snyder (1908d). He recognized them as *Rutilus symmetricus* and found them to be similar to roach from other Sacramento Valley tributaries. While he documented the considerable morphological differences between populations in the Sacramento and San Joaquin valleys, Snyder felt he did not have adequate collections from many inland populations to determine their relationships. Referring to differences among Central Valley roach populations Snyder (1908d, p. 175) stated: “whether any geographical significance can be attached to these can not be known until more extensive observations have been made.” By 1913, Snyder had acquired more roach samples but the collections were primarily from coastal basins. Consequently, when he revised the taxonomy of roach, he added four new species from coastal watersheds but only a single species from inland waters, the northern roach, from the upper Pit River and Goose Lake watershed (Snyder 1913). The Clear Lake population was not included in Snyder’s re-evaluation and was, therefore, by default, grouped with other *H. symmetricus* populations from the Central Valley.

In retrospect, it appears that Snyder’s focus on coastal populations steered the study of roach systematics away from inland populations, which received scant attention in the literature for the next half-century, even as considerable controversy embroiled the taxonomic status of coastal species. In a footnote in a paper on hybridization between hitch (*Lavinia exilicauda*) and roach in the Monterey basin, Miller (1945) suggested that Snyder’s roach species should be treated as “geographic subspecies.” In an unpublished

M.S. thesis, Murphy (1948) agreed with Miller and concluded that all coastal species of roach should be reduced to subspecific status of *H. symmetricus*. Murphy concluded Clear Lake roach were related to *H. symmetricus* from the Sacramento Valley, dismissing the phylogenetic significance of past hydrologic connection between the Russian River and the Clear Lake basin (Holway 1907, Snyder 1908a) by stating that any roach transferred from the Russian River to Clear Lake would have been "genetically swamped". Although critical of Murphy's reasoning, Hopkirk (1973) agreed with the diagnosis of placing all roach taxa within one species and that roach from Clear Lake were morphologically more similar to Central California roach than to Russian River roach.

While there remains considerable uncertainty regarding the interpretation of genetic information in the roach/ hitch species complex (Avise et al.1975, Avise and Ayala 1976, Jones 2001, Aguilar and Jones 2001), recent genetic evidence points to the close association of Clear Lake and Russian River roach populations. Mitochondrial DNA (mtDNA) analysis (Jones 2001) found that roach from the Russian River were closely related to roach from the Clear Lake basin, leading Moyle (2002) to propose the Russian River-Clear Lake roach as a new subspecies. The most recent genetic analysis used both mtDNA and nuclear DNA microsatellites (nDNA) (Aguilar and Jones 2009). The mtDNA analysis found that a number of mtDNA haplotypes were shared by fish from tributaries from the Russian River and Clear Lake, adding support to their grouping as a common lineage. The microsatellite analysis, however, provided greater resolution and suggested that roach from the Russian River and Clear Lake basins should be treated as separate taxonomic entities. Acknowledging that the systematics are still in flux, this account takes the precautionary approach of treating both the Clear Lake and Russian River roach as separate taxa.

Life History: Clear Lake roach presumably share much of their life history with the closely related Central California roach (Moyle 2002) but little information exists and their life history needs further research.

Habitat Requirements: Clear Lake roach occupy diverse stream habitats, from cool headwater reaches, where they are found with rainbow trout (*Oncorhynchus mykiss)* to warm, low-elevation mainstem reaches, where they associate with Sacramento pikeminnow (*Ptychocheilus grandis*) and Sacramento sucker (*Catostomus occidentalis*). They are most abundant in warm, exposed, mid to low-elevation stream reaches where they prefer quiet water, especially pools (Taylor et al. 1982). In the Clear Lake basin, roach abundance is positively correlated with stream temperature, conductivity, gradient, coarse substrates and bedrock, and negatively correlated with depth, cover, canopy (shade), and fast water (Taylor et al. 1982). It has been suggested that alteration of spawning and rearing habitats in the lower reaches of Clear Lake tributaries by agricultural land uses contributed to the decline or extinction of many of the lake's stream spawning native cyprinids, including the lake population of Clear Lake roach (Murphy 1948b, Hopkirk 1988). Agriculture has likely contributed to higher amounts of fines deposited over rocky riffle substrates where roach prefer to spawn.

At times, roach have been found at extraordinarily high densities (157 gram roach biomass/ cubic meter) in pools of intermittent streams where high temperatures, paired with low dissolved oxygen, tend to be lethal to other fish species (Taylor et al. 1982). Consequently, roach are often the first fish to recolonize stream reaches when surface flows resume in late fall.

