HARDHEAD
Mylopharodon conocephalus (Baird and Girard)

Status: Moderate Concern. Hardhead are still widespread in California but populations are likely declining and most are small and isolated, with exceptional vulnerability to climate change.

Description: Hardhead are large cyprinids, reaching lengths in excess of 60 cm SL. The body shape is similar to that of Sacramento pikeminnow (*Ptychocheilus grandis*), with which they co-occur, but the body is deeper and heavier and the head is less pointed. Hardhead also differ from pikeminnow in that their maxilla does not extend beyond the anterior margin of the eye and they possess a bridge of skin (frenum) connecting the premaxilla to the head. Hardhead have 8 dorsal rays, 8-9 anal rays, and 69-81 lateral line scales. Adults have large molariform pharyngeal teeth but juvenile teeth are hook-like. Juveniles are silver; adults are brown-bronze dorsally. During spawning, adult males develop small white nuptial tubercles on the head and along a band that extends from the head to the base of the caudal fin (Moyle 2002). Prolarvae and early postlarvae have scattered caudal pigmentation and two distinct dark spots, one above the flexion and one at the ventral base of the caudal peduncle (Wang and Reyes 2007). Some midventral pigmentation may also occur. Early juveniles have small mouths (maxilla ends in front of eye), high myomere counts (46-50) and enlarged nostril flaps.

Taxonomic Relationships: Hardhead were first described as *Gila conocephala* by Baird and Girard (Girard 1854) from one specimen collected from the San Joaquin River. Ayres (1854, 1855) later redescribed the species as *Mylopharodon robustus*. Girard (1856a) recognized the generic designation, reclassifying *G. conocephala* as *Mylopharodon conocephalus* and *M. robustus* as a closely allied, but separate, species. Jordan (1879), however, considered the genus monotypic and united both forms as *Mylopharodon conocephalus* (Jordan and Gilbert 1882). Electrophoretic studies by Avise and Ayala (1976) and morphometric analysis by Mayden et al. (1991) indicated that hardhead, although related to Sacramento pikeminnow, are sufficiently different from the pikeminnow to be retained in a separate genus.

Life History: Stream-dwelling juvenile (<150 mm SL) hardhead are often found in small aggregations in pools and runs during the day, actively feeding at the water's surface, holding in moving water to feed on drifting material, or browsing from the benthos (Alley 1977). Adults tend to school in the deepest part of pools, cruising about slowly during the day. They are most active when feeding, in early morning and evening (Moyle 2002). In small streams, they seldom move more than one kilometer away from home pools, except when spawning; the average summer home range of hardhead in a Sierra Nevada foothill stream was measured as 289 m (Grant and Maslin 1999). In Britton Reservoir (Shasta County), large hardhead will remain motionless near the water's surface (< 1 m depth) during warm summer days (Vondracek et al. 1988), making them readily accessible as prey to bald eagles, osprey and other fish eating birds (Hunt et al. 1988).

Hardhead are primarily bottom feeders that forage on invertebrates and aquatic plant material from stream substrates but they will also consume drifting insects and algae from the water column (Alley 1977). Occasionally, they will feed on plankton and surface insects and, in Shasta Reservoir (Shasta County), they were known to feed on cladocerans (Wales 1946). Smaller fish (<20 cm SL) feed primarily on benthic invertebrates, especially mayfly larvae, caddisfly larvae, and small snails (Reeves 1964). Larger fish feed on filamentous algae, as well as on crayfish and other large invertebrates (Moyle, unpubl. data). Ontogenetic changes in tooth structure reflect this shift in diet; juveniles have hooked teeth for capturing insects, while adults have molariform teeth that facilitate grinding of plants and large prey (Moyle 2002). Reeves (1964) did not find fish remains in the stomachs of large hardhead.

