Revised summary of proposed testimony on development of flow criteria for the Delta ecosystem necessary to protect public trust resources

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I offer this summary of proposed testimony in my professional capacity as a conservation biologist who also is a citizen of California. I am motivated by the opportunity to present scientific information that is highly relevant to management of the state's public trust resources and the hope that diverse interests will achieve consensus on biological facts. In presenting this testimony, I am speaking as an independent scientist, not as a representative of any private or public entity. I have not requested, nor have I received, any financial or other compensation for provision of testimony, nor has any group requested or granted approval of the testimony.

About one percent of species listed under the U.S. Endangered Species Act have met recovery standards, generally understood as levels of abundance and reproduction at which the species can sustain itself without human intervention, and the protections of the Act no longer are necessary (Scott et al. 2005). Most listed species will, at best, require ongoing, species-specific management intervention to remain extant. The latter species, which likely include delta smelt (*Hypomesus transpacificus*), have been characterized as "conservation reliant" (Scott et al. 2005). Evidence suggests that longfin smelt (*Spirinchus thaleichthys*), striped bass (*Morone saxatilis*), and threadfin shad (*Dorosoma petenense*) in the San Francisco Estuary also are likely to require sustained management action to remain extant. Striped bass and threadfin shad are not native to the San Francisco Estuary, and therefore are not eligible for protection under the Endangered Species Act in that region. Nevertheless, the striped bass population in the San Francisco Estuary supports a popular sport fishery, and threadfin shad is an important prey species for some native fishes. Therefore, striped bass and threadfin shad are of regional management concern.

Scott et al. (2005) identified five criteria to determine whether the abundance of a species may remain stable or increase over time if management actions of proven effectiveness are implemented and sustained. Data on abundance are less informative than demographic data (birth, death, emigration, and immigration rates) for estimating probabilities of persistence, but reliable time-series data on demographic variables rarely are available for species of concern. The five criteria discussed by Scott et al. are

1. Threats to the species' continued existence are known and treatable

2. Threats to the species are pervasive and recurrent

3. The threats render the species at risk of extinction, absent ongoing conservation management

4. Management actions sufficient to counter threats have been identified and can be implemented

5. Federal, state, or local governments—often in cooperation with private or tribal interests—are capable of carrying out the necessary management actions as long as necessary

Accordingly, determining whether a species may persist given ongoing management action first requires identification of major threats to its continued existence. Reduction in habitat quality is one of the most common and most substantial threats to persistence of imperiled species in the United States (Wilcove et al. 1998). Assessing habitat quality over time, in turn, requires that the concept of habitat be defined, components of habitat and drivers of those components identified, and the relation between habitat and individual or population-level measures of survival and reproduction quantified.

Concept of habitat. Habitat is the physical space within which an animal or plant lives and the abiotic and biotic resources in that space (Morrison and Hall 2002). Habitat is defined with respect to a given type of animal or plant; few if any species use resources in exactly the same way. The location, spatial extent, and quality of habitat for most species vary in time. The concept of habitat includes the assumption that resources are related in predictable ways to where an animal or plant occurs and to its survival and reproduction, which in turn affects the viability of a population and the persistence of a species.

Drivers of habitat quality for delta smelt and other pelagic fishes. Thomson et al. (in press) identified a non-exhaustive set of 19 abiotic and biotic variables that they expected, on the basis of expert knowledge and published studies, to directly or indirectly drive abundance of delta smelt, longfin smelt, age-0 striped bass, and threadfin shad and for which reliable data are available (Thomson et al. in press; see also Mac Nally et al. in press).

Some of the abiotic and biotic variables, such as average summer water temperature, turbidity, and average biomass of multiple sources of prey, typically would be considered as components of habitat for aquatic species. Other variables, such as the Pacific Decadal Oscillation Index, may affect abiotic and biotic components of habitat. Thomson et al. (in press) also identified variables that may affect the demography of declining pelagic fishes. For example, the volume of water exported by the California State Water Project and Central Valley Project was expected to serve as a surrogate measure of entrainment of juvenile and adult smelt and juvenile striped bass (Mac Nally et al. in press). The relative influence of different abiotic and biotic variables on habitat quality for fishes (as for other taxonomic groups), and the relative association of such variables with abundances of fishes, varies among species and in space and time (Kimmerer 2009). Data on components of habitat for declining pelagic fishes in the San Francisco Estuary often have not been collected in the same places and times as data on the fishes, which makes it difficult to draw strong scientific inference about relationships.