Distribution: Clear Lake roach are restricted today to the tributaries of Clear Lake, where they are widely distributed in the basin's seven major drainages. They were presumably native to the lake as well (Stone 1873), using it mainly for dispersal, but there are no recent collections from the lake; roach are now unable to occupy the lake because of their vulnerability to alien predators (Moyle 2002).

Roach were found in 46% of 120 sites sampled by Taylor et al. (1982) in the seven major drainages of the Clear Lake Basin which include: (1) Seigler Creek, (2) Cole Creek, (3) Kelsey Creek, (4) Adobe Creek, (5) Highland Creek (tributary to Adobe), (6) Scotts Creek and (7) Middle Creek. All streams except Cole Creek become intermittent by late fall in their lower reaches. Roach were the dominant species in the middle sections of many streams, especially Seigler and Middle creeks. Roach were not found above waterfalls and other high gradient stream sections which form barriers to their upstream dispersal (Taylor et al. 1982).

Roach are common in the Cache Creek watershed; Cache Creek is the outlet of Clear Lake. However, the taxonomic relationship of these fish to Clear Lake roach is not known.

Trends in Abundance: Livingston Stone (1873) noted that roach were present in Clear Lake in "vast abundance" in shallow water. While Stone could have mistaken juvenile Clear Lake hitch or splittail for roach, he also noted the presence of both of these species as well. Today, Clear Lake roach presumably continue to maintain large populations in many tributary systems. However, systematic surveys have not been performed since the study of Taylor et al. (1982).

Nature and Degree of Threats: While roach are very resilient, they tend to disappear from streams that are heavily altered or dewatered for residences, vineyards, or pasture, as well as those invaded by alien predators such as green sunfish (*Lepomis cyanellus*) (Table 1).

Major dams. Cache Creek Dam was built on upper Cache Creek in 1914 to provide water for Yolo County agriculture. The dam raised maximum lake level and causes Clear Lake to fluctuate more than it did historically. It is unlikely that the dam itself was a substantial factor in the extirpation of roach from the lake; however, it does block any potential upstream dispersal of roach from Cache Creek. Smaller dams, such as Kelsey Dam on Kelsey Creek, also impede fish movement, leading to isolation of stream reaches and increasing the chances of extirpation because they often prevent recolonization from nearby populations.

Agriculture. The high rate of conversion of oak woodlands to vineyards is likely the largest threat facing stream fishes in the Clear Lake basin today, following decades of clearing lowland areas for orchards and other agriculture. Vineyard expansion on hillslopes has a direct impact on tributary flow if surface water is used for irrigation or if groundwater extraction affects headwater springs that feed tributaries. Alterations to basin hydrology resulting from new vineyard development are of equal concern. Deitch et al. (2009a,b) showed that vineyard water use for irrigation and frost protection is significantly affecting in-stream flow in tributaries to the Russian River, Sonoma County. Clear Lake, in adjacent Lake County, has similar land uses but receives less rain, possibly exacerbating this threat.

Grazing. Heavy grazing of Clear Lake watersheds has occurred since the 1870s and has likely contributed to sedimentation and nutrient loading of the lake and its tributaries (Suchanek et al. 2002). Heavy grazing can lead to stream bank collapse, sedimentation of pools and other instream habitats, pollution from animal wastes, and reduced cover and shading. Under these conditions roach tend to disappear from streams, despite their high tolerance of adverse conditions. Stock ponds for watering cattle may divert water from streams and support populations of alien predatory fishes. These fishes (e.g., green sunfish, largemouth bass) may colonize adjacent streams if ponds spill during wet periods, competing with or preying upon roach and other native populations. See the Central California roach account in this report for more on interactions between roach and predatory fishes.

Rural residential. As Clear Lake became popular as a resort area in the 19th century, the lakeshore became increasingly developed with vacation and permanent homes. This development removed tule beds (*Schoenoplectus acutus*), which provided important habitat for fish, and filled wetlands that filtered sediment and nutrient delivery to the lake. Widespread development also lead to increased discharge of septic tank effluent and, ultimately, large-scale application of pesticides to the lake to control the native but pestiferous Clear Lake gnat (*Chaoborus astictopus*). Such factors presumably contributed to the loss of roach from the lake itself, as well as the lower ends of tributaries to the lake.