Hardhead reach 7-8 cm SL by their first year, 10-12 cm by the end of their second year and 16-17 cm by the end of their third year (Reeves 1964, Moyle et al. 1983, PG&E 1985, Grant 1992). They can reach 30 cm SL by age four (Reeves 1964) in the American River but only reach this size at age 5 or 6 in the Pit and Feather rivers (Moyle et al. 1983, PG&E 1985). Large (44-46 cm SL) hardhead from the Feather River were found to be 9-10 years old, but older and larger fish probably exist in the Sacramento River. In smaller streams, hardhead rarely grow beyond 28 cm SL (Grant 1992). Historic records suggest that hardhead reach up to 1 m TL (Jordan and Evermann 1896).

Hardhead mature following their second year and spawn in the spring, mainly in April and May (Reeves 1964, Grant and Maslin 1999), judging by the upstream migrations of adults into smaller tributary streams during this time of the year (Wales 1946, Murphy 1947, Bell and Kimsey 1955, Rowley 1955). Shapovalov (1932) reported the presence of mature eggs in females during March, but gonads of males and females caught in July and August were spent (Reeves 1964). Estimates based on juvenile recruitment suggest that hardhead spawn by April-June in Central Valley streams, although the spawning season may occasionally extend into August in the foothill streams of the Sacramento-San Joaquin drainage (Wang 1986). Spawning adults from larger rivers and reservoirs may migrate more than 75 km in April and May to spawn in tributary streams (Wales 1946, Moyle et al. 1995). In contrast, hardhead in small streams only migrate a short distance upstream or downstream of their home pool for spawning (Grant and Maslin 1999). In Pine Creek (Tehama County), spawning adults aggregate in nearby pools and return to home pools after spawning (Grant and Maslin 1999). Hardhead spawning has not been directly observed; however, it is likely similar to that of hitch and pikeminnow, which deposit their fertilized eggs in sand or gravel in riffles, runs, or heads of pools (Wang 1986; Moyle 2002). Spawning success of hardhead in the lower Tuolumne River is highest when there are higher flows during in April and May (Brown and Ford 2002).

Females are highly fecund, producing over 20,000 eggs (Burns 1966). Fecundity ranged from 7,100 to 23,900 eggs in females from Pine Creek (Tehama County) and the American River (Reeves 1964, Grant and Maslin 1999). The ovaries contain both developed and undeveloped eggs, suggesting that eggs mature after a full year (Grant and Maslin 1999). Fertilized eggs presumably develop in the interstices of the gravel until hatching. Larvae and postlarvae most likely move into stream margins with abundant cover (Wang 1986). They move into deeper habitats as they grow larger. Young from intermittent streams are swept downstream into areas of low velocity near the mouths of main rivers (Moyle 2002). In Deer Creek (Tehama County), small juveniles (2-5 cm SL) congregate in large schools in shallow backwaters. Small juveniles in the Kern River congregate among large substrates (cobble and boulders) along the stream margin (L. Brown, USGS, pers. comm. 1999).

Hardhead host a variety of parasites. Hardhead from the North Fork Feather River (Plumas and Butte counties) were infected with an average of three parasite species, including nematodes and trematodes (Alvarez 2008).

Habitat Requirements: Hardhead are often found at low to mid-elevations in relatively undisturbed habitats of larger streams (Moyle and Daniels 1982, Mayden et al. 1991) with high water quality (clear, cool). In the Sacramento River, however, they are common in both the mainstem and tributaries up to 1500 m in elevation (Reeves 1964). Summer temperatures in rivers where they are common reach 20°C, below optimal temperatures (24-28°) determined by laboratory experiments (Knight 1985). In a thermal plume in the Pit River, hardhead preferred the warmest temperatures available (17-21°C; Baltz et al. 1987). Similarly, hardhead acclimated to 12, 15, and 18 °C water temperatures, preferred water temperatures of 19.6 to 20 °C, and avoided water temperatures less than 17 °C in a laboratory setting (Cocherell et al. 2007). However, somewhat lower temperatures appear to increase swimming performance. Hardhead swimming performance was higher at 15 °C than at 10 or 20 °C (Myrick and Cech, Jr. 2000). Their distribution may be limited to well-oxygenated streams and reservoir surface waters by low oxygen levels at warm temperatures (Cech et al. 1990). They prefer pools and runs with deep (>80 cm), clear water, slow (20-40 cm/sec) velocities and sand-gravel-boulder substrates (Alley 1977, Cooper 1983, Knight 1985, Moyle and Baltz 1985, Mayden et al. 1991). May and Brown (2002) described summer water quality and habitat variables associated with a foothill group of mostly native fishes, including hardhead (Table 1).

