FISH SPECIES OF SPECIAL CONCERN IN CALIFORNIA

Third Edition

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Wild Klamath Mountain Province steelhead. Photo courtesy of Jeff Weaver.

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PREFACE

This is the third edition of the report on the status of California's Fish Species of Special Concern. The fishes addressed in this report all live and spawn in California's freshwater environments and face varying levels of threat. They are all species that could potentially become extinct by the end of this century, tracking trajectories set by seven species that are already extinct and 31 species that are formally listed as threatened or endangered within the state. The fact that 62 species are covered in this report, while 38 others are listed or extinct, means that 100 native fishes in California are in decline, headed toward extinction, or already extinct. *This represents 81% of California's highly distinctive inland fish fauna.* These species can be regarded as good indicators of the quality and quantity of freshwater habitats around the state which, as indicated by the high percentage of at-risk fishes, are apparently deteriorating.

This report differs from the previous two editions in that the reader does not have to take our word for the status of each of the fish species covered. We use a standardized system for evaluating status, so our assessments can be easily compared among species and can be repeated by others. Our goal is to create a baseline against which future assessments can be compared. Anyone reading this report, with some diligence, should be able to go through the scoring process for a given species and come up with a similar status rating. If the rating differs from ours, the reasons will be apparent from the scores of individual metrics. We assume that the accuracy of scores will improve with additional evaluations, especially if you, the reader, have new and better information about a species. More accurate scores are particularly likely for species where we indicate that there is a relatively low amount of reliable information on their biology. Ideally, each account should be updated as new studies are completed.

We intend that these accounts will be useful first references for those engaged in management of California's fishes or will provide basic background for anyone interested in native fishes. We hope this report will stimulate better and more extensive conservation efforts for each of these declining species. All species treated here need our protection if they are going to survive through the coming decades.

For those interested in easily accessible accounts of species not covered in this report, as well as photographs of the species, we recommend the UC Davis California Fish Website: http://calfish.ucdavis.edu/.

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INTRODUCTION

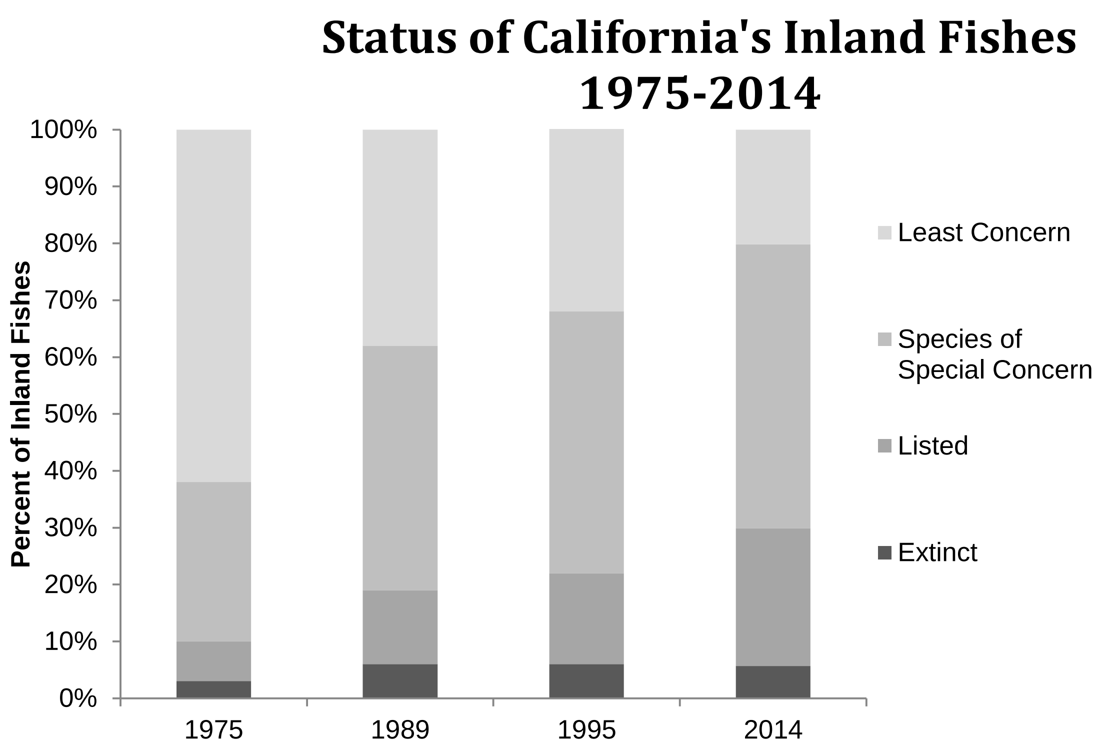
California has a rich fauna of native inland fishes. The state's large size (411,000 km^2), length (1,400 km and 10 degrees latitude) and complex topography result in diverse habitats from temperate rain forests to deserts, as well as 50 isolated, large watersheds in which fish evolution has occurred independently (Moyle 2002, Moyle and Marchetti 2006, Figure 1). For most of the state, the climate is Mediterranean; most precipitation falls in winter and spring, followed by long dry summers. This results in rivers that have high annual and seasonal variability in flows (Mount 1995) and native fishes adapted to hydrologic extremes. Of 124 native inland fishes (defined as those breeding in fresh water) evaluated for this report, 64% are endemic to the state, with an additional 19% also found in Nevada or Oregon. Thus, California has the high overlap between political and zoogeographic boundaries needed for this assessment to be considered bioregional (Moyle 2002).

The long coastline of California has produced a fish fauna containing an unusual proportion (23%) of anadromous (sea-run) taxa, while its dry interior watersheds have produced fishes that thrive in isolated environments such as desert springs, intermittent streams, and alkaline lakes. A majority of California's fishes live in rivers of the Central Valley and North Coast, areas with the most water and most diverse aquatic habitats. The Central Valley, in particular, has been a center of speciation, with 35 native taxa, many of them (16) endemic (found nowhere else) to the watershed, with some also giving rise to species now confined to adjacent watersheds. Recent genetic and taxonomic studies have increased appreciation of the distinctiveness of the California fish fauna, such that the total number of distinct taxa has risen from 113 recognized by Moyle and Williams (1990) to 124 analyzed for this report (Box 1, Table 8).

Figure 1. Map of California showing major watersheds. Each number represents a major zoogeographic region; each number + lowercase letter represents a distinct watershed that is physically separated from the other watersheds or is characterized by a distinct fish fauna, or both. Modified from Moyle 2002.

