Biological Conservation 144 (2011) 2414–2423

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Rapid decline of California's native inland fishes: A status assessment

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ARTICLE INFO

Article history:
Received 8 February 2011
Received in revised form 3 June 2011
Accepted 5 June 2011
Available online 19 July 2011

Keywords:
Aquatic conservation
Biodiversity
Endangered
Imperiled
Freshwater fishes

ABSTRACT

A quantitative protocol was developed to determine conservation status of all 129 freshwater fishes native to California. Seven (5%) were extinct; 33 (26%) were found to be in danger of extinction in the near future (endangered); 33 (26%) were rated as sufficiently threatened to be on a trajectory towards extinction if present trends continue (vulnerable); 34 (26%) were rated as declining species but not in immediate danger of extinction. Only 22 (17%) species were found to be of least concern. Of 31 species officially listed under federal and state endangered species acts (ESAs), 17 (55%) were rated as endangered by our criteria, while 12 (39%) were rated vulnerable. Conversely, of the 33 species that received our endangered rating, only 17 (51%) were officially listed under the ESAs. Among the seven metrics used to assess extinction threat, climate change, area occupied and anthropogenic threats had the largest negative impacts on status. Of 15 categories of causes of decline, those most likely to diminish status were alien species, agriculture, and dams. Overall, 83% of California's freshwater fishes are extinct or at risk of becoming so, a 16% increase since 1995 and a 21% increase since 1989. The rapid decline of California's inland fishes is probably typical of declines in other regions that are less well documented, indicating a strong need for improved conservation of freshwater ecosystems.

1. Introduction

Extinction in freshwater environments is a world-wide crisis (Moyle and Williams, 1990; Saunders et al., 2002; Dudgeon et al., 2006) which is poorly documented (Strayer and Dudgeon, 2010; Vörösmarty et al., 2010). Loss of biodiversity seems to be occurring more rapidly from fresh water than from any other broad habitat type (Jenkins, 2003; Dudgeon et al., 2006). Driven by recent global assessments of mollusks (Bogan, 2008), crabs (Cumberlidge et al., 2009), amphibians (Stuart et al., 2004), and dragonflies (Clausnitzer et al., 2009), the number of freshwater species listed on International Union for the Conservation of Nature (IUCN) Red Lists has more than tripled since 2003 (Darwall et al., 2008). Nevertheless, the best-studied indicators of the problem remain freshwater fishes (Magurran, 2009) which account for about one-third of all described vertebrates, with roughly 13,000 species (Helfman, 2007; Lèvêque et al., 2008). In 1992, 20% of the world's freshwater fish fauna was estimated to be extinct or in serious decline (Moyle and Leidy, 1992). Less than 20 years later, 37% of the 3481 freshwater fish species evaluated globally by IUCN were regarded as extinct or imperiled (declining towards, or threatened, with extinction, Vié et al., 2009), although the IUCN database is likely biased towards including declining species. At the continental scale, 46% of 1187 described freshwater and diadromous fish species native to North America are extinct, imperiled, or have one subspecies or distinct population that is imperiled (Jelks et al., 2008) with the rate of extinction steadily increasing (Ricciardi and Rasmussen, 1999). Not surprisingly, the number of imperiled fish species is highly correlated with human population and economic growth (Limburg et al., 2011).

While large-scale assessments spotlight the global extent of the crisis, severity and causes are best understood through intensive studies of regional fish faunas because status can be repeatedly, systematically, and quantitatively documented over relatively short time periods. In this paper, we analyze the status of California's 129 native freshwater fishes. This regional fauna is reasonably well documented, occupies a wide variety of habitats, and exhibits a wide range of life history patterns including anadromy (Moyle, 2002; Moyle et al., 2008, 2010). Their status was previously analyzed in 1989 (Moyle and Williams, 1990) and 1995 (Moyle et al., 1995). Here, we use a new quantitative protocol to determine conservation status of each species. This protocol allows us to make status determinations independent of official agency designations and to find species needing protection that have been overlooked so far by state and federal agencies. Comparisons with official status designations also serve as a check on the usefulness of our protocol. In this paper, we answer the following questions:

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doi:10.1016/j.biocon.2011.06.002

1. What is the status of California's inland fish fauna?
2. Are the fishes continuing to decline?
3. What factors are most strongly associated with declining status?
4. How do our results fit with official status designations?

1.1. The inland fishes of California

California's large size (411,000 km^2), length (1400 km and 10° latitude) and complex topography result in diverse habitats, including 50 isolated watersheds in which fish have evolved independently (Moyle, 2002, Moyle and Marchetti, 2006). 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. There are 129 native inland fishes (defined as those breeding in fresh water) currently recognized (Appendix 1, which includes scientific names of fishes mentioned). Of these, 63% are endemic to the state and an additional 19% are also found in one adjacent state. Thus California's fishes fall within political and zoogeographic boundaries that largely coincide, important for a bioregional assessment (Moyle, 2002).

