CLEAR LAKE HITCH
Lavinia exilicauda chi (Hopkirk)

Status: Class 1. Threatened listing recommended. Populations are endemic to the highly altered Clear Lake Basin. Extinction is expected if measures are not taken to improve spawning and lake habitats.

Description: Hitch are cyprinids with laterally compressed bodies, small heads and upward pointing mouths. They can grow to over 35 cm SL and have moderately large scales and decurved lateral lines. The body tapers to a narrow caudal peduncle (the feature responsible for the specific etymology) which supports a large forked tail and the belly lacks a sharp keel. The long anal fin (11-14 rays) separates the species from other California minnows. The origin of the dorsal fin (10-13 rays) is behind that of the pelvic fins. There are 54-62 lateral line scales and 17-26 gill rakers. The pharyngeal teeth (0-4 or 0-5) are long and narrow, slightly hooked, and have reasonably broad grinding surfaces. Small hitch are silvery with a black spot at the base of the tail. Older fish lose the spot and become darker. Large fish appear yellow- brown to silvery white on the back. The body becomes deeper as the length increases (Moyle 2002). There is little change in pigmentation during the breeding season (Hopkirk 1974).

Clear Lake hitch are a lake-adapted form distinguished by their deeper body, larger eyes, larger scales and more gill-rakers than Sacramento hitch. There are 10-12 dorsal fin rays, 11-14 anal fin rays and 26-32 gill-rakers (Hopkirk 1974).

Taxonomic relationships: The Clear Lake hitch was described by Hopkirk (1974) as a lake-adapted subspecies, primarily because of its greater number of fine gill-rakers. Analysis of 10 microsatellite loci supported subspecific designation (Aguilar et al. 2009). Two other subspecies exist, Sacramento hitch (*L. e. exilicauda)*, which is the type species, and Monterey hitch *(L. e. harengus)*.

Hitch are closely related to California roach (*Lavinia symmetricus*) with which they hybridize (Miller 1945b, Leidy 1984, 2007). Hybrids are fertile and may be common where the species are sympatric (Avise et al. 1975). However, documented hybrids are lacking from the Clear Lake Basin. Hitch can also hybridize with Sacramento blackfish (*Orthodon microlepidotus*) but the offspring are sterile (Moyle and Massingill 1981). In the past they hybridized with the now extinct thicktail chub (*Gila crassicauda*) (Miller 1963).

Life history: The deep, compressed body, small upturned mouth and many long slender gill-rakers reflect the zooplankton-feeding strategy of this pelagic forager (Moyle 2002). Clear Lake hitch greater than 50mm feed almost exclusively on *Daphnia* (Geary 1978, Geary and Moyle 1980). Juvenile less than 50 mm are found in shallow in-shore waters and feed primarily on the larvae and pupae of chironomid midges, planktonic crustaceans including *Bosnia* and *Daphnia,* and (formerly) the eggs, larvae and adults of Clear Lake gnat (*Chaoborus astictopus*) (Lindquist et al. 1943, Geary 1978). Gnat populations have been depressed by human pesticide applications to the lake and by introduced planktivorous fishes so that current Clear Lake gnat populations represent just a very small fraction of historic abundances. Clear Lake hitch switch to feeding on *Daphnia* after moving into the offshore limnetic habitat, although when insects are abundant they may be taken at the surface (Lindquist et al. 1943). Geary (1978) found that stomachs of hitch caught early in the morning were empty, while fish caught in the afternoon had fed, indicating that hitch feed primarily during daylight hours.

Hitch longer than 25 cm SL are rare and few are likely to live longer than 6-7 years. Females become mature by their second or third year, whereas males tend to mature in their first or second year (Kimsey 1960). Females grow faster and are larger at maturity than males (Geary 1978, Hopkirk 1974). Females average 11 cm SL at the end of their first year, 18 cm at the end of their second, 21 at the end of their third, 23 at the end of their fourth, and 26 at the end of their fifth. For males, the lengths are 10, 16, 20, 20, and 20 (Geary and Moyle 1980). Indicative of Clear Lake's extreme productivity, hitch grow much faster and reach larger size there than do populations of Sacramento hitch in a less productive high-elevation reservoir in the Sierra Nevada foothills. In Clear Lake, hitch reach 44 mm SL within three months and are 80-120 mm SL by the end of their first year (Geary and Moyle 1980). Sacramento hitch in Beardsley Reservoir, in contrast, are only 40-50 mm by the end of the first year (Nicola 1974). The larger size of Clear Lake hitch translates to greater fecundity. Accordingly, females in Clear Lake average 36, 000 eggs (Geary and Moyle 1980) compared to an average of 26, 000 eggs for Beardsley Reservoir (Nicola 1974).

