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Management by Assertion: Beavers and Songbirds at Lake Skinner (Riverside County, California)

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Abstract Management of ecological reserve lands should rely on the best available science to achieve the goal of biodiversity conservation. ''Adaptive Resource Management'' is the current template to ensure that management decisions are reasoned and that decisions increase understanding of the system being managed. In systems with little human disturbance, certain management decisions are clear; steps to protect native species usually include the removal of invasive species. In highly modified systems, however, appropriate management steps to conserve biodiversity are not as readily evident. Managers must, more than ever, rely upon the development and testing of hypotheses to make rational management decisions. We present a case study of modern reserve management wherein beavers (*Castor canadensis*) were suspected of destroying habitat for endangered songbirds (least Bell's vireo, *Vireo bellii pusillus*, and southwestern willow flycatcher, *Empidonax traillii extimus*) and for promoting the invasion of an exotic plant (tamarisk, *Tamarix* spp.) at an artificial reservoir in southern California. This case study documents the consequences of failing to follow the process of Adaptive Resource Management. Managers made decisions that were unsupported by the scientific literature, and actions taken were likely counterproductive. The opportunity to increase knowledge of the ecosystem was lost. Uninformed management decisions, essentially ''management by assertion,'' undermine the long-term prospects for biodiversity conservation.

Keywords Adaptive resource management · Endangered species · Succession · Invasive species · Tamarisk · Least Bell's vireo

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Introduction

As a response to ongoing habitat destruction and urbanization, conservation efforts often include the establishment of ecological reserves. Managing such ecological reserves for any goal, whether for game animals or for rare and endangered species, should be informed by the best available science. Indeed, the Endangered Species Act requires the use of science in decisions regarding listed species (Smallwood and others 1999). The best scientific data, however, often are not directly applicable to management problems. Rarely do published scientific studies address the challenge of a particular management situation, and guidance comes only through considering and interpreting the existing ''basic'' science. Historically, managers dealt with such situations through intuition and experience (Pullin and Knight 2003; Pullin and others 2004). While it is possible for this approach to be successful, it does not contribute to the greater scientific understanding that is necessary to improve subsequent management efforts. In response to the need for managers to learn about the systems they manage, ''Adaptive Resource Management'' was developed (Holling 1978; Walters 1986). Adaptive Resource Management is a hypothetico-deductive approach to wildlife and biodiversity management that provides a framework to learn about systems through management actions. Given a set of known management goals, Adaptive Resource Management allows for rational decision-making and management actions that result in scientific knowledge while conservation goals are achieved.

In ecosystems that are not greatly affected by human activities, management decisions are usually somewhat more straightforward than in systems that are highly modified. This is especially true for the conservation of endangered species and native biodiversity. In highly modified systems, however, some elements that under many circumstances would be considered undesirable are actually essential to the preservation of a sensitive species. For example, grazing by cattle serves to maintain the foodplant for bay checkerspot butterfly (*Euphydryas editha bayensis*) on Morgan Hill in northern California because of the amount of dry deposition of nitrogen that fertilizes the grasses at the site (Weiss 1999). In this instance, something that would often be considered detrimental to an undisturbed system, i.e., cattle grazing, aids in achieving conservation goals. Because the interactions between factors in such highly modified systems are complex, and results of management decisions may be unexpected, a sound Adaptive Resource Management approach is especially appropriate.

In this article, we present a case study to show the need for Adaptive Resource Management in modified systems. Using a science-based, iterative approach to managing reserve lands holds promise to increase scientific understanding and stakeholder satisfaction (Haney and Power 1996); this article illustrates the results of failing to do so. The case study involves the removal of beavers (*Castor canadensis*) from the Southwestern Riverside County Multi-Species Reserve (“Reserve”) near Temecula, California, for the stated purpose of protecting habitat for two endangered songbirds, least Bell’s vireo (*Vireo bellii pusillis*) and southwestern willow flycatcher (*Empidonax traillii extimus*). We review the process of Adaptive Resource Management and then contrast this with the process that led to the removal of the beavers from the Reserve.