Conditions in California have produced an unusual number of anadromous fishes (24%) as well as fishes that thrive in isolated environments such as desert springs, intermittent streams, and alkaline lakes. Most fishes live in rivers of the Central Valley and North Coast, areas having the most water and most diverse aquatic habitats. Recent genetic and taxonomic studies have underscored the distinctiveness of California fishes and increased the number of taxa from 113 in 1989 (Moyle and Williams, 1990) to 129 in the present study.

Most California rivers 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 formal evaluation of their status was not conducted until 1989. At that time, 7 species (5%) were extinct, 15 (13%) were formally listed as Threatened or Endangered under the state or federal ESAs, and 51 (43%) were designated as Species of Special Concern by the State of California, indicating they were in decline or had small, vulnerable populations but were not yet threatened with immediate extinction (Moyle and Williams, 1990). The number of declining species has steadily increased so that in 1995, there were 18 (16%) listed and 51 (44%) in decline (Moyle et al., 1995). Today, the numbers are 30 (23%) listed and 70 (54%) in decline, meaning that 83% of California's native fishes have the potential to go extinct in coming decades or are already extinct (Appendix 1) (Fig. 1).

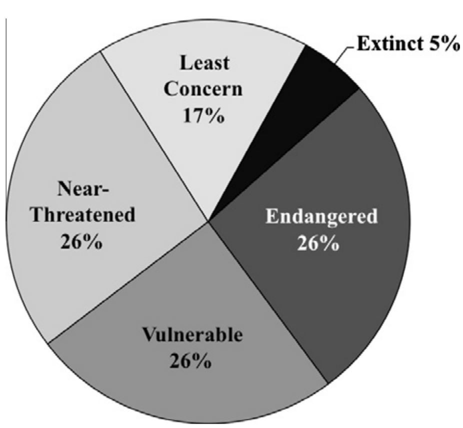

Fig. 1. Status of fishes ($N = 129$) native to inland waters of California in 2010. All threat categories are approximately equivalent to IUCN threat levels of the same name. Extinct = globally extinct or extirpated in the inland waters of California. Endangered = highly vulnerable to extinction in its native range, approximately equivalent to IUCN threat level of *endangered* or *critically endangered*. Vulnerable = could easily become threatened or endangered if current trends continue. Near threatened = populations in decline or highly fragmented. Least concern = no extinction threat for California populations.

2. Methods

2.1. Sources of information

Taxa used were those that qualified as species under the federal Endangered Species Act of 1973, so include species, subspecies, Evolutionarily Significant Units, and Distinct Population Segments recognized by one or more agencies. The biology and status of each species was determined from information in Moyle (2002), Moyle et al. (1995, 2008, 2010), additional reports and papers from intensive literature searches, and by personal communications with biologists working with each taxon. The information was summarized in standardized species accounts which included evaluation of status. All accounts were reviewed by experts on each species. In a few cases, information was updated by field investigations by the authors. The status of each species is as of December 31, 2010.

2.2. Quantitative evaluation of status

Species status was determined using seven metrics scored on a 1–5 scale (Table 1) where 1 was a low score indicating major negative impact on status and 5 was a high score, indicating either no or a positive impact on status. Scores were assigned according to a rubric which was standardized to each threat category (Table 2). Metrics were designed to capture all significant risk factors faced by freshwater fishes while keeping redundancy among metrics to a minimum. Principal component analysis revealed relatively equal weighting of all seven metrics on the final status scores (eigenvectors for principal component one: area occupied, 0.322; adult population, 0.398; intervention dependence, 0.405: tolerance 0.341: genetic risk 0.406; climate change 0.381: anthropogenic threats 0.382). For each species, the seven criteria were averaged to produce a single score for which the threat of near-term extinc-

Table 1
Metrics for determining the status of California fishes, with Sacramento splittail as example. 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. Scoring is described in Table 2.

Metric	Score	Justification
Area occupied	2	Two distinct populations in San Francisco Estuary, using different rivers for spawning
Estimated adult abundance	4	Large in upper estuary, likely small in lower
Intervention dependence	3	Floodplain areas need special management for spawning during droughts
Tolerance	5	One of the most physiologically tolerant native fishes
Genetic risk	3	Two populations; genetically fairly diverse
Climate change	1	Extremely vulnerable to droughts and sea level rise reducing habitat
Anthropogenic causes of decline	2	Multiple, see Table 3
Average	2.9	20/7
Certainty (1–4)	3	Well studied