In the Clear Lake Basin spawning occurs in tributary streams and the spawning migrations, which resemble salmon runs on a miniature scale, usually take place in response to heavy spring rains, from mid-February through May and occasionally into June (Murphy 1948b, Kimsey 1960, Swift 1963. Chi Council unpublished data 2004-2009, http://lakelive.info/chicouncil/index.html). During wet years, Clear Lake hitch will also opportunistically ascend and spawn in various small, unnamed tributaries and drainage ditches (R. Macedo, pers. comm.) and even flooded meadows (S. Hill, Chi Council, pers. comm.). Hitch have also been observed to spawn along the shores of Clear Lake, over clean gravel in water 1 to 10 cm deep where wave action keeps the gravels clean of silt (Kimsey 1960). However, the contribution to recruitment by such shore-spawners is uncertain; it may be negligible because of potentially heavy predation on eggs and larvae by carp and other alien fishes (Kimsey 1960).

Clear Lake hitch begin their spawning migration following late winter and early spring rains. They spawn in riffles, runs and back water areas in very shallow water at the streams edge; they prefer clean, fine-to-medium sized gravel and water temperatures of 14-18°C for spawning (Murphy 1948b, Kimsey 1960). When spawning, each female is pursued by 1-5 males that fertilize the eggs as they are released (Murphy 1948b, Moyle 2002). Eggs are non-adhesive and sink to the bottom after fertilization where they become lodged among the interstices in the gravel. Within half an hour of being fertilized hitch eggs swell and more than double their initial diameter via the absorption of water. This rapid expansion provides a cushion of water between the outer membrane and the developing embryo which protects against concussion (Swift 1965) and may help to secure eggs in gravel interstices. At times, the eggs, which resemble silica aquarium sand, can be seen piled up on the gravel beds "by the millions" (S. Hill, pers. comm.). The embryos hatch out after approximately seven days and the larvae become free-swimming after another seven days (Swift 1965). Larval fish must then move downstream to the lake quickly before streams dry (Moyle 2002). In the lake larvae remain inshore and are thought to depend on stands of tules (*Schoenoplectus acutus*) for cover until they reach approximately 50 mm and assume a pelagic lifestyle.

Adult Clear Lake hitch are most vulnerable to predation during their spawning migration when they are preyed upon by mergansers, herons, bald eagles, and other birds and by river otter, raccoons, skunks and, vary rarely, black bear (R. Macedo and S. Hill, pers. comm. 2009). Predation from introduced fish species is also significant, although no formal studies have been conducted. However, hitch are routinely found in the stomachs of bass caught in the lake (R. Macedo, pers. comm.2009).

Habitat Requirements: Adult Clear Lake hitch are usually found in the limnetic zone of Clear Lake. Juveniles are found in the near shore shallow-water habitat and move into the deeper offshore areas after approximately 80 days, when they are between 40-50 mm SL (Geary 1978). While in the near shore environment, juveniles require vegetation for refuge from predators. In early spring adults begin to migrate into low gradient tributary streams in response to elevated stream flows from storm events. They spawn at water temperatures of 14-18°C in the lower reaches of tributaries. Egg deposition occurs at stream margins in riffles, in very shallow water over clean, fine-to-medium sized gravel (Murphy 1948b, Kimsey 1960).

Distribution: This subspecies is confined to the Clear Lake basin, Lake County, California and to associated lakes and ponds such as Thurston Lake and Lampson Pond. Coleman (1930) states that it was the most abundant fish of the Blue Lakes, but it has not been observed there in modern surveys (J. Rowan, CDFG, T. Taylor, Entrix, Pers. Comm. 2009).