Modern rural residential development of the basin is accelerating, along with increasing human demand for water, which may negatively affect instream flows. Roach can persist in intermittent pools but increasing water demand in summer and early fall may cause complete drying of long portions of streams, so roach may be more prone to localized extirpation in many stream reaches or even entire watersheds.

Urbanization. Roach tend to disappear from streams flowing through urban areas, presumably because of the combined effects of habitat alteration, reduced flows and pollution. However, the Clear Lake basin is predominantly rural with limited urban development centered on or near the lake's shore. Local residents were leading proponents of the application of pesticides to the lake in an attempt to control gnat populations. Three treatment of Dichloro-diphenyl-dichloroethane (DDD) were applied in 1949, 1954, and 1957, before the gnat became resistant. DDD built up in animal tissues and was implicated in the reproductive failure of western grebes on the lake as well as the decline of local raptor populations. DDD accumulates in the fatty tissues of fish and may affect survival and reproduction (Hunt and Bischoff 1960). The effects of these basin-wide treatments on roach are unknown.

	Rating	Explanation
Major dams	Low	Impacts, if any, of Cache Creek Dam are minimal other than potential fragmentation of roach populations
Agriculture	Medium	Water withdrawal from streams reduces and degrades habitats
Grazing	Medium	Grazing is pervasive along roach streams
Rural Residential	Medium	Residential water withdrawal may contribute to decreased summer flows throughout the basin
Urbanization	Low	Growth of towns surrounding the lake contributes to pollution, alters aquatic habitat, and increases water withdrawal from streams
Instream mining	Low	Gravel mining has simplified stream habitat in the lower reaches of some streams
Mining	Low	Mining for mercury has left Clear Lake with extremely high toxicity levels but there are no known effects on roach populations
Transportation	Medium	Roads channelize streams and contribute silt and other pollutants throughout the basin
Logging	Low	Logging impacts in the Clear Lake basin are largely a legacy issue
Fire	Medium	Combined with predicted climate change conditions, fires may cause local extirpation more frequently in the future than in the past
Estuary alteration	n/a	
Recreation	Low	Effects of OHVs and other activities can be substantial but are generally localized
Harvest	n/a	
Hatcheries	n/a	
Alien species	High	Most roach streams are under continual threat of invasions by green sunfish, fathead minnows, and other non-native fishes

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Clear Lake roach in California. 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 is unlikely as a result. A factor rated “N/A” has no known negative impact. Certainty of these judgments is moderate. See methods section for descriptions of the factors and explanation of the rating protocol.

Mining. Mining wastes from the Sulphur Bank Mercury Mine were dumped into the Oaks Arm of Clear Lake intermittently between the 1920s and 1950s. These wastes contaminated the lake ecosystem with mercury and arsenic (Suchanek et al. 2002), although the effects on roach are not known. Gravel mining has affected some potential roach streams (e.g., Scott Creek) by simplifying habitats.

Transportation. Clear Lake is entirely surrounded by roads, which cross all major streams entering and exiting the lake. Bridges and culverts are major gradient control structures, significantly altering the hydrology and geomorphology of the lower reaches of many of Clear Lake's tributaries. These channel modifications may have been a contributing factor in the extirpation or reduction of roach populations. Extensive road networks also exist in the upper portions of Clear Lake basin watersheds; these roads may further contribute to siltation, channelization and habitat loss.

Logging. Logging in the Clear Lake area began in the 1840s. By 1905, approximately 1.5×10^6 board feet of lumber were being processed locally (Suchanek et al. 2002). Erosion from timber harvest lands likely contributed to historic simplification and siltation of streams, but effects on roach populations today are likely substantially reduced because most streams in the basin have presumably recovered due to greatly reduced timber harvest activity.

Recreation. The Clear Lake basin is extensively used for recreation including fishing, motorized boating and off-road vehicle use. The effects of such recreational activities have not been quantified but may include increased localized sedimentation, input of pollutants into the lake, disruption of fish behavior or movement, potential introductions of alien fishes, and other impacts.

Fire. Natural and human-induced fires are common in the watersheds that drain into Clear Lake (Suchanek et al. 2002) and may, occasionally, alter stream habitats. However, future fire effects may become more severe and frequent due to human changes to the landscape, changes to land management practices, and the predicted outcomes of climate change. More intense fires, especially in upper watersheds, may particularly affect fishes like roach, which are found mainly in smaller tributary streams that may be disproportionately impacted by fires.