Thomson et al. (in press) also noted the potential effect on abundance of declining pelagic fishes of the introduced clam *Corbula amurensis*, which ultimately reduces availability of prey (Alpine and Cloern 1992). Contaminants (e.g., nutrients, metals, pesticides, and other chemicals present in the estuary) arguably are too numerous and dispersed, sometimes lacking measurements over a sufficient period of time, and potential effects on abundance or fitness of declining pelagic fishes too poorly known, for analyses to provide useful correlative information (Thomson et al. in press).

Relation between abiotic and biotic variables and measures of survival and reproduction. Recent analyses (Thomson et al. in press) indicated sharp declines in abundance of delta smelt, longfin smelt, threadfin shad, and age-0 striped bass in the early 2000s. Abiotic variables including water clarity, position of the 2 psu (practical salinity units) isohaline (X2), and the volume of freshwater exported from the estuary explained some variation in species' abundances over the period of record, but no selected covariates could explain statistically the post-2000 change-points for delta smelt, longfin smelt, threadfin shad, and age-0 striped bass. A change-point is a point in time at which an abrupt change occurred in the functional relationship between the mean abundance of a species and time. A change-point may be either a step change, which is an abrupt change in abundance; a trend change, which is an abrupt change in the temporal trend in abundance; or both.

Potential ability of management actions to counter threats. The ability to evaluate whether management actions are likely to counter threats to persistence of declining pelagic fishes depends on both identification of threats and assessment of human capacity to counter those threats. There currently is no strong empirical evidence that abiotic and biotic components of habitat or drivers of abundance, including water clarity, X2, and the volume of freshwater exports, fully explain the so-called pelagic organism decline. Mac Nally et al. (in press) note that before delta smelt, longfin smelt, threadfin shad, and striped bass declined abruptly in the early 2000s, abiotic drivers of their distribution in the San Francisco Estuary were represented mainly as X2 because position of the salinity field was associated with measures of resource availability and abundances of many organisms (Jassby et al. 1995). However, several studies highlight the importance of other abiotic variables, including water clarity and water temperatures, in the estuary (Feyrer et al. 2007, Nobriga and Feyrer 2008). It has been suggested that management actions are unlikely to sustain declining pelagic fishes in the absence of improved understanding of how water exports may interact with abiotic conditions and the food web (Mac Nally et al. in press).

Theoretical modeling suggests that abundances of pelagic fishes might increase somewhat and then stabilize if numerous and diverse drivers of habitat and abundance (11 modeled in this case) could be manipulated: for example, water temperatures and freshwater exports maintained at moderate levels within the historical record of variation, food availability increased, predation decreased (R. Mac Nally, personal communication). In reality, however, there are concerns that abundances are sufficiently low that populations are susceptible to demographic stochasticity (that is, so-called small population effects) and may not be highly responsive to environmental changes (R. Mac Nally, personal communication). Thus, it is unclear whether changes in water clarity, X2, and the volume of freshwater exports would have a high probability of stabilizing or reversing the decline. This does not mean there is no relationship between these components or drivers of habitat and abundance of pelagic fishes. Actions that affect these components well may have positive effects on the fishes. Nevertheless, in and of themselves, changes in water quality, X2, and the volume of freshwater exports likely will not sustain pelagic fishes indefinitely.

Several feasible areas of future work might identify new or clarify currently understood components or drivers of habitat that are most strongly associated with abundance of pelagic fishes and that may be amenable to management. For example, Sommer et al. (2007) and Baxter et al. (2008) considered many hypotheses for declines in abundance, including changes in stock-recruitment relations and food webs, mortality from predation and water diversions, contaminants, and changes in the physical environment. Formal statistical methods (e.g., Green 1995) could be applied to existing data on attributes of habitat and abundances of fishes at different life-history stages to compare weights of evidence for the different hypotheses (Thomson et al. in press).

Many management planning efforts have assumed that different abiotic and biotic attributes represent habitat for multiple species, then assumed that management of those attributes will benefit many species simultaneously (Hunter 2005). In theory, by emphasizing elements of the environment (for example, X2) or processes (for example, primary production) that provide resources for multiple species, the number of species that require individually tailored management interventions may be reduced. But the effectiveness of this strategy relies on identification of environmental components that are critical to many species, and prediction of the response of a high proportion of the species to perturbations in those key components.

Inference is strong that long-term declines of delta smelt, longfin smelt, threadfin shad, and striped bass have been caused in large part by human land uses that have altered California's ecosystems in potentially irreversible ways. Given these circumstances, it is reasonable to assume that the species are at best conservation reliant. Science can help estimate probabilities that alternative management actions will result in certain biological responses. Nevertheless, determining the level of resources that should be allocated to management of species of concern ultimately is not a scientific decision but a societal decision (Scott et al. 2005).

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