Clear Lake hitch spawn in intermittent tributary streams to Clear Lake. Historically, large spawning runs occurred in Kelsey, Adobe, Scotts, Middle, Clover, Robinson, Seigler Canyon, Cole, Schindler and Manning creeks, and occasionally in other, smaller and unnamed tributaries. An ongoing volunteer monitoring effort which began in 2004 has documented consistent runs of fish in only Kelsey and Adobe Creeks (Chi Council, unpublished data). A smaller, less consistent spawning run occurs in Cole Creek. In 5 years of monitoring no spawning hitch have been observed in Seigler Canyon or Schindler Creeks and only very few in Scotts Creek and its tributaries Middle, Clover and Robinson creeks, (Chi Council, unpublished data).

Abundance: Compared to past abundances, Clear Lake hitch has substantially diminished populations. The populations in the Blue lakes have apparently been extirpated. As an indication of historic abundance and ubiquity of spawning locations Lindquist (1943 p 200) notes, “Tens of thousands of split-tail and hitch have been observed moving in a solid mass up a creek only 4 feet wide.” Splittail have been extinct in the lake since the 1970s. In 1992, surveys of three of the main hitch spawning streams, Seigler Canyon, Kelsey and Adobe creeks by CDFG, found “good” runs of hitch (R. Macedo, pers. comm.). Since that time the run in Seigler Canyon Creek has ceased, possibly due to a barrier to the spawning migration created when a sewer pipeline was modified, although hitch have not observed below this potential barrier either (Chi Council, unpublished data). No systematic census has been undertaken but qualitative monitoring of most of the lake tributaries over the last five years suggests that thousands of adult hitch spawn annually. Annual beach seine surveys conducted by the Lake County Vector Control District (Figure 1) indicate a declining trend in abundance.

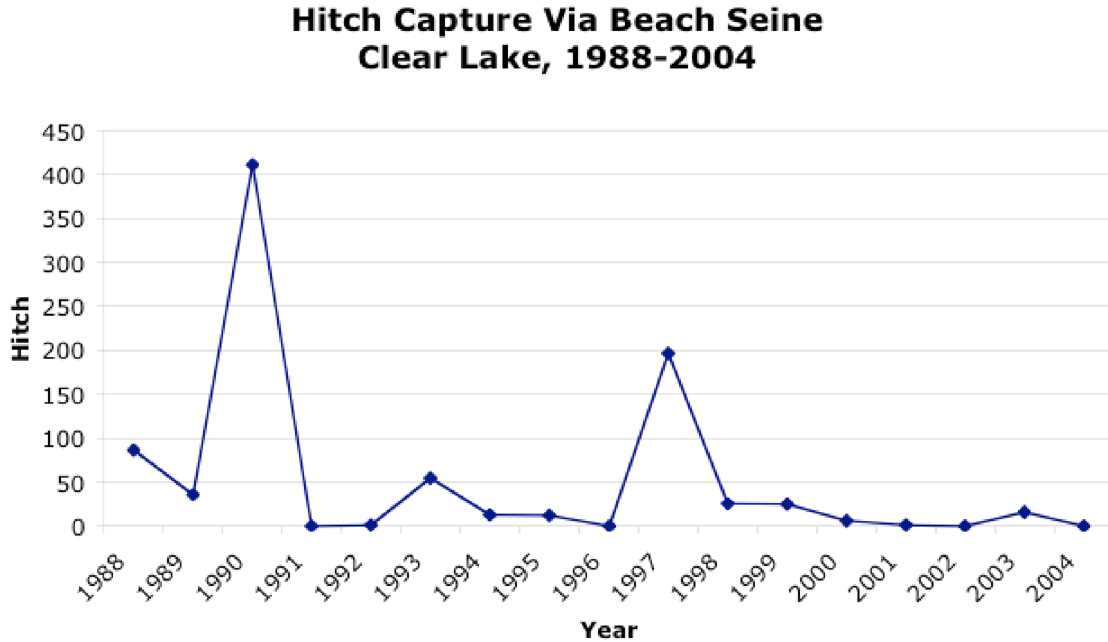

Figure 1. Hitch captured via beach seine 1988 through 2004. Lake County Vector Control District. Unpublished data.