pH	7.9
Specific conductivity (µS/cm)	144
Dissolved oxygen (mg/l)	8.8
Discharge (m/s)	3.2
Water temperature (°C)	19.7
Mean depth (m)	0.89
Mean velocity (m/s)	0.38
Mean dominant substrate size (mm)	2-64 (gravel)
Mean width (m)	18.9
Canopy cover (%)	25
Stream gradient (%)	0.71
Stream sinuosity	2.2
Elevation (m)	106
Agricultural + urban land (%)	2
Basin area (km^2)	519

Table 1. Mean summer water quality and habitat variables for a foothill fish assemblage, including hardhead (source: May and Brown 2002).

Adults mostly occupy the lower half of the water column in streams (Knight 1985, Moyle and Baltz 1985) but may stay close to the surface in reservoirs (Hunt et al. 1988, Vondracek et al. 1988). They are often sympatric with Sacramento pikeminnow and Sacramento sucker. Hardhead are usually absent from streams occupied by alien species, especially centrarchids

(Moyle and Daniels 1982, Mayden et al. 1991, Moyle et al. 2002) and streams that have been heavily altered (Baltz and Moyle 1993). Because they are poor swimmers, hardhead may also be absent from stream reaches above barriers, even if ladders are in place to allow salmonid passage (Myrick 1996, Myrick and Cech, Jr. 2000).

Hardhead populations are well established in mid-elevation reservoirs used exclusively for hydroelectric power generation, such as Redinger and Kerkhoff reservoirs on the San Joaquin River (Fresno County), and Britton Reservoir on the Pit River. In the Pit River, hardhead are most abundant in the upper portion of Britton Reservoir where habitat is more riverine; they are less abundant in the lacustrine habitat of the lower reservoir, where alien centrarchids, particularly predatory basses, are more abundant (PG&E 1985, Vondracek et al. 1988).

Distribution: Hardhead are widely distributed in streams at low to mid-elevations in the Sacramento-San Joaquin and Russian River drainages (Leidy 1984, Moyle 2002). Their range extends from the Pit River (south of the Goose Lake drainage), Modoc County, in the north to the Kern River, Kern County, in the south (Moyle and Daniels 1982, Cooper 1983). In the San Joaquin drainage, scattered hardhead populations are found in tributary streams, but only rarely in the valley reaches of the San Joaquin River (Moyle and Nichols 1973, Saiki 1984, Brown and Moyle 1987). Jones and Stokes (1987) found a very small number of hardhead during an extensive sampling program of the lower Kings and San Joaquin rivers, indicating that hardhead have opportunities to recolonize historic habitats but fail to do so, due to dewatering and other factors. They are absent from the Cosumnes River. In the Sacramento River drainage, hardhead are found in most large tributaries, as well as in the Sacramento River itself (Moyle 2002). In the South Fork Yuba River, they make up 55% of the fish caught in the lower 15 km (Gard 2002). They are present in the Russian and Napa rivers, although the Napa River population is very restricted in its distribution (R. Leidy, USEPA, pers. comm.). They are widely, if spottily, distributed in the Pit River drainage (Cooper 1983, Moyle and Daniels 1982), including the main stem Pit River and its series of hydroelectric reservoirs. Although their current status is uncertain, hardhead apparently also once occurred in Alameda and Coyote creeks, tributaries to the San Francisco Bay (Leidy 2007). They are present in the northern Coast Ranges, in the larger tributaries to the Sacramento River, such as Cache Creek, Putah Creek and Clear Creek, mainly in canyon reaches with deep pools.