Alien species. Starting in 1872, with the unsuccessful introduction of 25,000 lake whitefish by the California Fish Commission, most game and forage fishes popular in the eastern United States were introduced to Clear Lake. Today, 16 alien fishes are present in the lake and only five (of 14) native species remain (Moyle 2002). Alien fishes occupy streams usually through stocking of adjacent ponds for angling, although some upstream movement (e.g., green sunfish) is also possible. Roach are particularly susceptible to displacement by predatory centrarchids such as green sunfish.

Alien fish species constitute a barrier to native fish dispersal through Clear Lake, effectively isolating roach populations in small tributary streams. Isolation of native fish populations increases the likelihood that stochastic events such as drought or fire will result in localized extirpation without opportunity for recolonization. See the Central California roach account in this report for detailed coverage of the threats of isolation and interactions between roach and predatory fishes.

Effects of Climate Change: Clear Lake roach are well adapted to the warm, intermittent nature of most of the basin's streams. However, they are susceptible to long reaches of stream going dry, a process which is likely to become more frequent and widespread with climate change. Roach are one of the few native fishes that are able to endure life in isolated pools in the intermittent reaches of creeks which flow into Clear Lake. By late summer, stream flow goes subsurface, temperatures increase, dissolved oxygen levels drop to low levels and most fish in these remnant pools die, except roach. While such tenacity bodes well for roach in a future of dwindling in-stream water, it also suggests that they are likely to be extirpated from streams that dry completely under the dual strains of decreased rainfall and increased human water use. The latter, in the Clear Lake basin, includes surface and ground water utilization for vineyard expansion, rural residential development and urbanization. In a separate analysis of 10 metrics, Moyle et al. (2013) found that the Clear Lake roach was 'highly vulnerable' to extinction as the result of climate change if present trends in land and water use continue.

Status Determination Score = 3.6 – Moderate Concern (see Methods section Table 2). Clear Lake roach do not appear to be in immediate danger of extinction; however, isolation of tributary populations and the inability of roach to use Clear Lake for recolonization or dispersal to available habitats may contribute to further population declines or extirpations. The Clear Lake roach is listed as "G5T2T3, Imperiled" by NatureServ, where it is included in a taxon described as the Clear Lake-Russian River roach subspecies.

Metric	Score	Justification
Area occupied	3	Confined to tributary watersheds of Clear Lake
Estimated adult abundance	5	Populations appear to be robust and widespread although locally confined to tributaries
Intervention dependence	4	Monitoring and possible reintroductions needed
Tolerance	4	Remarkably resilient species
Genetic risk	4	Possible threat to genetic integrity due to isolation in tributaries
Climate change	3	Drying of streams could result in local extirpation
Anthropogenic threats	2	See Table 1
Average	3.6	25/7
Certainty (1-4)	2	Little published information

Table 2. Metrics for determining the status of Clear Lake roach, 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: The persistence of Clear Lake roach depends on maintaining its stream habitats. The following are recommendations based upon this fundamental requirement:

1. A thorough survey of all Clear Lake tributaries should be conducted in order to determine the distribution and status of roach populations. In particular, streams with past surveys should be resurveyed in order to establish trend information and surveys should be repeated on a regular basis. The life history and habitat requirements of Clear Lake roach need focused research.
2. Streams with intact habitats and minimal stressors should be selected as refuges for native fishes and amphibians and managed accordingly, including taking actions

to maintain summer and fall base flows. Opperman and Merenlender (2004) studied Russian River tributaries and provided management recommendations for such streams, including maintaining live trees (live woody debris), both in the riparian zone and within the stream channel in order to create pool habitats that roach prefer. These recommendations may benefit native fishes of the Clear Lake basin as well. In addition, Merenlender et al. (2008) developed GPS-based water resource analysis tools to quantify and balance water needs and water resources on a watershed scale. These tools were created to aid in sustaining stream flows, while simultaneously enhancing water security for local landowners and vineyard operators. The tools can be used to evaluate various water-policy scenarios, estimate cumulative effects of water extraction methods on the natural hydrograph across a large spatial scale (including temporal variation), and provide information for watershed-level planning required to recover/maintain environmental flows. Such tools would be of great value in the arid Clear Lake basin where water resources are increasingly in demand.

3. Protective measures for Clear Lake roach should be integrated into a general management plan for native fishes of Clear Lake basin streams, including local populations of low concern fishes such as rainbow trout, Sacramento sucker and Sacramento pikeminnow, as well as of poorly known species such as threespine stickleback (*Gasterosteus aculeatus*) and western brook lamprey (*Lampretra richardsoni*).

Figure 1. Distribution of Clear Lake roach, *Lavinia symmetricus* ssp., in California.