This case study is emblematic of the challenges facing conservation in the arid and semi-arid Southwest, and especially in urbanizing California. Management of riparian systems in the Southwest is particularly challenging because there is very little ecosystem redundancy. Furthermore, the rapid pace of urban development has resulted in conservation strategies that place the burden of maintaining ecosystems on a limited reserve system. These reserves must then be managed based on short-term datasets that cannot possibly incorporate the breadth of natural occurrences, including disturbance regimes. In a situation where information is limited and the baseline is inadequate, making repeated mistakes can be avoided by committing early and substantively to an Adaptive Resource Management approach.

Process of Adaptive Resource Management

Adaptive Resource Management can be thought of as a series of six steps (Haney and Power 1996). While it would be possible to implement the steps linearly, they more often work as a cycle, with repetition of steps as conditions change and results are obtained. Assuming that a management problem has been identified, and managers have decided that time, effort, and resources will be expended on the issue, the idealized process would then include the following steps.

1. Compile, Inventory, and Exchange Information. Information about the problem, the ecosystem, and previous scientific results are compiled and exchanged with stakeholders in the decision-making process. This information is used to formulate management options and develop testable hypotheses about ecosystem function. This step should include a literature review, field surveys, and compilation of ecological/geographic information such as maps, GIS layers, and historic data. At this stage, information can be exchanged with all stakeholders.
2. State Goals and Objectives. A clear statement of the specific goals and objectives must be devised and accepted by involved parties.
3. Develop Model. Based on the information gathered about the ecosystem, and the relevant published literature, managers must develop a set of working hypotheses about how they believe the ecosystem functions relative to the problem at hand. This may take the form of a mathematical model or conceptual model of ecosystem relationships and should be based on information gathered about the ecosystem and the relevant scientific literature.
4. Implement Management. Management actions should be taken to solve the problem and at the same time test portions of the conceptual model. Given that the model may contain uncertainty in terms of ecosystem function, different treatments may be implemented in different areas.
5. Monitor. After managing the system for some time, compare observed ecological changes to

outcomes predicted by the conceptual model. Monitoring schemes must be carefully designed to allow for rigorous testing of the hypotheses under investigation. Replication of treatments and provision of control sites may be necessary as part of a rigorous study design.
6. Analyze Data and Evaluate Model. Managers use the results of monitoring efforts to test the hypotheses derived from the underlying model of ecosystem function. Their evaluations may either confirm the model or result in its modification and the development of testable, alternative hypotheses.

This approach melds science and management to both increase knowledge and achieve management goals. As Haney and Power (1996; p. 885) conclude, ''Management will be successful in the face of complexity and uncertainty only with holistic approaches, good science, and critical evaluation of each step. Adaptive management is where it all comes together.'' By forcing managers and stakeholders to review existing knowledge and develop an explicit model of ecosystem function, adaptive management prepares practitioners for a wider range of possible ecosystem responses. This preparation is especially useful in situations where exotic species are interacting in combinations that have not yet been investigated.

Case Study: Beavers in the Southwestern Riverside County Multi-Species Reserve

''Beavers Will Die So Birds Can Survive.'' This headline ran in the local Riverside, California, newspaper in January 1999 (Farwell 1999a). It marked the beginning of an effort by the management of the Southwestern Riverside County Multi-Species Reserve to eliminate beavers with the purpose of protecting songbird habitat. The Reserve, located near Temecula, California, was established in 1992 as mitigation for development of a large reservoir by the Metropolitan Water District of Southern California. The Reserve is covered predominantly with coastal sage scrub, but also includes areas of chaparral, grassland, oak woodland, oak riparian forest, sycamore/alder riparian woodland, southern willow scrub, and cottonwood/willow riparian forest (Monroe and others 1992). Riparian habitat covers fewer than 50 acres across six drainages within the Reserve, but the Reserve is contiguous with a 2,000-acre reservoir, Lake Skinner, with additional riparian resources. The management goals of the Reserve are to protect habitats from human disturbance, promote recovery of ''historic, native plant and animal communities,'' and manage for ''bio-diversity'' (Monroe and others 1992). Management decisions require a unanimous vote of a five-member Reserve Management Committee. The Committee is composed of one representative each from the Metropolitan Water District, the Riverside County Habitat Conservation Authority, the California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the Riverside County Park and Open Space District (Monroe and others 1992).