Trends in Abundance: Historically, hardhead were regarded as widespread and locally abundant (Ayres 1854,1855, Jordan and Evermann 1896, Evermann 1905, Rutter 1908, Follett 1937, Murphy 1947, Soule 1951, Reeves 1964). Hardhead are still fairly widespread in foothill streams (May and Brown 2002) but their specialized habitat requirements, combined with widespread alteration of downstream habitats, has resulted in most populations being isolated from one another (Moyle 2002), making them vulnerable to localized extinctions. Consequently, hardhead are much less abundant than they were historically, especially in the southern half of their range (Moyle 2002). Historical records noted their presence in most foothill streams in the San Joaquin drainage (Reeves 1964), but Moyle and Nichols (1973) found them in only 9% of the streams sampled. Brown and Moyle (1987, 1993) subsequently resampled most of the same sites and found that a number of populations had disappeared during this 15-year period. Ford and Brown (2001) found they were uncommon in the lower Tuolumne River and largely confined to a cool-water reach about 30 km long, associating mainly with other native fishes. In the Cosumnes River, hardhead are absent despite a fairly natural flow regime, apparently because of the invasion of redeye bass (*Micropterus coosae*). They are still common in the mainstem Sacramento River, lower American and Feather rivers, some smaller streams (e.g., Deer, Pine, Clear creeks), and reaches upstream of foothill reservoirs (Moyle 2002). They are very rare in the Napa River (Leidy 1984 and pers. comm.) and uncommon in the Russian River (Moyle 2002). In the Pit River, they have a discontinuous distribution and are limited to canyon reaches and hydroelectric reservoirs (Moyle and Daniels 1982, Herbold and Moyle 1986).

Hardhead were once abundant enough in reservoirs to be regarded as a problem species, under the assumption they competed for food with game fishes such as trout (Moyle 2002). Most populations likely resulted from colonization by juveniles before introduced predators became abundant and largely extirpated hardhead from reservoirs. Populations declined dramatically within two years in Shasta Reservoir (Reeves 1964), leaving only a small number to persist (J. M. Hayes, CDFW, pers. comm.). Crashes of large populations in reservoirs were also reported from: Pardee Reservoir on the Mokelumne River, Amador/Calaveras County (Kimsey et al. 1956); Millerton Reservoir on the San Joaquin River, Fresno County (Bell and Kimsey 1955); Berryessa Reservoir, Napa County (Moyle 1976); Don Pedro Reservoir, Tuolumne County; and Folsom Reservoir, El Dorado County (Kimsey et al. 1956). Currently, they are largely absent from reservoirs that undergo strong annual variations in water level, although they can survive in hydroelectric reservoirs where water level fluctuations are less, such as Britton Reservoir on the Pit River and Redinger Reservoir on the San Joaquin River (Moyle 2002).

Nature and Degree of Threats: The apparent ongoing declines in hardhead distribution and abundance are a result of synergistic impacts from habitat loss, decline in water quality, and invasions of alien species (Moyle 2002, May and Brown 2002, Brown and Moyle 2005). The principal threats to hardhead include: (1) dams and diversions, (2) agriculture, (3) urbanization, (4) instream mining, (5) stream modification for transportation, (6) fisheries management (‘harvest’ associated with past eradication of ‘rough fishes’ to benefit recreational fisheries), and (7) alien species.

Dams and diversions. The large dams built on most California rivers have three principal effects: they greatly reduce flows and alter flow regimes downstream of dams; they alter water quality, usually making the downstream reaches warmer (but sometimes colder) with less dilution of pollutants; and they fragment watersheds, isolating fish populations. Dams also create conditions that favor alien fish species, especially in reservoirs. Generally, when flow regimes are altered so that elevated spring flows are uncommon, hardhead and other native fishes disappear from rivers (Brown and Moyle 2005). Pulsed flows also make hardhead juveniles susceptible to displacement and stranding (Chun et al. 2005). In addition, hardhead (71-91 mm SL) seem to exceptionally susceptible to entrainment by hydroelectric powerhouse turbines (ENTRIX Inc. 2001). Hardhead will persist in reaches below dams where habitat conditions are complex and high spring flows allow successful spawning. Where summer flows are low from dam releases or diversions, hardhead are absent from warm water reaches, which are often dominated by alien fishes (e.g., lower Tuolumne River, Brown and Ford 2002). Reservoirs associated with most dams harbor alien predator species that limit hardhead populations (see *Alien species* subsection below).

