SACRAMENTO PERCH
***Archoplites interruptus* (Girard)**

Status: Critical Concern. The Sacramento perch is already extinct in its native range and most, if not all, populations outside its native range could become extinct within the next 100 years.

Description: Moyle (2002, p. 376) describes Sacramento perch as follows: "Sacramento perch are deep-bodied (depth is up to 2.5 times the standard length) and laterally compressed, with long dorsal (12-14 spines, 10-11 rays) and anal (6-8 spines, 10-11 rays) fins. The mouth is large and oblique, with the maxilla extending just below the middle of the eye. Numerous small teeth are present on the jaws, tongue, and roof of the mouth. The 25-30 gill rakers are long. The scales are fairly large, numbering 38-48 along the lateral line. The spiny portion of the dorsal fin is continuous with the soft-rayed portion. Pectoral fin rays number 13-15 while vertebrae number 31-32, intermediate between the counts for bass and sunfish (Maybee 1993). Depending on the watershed in which they occur, live fish are brownish to silvery on the sides and top with a metallic green to purplish sheen and 6-7 brown/black irregular vertical bars on the sides, with the most anterior bar extending down onto the top of the opercula. Their bellies are silvery to white. Breeding males become darker, especially on the opercula, which may turn purple. Males may also develop a distinct silvery spotting that shows through the darker sides, but in females the color is more uniform." Although this color pattern is distinctive, it is also highly variable.

Taxonomic Relationships: As the only member of the family Centrarchidae native to waters west of the Rocky Mountains, the Sacramento perch is unique. All existing populations (unless there is still a population in Clear Lake) are derived from introductions. As a result, all populations are inbred to varying degrees and each population is genetically distinct from one another (Schwartz and May 2008, Crain and Moyle 2011).

Life History: The life history of Sacramento perch is reviewed in Crain and Moyle (2011) and the information here is condensed from that account.

Sacramento perch spawn for the first time in their second or third year of life, depending on size. They are highly fecund, with females producing up to 125,000 eggs, although most females (12-20 cm FL) produce 8,000-20,000 eggs per year. Spawning takes place at water temperatures of 18-28°C from the end of March through October, although most spawning takes place in March and April. Spawning is typically initiated when males move into shallow water (15-60 cm deep, although spawning has been observed down to 3 m depth) and set up territories over beds of aquatic macrophytes, rocks covered with filamentous algae, or flooded terrestrial plants. Each male typically clears out a depression or other area which is surrounded by plants. These territories are set up in loose aggregations and are defended from other males, as well as potential egg predators.

Females swim in groups close to the spawning area and actively seek out territorial males for spawning. Following a brief courtship period, each female is accepted by a male. Spawning occurs when both the male and female turn on their sides, with vents in close proximity, releasing eggs and sperm. The fertilized eggs attach to the vegetation or other debris in or around the nest. Males guard the nest for 2-4 days after spawning.

Embryos hatch in less than 72 hours, depending on temperature, and in another 2-4 days the larvae (<2mm TL) are able to swim freely. The larvae have a small filament attaching their heads to the egg capsules for 1-4 days. After the attachment is lost, larvae remain in the substrate for another 2-4 days before swim-up. Once they begin actively swimming, larvae either become planktonic or (mostly) live among aquatic plants. Small juveniles (15 -50 mm TL) shoal together in shallow water, gradually moving into deeper water as they grow larger. Individuals eventually become solitary or form only loose aggregations, usually in association with submerged tree branches or other types of structure.

Growth rates depend on temperature, food availability and other environmental conditions. At the end of years 1, 2, 3, 4, 5, and 6, fish are typically 6-13 cm FL, 12-19 cm, 17-25 cm, 20-28 cm, 21-32 cm, and 28-36 cm, respectively (Moyle 2002). Perch can live as long as nine years and reach 61 cm TL and 3.6 kg. The oldest fish known (9 years) were from Pyramid Lake, Nevada, with lengths ranging from 38-41 cm FL. However, the largest fish caught by angling was 43 cm TL, weighing 2.2 kg. Females grow faster and larger than males. Females also have higher survival rates after their first year, so fish that are four years and older tend to be females.