Unfortunately for the fishes, most of the rivers of California have been dammed and diverted to move water from places of abundance to places of scarcity, where most Californians live (Hundley 2001). Not surprisingly, native fishes have been in steady decline since the mid-19th century, although the first statewide evaluation was not done until 1975 (Moyle 1976) and an analysis of the formal conservation status was not published until 1989 (Figure 2). In 1975, 6 species were considered extinct but most species (64%) were considered stable. There has been only one recognized extinction in the intervening years, but the numbers of listed and imperiled species have steadily increased so that, in 1989, 15 species (13%) were formally listed as threatened or endangered under state and federal endangered species acts and 50 (44%) were regarded as imperiled (Moyle et al. 1989). By 1995, the numbers were 18 (16%) listed and 53 (46%) imperiled (Moyle et al. 1995). Of the 124 species considered for this report, 7 are extinct, 31 (25%) are officially listed, and 62 (50%) are considered of critical, high or moderate concern, which means that at least 81% of California's native fishes are imperiled or extinct (Fig. 2). The purpose of this report is to synthesize the information available on these imperiled species, referred to herein as *Fish Species of Special Concern* (FSSC), to provide a basis for their conservation, as well to provide an objective means of evaluating their status in order to provide a baseline for future analyses.

Figure 2. Conservation status of fishes native to inland waters of California, 1975-2014. Data from reports in 1975 (N = 108), 1989 (N = 115), 1995 (N = 116) and this edition of the report (N = 124). ESA listed species are those listed as threatened or endangered under either state or federal endangered species acts. Species lists change between reports due to extinction, recognition of new taxa, and other reasons (See Box 1).



METHODS

This section describes the: (1) species accounts used for status determination, (2) sources of information used, (3) process used for evaluation, (4) determination of information quality, (5) incorporation of climate change into each evaluation, and (6) evaluation of diverse anthropogenic effects on each species.

*1. **Species accounts***

The status of native fishes of California was evaluated by Moyle et al. (2011) and scores from that study were used as the initial basis for choosing species for inclusion. For this report, eight species were omitted from the analysis for a variety of reasons (Box 1). A species account was created for each fish taxon known to spawn in California's inland waters that is not formally listed as threatened or endangered but is considered to be in decline or limited in distribution to the extent that they may be particularly susceptible to one or more stressors. The species accounts represent the synthesis of available information for each taxon, published and unpublished. Data that had become available since the last report (1995) augmented information from Moyle (2002), Moyle et al. (2008), Moyle et al. (2011) and the two previous editions of this report. For this report, the 62 species accounts are presented in a standard format (Table 1). Literature

Box 1. Species omitted from this report.

The flannelmouth sucker, *Catostomus latipinnis*, was included in the analysis of Moyle et al. (2011) but apparently the only population that now exists in California is in the Colorado River as the result of an introduction; its status is uncertain.

Summer steelhead, *Oncorhynchus mykiss,* is a distinctive life history form of anadromous rainbow trout covered in previous editions of this report. For this report, they are considered to be part of two distinct ESUs of mostly winter-run steelhead, the North California Coast ESU and the Klamath Mountains Province ESU, so are omitted. For an alternative view see Moyle et al. (2008, 2011) and Katz et al. (2012). The two populations were considered together as a distinct taxon (summer steelhead) in previous editions of this report.

Pink salmon (*O. gorbuscha*) and chum salmon (*O. keta)* were included in previous editions (chum salmon in 1995 version only) of this report but reviewers of the accounts thought more information on the status, distribution and stressors affecting their populations was needed before assigning a status score. However, given that California represents the extreme southern end of their range, it is likely that their naturally small populations within the state still merit their inclusion as species of special concern. They are included in Table 8 because they are reproducing members of the California fish fauna (Moyle 2002).

The Shay Creek stickleback, *Gasterosteus sp*., a distinctive fish with a highly restricted distribution in the San Bernadino Mountains, was included in previous editions. However, it is treated by state and federal agencies as part of the unarmored threespine stickleback (*G. aculeatus williamsoni*) complex, which is fully protected as an endangered species under state and federal ESAs.

Staghorn sculpin, *Leptocottus armatus,* and starry flounder, *Platichthys stellatus*, are marine fishes that frequent fresh or brackish water as juveniles, but do not breed in fresh water. They are abundant and were considered part of the total fish fauna in previous editions.

cited is provided as a separate section at the end of the report, rather than at the end of each account, in order to reduce redundancy.

Table 1. Standard format of fish species accounts

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I.	Status summary -Species status category (Table 2) with a brief description of current conservation threats
II.	Description
III.	Taxonomic relationships -Summary of latest systematics
IV.	Life history -Synthesis of known information pertaining to life history
V.	Habitat requirements -Covers all life history stages and includes basic physiological tolerances (temperature ranges, etc.), where information is available
VI.	Distribution -Present and historic range of the species
VII.	Trends in abundance -An assessment of both long- and short-term trends, using quantitative data where available but, otherwise, assessments are based on whatever information is available
VIII.	Nature and degree of threats -A descriptive catalog of threats to the species, including a standardized table of anthropogenic factors limiting populations (Section 6, Table 7)
IX.	Effects of climate change -An evaluation of the likely effects of climate change on the species in the next 100 years (Section 5)
X.	Status determination -An evaluation of status based on seven metrics (Table 4), a certainty estimate (Table 5) and status ratings from other sources
XI.	Management recommendations -A discussion of what is being done, or proposed to be done, for management and conservation of the species, as well as possible management options
XII.	California range map -Maps included are general distributional maps, based on synthesis of all relevant information in the species accounts

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2. Sources of information

Taxa used are those that can be defined as “species” under the Federal Endangered Species Act of 1973, which include species, subspecies, Evolutionary Significant Units (ESU), and Distinct Population Segments (DPS). Information on the biology and status of each species was derived from detailed reviews in Moyle et al. (1995), Moyle (2002), Moyle et al. (2008), Moyle et al. (2010), Moyle et al. (2011), scientific literature and agency reports issued since the last FSSC report, and by personal communications with biologists working with each taxon. Non-salmonid species that have not yet been formally described in the taxonomic literature are treated as species if they clearly qualify as ESUs or DPSs, based on historic information, new genetic studies, or both. The rationale for inclusion is in the taxonomy section for each species. All species accounts underwent extensive peer-review by species experts. In a few cases, information was updated after field investigations by the authors. The status of each species is as of January 1, 2014. Note that species already listed under either federal or state endangered species acts (or both) are precluded from this report.

