NAVARRO ROACH

Lavinia symmetricus navarroensis (Snyder)

Status: Moderate Concern. Although apparently in no immediate danger of extinction, populations of Navarro roach are subject to the dual strains of alterations to streams and associated habitat loss, along with predicted impacts from climate change.

Description: Navarro roach are small (adult size typically 50-100 mm), bronzy cyprinids. They have a robust body, deep caudal peduncle, short snout and short rounded fins. They are dark on the upper half of the body, light below and very similar in appearance to the Gualala roach; both fishes were described by Snyder (1913) as having a light lateral stripe approximately 2 scales wide extending from upper edge of the gill opening to the base of tail and entirely above the lateral line; below is a somewhat wider dark stripe, which, in turn, is followed by several narrower and very distinct dark stripes which grow lighter ventrally. Navarro roach have a mean of 8 dorsal fin rays (Hopkirk 1973). Navarro roach differ from Gualala roach in having fewer anal fin rays (usually 8, Hopkirk 1973) and one less, on average, row of scales above the lateral line (Snyder 1913). Roach captured in downstream migrant fyke nets in 1972 ranged between 51 –99 mm fork length, with an average of 51mm (Brown 1972).
Data specific to Navarro roach are limited; therefore, the following general description of roach morphology is based on studies from other CA roach populations. Roach are small, stout-bodied minnows (cyprinids) with a narrow caudal peduncle and a deeply forked tail. Fish rarely achieve lengths greater than 100 mm total length. The head is large and conical. The eyes are large and the mouth is subterminal and slants at a downward angle. Some populations, especially those in the streams of the Sierra Nevada, develop a cartilaginous plate on the lower jaw, often referred to as a "chisel lip." The dorsal fin is short (7-9 rays) and is positioned behind the insertion point of the pelvic fin. The anal fin has between 6-9 rays. The pharyngeal teeth (0,5-4,0) have curved tips which overhang grinding surfaces of moderate size. 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 47-63 along the lateral line and 32-38 before the dorsal fin. Subspecies are distinguished by various distinctive subsets of characters, especially fin ray and scale counts.

Roach exhibit general (non-nuptial) sexual dimorphism (Snyder 1908b, Murphy 1943). In the tributaries to San Francisco Bay, Snyder (1905, 1908b) demonstrated that the sexes could be differentiated by the ratio of pectoral fin length to body length. Males exhibited a ratio of ≥.21 while females bore pectoral fins between .16 and .20 the length of their body. 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: Navarro roach were first collected by Snyder (1908d) who recognized them as *Rutilus symmetricus* but found that they (along with roach from the Gualala River, which are morphologically similar) were easily distinguished from other roach by their more robust body, deeper caudal peduncle, shorter rounded snout and shorter, less acute fins. While recognizing the close affinity between the Gualala and

Navarro roach, Snyder showed that the two taxa could be distinguished "without difficulty" by the greater number of anal fin rays and larger scales above the lateral line present in the Navarro roach (Snyder 1908d, p. 175).

In 1913, Snyder revised the systematics of roach, describing six full species (the Navarro and Gualala roaches among them) and erecting a new genus, *Hesperoleucus*, to house them. In a footnote from a paper on hybridization between hitch (*Lavinia exilicauda*) and roach in the Monterey basin, Miller (1945b) 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*. In his arguments for merging *Hesperoleucus,* Murphy did not dispute that Snyder's species were morphologically and genetically distinct. Instead, he followed what appears to be a strict interpretation of the biological species concept as outlined by Mayr (1942). Murphy argued that the distinctiveness of isolated populations, such as those in the coastal rivers, resulted from "merely a chance genetic divergence" resultant from small numbers of colonizing individuals and, that if physical barriers were removed from between forms isolated in separate basins, "a population would soon lose its identity."