Nature and Degree of Threats: The threats to Clear Lake hitch are multiple but most evident are (1) loss of spawning habitat through changes in land and water use (2) loss of nursery areas from alterations of the lakeshore, and (3) predation and competition from alien fishes (Murphy 1948b, 1951, Moyle 2002). The loss of spawning habitat in particular is the result of multiple threats, discussed individually below, acting together (Table 1). All Clear Lake tributaries are naturally intermittent, going dry in their lower reaches during summer, especially during low rainfall years. However, human land use has altered hydrologic patterns and stream morphology causing streamflow to go subsurface in these streams earlier in the season than previously. Dams and diversions, groundwater pumping, and sedimentation all contribute to the problem by either lowering the water table or filling the stream channel with aggregate and thereby causing flows to go subsurface. Conversely Instream gravel mining can strip the channel of suitable aggregate for spawning and cause water tables to decrease. Logging, grazing and urban development have all also exacerbated the problem by reducing the rate of rainwater infiltration. Rain that would have naturally recharged groundwater supplies and maintained streamflow into the summer months instead runs off bare hill slopes, compacted soils, and pavement; the water is delivered to the lake as storm flow during winter and spring. The importance of altered stream conditions to the fate of hitch is indicated by the fate of other native fishes that require streams for spawning: splittail, Sacramento sucker, and Sacramento pikeminnow are now absent from the lake . Only the blackfish (*Orthodon microlepitus*), a lake spawner, has apparently maintained stable populations. All stream spawners had “declined precipitously” by 1944 (Murphy 1951 p. 478). Today, splittail are extinct while pikeminnow and sucker are found primarily in the perennial sections of streams (with occasional individuals observed in the lake). The Clear Lake splittail formerly spawned somewhat later than did the hitch and the drying up of streams undoubtedly contributed to their demise. Continuation of this progressively earlier drying of streams seriously affects the hitch population as well, because hitch spawning period is already short.

Dams and migration barriers. Cache Creek Dam was built in 1914 to control lake outflows and levels, to provide water for Yolo County agriculture. The effects of lake drawdown on hitch populations are not known but it is possible that YOY hitch could be forced from cover as water levels dropped, making them more vulnerable to predation. Dams on tributary streams likely have a greater impact on hitch by blocking migratory routes and decreasing stream flows necessary for spawning. The impact of tributary dams and impoundments, such as Adobe Creek Dam (1962); Allen Dam (1955, on tributary of Kelsey Creek); Graham (1959, on tributary of Highland Creek); Highland Cr. Dam (1962); North Lake (1980, on tributary of Manning Creek) and Spring Valley (1968) need to be investigated. The Kelsey Creek Detention Structure continues to impede the spawning migration of Clear Lake hitch. While operational and physical modifications to this structure have been implemented over the years it continues to adversely impact spawning hitch, especially during years when spring flows are low.

Agriculture. The Clear Lake basin is the site of intense agriculture, specifically orchards and vineyards, which sends effluent, including fertilizers, sediment and pesticides, into the lake, more so historically than today. This effluent contributed to accelerated eutrophication in the 20th century that resulted in major blooms of bluegreen cyanobacteria (Osleger et al. 2008), but hitch persisted through the worst periods.

Because hitch are not aggressive swimmers, small diversion dams and other structures that impede upstream movement easily block spawning migrations. However, hitch access to adequate spawning habitat is also impaired by the removal of water. Their stream margin spawning habitat is very sensitive to changes in stream flow and can dry up very quickly after spawning takes place (Geary 1978, Moyle 2002). When this happens, reproductive failure may result. Murphy (1951 p. 480) describes how human water use contributed to this process, “In 1949 hitch were able to ascend Kelsey Creek and spawn. Their eggs were deposited on the gravel bars. In the lowland agricultural sections of the stream rapidly falling flows stranded a large percentage of the eggs. Many hatched, however, but the bulk of the young hitch would not have migrated out of the stream until the third week of June. As that spring was dry, farmers began irrigating in the third week of May. This immediately cut off the tenuous surface flow Kelsey Creek was maintaining with the lake. The bulk of the hitch crop was then stranded in the stream and ultimately perished.” In the intervening 60 years since Murphy’s description the human population in the basin has grown substantially and agricultural, especially vineyard, water use has increased. Residential and agricultural demand for water is expected to continue to grow. As a result, stream flow in Clear Lake tributaries may dry earlier in the spring and remain dry longer into the fall and early winter. Consequently, if measures to guarantee adequate spring flows in the creeks are not implemented extinction is expected.