3. Evaluation of status

Status assessments were produced from information contained in each account with the use of a standardized protocol designed to quantify threat of extinction (Tables 2-7). Status was determined by averaging numeric scores given to seven metrics (Table 3). Each metric was standardized on a 1-5 scale, where '1' was low (negative effect on status) and '5' was high (no or positive effect) and '2' through '4' were intermediate. Threat level ratings are roughly equivalent across metrics. Collectively, the metrics were designed to cover all factors affecting freshwater fish status in California, with minimal redundancy between metrics. Scores for each metric were awarded according to a standardized rubric (Table 4) and then averaged to produce an overall numeric threat score for each species. A principal components analysis using scores for the entire native freshwater fish fauna of California indicated that no one metric dominated the final threat score (Moyle et al. 2011).

Fishes scoring between 1.0 and 1.9 were labeled Critical Concern and regarded as being in serious danger of extinction in their native range (Table 2). Species with scores between 2.0 and 2.9 were labeled High Concern and considered to be under severe threat but extinction was less imminent than for species with lower scores. However, these species could easily slip into the first category if current trends continue. Species scoring 3.0 - 3.9 were considered to be under no immediate threat of extinction but were in long-term decline or had naturally small, isolated populations which warrant frequent status re-assessment; thus, they were labeled Moderate Concern. Taxa scoring 4.0 to 5.0 were regarded as of Low Concern in California. The scores only apply to populations that spawn in California, so species with a wide distribution outside the state (e.g., western river lamprey) could receive low scores within the state, reflecting California's position at the edge of their range. Data compilation and status assessment methodology are more thoroughly described in Moyle et al. (2011), including evaluations of species not included in this report.

Table 2. Status categories, score ranges, and definitions of status categories for California fishes.

Status	Scores	Definition
Extinct	0	Globally extinct or extirpated from inland waters of California
Critical Concern	1.0 - 1.9	High risk of extinction in the wild; range seriously reduced or greatly restricted in California; population abundance critically low or declining; threats projected to reduce remaining California habitat and populations in the short-term (<10 generations)
High Concern	2.0 - 2.9	High risk of becoming a critical concern species; range and abundance significantly reduced; existing habitat and populations continue to be vulnerable in the short-term (<10 generations)
Moderate Concern	3.0 - 3.9	Declining, fragmented and/or small populations possibly subject to rapid status change; management actions needed to prevent increased conservation concern
Low Concern	4.0 - 5.0	California populations do not appear to be in overall decline; abundant and widespread

Table 3. Rubric used to assign scores to seven metrics developed to assess status of native freshwater fishes in California. Final status score is the average of all seven metric scores. Each metric is scored on a 1-5 scale, 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.

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1A. Area occupied: resident fish

1. 1 watershed/stream system in California only, based on watershed designations in Moyle and Marchetti (2006)
2. 2-3 watersheds/stream systems without fluvial connections to each other
3. 3-5 watersheds/stream systems with or without fluvial connections
4. 6-10 watersheds/stream systems
5. More than 10 watersheds/stream systems

1B. Area occupied: anadromous fish

1. 0-1 apparent self-sustaining populations
2. 2-4 apparent self-sustaining populations
3. 5-7 apparent self-sustaining populations
4. 8-10 apparent self-sustaining populations
5. More than 10 apparent self-sustaining populations

2. Estimated adult abundance

1. ≤500
2. 501-5000
3. 5001-50,000
4. 50,001-500,000
5. 500,000 +

3. Dependence on human intervention for persistence

1. Captive broodstock program or similar extreme measures required to prevent extinction
2. Continuous active management of habitats (e.g., water addition to streams, establishment of refuge populations, hatchery propagation or similar measures) required
3. Frequent (usually annual) management actions needed (e.g., management of barriers, special flows, removal of alien species)
4. Long-term habitat protection or improvements (e.g., habitat restoration) needed but no immediate threats need to be addressed
5. Species has self-sustaining populations that require minimal intervention

4. Environmental tolerance under natural conditions

1. Extremely narrow physiological tolerance in all habitats
2. Narrow physiological tolerance to conditions in all existing habitats or broad physiological limits but species may exist at extreme edge of tolerances
3. Moderate physiological tolerance in all existing habitats
4. Broad physiological tolerance under most conditions likely to be encountered
5. Physiological tolerance rarely an issue for persistence

5. Genetic risks

1. Fragmentation, genetic drift and isolation by distance, owing to very low levels of migration, and/or frequent hybridization with related fish are the major forces reducing genetic viability
2. As above but limited gene flow among populations, although hybridization can be a threat
3. Moderately diverse genetically, some gene flow among populations; hybridization risks low but present
4. Genetically diverse but limited gene flow to other populations, often due to recent reductions in habitat connectivity
5. Genetically diverse with gene flow to other populations (good metapopulation structure)

6. Vulnerability to climate change

1. Vulnerable to extinction in all watersheds inhabited
2. Vulnerable in most watersheds inhabited (possible refuges present)
3. Vulnerable in portions of watersheds inhabited (e.g., headwaters, lowermost reaches of coastal streams)
4. Low vulnerability due to location, cold water sources and/or active management
5. Not vulnerable, most habitats will remain within tolerance ranges

7. Anthropogenic threats analysis (see Section 6)

1. 1 or more threats rated critical or 3 or more threats rated high - indicating species could be pushed to extinction by one or more threats in the immediate future (within 10 years or 3 generations)
2. 1 or 2 threats rated high - species could be pushed to extinction in the foreseeable future (within 50 years or 10 generations)
3. No high threats but 5 or more threats rated medium - no single threat likely to cause extinction but all threats, in aggregate, could push species to extinction in the foreseeable future (within the next century)
4. 2-4 threats rated medium - no immediate extinction risk but, taken in aggregate, threats reduce population viability
5. 1 medium all others low - known threats do not imperil the species

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Table 4. Example assessment table for determining status score for California golden trout. Each metric was scored on a 1-5 scale, 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. Scores are awarded according to the rubric in Table 3.