Twenty-five years later, Hopkirk (1973) pointed out that Murphy's principal argument in denying specific status to coastal roach populations (the concept of a "chance genetic divergence" during colonization) was an important mechanism in speciation, the "founder effect" (Mayr 1942, 1954). Hopkirk also asserted that natural selection contributed to differences among roach populations and, therefore, the distinctiveness of populations was "not due solely to the chance combination of genetic factors" as Murphy had asserted. However, despite his critique of Murphy's species concept, Hopkirk agreed that Murphy was correct in placing all roach in one species and Murphy's (1948c) diagnosis was adopted by subsequent workers (Hopkirk 1973, Moyle 1976, Hubbs et al. 1979), although it was never formally published.

However, in the subsequent four decades, much more has been learned about roach systematics. For example, genetic studies (Avise et al. 1975, Avise and Ayala 1976) demonstrated the close relationship of hitch and roach and led to the inclusion of *Hesperoleucus* within *Lavinia* (Moyle 2002); new subspecies have been discovered (Jones et al. 2002); and new groupings of lineages have been proposed (Moyle et al. 1995, Moyle 2002). While new genetic methods have allowed better resolution of *Lavinia* population boundaries, considerable confusion remains about the number and relationship of taxa (Aguilar et al. 2009).

Recently, Aguilar et al. (2009) used both nuclear microsatellite (nDNA) and mitochondrial DNA (mtDNA) markers in the most comprehensive genetic study of *Lavinia* to date. Employed in tandem, these two genetic markers supply insight into both the relationships between populations (phylogenetics) and the distinctiveness of individual populations (taxonomy). The microsatellite analysis of Aguilar et al. (2009) largely supports the distinct lineages that Snyder (1913) described as species and Moyle (2002) recognized as subspecies. In light of these recent genetic analyses and the fact that Snyder's original species names were never properly submerged (i.e., through formal publication of an analysis in the peer-reviewed literature), the subspecies designation for the Navarro roach should be retained. This and other roach taxa now listed as subspecies may be sufficiently distinct to warrant full species status, pending further analyses and publication of findings in the peer-reviewed literature. For additional information and a more comprehensive treatment of roach systematics in California, see the Central California roach account in this report.

Life History: No studies have specifically addressed Navarro roach life history but theirs is assumed to be similar to life histories of other roach subspecies. A general summary of California roach life history can be found in the Central California roach account.

Habitat Requirements: Compared to many other northern coastal watersheds in California, the Navarro has been the focus of extensive habitat and fisheries surveys. Roach are found throughout the system but are rare in the heavily forested North Fork and Mill Creek watersheds (CDFG 1945-1997, Entrix 1998, Feliciano 2004), where colder stream temperatures predominate (NCRWQCB 2000 Appendix A).

Navarro roach prefer pool habitats, with low water velocity, where they tend to be found throughout the water column. They are the dominant fish by number in the Navarro watershed and adults are found in large mixed-size schools that can number well into the hundreds of individuals (Feliciano 2004). Since roach are often found in open pool habitats, they are highly conspicuous for underwater observation. As such, single pass snorkel-surveys are a relatively accurate method for estimating roach abundance (Feliciano 2004). Larvae (less than 20-30mm) bunch in dense schools in low velocity habitats often associated with structural cover (Feliciano 2004). Navarro roach are freshwater obligate fish which can tolerate only very low levels of salinity. In the Navarro estuary, they have been collected at salinities of 3 ppt but perished as salinities reached 9-10 ppt due to the incoming tide (Moyle, unpublished observations). However, they apparently frequent the upper estuary in large shoals, usually around woody debris, and have been recorded in small numbers in the lower estuary (Cannata 1998). Roach use of the estuary is dependent on salinity, which fluctuates according to many variables including tide and the opening and closing of the sand bar at the river's mouth.