From 1999 to 2001, we participated in, observed, and recorded the debate over removal of beavers from Lake Skinner and the Reserve. We communicated extensively with personnel from the Reserve and the Reserve Management Committee, both in writing and orally, as advocates for a deliberative scientific approach to the perceived problem and for humane treatment of the beavers. We believed that the management action as originally proposed was inhumane, not supported by the available science, and not designed in a manner that would have allowed a scientific assessment of whether the proposed action was successful. After the completion of the management action, we submitted a Freedom of Information Act (''FOIA'') request to the local U.S. Fish and Wildlife Service office to obtain copies of all materials pertaining to beavers and endangered songbirds at the Reserve. In response to this request, we received many primary documents, including minutes of the Reserve Management Committee meetings.

In 1998, Reserve managers made the determination that the presence of beavers in Lake Skinner and the adjacent Reserve posed a problem that should be addressed. The managers presented this issue to the Reserve Management Committee in December 1998. In response, the Committee passed Resolution 80 authorizing the removal of ''all beavers in the Reserve and on Metropolitan property at Lake Skinner'' (Reserve Management Committee 1998). This document was written by Reserve staff for approval by the Reserve Management Committee and contained a brief summary of the proposed action and its rationale.

Resolution 80 and Adaptive Resource Management

Resolution 80 included information that is similar to various aspects of the first four steps of the Adaptive Resource Management process. Certain information was presented, goals were stated, a model of ecosystem function was assumed, and a management action was implemented.

Compile, Inventory, and Exchange Information

The authors of Resolution 80 wrote that from 1995 through 1998, a population of 15 to 20 beavers lived in the riparian habitat at the east end of Lake Skinner, where the Reserve is located (Fig. 1). Agency staff estimated that over 100 beavers were living in Lake Skinner, which does not fall under the same management as the Reserve. Resolution 80 asserted that, according to (unspecified) research on the Reserve, the greatest threat to the Reserve was invasion by exotic species (Reserve Management Committee 1998), of which tamarisk (*Tamarix* spp.) was the only species identified that affects riparian areas. The resolution described that in two creeks on the Reserve, Tucalota and Middle, beavers had cut down mature cottonwoods (*Populus* sp.) and willows (*Salix* sp.), including trees up to two feet in diameter. In some locations, tamarisk had replaced those trees cut down. The riparian zone of Middle and Tucalota creeks also supported nesting pairs of least Bell's vireo, a federally listed endangered species, along with other sensitive riparian bird species.

The internal staff notes and meeting minutes provided in response to our FOIA request did not contain any documents that supported the assertions made in Resolution 80. None of the relevant scientific literature about beavers, tamarisk, least Bell's vireo, southwestern willow flycatcher, or riparian vegetation was referenced or reviewed, nor were any unpublished field data included. The observations of ''beaver damage'' were not accompanied by quantitative measurements and no record of the overall distribution and activity of beavers was presented. No permanent plots were established and no baseline conditions were described quantitatively.

State Goals and Objectives

Resolution 80 is clear about goals and objectives. The goal of the Reserve is to preserve threatened and endangered species, primarily by protecting and enhancing habitat for those species. For the purposes of Resolution 80, this goal translated into the objective of protecting riparian habitat for endangered bird species from damage by beavers. We noted, however,