Metric	Score	Justification
Area occupied	1	"Pure" California golden trout are confined to a few small tributaries in one watershed
Estimated adult abundance	3	Volcano Creek populations may be <1,000 but, if other populations with conservation value within native range are counted, the numbers would be much higher, perhaps 50,000
Intervention dependence	3	Annual monitoring of barrier performance required; continued implementation of Conservation Strategy is critical
Tolerance	3	Generally tolerant of a wide range of conditions and habitats within their native range
Genetic risk	1	Hybridization with rainbow trout is a constant high risk
Climate change	2	Smaller streams may be negatively impacted by changing climate; improved watershed management may offset some impacts
Anthropogenic threats	2	See Table 1 (within species account)
Average	2.1	15/7
Certainty (1-4)	4	Well documented

4. Certainty of information

Because the quality and quantity of information varied among species, each species account was rated, on a 1-4 scale, for certainty of status determination (Table 5). A score of 1 represented a species for which the score largely depended on the authors' professional judgment, with little or no published information. Scores of 2 and 3 were assigned to species with ratings based on moderate amounts of published or gray literature, or where gaps existed in some important areas. A score of 4 was based on highly reliable information, with accounts in the peer reviewed and agency literature.

Table 5. Certainty of information for status evaluations

1.	Status is based on professional judgment, with little or no published information
2.	Status is based on professional judgment augmented by moderate amounts of published or gray literature
3.	Status is based on reports found mainly in the in gray literature with some information in peer-reviewed sources, but where gaps existed in some important areas (e.g., genetics)
4.	Status is based on highly reliable information, with numerous accounts in the peer reviewed and agency literature

5. Climate change

Climate change is already altering fish habitats in California and will continue to do so at an accelerating pace if trends do not change, so it was essential to incorporate ongoing and predicted impacts of climate change into each species evaluation. In general, conditions are worsening for native fishes and improving for many alien fishes. Moyle et al. (2012, 2013) developed a protocol, using 20 metrics, for rating the effects of climate change on each fish species in the state. These ratings are incorporated into this report. The ratings are based on climate change modeling from 2011, and likely underestimate the negative effects of climate change on aquatic ecosystems. For most species of fish in this report, the predicted outcomes of climate change are likely to accelerate current declines, potentially leading to extinction in the next 50-100 years if nothing is done to offset climatic impacts. This section is focused on three major aspects of climate change that affect fish distribution and abundance in California: temperature, precipitation, and sea level rise. This general discussion of expected changes to aquatic systems in California provides background for the individualized climate change sections in each species account.

Temperature. Temperatures have been rising in streams for some time and are continuing to rise (Kaushal et al. 2010). In California, there are diverse climate change models to predict future temperatures, but the more conservative models generally converge on scenarios that assume that within 50–100 years, if not sooner, winter and summer air temperatures will average between 1°C–4°C (1.8°F–7.2°F) and 1.5°C–6°C (2.7°F–10.8°F) warmer, respectively (Miller et al. 2003, Cayan et al. 2009). Further, annual snowpack in the Sierra Nevada and Cascade ranges is expected to diminish greatly, so stream flows will be increasingly driven by rainfall events. An increase in the ratio of rain to snow will result in more peak flows during winter, increased frequency of high flow events (floods), diminished spring pulses, and protracted periods of low (base) flow. In addition, there will be more extended droughts, as well as series of extremely wet years, albeit with dry summers. These conditions will translate into warmer water temperatures at most elevations, reflecting both increases in air temperatures and reduced summer flows.

The region of the state with the greatest uncertainty regarding the future effects of climate change is the North Coast, including the San Francisco Estuary (SFE), because of uncertainties in future changes in ocean temperature, coastal currents, and other factors. If summer fog does not diminish (Diffenbaugh et al. 2004), then many coastal streams may stay cool, if with reduced summer flows. However, observations of foggy day frequency indicate that fog is already decreasing on the coast (Johnstone and Dawson 2010), leading to increasing stream temperatures and decreasing summer flows.

From a fish perspective, the impacts of climate change are likely to be most severe on species requiring cold water (<18°C–20°C, or 64°F–68°F) for persistence, especially the iconic salmon and trout (Katz et al. 2012). The ability of waters of the United States to support cold-water fishes is projected to decrease by 4 to 20 percent by 2030 and by as much as 60 percent by 2100 (Eaton and Scheller 1996), with the greatest loss projected for California because of its naturally warm summer climate (O'Neal 2002, Preston 2006). Warming (more days with maximum temperatures >20°C or >68°F) of the more freshwater regions of the SFE is regarded as an additional threat to declining endemic species such as delta smelt (*Hypomesus transpacificus*) (Wagner et al. 2011).

California's rivers and streams have already been affected by increases in air temperature. Summer water temperatures have likely increased, on average, 0.5°C–1.0°C (0.9°F–1.8°F) in the past 20 years or so (e.g., Bartholow 2005). While such increases may seem small, they can push already marginal waters over thresholds for supporting cold-water fishes. In the Klamath River, where summer temperatures often exceed 22°C (72°F) (McCullough 1999, CDEC 2008), small temperature increases are making the mainstem increasingly inhospitable for Pacific salmon (*Oncorhynchus* spp.) and steelhead trout (*O. mykiss*) that use the river in summer and fall (Quiñones, in press). Likewise, Butte Creek, a salmonid stronghold tributary to the Sacramento River in Tehama County, will likely lose its salmonid fishes in the next 50–100 years as the result of temperature changes (Thompson et al. 2012). Similarly, streams tributary to the SFE are increasingly losing their capacity to support salmonid fishes as water temperatures warm, although the degree to which cold-water habitats will be lost depends on interactions among stream flow (including cold-water releases from dams), urbanization, and effectiveness of restoration efforts (Leidy 2007).

Precipitation. Models indicate that precipitation in California will become more variable, with more falling as rain and less as snow (Cayan et al. 2009). Generally, the total amount of precipitation by 2100 is projected to be less, although the extent of loss is highly uncertain (Cayan et al. 2009). From a fish perspective, present rain-dependent streams will respond somewhat differently than snowmelt-dependent streams, although, as temperatures rise, the hydrologic character of snowmelt streams will become more like those of rain-driven streams.

Snowmelt streams are mainly characteristic of the Sierra Nevada and Cascade mountain ranges. Historically, these mountains had extended spring flows to which local fishes were adapted. However, the hydrograph of many snowmelt streams has been greatly altered by the capture of spring recessional flows by dams. In general, streams will become more variable in flow, with warmer summer and fall temperatures as the result of lower flows and shallower depths (Allan and Castillo 2007). Reductions in flow and depth will result from reduced snowpack, increased frequency of rain storms, and reduced seasonal retention of water in soils and other natural reservoirs (Hayhoe et al. 2004, Stewart et al. 2004, 2005, Hamlet et al. 2005). Elevations below 3000 meters (m) will likely suffer the most (80 percent) loss of snowpack (Hayhoe et al. 2004), as well as reduction in water content of remaining snow (e.g., Van Kirk and Naman 2008). Earlier snowmelt has already moved the timing of high flows forward by 10 to 30 days, on average (Stewart et al. 2005), with annual peak discharges, in particular, occurring earlier

(Cayan et al. 2001, 2009). These changes dramatically affect flows in low-elevation rivers in the Central Valley and are leading to modified operation of reservoirs (dam releases), which further affect flows.