Grazing. Heavy grazing of Clear Lake watersheds has occurred since the 1870s and has likely contributed to sedimentation and nutrient loading of the lake (Suchanek et al.

2002). Today stock numbers are much reduced but past soil compaction from stock may still contribute to increased runoff during winter, decreasing aquifer recharge and contributing to earlier drying of streams.

Rural residential development. 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 wetlands which trapped sediment and nutrients, added septic tank effluent to the lake, and caused large-scale application pesticides to the lake to control pestiferous gnats. While hitch persisted despite the changes to the shoreline, it is likely they declined in abundance as cover, such as tule beds and dead trees, became less abundant. Development also uses large amounts of water that either is diverted from streams or pumped from ground water, which is connected to streams. Either way, the streams lose flow. Today continued residential developments that rely on shallow wells adjacent to or near streams exacerbate already diminished streamflow in Clear Lake tributaries.

Urbanization. Urbanization alters stream function and habitat and infrastructure built across creeks represents potential barriers to hitch spawning migration. For instance a sewer pipeline which crosses Seigler Canyon Creek was modified in the 1990s and now seems to completely block access to that creek, once a major spawning tributary.

The many small towns around the lake also contribute to eutrophication through sewage spills, increase in sedimentation, and removal of wetlands. Townspeople were leading proponents of applying pesticides to the lake. In particular, dichloro diphenyl dichloromethane (DDD) was applied (1949, 1954, 1957) to control gnat populations. The Clear Lake gnat is a non-biting midge that historically occurred in Clear Lake is such astounding numbers that large piles of dead adults would gather beneath streetlights and it was regarded as a pest. The gnat was the primary food resource for the Clear Lake splittail and likely provided a very important food source for the hitch and other Clear Lake native fishes (Lindquist et al. 1943). While gnat numbers rebounded subsequent to DDD in the late 1950s, applications of another pesticide, methyl parathion, in the 1960s and 1970s reduced gnat populations to near zero. After the last treatment of methyl parathion in 1975, gnat numbers never regained historic numbers and today they are near historic lows (D. Woodward, Lake County Vector Control, unpublished data). This is likely due to the introduction of two zooplankton feeding fish, Mississippi silverside (*Menidia audens*) and threadfin shad *(Dorosoma petenense).* The legacy of DDD application continues because DDD accumulates in the fatty tissues of animals and may effect survival and reproduction (Hunt and Bischoff 1960).

	Rating	Explanation
Major dams	High	Dams on tributaries decrease storm (spawning) streamflows, while dams, exposed pipelines, grade control structures continue to hinder spawning hitch migration on numerous Clear Lake tributaries
Agriculture	High	Contributes to water drawdown in spawning streams and to eutrophication and sedimentation of lake
Grazing	Low	Grazing may contribute to erosion, sedimentation and earlier drying of streams
Rural residential	High	Clear and the Blue Lakes are surrounded by housing which was built on historic wetlands and which require water for domestic uses and irrigation
Urbanization	High	Infrastructure for towns around the lake has destroyed wetlands, created migration barriers, contributed pollution, and altered aquatic habitat
Instream mining	Intermediate	Legacy effects continue to simplify habitat and lower the water table, contributing to earlier drying of streams
Mining	Intermediate	Possible effects from contamination of foodwebs by mercury
Transportation	High	Roads create migration barriers, as well as contribute to sedimentation and other pollutants
Estuarine alteration	N/A	
Logging	Low	Legacy effects of sedimentation, etc.
Fire	Low	Frequent fire may increase sedimentation rates
Recreation	Intermediate	Removal of tule beds, fallen trees etc. to improve boat access or reduce hazards reduces habitat
Harvest	Low	Incidental catch in commercial fishery; some tribal harvest
Hatcheries	N/A	
Alien species	High	Effects are not quantified but competition from introduced planktivorous fishes and predation from bass are likely having significant negative effects

Table 1. Major anthropogenic factors limiting, or potentially limiting viability of Clear Lake hitch (*Lavinia exilicauda chi*) populations in California, where a factor rated "high" is a major limiting factor, a factor rated "intermediate" is a factor that has the potential to be a major limiting factor but has had only a moderate effect so far on population viability, and a factor rated "low" has a low or unknown effect on population viability. Certainty of these judgments is moderate.