Roach tend to be most abundant in mid-elevation stream habitats associated with agricultural land use, rangeland and development. In the Navarro watershed, where the pre-European land cover was primarily redwood forest (Palmer 1967, Holmes 1996), roach are associated with the altered mixed deciduous/evergreen forest, a sign that the roach are capable of existing in heavily modified habitats. On a local stream-reach scale, roach abundance is also positively correlated to the level of disturbance. In a survey of 19 sites from throughout the basin, Navarro roach were closely associated with the most disturbed sites, including: (1) an active restoration site that had been dewatered before the restoration process, (2) a stream reach running through the center of a small town, and (3) a reach of stream immediately downstream from a seasonal gravel dam, used to create a pool for recreational use (Feliciano 2004). Overall, roach were found in the warmest and widest stream localities, where substrates were highly embedded and which had the least amount of shade and in-stream cover. Roach were also associated with riparian forest (buffer widths of 100 m) that had been highly disturbed (Feliciano 2004).

Feliciano (2004) observed interactions between Navarro roach and steelhead trout (*Oncorhynchus mykiss*) in experimental stream enclosures. Roach were never observed to initiate attacks on trout and, consequently, had little effect on trout habitat use or feeding behavior. The trout, on the other hand, aggressively displaced roach from prime feeding habitats and preyed upon both juvenile and adult roach (Fite 1973, Power 1990, Feliciano 2004). However, because the competition between roach and steelhead is likely moderated by temperature (i.e., roach can tolerate temperatures that cause extreme physiological stress to steelhead), roach may attain competitive advantage at higher temperatures than those under which the experiment was held. Feliciano (2004) asserts: "continuing anthropogenic modification of the stream system and surrounding watershed (e.g. surface and groundwater pumping, forest removal, suburbanization) results in streams that are shallower, warmer, less shaded, and thus more favorable for roach and more stressful to steelhead trout."

Navarro roach are also often found with three-spine stickleback (*Gasterosteus aculeatus*) and associated with distinct insect assemblages (Feliciano 2004). Both insect and fish assemblages in many areas shifted with the progression of summer, as cold water-dependent salmonids and insects were replaced by roach and other warm water-adapted species.

Distribution: Navarro roach are confined to the Navarro River and its tributaries.

Trends in Abundance: Although no population estimates have been conducted for roach in the Navarro watershed, stream surveys carried out by the California Department of Fish and Wildlife and the University of California, Davis over the past several decades show that roach have increased in abundance, while coho salmon are on the verge of localized extinction and steelhead abundance has declined dramatically. These population trends (increase of roach, decline of salmonids) are the direct result of warmer water associated with habitat degradation related to deforestation. Roach are a warm water-adapted species and can survive extremely warm water temperatures, while salmonids are cold water-dependent. Presumably, when the Navarro River watershed was more heavily forested, Navarro roach were less abundant and less widely distributed within the watershed.

Nature and Degree of Threats: Historic and contemporary land use practices in the Navarro watershed have resulted in severe alteration of the basin's hydrology, reduced the amount and quality of aquatic habitats, and have led to extreme simplification of the habitats that remains (Table 1). In 1996, habitat surveys of 11 streams from throughout the Navarro basin found excessive deposition of fine sediments in pools and riffles in all reaches surveyed (Entrix 1998). Aggradation (deposition of gravel and fine sediment in the stream channel) has led to higher water temperatures and significantly decreased aquatic habitat in summer as water retreats beneath aggraded gravel streambeds (North Coast Regional Water Quality Control Board 2000), while increasing human water demands for towns, rural residential development and, especially, for new vineyards, compound these legacy effects.

In 2000, the United States Environmental Protection Agency listed the Navarro River under 303(d) of the Clean Water Act as "impaired due to excessive sediment and high temperatures." In preparing the Total Maximum Daily Load (TMDL) report required for all 303(d) listed streams, the North Coast Water Quality Control Board (NCRWQCB 2000) found that in the Navarro:

> "Surface water diversions and groundwater extraction, from residential, commercial, and agricultural uses, can lower water tables and reduce baseflow contributions. Summer low-flow periods reduce the available pool habitat, increase stream temperatures, and may completely dry the channel. Streamflow monitoring performed by the Mendocino County Water Agency and the State Water Resources Control Board, Division of Water Rights indicate that segments of Anderson Creek can go dry for brief periods due to pumping (Entrix 1998)."