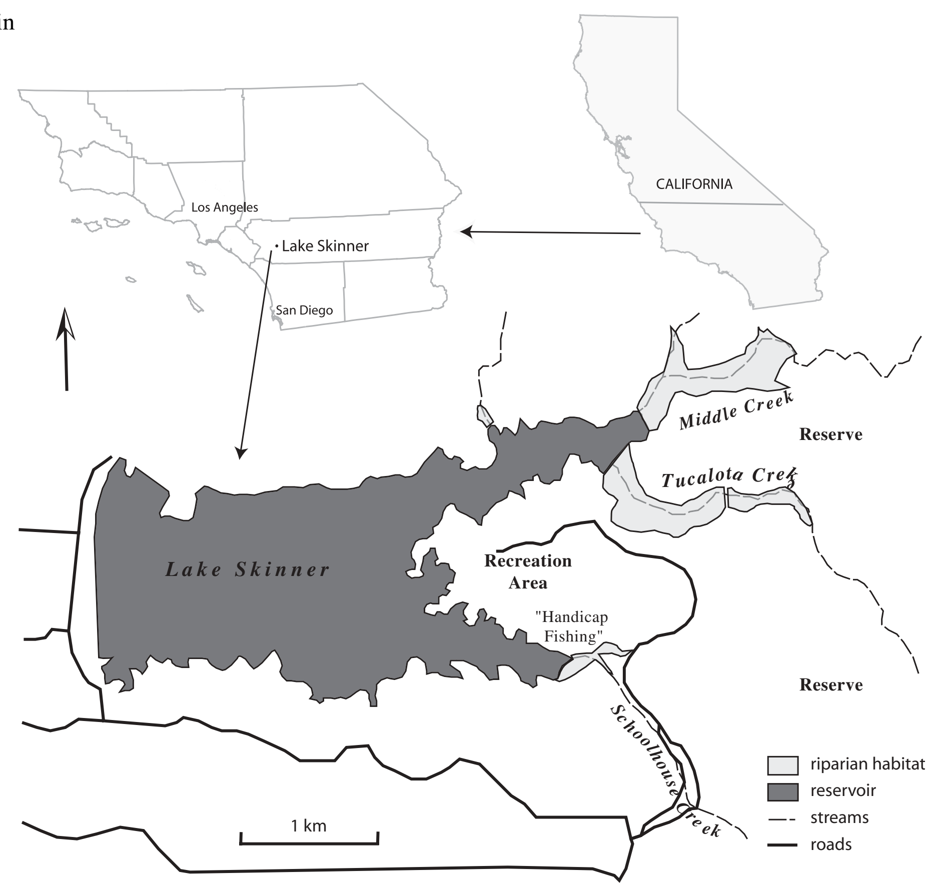


Fig. 1 Map of Lake Skinner reservoir in western Riverside County, California

several other unstated goals that may have been involved in the decision to remove the beavers. For example, in our discussions with Reserve staff, we became convinced that there was considerable concern about beavers removing cottonwood trees along a portion of the shoreline of Lake Skinner (not under Reserve management) that is heavily used for recreation. This motivation was plainly stated by Reserve staff on an invited tour. Furthermore, during the public uproar over the plan, staff members tallied calls from the public on a blackboard in the Reserve office, which we (TL/CR) observed, as being for "beavers" or "trees" (there was no column for "birds"). They clearly were referring to the cottonwood trees around the reservoir, not the willow trees in the Reserve, which were not accessible to the public. Although the cottonwood trees around the reservoir were not important to the endangered birds, managers had installed metal guards around some of these trees in an effort to protect them. Similarly, the eventual trapping also occurred in areas off Reserve lands (i.e., Schoolhouse Creek), despite the restriction to Reserve lands imposed by the permit for removal (DFG Permit no. 20210).