Agriculture. Hardhead are now largely absent from waters directly influenced by agricultural practices, such as streams polluted with irrigation return water and other waste water, or those bound by levees to reduce flooding, affected by silt-laden run-off, or with reduced flows due to irrigation diversions. Historically, hardhead were abundant throughout the Sacramento and San Joaquin watersheds, as indicated by their common presence in middens of native peoples at low-elevation sites (Gobalet 1989, Broughton 1994). While they disappeared from most of these waters before being documented, their absence is presumably the result of impaired water quality (high temperatures, low dissolved oxygen, high turbidity, high pollutant levels); these same conditions often favor alien species, further contributing to hardhead declines. Their persistence in the lower Sacramento River is presumably the result of increased summer flows to deliver water for agricultural and urban uses, which moderates water temperatures and dilutes pollutants to survivable levels.

Urbanization. The effects of urbanization include severe alteration to habitats, diversion of water and influx of pollutants. Hardhead are generally absent from urban streams; other native fishes are also scarce in such environments (Brown and Moyle 1993). Urban development near Alameda Creek was associated with declines of hardhead in this stream (Leidy 2007).

Instream mining. Ford and Brown (2001) noted that the downstream limits of hardhead in the lower Tuolumne River coincided with the presence of pits left over from gravel mining, which were 'captured' by the river. Such pits are common in the San Joaquin River basin and elsewhere. Mining pits create warm lake-like habitats that support centrarchid basses (*Micropterus* spp.) and the combination of poor habitat quality and presence of alien species appears to be lethal to hardhead. Similarly, there are legacy effects of placer, dredge and hydraulic mining for gold, which dramatically altered many hardhead streams, although hardhead populations have recovered somewhat as these streams have recovered (e.g., South Fork Yuba River). However, hydraulic mining has had lasting legacy effects that compromised much of the suitable fish habitat in streams such as the mainstem Yuba River, changing habitats from shaded pool-riffles to long, unshaded runs (True 2004). High seasonal sediment loads are also a legacy of past mining. Increased turbidities in the South Fork Yuba River decreased hardhead growth rates and increased physiological stress (Gard 2002). A poorly understood legacy effect of Gold Rush-era mining is the influx of mercury into many streams. Mercury has concentrated in the tissues of hardhead from Cache Creek (OEHHA 2005). Mercury can be toxic in high concentrations via disruption of the central nervous system. Hardhead appear to be relatively intolerant of pollutants, but whether or not mercury has affected their populations is not known.

Transportation. The best habitats for hardhead are at intermediate elevations in the larger streams of the Sierra Nevada foothills and Coast Ranges. These are also areas with extensive networks of highways and railroads, which often follow river courses. These transportation corridors can lead to partially channelized streambeds with fewer pools, coupled with increased siltation and pollution from road and railroad beds. Moyle and Randall (1998) found that native fishes, including hardhead, had a negative association with stream reaches that had high road densities.

	Rating	Explanation
Major dams	High	Many of the streams and rivers occupied by hardhead have altered flow regimes; dams isolate populations
Agriculture	High	Hardhead are largely absent from streams heavily influenced by agriculture
Grazing	Low	The impact of grazing on hardhead is likely minimal, although grazing may cause increased siltation or other habitat degradation in some streams
Urbanization	Medium	Hardhead populations decline and disappear where development alters their habitats
Instream mining	Medium	Instream mining has altered many of the stream reaches within hardhead range
Mining	Low	Most of the streams within hardhead range had hard rock mines adjacent to them which feed acidic, heavy metal pollutants into streams; direct effects on hardhead are unknown
Transportation	Medium	Proximity of roads and railroads to streams can lead to increased pollution, sedimentation and impaired habitats
Logging	Low	Increased sedimentation and stream temperatures resulting from logging practices may affect hardhead in some areas; greater impacts in the past
Fire	Low	Fire is a natural process within their range; impacts on hardhead are unknown, although probably low because hardhead occur mainly in larger rivers
Estuary alteration	n/a	
Recreation	Low	Stream-based recreation occurs throughout much of their range but impacts on hardhead are unknown
Harvest	Low	Past 'harvest' from fish eradication projects may have affected some populations
Hatcheries	n/a	
Alien species	High	Predation by alien centrarchids has been a major factor contributing to the decline of hardhead throughout its range