While this pattern of watershed use has probably increased roach populations in recent years, the potential for future overutilization of water resources in the basin may pose a threat. Stressors in the Navarro River watershed that impact roach and other native fishes: are (1) logging, (2) agriculture, (3) rural residential development, (4) urbanization, (5) transportation, (6) grazing, (7) fire, and (8) and alien species (Table 1). These impacts are not necessarily listed in order of importance and do not operate independently but, instead, must be viewed in aggregate as cumulative watershed impacts.

Agriculture. Vineyards are now being developed on a very large scale within the watershed (Anderson Valley) and their use of water for irrigation and frost protection is reducing summer flow in Navarro watershed streams. Vineyard expansion has a direct impact on tributary flow if either surface water or groundwater is used for irrigation. Pumping from wells affects groundwater inflow and flow from springs. Deitch et al. (2009b) showed that vineyard water use for irrigation and frost protection is significantly affecting in-stream flow in the Russian River tributaries in Sonoma County. These finding apply equally to the adjacent Navarro River basin where Entrix (1998) states:

> "Summer flows in the lower reaches of Anderson, Rancheria, and Indian Creek are at times significantly reduced by agricultural pumping. In aggraded stream reaches, summer flow may be entirely subsurface."

Pumping for frost protection in spring is also an acute threat because the simultaneous withdrawal by vineyards on a regional scale can dry streams quickly and eliminate all life stages of fish present, including eggs incubating in streambed gravels. Fertilizer and agricultural chemicals are also of concern in that both are known to augment algal production in rivers. Increased eutrophication in the Navarro River would further degrade habitats that are already compromised by both excessive sediment and high temperatures (US EPA 2000).

	Rating	Explanation
Major dams	n/a	No major dams in watershed
Agriculture	Medium	Water withdrawal for irrigation and frost protection decreases flows; pollution inputs from return waters and runoff
Grazing	Medium	Grazing reduces shade and cover in riparian areas
Rural residential	Medium	Residential water withdrawal decreases summer base flows
Urbanization	Low	Urbanization is increasing but remains limited in the watershed
Instream mining	Low	Little or no mining takes place today
Mining	n/a	
Transportation	Medium	Much of the river is bordered by paved roads, while the watershed has a vast network of logging and ranch roads
Logging	Medium	Logging is the largest land use in the watershed; much greater historical impact but legacy effects of widespread deforestation remain
Fire	Low	Infrequent fires may cause localized extirpation, especially in smaller headwater tributaries
Estuary alteration	n/a	
Recreation	Low	Channel alterations from removal of dead trees and construction of summer dams
Harvest	n/a	
Hatcheries	n/a	
Alien species	Medium	Intolerant of introduced predatory fish, especially centrarchids such as green sunfish

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Navarro 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.

Grazing. Sheep and cattle have been grazed in the Navarro River watershed since the 1870s (NCRWQCB 2000). Impacts from grazing in the Navarro River watershed are pervasive but are likely reduced from historic levels. Cattle grazing along streams may result in stream bank collapse, pools filled with sediment, riparian vegetation removal, pollution from animal wastes and reduction in cover and associated shading. In these situations, roach tend to disappear from streams despite their high tolerance of adverse conditions (Feliciano 2004). Stock ponds, which provide water sources for cattle, can divert water from streams and support populations of alien predatory fishes. These fishes (e.g., green sunfish, largemouth bass) may colonize adjacent streams during wet periods (when ponds spill), potentially eliminating roach populations. Capture of green sunfish in recent surveys may be the result of escapement from stock ponds (Feliciano 2004).

Rural residential development. The Franciscan geologic formation, which underlies much of the Navarro River watershed, is considered to be essentially non-water bearing. Only limited amounts of ground water can be found in the Franciscan formation's joints and fractures (NCRWQCB 2000). Ground water is present mainly in shallow surface gravel deposits and is easily depleted. The watershed is experiencing increased rural development and, while roach can coexist with humans in such environments (and even increase under certain conditions), populations may be negatively impacted by the combination of overutilization of water during low-flow periods, polluted inflow from septic tanks and agricultural runoff, siltation from roads, and loss of complex habitat through bank stabilization projects.

