Conservation Practice and Policy

A Critical Assessment of the Use of Surrogate Species in Conservation Planning in the Sacramento-San Joaquin Delta, California (U.S.A.)

DENNIS D. MURPHY,* PAUL S. WEILAND,† AND KENNETH W. CUMMINS‡

*Biology Department, University of Nevada, Reno, NV 89511, U.S.A., email ddmurphy@biodiversity.unr.edu
†Nossaman LLP, Irvine, CA 92612, U.S.A.
‡California Cooperative Fisheries Unit, Humboldt State University, Arcata, CA 95521, U.S.A.

Abstract: *Conservation biology has provided wildlife managers with a wealth of concepts and tools for use in conservation planning; among them is the surrogate species concept. Over the past 20 years, a growing body of empirical literature has demonstrated the limited effectiveness of surrogates as management tools, unless it is first established that the target species and surrogate will respond similarly to a given set of environmental conditions. Wildlife managers and policy makers have adopted the surrogate species concept, reflecting the limited information available on most species at risk of extirpation or extinction and constraints on resources available to support conservation efforts. We examined the use of surrogate species, in the form of cross-tax on response-indicator species (that is, one species from which data are used to guide management planning for another, distinct species) in the Sacramento-San Joaquin Delta, California (U.S.A.). In that system there has been increasing reliance on surrogates in conservation planning for species listed under federal or state endangered species acts, although the agencies applying the surrogate species concept did not first validate that the surrogate and target species respond similarly to relevant environmental conditions. During the same period, conservation biologists demonstrated that the surrogate concept is generally unsupported by ecological theory and empirical evidence. Recently developed validation procedures may allow for the productive use of surrogates in conservation planning, but, used without validation, the surrogate species concept is not a reliable planning tool.*

Keywords: best available science, Chinook salmon, green sturgeon, National Marine Fisheries Service, steelhead, surrogates, surrogate species

Una Evaluación Crítica del Uso de Especies Sucedáneas en la Planificación de la Conservación en el Delta Sacramento-San Joaquín, California (E.U.A.)

Resumen: *La biología de la conservación ha proporcionado a los manejadores de vida silvestre una amplia gama de conceptos y herramientas para la planificación de la conservación, entre ellos el concepto de especies sucedáneas. En los últimos 20 años, un creciente cuerpo de literatura empírica ha demostrado la efectividad limitada de los sucedáneos como herramientas de manejo, a menos que primero se establezca que la especie blanco y la sucedánea responderán de manera similar a un conjunto determinado de condiciones ambientales. Los manejadores de vida silvestre y los tomadores de decisiones han adoptado el concepto de especie sucedánea, reflejando la limitada información disponible sobre la mayoría de las especies en riesgo de extirpación o extinción y las limitaciones en los recursos disponibles para financiar los esfuerzos de conservación. Examinamos el uso de especies sucedáneas, en la forma de especies trans-taxón indicadoras de respuesta (esto es, una especie de la que se usan datos para guiar la planificación del manejo de otra especie),*

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en el Delta Sacramento-San Joaquín, California (E. U. A.). En ese sistema ha habido creciente confianza en los sucedáneos en la planificación de la conservación de especies enlistadas en las actas federales o estatales de especies en peligro, aunque las agencias que aplican el concepto de especie sucedánea primero no validan que la especie sucedánea y la especie blanco respondan similarmente a condiciones ambientales relevantes. Durante este mismo período, los biólogos de la conservación demostraron que el concepto de especie sucedánea generalmente no es sostenido por la teoría ecológica ni la evidencia empírica. Procedimientos de validación desarrollados recientemente pueden permitir el uso productivo de sucedáneos en la planificación de la conservación, pero, utilizados sin validación, el concepto de especies sucedáneas no es una herramienta de planificación confiable.