Sacramento perch are ambush predators that feed upon invertebrates and fish, with prey size increasing with mouth gape. Their mouth is quite large, so they can feed on relatively large prey in relation to their body size. Larvae and small juveniles feed on planktonic crustaceans and early instars of insects, especially midges and mosquitoes. Although juveniles are fairly opportunistic, they typically feed on chironomid midge larvae and pupae, as well as amphipods. Larger insects and small fish become increasingly important in the diet of larger perch and those >9 cm FL feed almost exclusively on fish, especially minnows and other soft-rayed native fishes. They feed most actively at dawn and dusk.

Habitat Requirements: This section is based on the studies of Woodley (2007) and the review of Crain and Moyle (2011).

Sacramento perch are adapted for life in sloughs, slow moving rivers, and large lakes, including floodplain lakes, of the Central Valley. These habitats often become very warm and alkaline during periods of drought or in late summer. Their distribution in such habitats led 19th century biologists to conclude that Sacramento perch actually preferred harsh conditions including high alkalinity and salinity. As a result, Sacramento perch were planted as game fish in alkaline waters throughout the western United States. Recent studies suggest that, while Sacramento perch have considerable capacity to survive under such conditions, their preferred habitats are in rivers, large lakes, and estuaries that are fairly cool and fresh much of the year.

Sacramento perch can live in alkaline waters (pH 8-10), but tend to have physiological problems when alkalinities reach 1500 mg/L, with reproduction ceasing at 2000 mg/L. However, they can withstand salinity levels of 24-28 ppt and can grow at salinities in the 10 ppt range, suggesting that they once lived, in part, in estuarine habitats.

In the laboratory, juveniles tolerate temperatures of 7-37°C, including withstanding abrupt temperature shifts of 11-16°C; optimal temperatures for growth are 18-23°. Adult perch require somewhat cooler water, with upper tolerance limits of approximately 29°C. Optimal temperatures for growth appear to be about 15-22° C. Both adults and juveniles can live in lakes that ice over in winter, so they can persist through periods of low temperature as well. While Sacramento perch appear to require cooler water than most other centrarchids, their oxygen requirements at a given temperature are lower, so they can survive relatively low dissolved oxygen conditions for extended periods of time. Likewise, Sacramento perch have a greater capacity to swim in flowing water than similar deep-bodied centrarchids. These attributes suggest that the historic habitats of Sacramento perch were varied and included alkaline valley floor lakes, rivers, floodplains, and estuaries.

Distribution: The historic range of Sacramento perch has been determined from limited collection records and remains in middens left by native peoples. Their range included the Tulare and Buena Vista basins to the south, the San Joaquin River basin, the San Francisco Estuary and its tributaries, and the Sacramento Valley (Moyle 2002, Crain and Moyle 2011). Other populations existed in the Pajaro-Salinas drainage and in Clear Lake, Lake County. The Central Valley populations were distributed in valley floor waters and, presumably, perch did not ascend streams more than a few hundred meters in elevation. It is possible a population also once existed in the Russian River but evidence is equivocal.

Sacramento perch have been widely introduced outside their native range, mainly to alkaline waters where other game fishes generally do not survive. In California, populations were established in stock ponds (no recent records of establishment outside of Yolo County), in the Owens Valley (mainly in Crowley Reservoir), in the Walker River watershed (mainly in Bridgeport Reservoir), in the Cedar Creek drainage (West Valley and Moon reservoirs), in Clear Lake Reservoir within the Lost River drainage (spreading into the Lost River, Copco Reservoir, and Sheepy and Indian Tom lakes), in Abbott's Lagoon in Point Reyes National Seashore, and in a few other small reservoirs (Table 1). Declines have occurred in many of these reservoirs. Moyle (2002) recorded their presence in 28 waters in California (22 if the four Upper Klamath and two Cedar Creek populations are lumped together as one population), but Crain and Moyle (2011) determined that they have been extirpated from at least eight of these waters (Table 1). If the six populations of unknown status are counted as extirpated, which is likely, then the total number of populations in California is 22 (16 independent). Outside of California, as of 2008, nine populations existed in Nevada, one in Utah, and one in Colorado. In all, there are 25 independent populations, mostly in reservoirs, still known to exist with a high degree of certainty as of 2008.