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

Fisheries management (harvest). From the 1950s-1980s, hardhead were one of the focal species for fish eradication programs by the CDFW, on the assumption they were competitors with trout and recreational fisheries would be improved through the elimination of so-called 'rough fish' (Moyle et al. 1982). Although these activities may have negatively affected hardhead (and other native fishes) at a localized level, in the one well-studied fish eradication program, hardhead showed considerable powers of recovery (Moyle et al. 1982). Otherwise, hardhead are rarely harvested for any purpose, although they are incidentally caught on occasion by anglers.

Alien species. It is likely that hardhead would have a much broader distribution in the absence of alien predatory fishes, especially centrarchid basses. In general, where bass are common, hardhead are absent or rare (Brown and Moyle 2005). Hardhead have largely disappeared from the upper Kings River, where smallmouth bass (*Micropterus dolomieui*) are now abundant (Brown and Moyle 1993). Gard (2004) observed that the lowermost reaches of the South Fork Yuba River (above Englebright Reservoir) had been colonized by smallmouth bass up to a waterfall. Hardhead were present both above and below the waterfall, but the hardhead below the waterfall were mostly large adults and small juveniles. The juveniles disappeared by the end of the summer, suggesting elimination by bass predation because they remained present in upstream areas. Presumably, the larger hardhead had moved down from upstream and were large enough to avoid predation. A viable hardhead population in the South Fork Yuba River is, as a consequence, confined to a relatively short stretch of river above the waterfall. More dramatically, hardhead (and other native fishes) are absent from long reaches of the Cosumnes River where they should be present, based on habitat characteristics (natural flow regime, deep pools, clear, cool water). This habitat is now occupied almost exclusively by redeye bass (*M. coosae*). Hardhead in reservoirs only persist if alien predators, especially centrarchid basses, are not abundant. Hardhead are abundant today only in those reservoirs that undergo short-term water level fluctuations (such as for power-generating flows), which impede alien species reproduction (Moyle 2002).

Effects of Climate Change: Predicted climate change impacts to hardhead habitats in California will vary greatly, given their wide distribution. In general, water temperatures are expected to increase, seasonal peak flow is expected to shift from late spring to late winter months, base flows in late summer and fall are expected to decrease (Knox and Scheuring 1991, Field et al. 1999, CDWR 2006) and the overall flow regime of streams will be altered by more frequent and extreme droughts and floods. Summer water temperatures for inland streams are predicted to increase, on average, by approximately 1-4°C by 2099, based on conversion factors developed by Eaton and Scheller (1996). Although hardhead can withstand higher temperatures than trout (Myrick and Cech 2000), exposure to higher water temperatures may increase the potential for bacterial infection. Hardhead collected from the Yuba River in 2003 were infected with bacteria (*Pseudomonad spp.*) at levels (29% of collected fish) that posed a health risk to this population (True 2004). Bacterial infections can lead to kidney disease and higher stream temperatures may reduce individual fitness by increasing physiological maintenance costs (Moyle and Cech 2004).

Elevated air temperatures associated with climate change will change the periodicity and magnitude of peak and base flows in streams due to a reduction in snow pack levels and seasonal retention. Streams may be especially impacted at lower elevations (<1000 m) in the central Sierra Nevada (Hayhoe et al. 2004), due to the already arid nature of this region, coupled with increasing urban, suburban and rural development and corresponding human water demands. Because of these combined factors, Moyle et al. (2013) rated hardhead as "critically vulnerable" to extinction from climate change.