Urbanization. Although the Navarro basin is largely rural, urban development is increasing around Booneville and Philo, increasing water demand and further degrading water quality and channel habitats.

Instream mining. Gravel mining can simplify habitats, increase turbidity and contribute to drying of intermittent pools (NMFS 2008). Instream mining appears limited at present but legacy effects from past mining activities may still affect aquatic habitats.

Transportation. Small streambeds are disproportionately affected by roads and road crossings, which simplify and degrade riparian and instream habitats. When roads severely channelize small streams, roach tend to disappear from those streams (Feliciano 2004). Culverts and other road crossing may also form barriers to upstream fish movement, which can lead to isolation of populations and prevent recolonization of upstream habitats. Road building to facilitate logging, rural development and vineyard expansion changes the annual hydrograph by facilitating more runoff during storm events and reducing groundwater storage capacity, leading to reduced summer and fall base flows. Ranch and logging roads are also a leading source of sediment delivery to Navarro system streams (CDFG 1998), potentially limiting reproductive success of roach and other small fishes.

Logging. The Navarro River has a history of intensive logging that began in the mid-1850s, following the Gold Rush. A second logging boom occurred in the watershed from the late 1930s to the early 1950s, when large tracts of redwood-dominated forest were re-cut and the Douglas fir forests in the North Fork Navarro were cut for the first time (Adams 1971). Today almost all forestlands are second or third growth redwood or Douglas fir, intermixed with tanoak and other deciduous trees. The consequent reduced value of these timberlands is one reason that forestlands are being converted to vineyards, resulting in changes in stream flows and temperatures. The primary cause of high stream temperatures in the Navarro basin is the discontinuous canopy closure and consequent lack of shading. Aerial photography reveals that, in the early 1950s, many tributary streams were shaded by complete canopy closure; many of these same streams are now exposed to direct solar heating due to the loss of riparian forest to logging, development, and widening stream channels resultant from increased sediment delivery to streams. The NCRWQCB (2000) found that the Navarro River stream bed has been elevated by "over three to five feet" when compared to "the elevation that existed prior to Anglo-

American resource exploitation." More recent evidence of stream aggradation due to logging is also given:

> "The Greenwood Road Bridge cross-sections also illustrate the impacts of sedimentation. Comparison of the 1950 and 1999 cross-sections show that the maximum depth of the pool along the right bank of the channel has filled approximately five feet since 1950. The change in depth has been accompanied by an increase in width of approximately 20 feet. Entrix (1998) found that the width of unconfined stream channels increased substantially from 1952 to 1965 throughout the Navarro Watershed. Given the extent of logging activities observed in the 1952 aerial photos and the yarding methods employed at that time, it is reasonable to assume that the channel had been affected by increased sediment yields prior to 1950."

To a certain extent, logging has benefited Navarro roach by causing streams to warm and by eliminating cold-water requiring competitors and predators (albeit native ones), such as steelhead and coho salmon. In the long-run, however, the conversion of a diverse forested landscape to agricultural use is likely to eliminate large areas of roach habitat through reduced stream flows, impaired habitats (e.g., wider, shallower stream segments, lack of shading, filled pools, and lack of fallen trees in streams), and warm, polluted return waters that may exceed even the roach's wide thermal tolerances.

Fire. Fire is a natural, if historically infrequent, part of the Navarro River watershed. However, fires are now more frequent and their effects are more severe because of land management practices and associated changes to the landscape. Long-standing fire suppression policies have increased fuel loads, while historic logging has dramatically increased solar input in deforested areas and led to drier fuels. Thus, more severe and frequent wildfires may reduce roach habitat or eliminate localized populations, especially in smaller headwater tributaries.