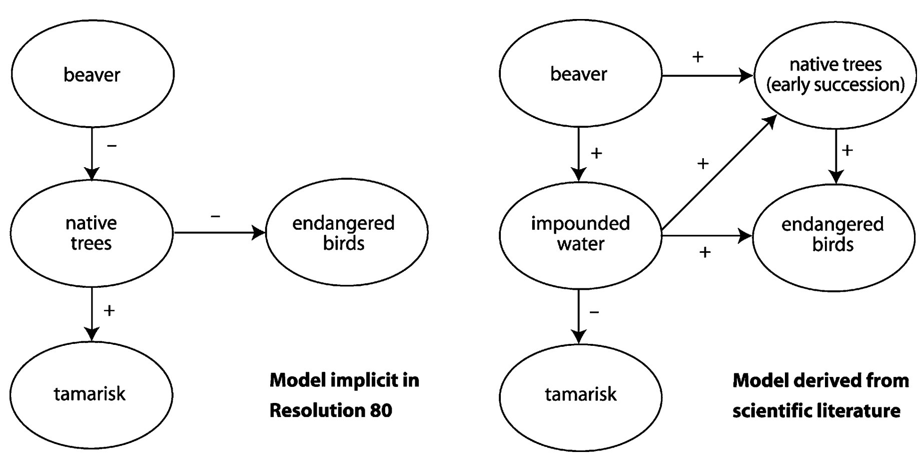
Another motivation may have been at work as well. When the beavers were first noticed in Lake Skinner, the Metropolitan Water District was concerned about water quality. A Metropolitan Water District staff member stated that with respect to the beavers "our primary concern is water quality" (Garcia 1997). This concern was not mentioned in Resolution 80, but U.S. Fish and Wildlife Service staff notes from the February 1999 Reserve Management Committee meeting read, "Wouldn't there be an additional interest in terms of water quality if in fact these animals are carrying diseases?" As it turned out, the animals were tested after being trapped and determined not to be carrying any diseases communicable to humans. This information was available only after the trapping was completed so we could not assess whether this knowledge would have changed management decisions.

Develop Model

Although the Reserve Management Committee did not review the existing literature and offered little referenced support, the Committee did present a model of the ecosystem in Resolution 80. The Resolution stated that exotic species are the largest threat to the Reserve, identifying the most significant threats as exotic grasses, mustard, and tamarisk. The Resolution stated that beavers are not native to the Reserve and were exploiting "artificial conditions created by the reservoir." The Reserve Management Committee believed that the beavers would remove existing riparian trees, causing harm to endangered least Bell's vireo and other riparian bird species, and that these trees would be replaced by tamarisk. The Committee implied that the removal of riparian trees by beavers created a regeneration niche for tamarisk and that tamarisk would replace cottonwood and willow (Fig. 2). Resolution 80 describes the effect of beavers as "virtually total loss of riparian habitat integrity in Middle and Tucalota creeks. In the worst case, this habitat would be completely replaced by tamarisk and other exotic plants. In the best case, the habitat damage caused by beavers would result in a 20–40-year loss of a functional native riparian habitat" (Reserve Management Committee 1998).

It is unclear how the Reserve Management Committee concluded that the management effort would eliminate beavers. The Committee members were well aware that the management action would not remove all beavers in Lake Skinner. Prior to implementation of the trapping program, they were also told by various interested parties, including us, that beavers can

Fig. 2 Model of interactions between beavers and selected ecosystem components from Resolution 80 (left) and scientific literature (right)



disperse significant distances and would quickly recolonize the Reserve from the contiguous, occupied habitat (see Houston and others 1995; Jenkins and Busher 1979; Olson and Hubert 1994). Nevertheless, they implemented Resolution 80 with the justification that it would protect endangered songbird species from habitat destruction by beavers.

Implement Management

In early 1999, the Reserve Management Committee hired a pest control company to set lethal traps for beavers on Reserve lands. A public outcry ensued, with two major points being raised. First was the concern that removal might not be necessary for the stated purposes and was not supported by the best available science. Second was dismay at killing the animals, especially in an inhumane manner. The arguments about necessity were raised by scientific experts from three nonprofit stakeholders: The Urban Wildlands Group, The Humane Society of the United States, and Beavers: Wetlands & Wildlife. This concern did not seem to affect the decisions made by the Reserve Management Committee, which deferred to the biological judgment of the non-scientist Reserve Manager. During the ensuing weeks, the Reserve Manager agreed to relocate rather than kill the animals. Thirteen beavers were trapped live and removed (Farwell 2001b), one died struggling in a snare, and one was killed by a predator while held in a snare (Farwell 1999b). Virtually all mortality could have been avoided if Hancock traps had been used (and properly deployed) (Collins 1976; Hammerson 1994). The end result was not satisfactory to the majority of opponents because of the Reserve's failure to engage the underlying scientific questions, the mortality during trapping, and philosophical opposition to the exploitative placement of the relocated animals. Six beavers were confined in zoos or other captive display facilities (one beaver subsequently died in a fight resulting from inappropriately co-housing two males), four were relocated to a reserve in Texas, and three went to a movie production company. The trapping was complete by Spring 1999.