Streams that are already dependent on rain will become even more variable, with greater extremes in high and low flows, leading to drying of long stream reaches on occasion. In interior and south-coastal California, such streams already show highly variable flow regimes, with "flashy" flows in winter in response to rain events (e.g., Cosumnes River; Moyle et al. 2003). Winter rains created some of the most extreme flow events ever recorded for California such as the major floods of 1955 and 1964 in the Eel and other coastal rivers (e.g., Yoshiyama and Moyle 2010), as well as the 'New Year floods' of 1997 that had widespread impacts to riverine habitats.

Overall, the amount of water carried by streams in California (and the rest of the western United States), if present trends continue, will decrease by 10 to 50 percent during drier months (e.g., Cayan et al. 2001). More important, extreme high- and low-flow events are projected to increase by 15 to 20 percent (Leung et al. 2004), especially in the northern Sierra Nevada and southern Cascade Range (Kim 2005). This increased incidence of extreme events will test the adaptive ability of native stream fishes.

Sea level rise. Projections of the rate of sea level rise are changing, usually upwards, as better information becomes available. Cayan et al. (2009) project a rise in sea level of 35–50 centimeters (cm) in the next 50 years, while Knowles (2010) projects a rise of as much as 150 cm by 2100. Other scenarios range from optimistic projections of 45–70 cm by 2100 to pessimistic projections of 1500 to 3500 cm (Knowles 2010). Accompanying the mean rise of sea level will be an increase in major events that enhance effects of sea rise, such as high tides, storm surges, and coincidence of high tides with high outflows from rivers (Cayan et al. 2009). For fishes, a major consequence of sea level rise will be the reduction or loss of tidal marsh habitats (Moyle et al. 2012).

These predictions for climate change effects are consistent with other recent reports of large-scale climate change effects in California and how aquatic habitats and native flora and fauna will adapt to them (e.g., RLF 2012, Kadir et al. 2013).

6. Anthropogenic threats analysis

For each species, an analysis was conducted of 15 anthropogenic factors (listed below) which limit, or potentially limit, a taxon's viability (Table 7); the ratings of these factors were then combined to create a single evaluation variable. Factors were rated on a five-level ordinal scale (Table 6), 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 a 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; and a factor rated "n/a" has no known negative impact to the taxon under consideration. Descriptions of most of these factors, with access to literature on which they are based, can be found in Moyle (2002).

Table 6. Criteria for ratings assigned to anthropogenic threat factors with correlated time-lines.

Factor Threat Rating	Criteria	Time-line
Critical	Could push species to extinction	3 generations or 10 years, whichever is less
High	Could push species to extinction	10 generations or 11-50 years, whichever is less
Medium	Unlikely to drive a species to extinction by itself but contributes to increased extinction risk	Next 100 years
Low	May reduce populations but extinction unlikely as a result	Next 100 years
Not applicable (n/a)	Metric is not applicable to species under consideration	-

Major dams. Dams were recorded as having a high impact on a species if they prevent access to a large amount of its range, if they caused major changes to habitats, or if they significantly changed downstream water quality and or quantity. The effects and impacts of reservoirs created by dams were also evaluated. Dams were regarded as having a low impact if they were present within the range of the species but their effects were either minimal or poorly known.

Agriculture. The impacts from agriculture were regarded as high if agricultural return water or farm effluent heavily polluted streams, if agricultural diversions severely reduced flow or affected migratory patterns, if large amounts of silt flowed into streams from farmlands, if pesticides had significant impacts or were suspected of having them, or if other agriculture-related factors directly affected the streams in which a species lived. Agriculture was regarded as having a low impact if it was not pervasive in the watersheds in which the species occurs or was not causing significant degradation of aquatic habitats.

Grazing. Livestock grazing was separated from other forms of agriculture because its effects are widespread on range and forest lands throughout California and can have disproportionate impacts on stream and riparian habitats. Impacts were considered high in areas where stream channel morphology has been altered (e.g., head cuts, stream bank sloughing, stream channel shallowing, loss of meander) and riparian vegetation removed, resulting in streams becoming incised with accompanying drying of adjacent wetlands or meadow systems. Other impacts contributing to a high rating include removal of vegetation and unimpeded cattle movement through streams, resulting in large amounts of silt and nutrient input, increased summer temperatures, and decreased summer flows. Impacts were rated low where grazing occurs in watersheds occupied by a species, but changes described above are minimal.

Rural residential. As California's human population grows, rural development increasingly occurs in diffuse patterns along or near streams. Resulting impacts include water removal, streambed alteration (to protect houses from flooding, create swimming holes, construct road crossings, etc.), and pollution (especially from septic tanks and illegal waste dumping). Where such rural development is increasing rapidly and is largely unregulated, it may cause major changes to stream habitat quality and quantity and was rated as a high impact. Where such housing is present but widely dispersed and or not rapidly increasing, the effects were rated as low.

Urbanization. Development of towns and cities often negatively affects nearby streams, largely due to flood prevention, channelization, water diversion, and increased waste inputs. The timing and magnitude of flows are altered by the increase in impervious surfaces associated with heavily developed areas. Streams in urban settings may be channelized, sometimes confined to cement canals, and or diverted into underground culverts, significantly reducing the quality of fish habitat. Pollution from surface runoff, sewage discharges and storm drains can substantially degrade water quality and aquatic habitats. The impacts from urbanization were rated high where a species occupies habitats proximate to heavily developed urban areas for much of its life cycle or during important or particularly vulnerable life history stages.