Alien species. Roach cannot coexist with large populations of alien fishes, especially centrarchids such as green sunfish (*Lepomis cyanellus*) and black basses (*Micropterus* spp.). Centrarchids have been recorded in stream surveys in the Navarro system and could threaten roach populations in many stream reaches, as they have done in other areas of the state (see the Central California roach account in this report for examples). Thus, the transportation of alien fishes over natural barriers by humans and the escape of alien fishes (usually centrarchids) from stock ponds in the watershed can pose a serious threat to the persistence of roach in the Navarro watershed, although this may be mitigated by the winter flood hydrology of coastal rivers that may inhibit the establishment and persistence of alien fishes.

Effects of Climate Change: Navarro roach are well adapted to the warm, arid conditions of California's Mediterranean climate. However, their frequent dependence in late summer on intermittent pools suggests that they are also particularly susceptible to decreases in summer and fall base flows. Roach are one of the few native fish that are able to endure life in isolated, warm pools with low dissolved oxygen levels in intermittent streams. However, increasing water demands, coupled with predicted climate change impacts, may lead to complete drying of stream segments and elimination of roach populations. In the summer of 1992, the mainstem Navarro was pumped completely dry and, increasingly, flows of many aggraded stream reaches (e.g., lower Rancheria Creek, Little North Fork) go entirely subsurface even in "normal" water years. Already diminishing summer stream flows illustrate the possibility that Navarro roach could be extirpated from stream reaches or even entire tributary watersheds if annual precipitation decreases or becomes more variable. Because of its limited distribution in a highly altered watershed, Moyle et al. (2013) rated the Navarro roach as "highly vulnerable' to extinction from climate change.

Status Determination Score = 3.3 – Moderate Concern (see Methods section Table 2). Although apparently in no immediate danger of extinction, populations could decline rapidly and disappear in some areas as the result of alterations to streams, changes in climate, water withdrawal for rural development and viticulture, and invasion of alien fishes. The Navarro roach is listed by NatureServe as Critically Imperiled.

Metric	Score	Justification
Area occupied	1	Confined to the Navarro River and its tributaries
Estimated adult abundance	5	Population large at present
Intervention dependence	3	The Navarro is a rapidly changing watershed so annual monitoring and management are needed
Tolerance	5	Remarkably resilient fish
Genetic risk	4	Little threat to genetic integrity at present
Climate change	2	Highly vulnerable in combination with watershed changes
Anthropogenic threats	3	See Table 1
Average	3.3	23/7
Certainty (1-4)	3	

Table 2. Metrics for determining the status of Navarro roach in California, 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 principal management need in the Navarro River watershed is a regular monitoring program, with basin-wide fish surveys every five years to determine population status and trends and to detect alien fishes and document their distribution. A secondary need is the development of an educational program for watershed residents, especially agricultural water users, to develop cooperative ventures to restore watershed function in ways that benefit fish. Additionally, reaches or tributaries that can be managed as native fish refuges should be identified and established, as insurance against long-term drought and changes in land and water use in the watershed.

Water quality standards recommended by state and federal agencies should be adopted and vigorously enforced, including restoration actions to reduce sediment loads (e.g., reducing the impact of roads of all types). Water rights in the watershed need to be adjudicated and a minimum flow established for all streams, including late summer and early fall low flow periods, to protect fishes and other aquatic organisms. Riparian vegetation buffers should be established and maintained throughout the watershed to increase shade and cover. In addition, Merenlender et al. (2008) developed GPS-based water resource analysis tools which quantify and balance water needs and water resources on a watershed scale. The tools were created to aid in sustaining instream flow while simultaneously enhancing water security for local landowners and vineyard operators. The tools can be used to evaluate various water-policy scenarios, estimate the cumulative effects of water extraction methods on the natural hydrograph across a large spatial scale (including temporal variation), and provide information for the watershed-level planning required to recover environmental flows. Such tools would be of great value in the Navarro River basin where water resources are increasingly over-allocated.

Figure 1. Distribution of Navarro roach, *Lavinia symmetricus navarroensis* (Snyder), in California.