Status Determination Score = 3.1 - Moderate Concern (see Methods section Table 2)**.** Hardhead should continue to be considered a Species of Special Concern (Table 3). NatureServe lists hardhead as Vulnerable at both the global (G3) and state level (S3).

Metric	Score	Justification
Area occupied	5	Still widely distributed in the Sacramento-San Joaquin watershed and the Russian River
Estimated adult abundance	4	Not known but large populations apparently exist
Intervention dependence	4	Monitoring is needed to establish current status but known stressors (e.g. unnatural flow regimes, alien species predation) should be mitigated
Tolerance	2	Hardhead are sensitive to habitat alterations associated with flow, turbidity and temperature
Genetic risk	4	Many populations are small and isolated
Climate change	1	Hardhead are confined to waters exceptionally vulnerable to climate change
Anthropogenic threats	2	See Table 2
Average	2.9	22/7
Certainty (1-4)	3	Information on current status (e.g. population index, abundance estimates) is largely absent

Table 3. Metrics for determining the status of hardhead in California, where 1 is a major negative factor contributing to status, 5 is factor with no or positive effects on status, and 2-4 are intermediate values. See methods section for further explanation.

Management Recommendations: In general, hardhead are widely distributed but their recent downward population trend is similar to that of other California native fishes and is cause for concern (Moyle 2002). Hardhead seem especially susceptible to the combination of alien species and habitat change, especially impacts predicted by climate change models. Consequently, hardhead populations should be monitored and, where possible, cool water habitats in key portions of their range should be protected in order to prevent further declines. Management recommendations include the following:

Establish special management areas. Establishment of a number of protected areas in mid-elevation streams with natural flow regimes and high water quality will offer the best protection for hardhead in the long-term (Moyle and Yoshiyama 1992, Baltz and Moyle 1993). If managed properly, these areas would likely protect the entire native aquatic faunal assemblage and, given that they are a good indicator species for relatively undisturbed habitats, regular hardhead population monitoring should be implemented in these refuge areas (Moyle 2002).

Monitor populations. Streams known to support hardhead populations should be surveyed on a regular basis (e.g. every 5 years) in order to develop trend information. Special focus should be placed on monitoring the Napa, Russian and San Joaquin rivers, as well as Alameda Creek, from which hardhead populations appear to be disappearing rapidly and are highly isolated from other populations. Populations in the Napa River and Alameda Creek, in particular, are likely restricted to a few miles of suitable habitat; their populations should be a priority for protection because they represent remnant populations (Leidy 2007). Some watershed groups and other governmental and non-governmental organizations have begun monitoring native fishes, including hardhead. The hardhead monitoring plan in the South Fork American River seeks to establish baseline data on distribution and population structure (length, weight data) and establish 5 year interval monitoring (El Dorado Irrigation District 2007). Likewise, the Battle Creek Working Group has a plan that includes restoration within the range of hardhead, as well as the establishment of a population index (Ward and Kier 1999).

Re-establish populations where possible. The San Joaquin River is being restored and it is likely that hardhead will only reestablish themselves in this part of their native range through active reintroduction (Moyle 2008). Other areas within historic hardhead distribution where they are currently absent should, likewise, be evaluated for habitat suitability and potential reintroductions.

Manage flow regimes to favor native fishes. Major stressors to hardhead populations include changes to natural flow regimes (e.g. pulsed flows and water diversion) and predation from alien predators. These stressors can be mitigated through improving flow regimes below dams to favor native fishes. For example, in regulated rivers, flows should be managed to provide high spring flows in order to improve native fish reproductive success (May and Brown 2002, Moyle 2002).

Improve passage flows. Fish passage structures within hardhead range should be able to pass adult hardhead on spawning migrations and modified accordingly, where necessary. Velocities should not exceed 0.4 m/s, a velocity lower than is currently used as a guideline based on salmonid passage needs (Myrick and Cech, Jr. 2000). Hardhead are relatively poor swimmers and likely cannot navigate approaches managed for same-sized salmonids.