Instream mining. Widespread and often severe instream mining impacts occurred during the mid-19th and early 20th century in California, due largely to 'Gold Rush fever.' Many rivers were excavated, dredged and hydraulically mined for gold, causing dramatic stream degradation; these legacy effects are still evident in numerous watersheds (e.g., the so-called 'Gold Fields' on the lower Yuba River and the expansive tailing piles along the lower American and Trinity rivers). Locally severe impacts also occurred as a result of instream gravel mining operations, for which large pits were dug into streambeds and stream banks and riparian vegetation were highly degraded. Such mining is now largely banned (in favor of mining off-channel areas) but lasting habitat impacts remain in many areas. Instream mining was usually rated moderate when present, although severe legacy effects at a localized level resulted in high ratings for impacts to some species. The negative effects from contemporary recreational and professional suction dredge mining for gold (although currently under moratorium in California) led to high ratings in some instances, due to relatively recent (within the past 10 years) intensive suction dredging in some areas.

Mining. This factor refers to hard rock mining, from which tailings may have been dumped into streams, largely due to proximity of mines to stream courses, along with toxic pollutants entering streams from mine effluents, mostly from abandoned mines. Effects of mercury mining, used for processing gold in placer and dredge mining, are also included. High ratings stemmed from large-scale mines, even if abandoned or remediated, that may constitute a major threat because their wastes are considerable and adjacent to rivers (e.g. Iron Mountain Mine, near Redding, and Leviathan Mine, in the upper reaches of the East Fork Carson River). Low ratings were applied to mines near water courses with effects unknown or deemed to be minimal.

Transportation. Road and railroad construction historically followed river courses across many parts of California; thus, a large number of rivers and streams have roads and/or railroads running along one or both banks, often for long distances (e.g., Klamath, Trinity, and Salmon rivers). These transportation corridors generally confine stream channels and subject waterways to increased sediment input, pollution, and habitat simplification. Culverts and other passage or drainage modifications associated with roads often block fish migration or restrict fish movements, sometimes fragmenting populations. Unsurfaced roads can become hydrologically connected to streams, increasing siltation and changing local flow regimes, with corresponding impacts to aquatic habitats. Ratings were generated based on how pervasive and proximate paved or surfaced roads, unsurfaced roads, railroads, or other transportation corridors are to streams in the areas occupied by a given species.

Logging. Timber harvest has been a principal land use of forested watersheds in California since the massive influx of European and other immigrants in the mid-19th century. Timber harvest that supported historic development of mining towns, mines, railroads, and suburban and urban development led to deforestation of most of California's timber lands, often several times over. Many heavily-logged watersheds are those that supported the highest species diversity and abundance of fishes, including anadromous salmon and steelhead (particularly north-coast watersheds). Logging was generally unregulated until the mid-20th century, resulting in substantial stream degradation across the state. Impacts, past and present, include: increased sedimentation of streams, increased solar input and resultant warming of stream temperatures, degradation or elimination of riparian vegetative cover, and an extensive network of statewide unimproved roads to support timber extraction, many of which continue to contribute to stream habitat degradation. Logging continues across large portions of the state and, while now considerably better regulated than in the past, legacy effects of past unregulated timber harvest continue to impact streams across California. High ratings were applied where a species occupies streams notably degraded by either legacy or contemporary impacts from logging. Low ratings were applied to species that occupy forested watersheds where the impacts from logging have either been mitigated or are considered to be of minimal impact.

Fire. Wildfires are a natural and fundamental component of California's landscape in most parts of the state; however, human activities (especially fire suppression for greater than 100+ years), coupled with climate change influences, have made modern fires more frequent, severe and catastrophic (Gresswell 1999, Noss et al. 2006, Sugihara et al. 2006). Transition from relatively frequent understory fires to less frequent, but catastrophic, crown fires has been implicated as a major driver in the extinction risk of Gila trout (*Oncorhynchus gilae*) in New Mexico (Brown et al. 2001). It is quite likely that similar changes in fire behavior in California will affect native fishes in the same fashion. Ratings were based upon the extent to which habitats occupied by a species exist in fire-prone watersheds. Larger, main-stem river systems (e.g., Sacramento River), not often directly influenced by fires, were given low ratings.

Estuary alteration. Many California fishes depend on estuaries for at least part of their life cycle. Most estuaries in the state are highly altered from human activities, especially diking and draining, as well as removal of sandbars between the estuary and ocean. Land use practices surrounding estuaries often involve extensive wetland reclamation, greatly reducing nutrient inputs, ecological functions and habitat complexity of estuaries. Impacts to fish species that are highly dependent on estuary habitats for one or more portion of their life history and that occupy rivers or streams with altered or degraded estuarine habitats were rated high. Impacts to those species not dependent on, but still using, estuary habitats or present in drainages with little-modified estuaries were rated low.

Recreation. Human use of streams, lakes and surrounding watersheds for recreational purposes has greatly increased with human population expansion in California. Recreational uses that may cause negative impacts to fish populations and their habitats include: boating (motorized and non-motorized) or use of other personal watercraft, swimming, angling, gold panning, off-road vehicles, ski resort development, golf courses and other activities or land uses. Recreational impacts to fish populations are generally minor; however, concentration of multiple activities in one region or during certain portions of the year may cause localized impacts. Recreation was rated high in situations where one or more factors have been documented to substantially impact riparian or instream habitats (including water quality), fish abundance or habitat utilization (e.g., spawning disruption), or in instances where the species has very limited distribution and recreational impacts may further restrict its range or abundance. Recreation was rated low in cases where one or more recreational factors exist within the species' range, but effects are either minimal or unknown.

Harvest. Harvest relates to legally regulated commercial and recreational fisheries, as well as illegal harvest (poaching). Both, if not carefully monitored and enforced, can have substantial impacts on fish populations, particularly those with already limited abundance or distribution, those which are isolated or reside for long periods in discrete habitats and are, therefore, easy to catch (e.g. summer steelhead), or those that are comprised of long-lived individuals or those that attain large adult size (e.g., sturgeon), making them especially susceptible to over-harvest. Harvest was rated high where a species was affected by one or more stressors noted above and it is believed that harvest is a contributing factor to limiting its abundance. Harvest was rated low where legal take is allowed for a species but harvest rates are low and known effects are minimal or do not appear to limit abundance.

Hatcheries. Hatcheries and releases of hatchery-reared fish into the wild can negatively impact wild fish populations through competition, predation, potential introduction of disease, and loss of fitness and genetic diversity (Kostow 2008, Chilcote et al. 2011). Many California fish species of concern have no hatchery augmentation and or occur in waters that are not stocked; hatchery influences are largely relegated to anadromous fishes that occur in rivers blocked by major dams (e.g., the various races of salmon and steelhead trout) or those that occur in lake or reservoir habitats that are stocked for recreational purposes (e.g., Eagle Lake rainbow trout, Lahontan Lake tui chub). The severity of hatchery impacts were rated based, in part, on hatchery dependence to support a species of concern and or the threat of interbreeding between wild and hatchery populations.