Mining. The Sulphur Bank Mercury Mine dumped mining waste (~193,600 cubic yards) containing mercury directly into the Oaks Arm of the lake and shore beginning in the 1920's and ending in 1957. Osleger et al. (2008) examined sediment cores from the lake and found an abrupt change in sediment characteristics starting around 1927, when the Sulphur Bank mercury mine opened up on the edges of the lake. " …[T]he cultural eutrophication … of Clear Lake began with the advent of large-scale open-pit Hg mining in 1927 and subsequent human-induced landscape modification involving heavy earthmoving equipment. These activities resulted in increased erosion/sedimentation rates and associate nutrient input into the lake, culminating in algae blooms and reduced surface water quality through the rest of the 20th century," (Osleger et al. 2008, p. A255). The mine wastes also contaminated the lake ecosystem with mercury and arsenic (summarized in Suchanek et al. 2002). Elevated levels of mercury introduced have been found in fish and waterfowl. A current health advisory (first issued in 1986) recommends that not more than one fish from Clear Lake be consumed per week. The water column does not seem to contain high concentrations of methyl mercury, in contrast to some lake sediments. Indirect effects from mercury exposure include behavior disruption (prey capture, inhibition of reproduction), reduced growth rate, and disruption of physiological functions (olfaction, thyroid function, blood chemistry; Suchanek et al. 2008), potentially making hitch more vulnerable to predation.

In addition, gravel mining on Kelsey, Scotts and Middle creeks has lowered the water table as much as 15 feet in some places. Construction of structures (mainly on Kelsey Creek) intended to aggrade gravel and raise the streambed act as partial barriers to fish migration, especially during periods of low flow (R. Macedo, P. Windrem, Chi Council, pers. comm.). Instream gravel mining has been curtailed by Lake County and the California Department of Fish and Game; however legacy effects continue simplify habitat and lower the water table, contributing to earlier drying of streams

Transportation. Clear Lake is entirely ringed by roads which cross all major streams entering and exiting the lake. Bridges and culverts are major gradient control structures and have significantly altered the hydrology and geomorphology of the lower reaches of all of Clear Lake's tributaries. Most importantly bridges and other transportation infrastructure constitute the majority of migration barriers to the hitch migration and are a major factor in the extirpation or reduction of hitch spawning populations in specific creeks. Miles of roads in the upper portions of these tributary drainages also contribute to siltation, channelization, and rapid run off.

Logging. Clearing of forest lands around Clear Lake began in the 1840s but accelerated post World War II, contributing to eutrophication and siltation of the lake.

Recreation. Removal of tule beds, fallen trees and other obstacles to improve boat access or reduce boating hazards in Clear Lake reduces habitat for juveniles in their first months in the lake. Public areas in the Clear Lake watershed are extensively used for recreation including heavy off-road vehicle use. The effects of such recreational activities have not been quantified but they likely increase sedimentation and have other effects. Pollution from extensive use of gas-powered watercraft in Clear Lake may stress hitch.

Fish that reach their spawning areas are vulnerable in shallow water to the local "sport" of "hitching", whereby the fish are clubbed and thrown on the shore. Recent increased protection by CDFG wardens and some educational activities for school children hopefully will lessen this destruction. In addition, most alien fishes in the lake were introduced for recreational fishing.

Harvest. Clear Lake's historic commercial fishery for blackfish and carp resulted in incidental catches of hitch, with unknown effects on the population. Recent commercial fishery permits require release of hitch back into Clear Lake. Clear Lake hitch were an important component of the diet and culture of local Native American peoples. Although hitch presently are used by them less than before, renewed interest in traditional foods has led to a recent increase in requests by Native Americans to harvest hitch from State Park areas (S. Hill, pers. comm.). There is an annual gathering to smoke and dry hitch, but Native American harvests are still low (R. Macedo, pers. comm. 2009).