Palabras Clave: especies sucedáneas, esturión verde, mejor ciencia disponible, salmón Chinook, Servicio Nacional de Pesquerías Marinas, sucedáneos, trucha arco iris

It could be that conservation biology has proven so useful in advancing concepts and designing tools for conservation planning that agencies with jurisdiction over fish and wildlife have grown accustomed to drawing affirmative direction from the scientific literature without considering whether the concepts or tools are applicable in real-world circumstances. It has become commonplace to find the application of basic rules of reserve design, reference to metapopulation structure in the distribution of a species at risk of extirpation or extinction, and attempts at population viability analyses in individual agency determinations made under the U.S. Endangered Species Act. A generation ago these products of conservation biology and their application were the subjects of vigorous academic exchanges; today they are routinely applied in efforts to meet the challenges in protecting and recovering imperiled species and the ecosystems on which they depend. The pragmatic and successful application of reserve-design and management-planning tools in a wide array of circumstances may have led to the false impression that essentially all ideas emerging from conservation biology have strong scientific support. But, some of the concepts and tools that conservation biologists have developed and refined over time have not proven as reliable as others. We argue that the standing scientific literature clearly indicates that the surrogate species concept does not have universal application and must be applied prudently.

The use of surrogate species to guide management of imperiled species for which little ecological or behavioral data are available has obvious intuitive appeal. Protected species frequently are rare, elusive, or cryptic. They seldom are readily counted, measured, or surveyed. There is an almost universal shortfall of information to guide their management; and, many species at risk of extirpation or extinction are so sensitive to disturbance that the very process of gathering essential information can be inadvisable. What better than to draw inferences from species that are better known, more readily tracked and measured, and less imperiled? This attractive idea, combined with severe resource constraints in conservation planning that necessitate the use of shortcuts wherever possible, has in some cases led to the inappropriate use of surrogate species. The predictable outcomes are decisions that are unlikely to achieve conservation objectives and ineffective expenditures of scarce funds dedicated to conservation planning efforts.

Researchers, wildlife managers in government agencies, and policy makers embraced the use of readily available data on certain species to inform agency determinations and actions involving other species for which there was a paucity of data (Landres 1992; Cushman & McKelvey 2009); however, the efficacy of surrogates in management of imperiled species was not supported by ecological theory or by empirical research. And, it was the assumption that information derived from surrogate species could substitute for information for other, distinct species, without validation, that caught the attention of early critics. Concern over both the frequent invocation of surrogates in U.S. Forest Service planning and institutional reliance on "management indicator species" led Landres et al. (1988:317) to conclude that the assumptions on which the use of surrogates are based "fail on conceptual and empirical grounds." They proffered a definition of indicator species that is consistent with the definition of surrogate species we use here—that is, an organism that responds to relevant environmental conditions in a manner similar to the target species, for which data are too difficult, inconvenient, or expensive to gather. Landres et al. also initiated an intellectual exchange on the reliability of using surrogate species in conservation planning.

Over the next 2 decades, conservation biologists engaged in a dialogue and concluded that, without prior validation, reliable information on select species or environmental attributes cannot be readily applied to guide conservation actions for species for which data are lacking. Landres et al. (1988:316) caution that "an absence of precise definitions and procedures, confounded criteria used to select species, and discordance with ecological literature severely weaken the effectiveness and credibility of using vertebrates as ecological indicators," including surrogate species. Lambeck (1997:855) stated that "critical appraisal" must be made of the data available to determine whether surrogate approaches are warranted. Caro and O'Doherty (1999:811) note that studies involving surrogates require "that criteria on which surrogates are being chosen be specified explicitly" and meet objective criteria, and they recommend "preliminary study of the efficacy of proposed surrogates" before investigations are initiated. Andelman & Fagan (2000:5959) found that use of distributional data for a random assortment of species is as effective or more effective for conservation planning as use of data on surrogates. Lindenmayer et al. (2002:342) note that a defensible surrogate or a focal-species approach is "data intensive and demands detailed information" about the species involved. More recently, Caro et al. (2005:1825) devised a validation process that could provide for the defensible use of surrogates, but offer a coda that "the assumptions required to use substitute species in conservation biology are too onerous when applied to trying to predict population responses to anthropogenic disturbance. Where at all possible, we advocate making every possible effort to examine the target species directly before resorting to substitute species." During the same period, numerous researchers reported findings of studies of species co-occurrences and, in several cases, of species' responses to environmental stressors and found few examples in which one species is an effective surrogate for one or more other species or in which conservation of one species reliably serves to conserve others (Dickson et al. 2009; Fleishman & Murphy 2009; Banks et al. 2010). The studies included assessments of plants, invertebrates, mammals, birds, and fish (e.g., Austin et al. 1990; Launer & Murphy 1994; Rowland et al. 2006).