Alien species. Non-native species (including fishes and other aquatic organisms, aquatic vegetation, etc.) are ubiquitous across many of California's watersheds; their impacts on native species through hybridization, predation, competition, disease, and habitat alteration can be severe (Moyle and Marchetti 2006). This factor was rated high if studies and publications exist that demonstrate major direct or indirect impacts from alien invaders on a given native species. The presence of alien species was rated low if the potential for contact with non-native species exists, but no documented negative impacts are known.

Table 7. Major anthropogenic factors limiting, or potentially limiting, viability of native freshwater fishes of California, using California golden trout as an example.

	Rating	Explanation
Major dams	n/a	All major dams are outside the native range of California golden trout
Agriculture	n/a	
Grazing	Medium	Ongoing threat but greatly reduced from the past
Rural residential	n/a	
Urbanization	n/a	
Instream mining	n/a	
Mining	n/a	Historic mines are present but have no known impacts
Transportation	Low	Trails and off-road vehicle routes can be a source of sediment and pollution input into streams; direct habitat impacts from wet route crossings
Logging	Low	This is an important land use in the broader region but probably has no direct effect on golden trout streams
Fire	Low	Because of fire suppression, headwater areas could be impacted by hot fires, although this is unlikely given the sparse plant communities in region
Estuary alteration	n/a	
Recreation	Low	Pure populations within the Golden Trout Creek watershed are entirely within designated wilderness; South Fork populations with conservation value are also within designated wilderness
Harvest	Low	Potential impact but light pressure and most fishing is thought to be catch and release
Hatcheries	Low	Residual effects of hybridization with hatchery fish
Alien species	High	Major cause of limited distribution in South Fork Kern; however, very limited introgression with rainbow trout and no brown trout in waters within Golden Trout Creek watershed

Table 8. List of native freshwater fishes in California, showing status scores (from this report and Moyle et al. 2011) and status rating. See Box 1 for eight species not covered by this report. Species with names in bold are covered in this report. Species noted with an asterisk (*) are already listed under federal or state (or both) endangered species acts and, therefore, not included in this report. Species rated as Low Concern are not included, for intuitive reasons, with one exception. The following are roughly equivalent designations using criteria of the International Union for the Conservation of Nature (IUCN): Critical Concern = IUCN endangered; High Concern = IUCN vulnerable; Moderate Concern = IUCN near-threatened; Low Concern = IUCN least concern.

Species	**Score**	**Status (concern)**
Petromyzontidae		
Pacific lamprey, *Entosphenus tridentata*	3.3	Moderate
Goose Lake lamprey, *Entosphenus sp*.	2.9	High
Northern California brook lamprey, *E. folletti*	2.4	High
Klamath River lamprey, *E. similis*	3.9	Moderate
Western river lamprey, *Lampetra ayersi*	3.6	Moderate
Kern brook lamprey, *L. hubbsi*	2.3	High
Western brook lamprey, *L. richardsoni*	3.0	Moderate
Pit-Klamath brook lamprey, *L. lethophaga*	3.7	Moderate
Acipenseridae		
Northern green sturgeon, *Acipenser medirostris*	2.7	High
Southern green sturgeon, *A. medirostris**	1.6	Critical
White sturgeon, *A. transmontanus*	2.6	High
Cyprinidae		
Thicktail chub, *Siphatales crassicauda*	0.0	Extinct
Goose Lake tui chub, *S. t. thalassinus*	3.1	Moderate
Pit River tui chub, *S. thalassinus subsp.*	4.0	Low
Cow Head tui chub, *S. t. vaccaceps*	2.4	High
Klamath tui chub, *S. b. bicolor*	4.1	Low
High Rock Springs tui chub, *S. b. subsp.*	0.0	Extinct
Lahontan lake tui chub, *S. b. pectinifer*	2.4	High
Lahontan stream tui chub, *S. b. obesus*	4.7	Low
Eagle Lake tui chub, *S. b. subsp*.	3.3	Moderate
Owens tui chub, *S. b. snyderi**	1.4	Critical
Mojave tui chub, *S. mohavensis**	1.4	Critical
Bonytail, *Gila elegans*	0.0	Extinct

Blue chub, *Gila coerulea*	3.4	Moderate
Arroyo chub, *Gila orcutti*[1]	2.1	High
Lahontan redside, *Richardsonius egregius*	4.8	Low
Sacramento hitch, *Lavinia e. exilicauda*	3.1	Moderate
Clear Lake hitch, *L. e. chi**	1.7	Critical
Monterey hitch, *L. e. harengeus*	3.1	Moderate
Central California roach, *L. s. symmetricus*	3.3	Moderate
Red Hills roach, *L. s. subsp.*	2.1	High
Russian River roach, *L. s. subsp*	3.3	Moderate
Clear Lake roach, *L s. subsp.*	3.6	Moderate
Monterey roach, *L. s. subditus*	3.4	Moderate
Navarro roach, *L. s. navarroensis*	3.3	Moderate
Tomales roach, *L. s. subspecies*	3.1	Moderate
Gualala roach, *L. parvipinnus*	3.0	Moderate
Northern roach, *L. mitrulus*	2.9	High
Sacramento blackfish, *Orthodon microlepidotus*	4.4	Low
Sacramento splittail, *Pogonichthys macrolepidotus*	3.1	Moderate
Clear Lake splittail, *P. ciscoides*	0.0	Extinct
Hardhead, *Mylopharodon conocephalus*	3.1	Moderate
Sacramento pikeminow, *Ptychocheilus grandis*	4.7	Low
Colorado pikeminnow, *P. lucius*	0.0	Extinct
Sacramento speckled dace, *Rhinichthys osculus* subp.	4.1	Low
Lahontan speckled dace, *R. o. robustus*	4.8	Low
Klamath speckled dace, *R. o. klamathensis*	4.8	Low
Owens speckled dace, *R. o. subsp.*	2.6	High
Long Valley speckled dace, *R. o. subsp.*	1.0	Critical
Amargosa Canyon speckled dace, *R. o. nevadensis*	1.9	Critical
Santa Ana speckled dace, *R. o. subsp.*	1.6	Critical
<u>Catostomidae</u>		
Tahoe sucker, *Catostomus tahoensis*	5.0	Low
Owens sucker, *C. fumeiventris*[2]	4.0	Low
Lahontan mountain sucker, *C. platyrhynchus*	3.1	Moderate
Sacramento sucker, *C. o. occidentalis*	5.0	Low
Goose Lake sucker, *C. o. lacusanserinus*	2.3	High
Monterey sucker, *C. o. mniotiltus*	4.1	Low
Humboldt sucker, *C. o. humboldtianus*	4.3	Low
Modoc sucker, *C. microps**	1.6	Critical
Klamath smallscale sucker, *C. rimiculus*	4.1	Low
Klamath largescale sucker, *C. snyderi*	1.9	Critical

[1] Arroyo chub is rated 3.1 (Moderate Concern) if populations outside its native range are included in status assessment.
[2] The Owens sucker was a species of special concern in previous reports but our evaluation indicates it is secure; we leave it in this edition because of remaining uncertainties and its inclusion in previous reports.