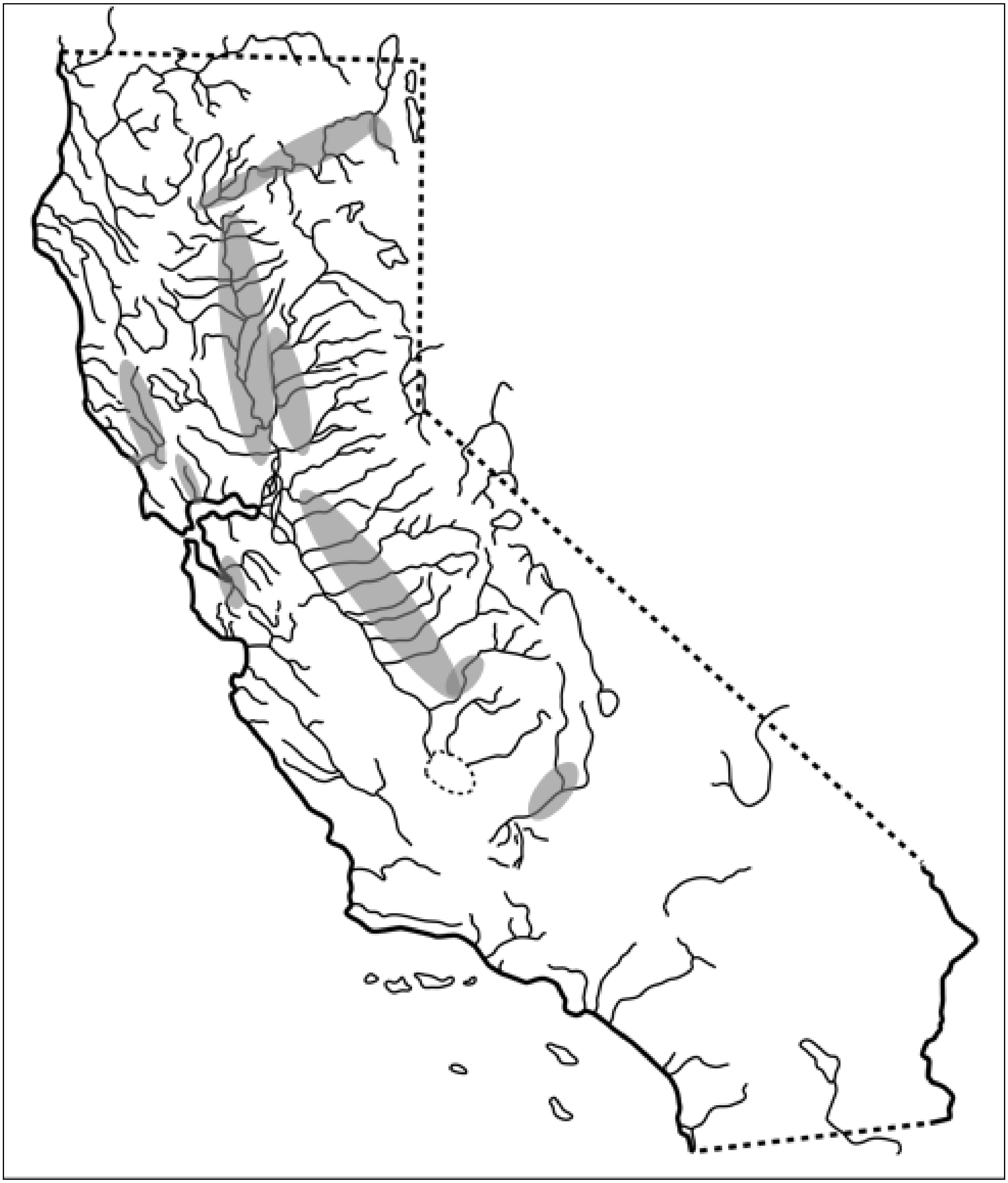

Figure 1. Generalized distribution of hardhead, *Mylopharodon conocephalus* (Baird and Girard), in California. Actual distribution is fragmented.