Location	County	Status (2008)
Calaveras Reservoir	Alameda/Contra Costa	Extirpated
Alameda Cr. gravel ponds	Alameda	Extirpated
Lake Anza	Contra Costa	Extirpated
Jewel Lake	Contra Costa	Present
Lagoon Valley Reservoir	Solano	Present
Hume Lake	Fresno	Present
Sequoia Lake	Fresno	Present
San Luis Reservoir	Merced	Present
Middle Lake	San Francisco	Extirpated
Almanor Reservoir	Plumas	Present
Butt Valley Reservoir	Plumas	Unknown
Abbott's Lagoon	Marin	Present
Sonoma Reservoir	Sonoma	Unknown
West Valley Reservoir[1]	Modoc	Present
Moon Reservoir	Lassen	Present
Honey Lake	Lassen	Unknown
Clear Lake Reservoir	Modoc	Present
Lost River and Tule Lake	Modoc	Present
Copco Reservoir	Siskiyou	Present
Sheepy and Indian Tom Lake	Siskiyou	Unknown
Bridgeport Reservoir	Mono	Present
East Walker River	Mono	Present
West Walker River	Mono	Unknown
Topaz Lake	Mono	Unknown
Gull, June, Silver, and Grant Lakes	Mono	Present
Crowley Reservoir	Mono	Present
Lower Owens River, Pleasants Valley Reservoir	Mono	Present

Table 1. Major water bodies listed as containing Sacramento Perch in California in the 1990s by Moyle (2002) with a determination of status in 2008. Populations labeled unknown are likely extirpated.

Trends in Abundance: Sacramento perch have been in a steady decline since the 19th century, when they were once abundant enough to be fished commercially to supply the San Francisco markets. Prior to that, perch were a major food source for Native Americans who lived in the Central Valley. The decline of Sacramento perch was noted by the early 20th century and it was regarded as scarce in its native range by the 1930s. However, little attention was paid because they had been widely introduced outside their native range, replaced within the native range by desirable non-native centrarchids, and restoration to historical abundance was deemed unlikely because alien species were

[1] West Valley Reservoir and Moon (Tule) Reservoir are both in the Cedar Creek watershed so are interconnected. The population was apparently extirpated in the 1980s when water levels were low and the reservoirs became ice-covered in winter. Sacramento perch were subsequently reintroduced (P. Chappell, CDFW, pers. comm. 1995).

perceived to be the principal cause of decline. In the 1950s and 1960s, agency biologists planted Sacramento perch in isolated lakes and reservoirs around the state but they were extirpated from most of the native range by the 1970s, except for a population in Clear Lake (Crain and Moyle 2011). At present, there are 25 confirmed independent populations, nine of them in three other western states. In California, it appears that six populations have been lost in the recent past. In addition, a few populations have been established in farms ponds in Yolo County, including the UC Davis campus, but such populations are ephemeral (P. Crain, UCD, unpublished data, 2010).

The sizes of existing populations are unknown but some are apparently very small (Jewel Lake) while others (Lost River basin and Crowley Reservoir) may be quite large. All have limited genetic diversity, however, because of the small numbers of fish used to start each initial population (Schwartz and May 2008, Crain and Moyle 2011). Each isolated population is different from others genetically and, as populations are lost, the genetic diversity of Sacramento perch is further reduced.

Nature and Degree of Threats: Sacramento perch have declined because of the combined effects of habitat loss and interactions with alien species (Table 2). Given their physiological tolerances, it is likely they would persist today in parts of their native range in the absence of alien fishes. However, their native valley floor habitats were already so heavily altered by the late 19th century, their distribution and abundance were likely severely restricted even prior to introduction of alien fishes.

Major dams. The decline of Sacramento perch in its native range coincided with the construction of dams, including the large 'rim' dams, around the Central Valley. The capture and export of water by these dams was accompanied by conversion of habitats in valley floor rivers and lakes to farms and cities, especially through the draining of wetlands and construction of dikes and levees, which isolated rivers from their floodplains.

Agriculture. Recent physiological and behavioral studies suggest that Sacramento perch were especially well adapted for living in large valley floor rivers and spawning on floodplains (Crain and Moyle 2011). Farming permanently and severely altered these habitats, including drying of the San Joaquin River, draining Lake Tulare and Lake Buena Vista, channelizing the Sacramento River, and building vast networks of levees to protect 'islands' (now sinks often many meters below water level) across the Delta. In addition, agricultural return waters are often warm and laden with pesticides and fertilizers, creating poor water quality for most fishes, including Sacramento perch.