A final issue surrounding trapping was the failure to complete environmental review under the California Environmental Quality Act. Such review would have provided the public an opportunity to comment, and theoretically would have revealed the extensive scientific literature that could have informed the management decision. The *ad hoc* group Friends of Lake Skinner Wildlife sued the Reserve over this failure and ultimately prevailed, with the court ruling that environmental review would be required if beavers were to be removed in the future (Schexnayder 2001).

Monitor

Reserve managers did not implement a systematic monitoring plan to document changes to the riparian area following the removal of beavers. However, the Reserve biologist made claims in the local press that, "The quality and size of the habitat has improved dramatically since the beavers were removed," and, "As long as the habitat is improving—and that's what we're seeing—you can expect to see more and more birds [least Bell's vireos]" (Farwell 2001a). No publicly available data existed at the time to assess any of these claims and to our knowledge no data were ever collected to test this assertion.

Surveys of least Bell's vireo continued, with an increase from two pairs in 1999 to seven pairs in 2001 (Farwell 2001b). Reserve staff noted this increase to the press, but did not provide any evidence that the increase resulted from removal of beavers, that it represented a statistically significant trend rather than random variation, or that the increase was not the result of early succession riparian habitat created by activity of beavers in prior years. The latter is a distinct possibility, because beavers maintain riparian vegetation in a dense, shrubby mode (McGinley and Whitham 1985), which is preferred habitat for least Bell's vireos.

Analyze Data and Evaluate Model

This step in Adaptive Resource Management was not completed because no useful quantitative data were collected. From press accounts, Reserve staff members believed that the management action benefited the endangered vireo. However, managers later reported that tamarisk seedlings were growing in great numbers on dried beaver ponds, which contradicted the implicit model that beaver activities were providing regeneration opportunities for tamarisk. To the contrary, removal of beavers resulted in the qualitative observation of dense tamarisk sprouting. One of the hypotheses in the literature is that beavers inhibit tamarisk spread by raising the water table, producing conditions that are too wet for tamarisk but suitable for willow and other native trees (Baker and others 1992; p. 69). Had the Reserve Management Committee followed the Adaptive Resource Management process, the sprouting of tamarisk on dried beaver ponds would not have been surprising.

In the next section, we compare the model of the ecosystem that can be derived from the relevant scientific literature with the model assumed by the Reserve Management Committee (Fig. 2). Although the following literature review contains citations that would not have been available to the Reserve Management Committee, the more recent citations only reinforce the literature that would have been available at the time, which shows a different model of ecosystem function than that presumed by the Reserve Management Committee. This review illustrates the type of documentation that could have been completed prior to developing an ecosystem model, summarizes the literature for future conflicts over beavers in the arid and semi-arid Southwest, and contrasts this literature with statements made by the managers at Lake Skinner.

Beavers, Songbirds, Tamarisk, and Southern California Riparian Systems

Resolution 80 states that beavers are exotic to Lake Skinner (an artificial impoundment), would cause great harm to the native ecosystem, and if allowed to stay would cause the need for a ‘‘massive restoration project’’ (Reserve Management Committee 1998). Indeed, invasion of exotic species is a primary threat to native ecosystems, and exotic species can transform such systems dramatically (Vitousek 1986). While a ‘‘pristine’’ ecosystem free of exotic species may be a goal of land managers, this goal is often impossible to attain and limited resources must be allocated to control only those exotic species that are most damaging (Myers and others 2000). This requires an implicit or explicit ranking of exotic species, considering whether a species is invasive, whether it threatens native diversity, whether there are natural control measures such as predators, and whether the conditions that allow the presence of the species can be changed.