The proposition that surrogate species should be used only as a last resort and then only after ascertaining whether the surrogate and the target species would respond in the same manner to particular environmental conditions has been broadly, but not universally, accepted. The use of surrogate species in conservation planning in California's Sacramento-San Joaquin Delta over the 2-decade period during which the issue of surrogate species was actively debated in academic circles exemplifies the chasm that can exist between the conservation biology literature and management practices. The Sacramento-San Joaquin Delta has been highly altered by human activity and is composed of hardened channels and reclaimed islands (that were previously inundated, perennially or seasonally) at the confluence of the Sacramento and San Joaquin rivers in northern California. It is occupied by dozens of imperiled species, including six fishes that were listed as threatened or endangered under the California Endangered Species Act, the U.S. Endangered Species Act, or both between 1989 and 2009. The delta is also the hub of the federal Central Valley Project and State Water Project, an expansive collection of dams and reservoirs upstream of the delta and water export facilities in the delta. Together the projects provide water for more than 20 million Californians and approximately 1.5 million ha of productive agricultural land.

Since the federal listing of the Sacramento River winter-run Chinook salmon (*Oncorhynchust shawytscha*) in 1989, operations of the water-supply system have been constrained by regulatory agencies implementing federal and state laws intended to contribute to the conservation of the protected fishes. Directives to reduce water exports and adjust their timing are implemented under federal law through interagency consultation, which is a process mandated by provisions in section 7 of the U.S. Endangered Species Act. Those provisions require every federal agency, in consultation with and with the assistance of the National Marine Fisheries Service (NMFS) or Fish and Wildlife Service (FWS), to ensure that any action authorized, funded, or carried out by such an agency is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat of such species. In fulfillment of this requirement, NMFS or FWS must prepare a biological opinion documenting that agency's position on the effects of a proposed federal action on the apposite species and on conditions necessary to limit those effects.

The National Marine Fisheries Service first imposed a set of water-export constraints in 1993 under a biological opinion that addressed the effects of long-term operations of the Central Valley and State Water Projects on Sacramento River winter-run Chinook salmon (NMFS 1993). The agency did not make extensive use of surrogate species, or, more precisely, of cross-tax on response-indicator species (i.e., a species other than the target species, data on which are used inferentially to inform management of the target species [Caro 2010]) in that biological opinion. Nevertheless, NMFS drew inferences about the probable responses of winter-run Chinook to particular environmental conditions on the basis of available data on the responses of other runs (that is, other evolutionarily significant units) of Chinook to those conditions. Specifically, NMFS referenced studies that compared losses of juvenile fall-run Chinook that had been released upstream and downstream of Red Bluff Diversion Dam, which is located on the Sacramento River upstream of the delta, and opined that winter-run Chinook would likely have similar rates of mortality around the same facility (NMFS 1993:38). The agency noted that the targeted winter-run Chinook salmon and surrogate fall-run Chinook have different residence times in freshwater prior to emigration and exhibit different average body lengths at time of entry into saltwater (NMFS 1993:27–28), attributes that could be expected to substantively affect the responses of the two different salmon runs to many environmental stressors.

In 2004 NMFS released an updated biological opinion to address the effects of long-term operation of the water projects on Sacramento River winter-run Chinook salmon, Central Valley steelhead (*Oncorhynchus mykiss*), and Central Valley spring-run Chinook salmon, which NMFS listed as threatened in 1998 and 1999, respectively (NMFS 2004). In this updated opinion, NMFS made greater use of surrogate species. The agency assumed spring-run Chinook would have rates of mortality similar to conspecific late-fall-run Chinook at the delta water-export facilities (NMFS 2004). At the same time, NMFS assumed steelhead would have rates of mortality similar to Chinook salmon at those facilities (NMFS 2004). The agency did not establish the validity of the use of surrogates in its determinations, but explicitly characterized its use of late fall-run Chinook salmon for spring-run Chinook and Chinook salmon for steelhead as assumptions that informed the analyses it carried out.