Alien species. Historically, 10 native fish species were found in Clear Lake (Moyle 2002). Presently, only four (hitch, blackfish, tule perch and prickly sculpin) of these species remain in the lake, along with at least 16 alien fish species. Several species such as Sacramento sucker, Sacramento pikeminnow, rainbow trout and threespine stickleback persist in tributaries but are only occasionally observed in the lake. Hitch have persisted despite the introduction of many potential predators and competition for food resources from introduced planktivorous fishes. Likely, increased predation and forage competition from alien species in combination with a decrease in the quality of habitat (sedimentation, reduced water quality, removal of cover) has effected hitch populations. The greatest threat to hitch, however, is competition from Mississippi silverside and threadfin shad for the plankton food resources in the limnetic zone of the Lake. In 1988, threadfin shad constituted 70% of the fish caught in beach seine samples by the Lake County Mosquito Abatement District (N. Anderson, unpubl. data). By 2006 largemouth bass numbers had greatly increased, as had the frequency of large bass, increasing the likelihood of serious predation impacts, especially during years when alternative prey populations are low (Eagles-Smith et al. 2008). Two record largemouth bass from the lake both contained large hitch and several channel catfish captured by CDFG were observed to have eaten hitch (R. Macedo, pers. comm. 2009). However, recent electro-shocking surveys by CDFG show a decease in the frequency of large bass, as well as very low recruitment for the 2007 and 2008 year classes, suggesting that for the next several years medium sized bass (3-5 lbs) should predominate in the lake (J. Rowan, CDFG pers. comm. 2009). It is also possible that during periods of high threadfin shad abundance zooplankton food is reduced and predator densities, especially fish-eating birds, is increased. Capture of hitch as incidental prey by predators attracted to the lake by the high abundances of shad and silverside may affect hitch populations. The shad population was severely reduced during the cold winter of 1990-91. However, threadfin populations rebounded rapidly, reaching high populations which supported vast numbers of predatory grebes. September of 2008 saw a huge population explosion of Mississippi silverside. Abundances were so vast as to be “unquantifiable” (J. Rowan CDFG, pers comm. 2009). Such high densities of silversides and/or shad have the capacity to greatly deplete plankton food resources for hitch and are likely a major negative factor affecting hitch abundance.

Effect of Climate Change: The primary threat to hitch, water availability in tributaries during spring spawning migrations, is also likely to be exacerbated by a climatic shift towards greater aridity and/or variability in rainfall. Near complete spawning failure has been observed during dry years in the past (Murphy 1948b, 1951, Moyle 2002). A long lifespan of 5 to 7 years may allow hitch populations to weather bad spawning years. However, an increase in the length of dry seasons, especially for consecutive years, combined with increased mortality in the lake could result in extinction.

Climate change would presumably increase water temperatures and create lower lake levels on a more frequent basis. This could result in decreased water quality, less cover (tule beds), improved conditions for alien predators, and other factors that would have a negative effect on hitch in Clear Lake. Climate change predictions also indicate that the frequency and intensity of winter storm events will increase, potentially increasing sedimentation, nutrient loading and pollution (from mine wastes) into Clear Lake (Suchanek et al. 2002).

Status Determination. Score = 1. The combined severe pressures of habitat alteration and alien species (Table 2) clearly threaten the Clear Lake hitch with extinction in the foreseeable future. Many of the spawning runs have disappeared as have populations in the Blue lakes. The limited data that exists, suggests that remaining hitch runs are much reduced and are continuing to decline. Dewatering of tributary streams, barriers to spawning migrations and predation and competition from alien species may interact to cause extinction in the foreseeable future. The American Fisheries Society lists the Clear Lake hitch as "Vulnerable" while NatureServe lists it as G5T2 "Imperiled" (Jelks et al. 2008).

Metric	Score	Justification
Area occupied	1	Clear Lake basin
Effective population size	3	Overall population not known but the few remaining spawning runs are increasingly small
Intervention dependence	2	Persistence requires restoration of spawning streams and lake habitat
Tolerance	3	Tolerant of conditions in Clear Lake although susceptible to warm temperatures and pollutants
Genetic risk	2	Small populations make bottlenecking a threat
Climate change	1	Threatened by increased temperatures, lower lake levels, reduced stream flows
Limiting factors analysis	1	Multiple threats (Table 1)
Average	1.8	13/7
Certainty (1-4)	3	Good recent surveys

Table 2. Metrics for determining the status of Clear Lake hitch, 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 Introduction for further explanation.