Urbanization. Many California cities are built on floodplains along major rivers in areas that were once habitat for Sacramento perch and other native fishes. The impacts of massive urban and suburban expansion post-WWII in California upon already diminished populations of Sacramento perch likely contributed substantially to their fragmentation and further decline.

Mining. Hydraulic mining had an enormous impact on foothill rivers and valley floor habitats in the 19th century and severely altered many riverine habitats. Although relatively short-lived, the legacy of hydraulic mining still affects habitat quantity and quality for Sacramento perch and other fishes, potentially limiting their distribution and capability of expansion into formerly suitable habitats.

Estuary alteration. The Sacramento-San Joaquin Delta and brackish areas of the rest of the San Francisco Estuary were once major habitats of Sacramento perch, as indicated by large numbers taken in 19th century fisheries. The decline of perch was coincident with the loss of complex estuarine habitats, especially in the Delta, as well the introduction and establishment of non-native centrarchids.

	Rating	Explanation
Major dams	Medium	Dams contribute to reduced and highly manipulated flows and allowed for development of farms and cities in the past
Agriculture	High	Agriculture is a dominant land use across range; diversions, low quality return water, channel alteration, draining of lakes, levee building and other impacts are pervasive
Grazing	Low	Some impacts in lowland areas on aquatic habitats, although most grazing occurs at higher elevations than historic perch range
Rural residential	Medium	Rural development has expanded dramatically across the range of Sacramento perch, contribution to habitat degradation and simplification
Urbanization	Medium	Cities contribute to extensive alteration or loss of habitats, input of pollutants and municipal water demand
Instream mining	Low	Placer and gravel mining presumably altered habitats
Mining	Medium	Hydraulic mining in 19th century may have affected populations and legacy effects remain in many areas
Transportation	Low	Most habitats lined with roads, etc.; potential sources of pollutant inputs
Logging	Low	Impacts mostly indirect from sedimentation; logging largely occurs at higher elevations than historic perch range
Fire	n/a	
Estuary alteration	Medium	Once abundant in complex habitats of Delta; habitats now greatly altered and floodplains mostly disconnected from rivers
Recreation	n/a	
Harvest	Medium	Heavy harvest in 19th century may have contributed to initial declines
Hatcheries	n/a	
Alien species	Critical	Greatest cause of decline; especially acute in the Delta

Table 2. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Sacramento perch 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.

Harvest. Sacramento perch were an important food fish in San Francisco fish markets in the 19th century, with 40,000-432,000 pounds of fish harvested per year (Skinner 1962). It is likely that these fish came from the lower Sacramento River and Delta. It is possible that heavy harvest contributed to their decline, making it easier for other species of fish to invade.

Alien species. The negative effects of alien species on Sacramento perch populations have long been documented. Jordan and Evermann (1896) thought their decline was due to carp and catfish "infesting their spawning grounds." Alien centrarchids, especially bluegill and black crappie, spread throughout California in the early 20th century. Their similarity in ecology and spawning habits to Sacramento perch was noted and, combined with their more aggressive behavior, they were consequently thought to eliminate Sacramento perch wherever they came in contact. Given the rather weak and short protection time of the nest given by male Sacramento perch, it is highly likely that embryo and larval predation by alien fishes has played a major role in their decline (Crain and Moyle 2011). In general, the only habitats where Sacramento perch persist today are those that lack alien sunfish and crappie.

Effects of Climate Change: The Sacramento perch exists mainly in populations in reservoirs or ponds, many of them quite small. Reservoir populations are subject to widely varying habitat quality and potential desiccation of the reservoirs during extended drought periods or when reservoirs are drawn down for dam repairs or other purposes. For example, Crowley Reservoir (Mono County), could drop to low levels and become too alkaline for perch reproduction, as could Bridgeport Reservoir (Mono County). In addition, climate change will likely cause additional stress on remaining Sacramento perch populations through increasing water temperatures and increasing alkalinities as lake levels drop. Moyle et al. (2013) rated the Sacramento perch as 'highly vulnerable' to climate change because of the likely impacts of drought and other factors on their limited, mostly artificial, habitats.

Status Determination Score = 1.9 - Critical Concern (see Methods section Table 2). There are only 25 isolated populations of Sacramento perch remaining and these populations have been declining or disappearing at a steady rate in recent decades. In addition, these isolated populations have relatively low genetic diversity. The American Fisheries Society considers Sacramento perch to be Threatened (Jelks et al. 2008), while NatureServe lists them as Vulnerable (G3). Sacramento perch were included as a declining species in the Delta Native Fishes Recovery Plan (USFWS 1996). Overall, the Sacramento perch appears to be extinct in its native range with most outside populations declining, genetically bottlenecked, and restricted to artificial and potentially insecure bodies of water.