The National Marine Fisheries Service made these assumptions while recognizing, for example, "that steelhead mortality through the delta facilities may be less than for Chinook salmon" (NMFS 2004:97). We think this recognized difference between the two species is essential to conservation planning, given that juvenile steelhead spend substantially more time on average rearing in freshwater than juvenile Chinook salmon (1–3 years for steelhead versus 6 months to 2 years for Chinook) and, therefore, are two to five times larger during emigration through the delta. Differences in age and size, therefore swimming strength, during emigration influence the prey base used by the two salmonid species, their susceptibility to predation and other sources of mortality, and the duration of their migration to the ocean. These differences, which can affect survival during emigration, are relevant because NMFS attributes all mortality during passage through the south delta to Central Valley and State Water Project operations and their effects on hydrodynamic conditions.

In 2009 NMFS issued a third biological opinion that was intended to address again the effects of long-term operation of the Central Valley Project and State Water Project on Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead. In this opinion the agency added the southern distinct population segment of North American green sturgeon (*Acipenser medirostris*), which received federal protection in 2006. To a greater extent than in the 1993 and 2004 biological opinions, the 2009 opinion relied on surrogate species to evaluate the effects of water project operations and to prescribe conservation measures (referred to collectively as a reasonable and prudent alternative) to accompany water-export actions. The National Marine Fisheries Service used data derived from hatchery Chinook salmon to predict the behavior of wild Chinook in response to certain environmental conditions and used data on fall-run and late fall-run Chinook to predict the behavioral responses of steelhead and green sturgeon (NMFS 2009*a*). The agency acknowledged that the responses of hatchery and wild Chinook salmon to certain environmental conditions may differ (NMFS 2009*a*:62), and empirical research provides a basis for adopting the working hypothesis that hatchery salmon have lower fitness than wild salmon (Roper & Scarnecchia 1996; Jonsson et al. 2003; Buchanan et al. 2010). Furthermore, research from the Columbia River system published after the agency issued the biological opinion for Sacramento-San Joaquin Delta fishes provides empirical support for the proposition that levels of mortality differ between hatchery and wild Chinook during emigration (Buchanan et al. 2010).

The agency also acknowledged that Chinook salmon and steelhead survival rates during emigration down the San Joaquin River may differ. An independent review body, which was impaneled to evaluate conservation actions on the San Joaquin River, was sufficiently certain of these differences to conclude that data regarding Chinook salmon behavior do not provide a reliable basis for inference regarding steelhead behavior (Hankin et al. 2010:11). Use of data from Chinook salmon most likely is not reliable for purposes of predicting green sturgeon behavior, given the substantially different life histories of the two species. Phylogenic differences are great between these species, as are salient fitness-related differences in lifespan, spawning, and fecundity. Chinook salmon can live to be 3–5 years old, spawn once, and produce 2,000 to 17,000 eggs, whereas green sturgeon can live to be 60–80 years old, are repeat spawners, and produce 60,000–140,000 eggs (Moyle 2002).

The use of data on comparative survival of one run of Chinook salmon to predict the comparative survival of a different run of the same species in response to an identical environmental condition comported with management practices in the early 1990s, although not with emerging scientific literature on the use of surrogate species. In the 2004 biological opinion, however, NMFS referenced neither advances in knowledge of the ecology and behavior of Chinook salmon nor the growing body of empirical research (e.g., Caro & O'Doherty 1999; Andelman & Fagan 2000) indicating presumptive surrogate species do not respond in the same manner as target species to given environmental conditions. Instead, the agency used data regarding surrogate species to predict the behavior of target species without first validating its decision to use surrogates and while recognizing that the surrogate and target were likely to respond differently. Five years later, in NMFS' 2009 biological opinion, the agency relied even more extensively on data from surrogate species to predict the behavior of other distinct species, including those with disparate life histories. As described above, it used data regarding Chinook salmon to predict the ecological responses of green sturgeon to water-export actions in the delta. The agency did not provide an explanation for its decision to rely on surrogate data to, for example, predict the behavior of steelhead when substantial data exists regarding the survival of steelhead during emigration in other river systems (e.g., Smith et al. 2002).