Lost River sucker, *C. luxatus**	1.7	Critical
Santa Ana sucker, *C. santaanae**	1.7	Critical
Shortnose sucker, *Chasmistes brevirostris**	2.0	High
Razorback sucker, *Xyrauchen texanus**	1.3	Critical
<u>Osmeridae</u>		
Eulachon, *Thaleichthys pacificus**	1.6	Critical
Longfin smelt, *Spirinchus thaleichthys**	2.0	High
Delta smelt, *Hypomesus transpacificus**	1.4	Critical
<u>Salmonidae</u>		
Mountain whitefish, *Prosopium williamsoni*	3.9	Moderate
Bull trout, *Salvelinus confluentus*	0.0	Extinct
Upper Klamath-Trinity fall Chinook salmon, *Oncorhynchus tshawytscha*	3.0	Moderate
Upper Klamath-Trinity spring Chinook salmon, *O. tshawytscha*	1.7	Critical
Southern Oregon-Northern California coast fall Chinook salmon, *O. tshawytscha*	3.3	Moderate
California Coast fall Chinook salmon, *O. tshawytscha**	2.4	High
Central Valley winter Chinook salmon, *O. tshawytscha**	2.0	High
Central Valley spring Chinook salmon, *O. tshawytscha**	2.0	High
Central Valley late fall Chinook salmon, *O. tshawytscha*	2.6	High
Central Valley fall Chinook salmon, *O. tshawytscha*	2.7	High
Central coast coho salmon, *O. kisutch**	1.1	Critical
Southern Oregon Northern California coast coho salmon, *O. kisutch**	1.6	Critical
Pink salmon, *O. gorbuscha*[3]	?	Undecided
Chum salmon, *O. keta*[4]	?	Undecided
Northern California coast winter steelhead, *O. mykiss**	3.3	Moderate
Klamath Mountains Province steelhead, *O. mykiss*	2.8	High
Central California coast winter steelhead, *O. mykiss**	2.7	High
South Central California coast steelhead, *O. mykiss**	2.4	High
Southern California steelhead, *O. mykiss**	1.7	Critical
Central Valley steelhead, *O. mykiss**[5]	2.4	High
Coastal rainbow trout, *O. m. irideus*	4.7	Low
McCloud River redband trout, *O. m. stonei*	2.0	High
Goose Lake redband trout, *O. m. subsp.*	3.3	Moderate
Eagle Lake rainbow trout, *O. m. aquilarum*	2.1	High

[3] More information on the status, distribution and stressors affecting pink salmon populations in California is needed in order to score this species. However, given that California represents the extreme southern end of their range, it is likely that naturally small populations in relatively low numbers within the state would merit their inclusion as a species of special concern. See Box 1.

[4] Same comment as for pink salmon.

[5] Genetic evidence indicates that all CV steelhead as currently defined by NMFS are hybridized with north coast steelhead of hatchery origin.

Kern River rainbow trout, *O. m. gilberti*	1.7	Critical
California golden trout, *O. m. aguabonita*	2.1	High
Little Kern golden trout, *O. m. whitei**	2.0	High
Coastal cutthroat trout, *O. clarkii clarkii*	3.0	Moderate
Paiute cutthroat trout, *O. c. seleneris**	1.7	Critical
Lahontan cutthroat trout, *O. c. henshawi**	2.1	High
<u>Fundulidae</u>		
California killifish, *Fundulus parvipinnis*	4.1	Low
<u>Cyprinodontidae</u>		
Desert pupfish, *Cyprinodon macularius**	1.9	Critical
Owens pupfish, *C. radiosus**	1.4	Critical
Saratoga Springs pupfish, *C. n. nevadensis*	2.3	High
Amargosa River pupfish, *C. n. amargosae*	2.3	High
Tecopa pupfish, *C. n. calidae*	0.0	Extinct
Shoshone pupfish, *C. n. shoshone*	1.1	Critical
Salt Creek pupfish, *C. s. salinus*	2.7	High
Cottonball Marsh pupfish, *C. s. milleri**	2.4	High
<u>Cottidae</u>		
Rough sculpin, *Cottus asperrimus**	3.4	Moderate
Bigeye marbled sculpin, *C. klamathensis macrops*	3.0	Moderate
Lower Klamath marbled sculpin, *C. k. polyporus*	3.9	Moderate
Upper Klamath marbled sculpin, *C. k. klamathensis*	1.7	Critical
Coastal Prickly sculpin, *C. asper subsp*.	4.7	Low
Clear Lake prickly sculpin, *C. a. subsp*.	3.3	Moderate
Coastrange sculpin, *C. aleuticus*	4.4	Low
Riffle sculpin, *C. gulosus*	3.0	Moderate
Pit sculpin, C. pitensis	4.3	Low
Paiute sculpin, *C. beldingi*	4.4	Low
Reticulate sculpin, *C. perplexus*	4.0	Low
<u>Gasterosteidae</u>		
Coastal threespine stickleback, *Gasterosteus a. aculeatus*	4.6	Low
Inland threespine stickleback *G. a. microcephalus*	4.1	Low
Unarmored threespine stickleback, *G. a. williamsoni**	1.9	Critical
<u>Centrarchidae</u>		
Sacramento perch, *Archoplites interruptus*	1.9	Critical
<u>Embiotocidae</u>		
Sacramento tule perch, *Hysterocarpus traski traski*	4.0	Low
Russian River tule perch, *H.t. pomo*	3.7	Moderate
Clear Lake tule perch, *H. t. lagunae*	2.3	High
<u>Gobiidae</u>		
Tidewater goby, *Eucyclogobius newberryi**	2.9	High