Metric	Score	Justification
Area occupied	1	One native population may remain in historic range (Clear Lake); status unknown
Estimated adult abundance	3	Existing populations are limited and isolated but some appear to be fairly large (sizes unknown)
Intervention dependence	1	Re-establishment in native range requires active rearing program and isolation of suitable habitats from alien species
Tolerance	4	Very tolerant, except of extremely warm water
Genetic risk	2	All populations bottlenecked
Climate change	1	Drought and increasing temperatures will have negative effects on their limited, mostly artificial, habitats
Anthropogenic threats	1	See Table 1
Average	1.9	13/7
Certainty (1-4)	4	

Table 3. Metrics for determining the status of Sacramento perch, 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 following ten recommendations are from a conservation proposal developed by Moyle and Crain (2011, p. 30):

1. Establish backup populations for all existing populations, including those outside of California. Ideally, these would be located in habitats within the native range of Sacramento perch but ponds or lakes under controlled conditions are probably necessary.

2. Re-establish a genetically diverse source population for future planting programs through a program that brings genotypes together from isolated populations. This program would have to be implemented under carefully controlled conditions with genetic monitoring of fish produced as new source stock.

3. In order to accomplish recommendations 1 and 2, establish a Sacramento perch rearing facility in the Central Valley, with facilities for selective breeding and ponds for large-scale rearing of fish for planting where suitable habitats exist. It may be necessary to maintain this facility indefinitely as a source of Sacramento perch for recreational ponds and reservoirs and as an insurance policy for wild populations.

4. Reintroduce fish into habitats that are determined to be suitable (e.g., other species present/absent, appropriate environmental conditions). Physiological and ecological studies suggest that habitats may exist, from which Sacramento perch were extirpated decades ago, that have changed enough so that they may once again be suitable. Some of these habitats are listed in Crain and Moyle (2011).

5. Develop a strategy to use floodplain ponds in order to allow Sacramento perch to colonize natural environments during periods of flooding, linked with a more general

strategy to develop flow regimes and habitats below dams that are generally more favorable to native fishes. A successful reintroduction will require a fairly large number of fish, distributed across a broad geographic area. This strategy could take advantage of previous studies of restoration of flooded habitat on the McCormick-Williamson Tract (CALFED project #99-B193) and the Cosumnes River Floodplain (CALFED Project #99-N06) (Moyle et al. 2007).

6. Develop a source-sink strategy by locating rearing ponds next to streams or sloughs so the ponds can 'leak' Sacramento perch on regular basis into natural habitats. Populations of Sacramento perch have been established in ponds on the UC Davis campus and small numbers of perch now occur in nearby Putah Creek which, presumably, was colonized via interconnected drainage canals.

7. Rear Sacramento perch in large numbers in ponds and other artificial facilities for large-scale introduction into the wild. This is the least desirable options but may be necessary if a large propagule size is required for re-establishment in the wild. This strategy may be especially important for re-establishment or bolstering of Sacramento perch populations in Clear Lake, Lake County, historically one of the last strongholds of wild Sacramento perch in their native range.

8. Conduct comprehensive trawl and seine surveys of Clear Lake to determine if Sacramento perch remain, estimate their abundance, assess population structure, and potentially acquire tissue samples for genetic analyses. If surveys indicate that Sacramento perch exist in Clear Lake in low abundance, captured perch should be taken into captivity so they can be protected and propagated.

9. Develop and maintain an annual monitoring program for all known Sacramento perch populations in California. Monitoring will provide crucial information as to which populations are either maintaining themselves or declining. Genetic monitoring of wild populations should be performed in concert with population monitoring.

10. Promote the use of Sacramento perch in recreational fisheries, especially farm ponds and city fishing programs. Such a program could both acquaint the public with an edible native sport fish and increase the likelihood of Sacramento perch being maintained in greater numbers of private ponds. This, in turn, would increase the probability that some may escape to the wild.

Figure 1. Distribution of Sacramento Perch, *Archoplites interruptus* (Girard), in California. All populations shown are introduced outside the historic range.