The reliance by NMFS on inferences from surrogate species to direct actions intended to conserve several of California's imperiled fishes is not just a manifestation of a disconnect between resource management and evolving scientific consensus. The ecological ramifications of NMFS' reliance on surrogate species are uncertain, and empirical investigation of those ramifications is beyond the scope of this article. But the assumptions embodied in the agency's application of surrogates may lead to conservation actions that have real societal effects (e.g., by affecting the timing and volume of water exports from the delta) and do not contribute to maintaining or increasing the viability of several of the delta's most imperiled species. The Sacramento River winter-run Chinook salmon, for example, has a substantially lower population size than 40 years ago, declining from an estimated population of more than 40,000 in 1970 to 2,800 in 2008 (NMFS 2009*b*:17). Although there is no evidence that conservation actions, drawn in large part from information on surrogates, have led to increases in abundance of target species, other regulatory agencies have followed the lead of NMFS and extended their use of the surrogate approach. California's State Water Resources Control Board recently released a draft technical report on the scientific basis for alternative San Joaquin River flow regimes and southern delta salinity control objectives. Citing NMFS' 2009 biological opinion, the state board stated "conditions that favor fall-run Chinook salmon are assumed to provide benefits to co-occurring steelhead populations and other native fishes" (SWRCB 2010:35). The open-ended suggestion that some number of unidentified native fishes will benefit from the same flow regime as Chinook salmon remains unsupported by theory or by evidence that the life history and biological requirements of the unidentified species are such that the fishes will respond in the same manner to flows in the San Joaquin River system.

The State of California and agricultural and urban water users filed lawsuits in federal court challenging the 2009 biological opinion, including the scientific basis for the export restrictions in the opinion that are intended to benefit emigrating salmonids and the green sturgeon. Among contended issues is the use of data from a surrogate species, without confirmation that the target and surrogate species will respond similarly, to determine water export schedules in the delta. In court filings, NMFS responded that it "has a long history of using hatchery fish as standard surrogates for wild salmon and steelhead to assess the impacts of various water project operations" throughout the western United States and that to discontinue the approach would be "disregarding a preponderance of the studies in the Central Valley," including in the delta (NMFS 2010*a*:14). Furthermore, NMFS inferred that, because the surrogate hatchery-derived Chinook salmon and the target species occur in the same rivers and are both subject to the same environmental conditions, their ecological and behavioral responses to their environment will be similar (NMFS 2010*b*). But co-occurrence and general biological similarities between a target species and a substitute do not justify using data from a surrogate species to inform conservation planning for a target species; rather, it is similarities in ecological and behavioral responses to specific environmental conditions that are shared or not shared by a target and a candidate surrogate that should inform that decision.

Both the National Marine Fisheries Service and the Fish and Wildlife Service are required by law to "use the best available scientific and commercial data" to inform their policy determinations. The literature (e.g., Landres 1992; Caro & O'Doherty 1999; Andelman & Fagan 2000; Weins et al. 2008) provides scientifically credible guidance for the use of surrogates. Combine that guidance with the reasoned validation procedures invoking salient demographic data and thresholds in Caro et al. (2005) and a subsequent effort to test a more parsimonious approach to surrogate validation using data from co-occurring species by Wenger (2008), and one can argue fairly that the federal wildlife agencies have a defensible basis for making decisions whether to use surrogates or substitute species in their policy determinations.

In our judgment, the time is ripe for the federal government to adopt regulations and provide policy guidance regarding the use of surrogate species in the course of implementing the Endangered Species Act. The surrogate species concept has developed considerably over the past quarter century (Caro 2010). We think policy guidance should begin with the acknowledgment that, in conservation planning, data on the ecology and behavior of the species targeted by conservation efforts are always preferable to data from a surrogate species. Where a decision is made that data on the target species are insufficient, we think it should first be established that the surrogate species and the target species are highly likely to have similar demographic responses to the environmental conditions that can be managed. A growing number of conservation biologists have posited means to validate the use of surrogate species (e.g., Caro et al. 2005; Wenger 2008). Limited data and looming regulatory deadlines can be the impetus to seek information from a reliable surrogate to guide conservation actions, but those same conditions do not justify default to surrogate species on the basis of a surmise that the two species are sufficiently alike.

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