Management Recommendations: The Clear Lake hitch is clearly experiencing multiple, simultaneous threats to its existence, all the result of intensive human use and alteration of the basin. The Chi Council for the Clear Lake Hitch is working hard to monitor populations and find solutions to problems but saving hitch will take concerted effort by everyone and every organization in the Clear Lake basin. A first recommendation is therefore to fund the Chi Council or similar organization to develop a complete recovery plan for the Clear Lake hitch. The following list of general management recommendations is only a start. What is needed is a basin-wide plan to restore hitch populations with specifics about problems from each stream and each piece of lakeshore.

1. Following the lead of the Chi Council, set up a systematic monitoring program for all hitch streams that records the timing and abundance of each run, as well as key spawning habitats. A similar monitoring program, using multiple techniques, is needed to establish which native fishes remain in Clear Lake. Hitch, blackfish, tule perch, and prickly sculpin are known to have extant Clear Lake populations, while rainbow trout, Sacramento sucker and the Sacramento pikeminnow are thought to be extirpated from the lake but maintain populations in tributary streams. The Sacramento perch is thought to be extirpated from the entire basin and the Clear Lake splittail is thought to be globally extinct. Likewise, the status of native fishes in Upper and Lower Blue lakes needs to be determined.
2. Develop a systematic research program on the biology of hitch. This should include a thorough life history investigation of Clear Lake hitch, especially their needs in Clear Lake, updating the study of Geary and Moyle (1980). It should also include physiological studies to establish the environmental tolerances of the Clear Lake hitch. Parameters studied should include temperature, dissolved oxygen, as well as exposure to methyl mercury, pesticides, and other pollutants.
3. For all streams, prioritize and remove migration barriers, as soon as possible. Five such barriers have already been identified by the Chi Council:
    - Bridge protection structure across Kelsey Creek at Main Street Bridge, Kelseyville.
    - Bridge protection structure across Middle Creek at Rancheria Road Bridge, Upper Lake.
    - Bridge protection structure across Scotts Creek at Decker Bridge, Lakeport.
    - Kelsey Creek gravel detention structure. Although not a complete barrier it is an impediment to free migration, and hitch navigate it with difficulty especially on the downstream passage.
    - Sewer line across Seigler Canyon Creek for Anderson Marsh State Park, Lower Lake.

4. Determine the major causes of stream flow loss for all streams and find ways to increase spawning flows for hitch. Enforce regulations that prohibit illegal stream diversions and wells adjacent to streams. As part of this program, establish stream gages where needed to monitor flows.
5. Develop ways to restore hitch spawning runs to historic spawning streams, through artificial rearing if necessary. Before hatchery programs are instituted careful consideration needs to be given to the impact of such a program especially in light of recent results from salmonid fishes that show artificial propagation can significantly and permanently reduce fitness (Araki et al. 2009).
6. Increase cover in areas along the lakeshore, including expanding tule beds near the mouths of streams, allowing fallen trees to stay in the water, and other means of creating shoreline complexity.
7. Determine if and how the management of Cache Creek Dam affects lake levels while juvenile hitch are rearing in tule beds along shore. If draw-down exposes hitch to increased predation, by forcing them from this habitat, it should be halted until the juvenile hitch have left the habitat voluntarily. The impact of tributary

dams and impoundments, such as Adobe Creek Dam (1962); Allen Dam (1955, on tributary of Kelsey Creek); Graham (1959, on tributary of Highland Creek); Highland Cr. Dam (1962); North Lake (1980, on tributary of Manning Creek) and Spring Valley (1968) should also be investigated.

8. Determine the direct and indirect effects of fisheries (including the commercial fishery) on hitch populations. This includes determining the impact of predation and competition from alien species on hitch populations.
9. Develop some off-lake pond populations of Clear Lake hitch as insurance against extinction of the lake population.
10. Expand existing informational campaigns to increase awareness of and pride for the Clear Lake hitch as a unique feature of the Clear Lake basin.

FIGURE 2. Distribution of Clear Lake hitch, *Lavinia exilicauda chi* (Hopkirk), in California.