Beavers

Beavers (*Castor canadensis*) are native to much of North America, including California. The classic review of the species distribution in California identifies three subspecies: *shastensis* in the northern portion of the state, *subauratus* in the Central Valley, and *repentinus* along the Colorado River in the southeastern part of the state (Tappe 1942). Others have suggested that the range extended as far south on the coast as Los Angeles (Davis 1998; p. 210). The southern distribution of beavers along the Colorado River is less than 100 miles from Lake Skinner (Fig. 3). During the Holocene, beavers were certainly found in southern California, and their apparent restriction to the northern, central, and southeastern portions of the state is either the result of recent climate change or overexploitation. The flora of California, and indeed southern California, coexisted for thousands of years with beavers. Furthermore, the natural predators of beavers such as coyotes are found in southern California.

Beavers are important ecosystem engineers (Müller-Schwarze and Sun 2003; Naiman and others 1988; Wright and others 2002). The exact sites occupied by beavers at Lake Skinner could not have been occupied historically—Lake Skinner is an artificial impoundment and the riparian zones adjacent to it in the Reserve were facilitated by its construction. The changes to riparian systems from beaver presence usually are seen as ecologically beneficial, and beavers are reintroduced to restore riparian areas in arid and semi-arid western North America and elsewhere (Albert 1999; Albert and Trimble 2000; Baker 1995; Collen 1995; McKinstry and others 2001; O’Connell 1999), including in California (Cook 2000). By impounding water behind dams, beavers influence riparian landscapes by changing the geomorphology and hydrology of stream channels, creating wetlands, altering nutrient cycles, affecting water flows and quality, retaining sediment, and transforming vegetation patterns, all of which influence patterns of aquatic and terrestrial biodiversity (Rosell and Parker 1996). Changes to aquatic invertebrate community composition can be substantial, with lentic species (those living in still water) increasing while lotic species (those living in moving water) decline (Naiman and others 1988; Rosell and Parker 1996). Beaver impoundments can result in improved water quality, reducing suspended solids, phosphorus, and total Kjeldahl nitrogen (Parker 1986). Beaver dams also decrease the erosive power of water and protect riparian areas from erosion events, within certain limits (Parker 1986). In general, beavers create habitats that are beneficial to riparian birds, by expanding water availability and through provision of dead trees that attract insects for prey (Rosell and Parker 1996).

Least Bell’s Vireo, Southwestern Willow Flycatcher, and Beaver

Neither the surveys conducted at Lake Skinner nor the scientific literature supported the hypothesis that the beavers were destroying habitat for endangered birds.

Fig. 3 Ranges of Bell's vireo (Grinnell and Miller 1944) and beaver (Tappe 1942) in California. The species overlap throughout much of their historic ranges in the Central Valley of California and along the Colorado River

Least Bell's vireos coexist with beavers over much of the vireo's range (Fig. 3). They prefer ''[l]ow riparian growth either in the vicinity of water or in dry parts of river bottoms'' (Grinnell and Miller 1944; p. 385). Beavers coppice willow and cottonwood trees, creating the low, dense habitat preferred by vireos (McGinley and Whitham 1985). Indeed, beaver foraging promotes the growth of willow (Kindschy 1985; Kindschy 1989). Least Bell's vireos are characterized as preferring early succession riparian habitat (Brown 1993), not ''mature riparian habitats'' as asserted in Resolution 80 (Reserve Management Committee 1998). Both vireos and beavers were observed in the drainages surrounding Lake Skinner in 1995 (Garcia 1997; Griffith 1995), and even more vireos were found in 1999 after four years of co-occupation with beavers (Griffith 1999). Two of the drainages, Middle and Tucalota creeks, were colonized by vireos *after* several years of beaver activity. In the two ornithological survey reports provided in response to our FOIA request (Griffith 1995; 1999), no mention is made of beavers degrading the habitat. While the Reserve biologist attributed the increased abundance of vireos in 2001 to the 1999 removal of beavers (Farwell 2001a), he did not present evidence to support such a causal relation. We suggested an alternative hypothesis that any increased vireo population size resulted from the creation of high-quality riparian habitat by beavers (Farwell 2001b). Neither hypothesis has been tested.

Similarly, southwestern willow flycatchers coexist well with beavers. In some instances, land managers have reintroduced beavers to watercourses to restore flycatcher habitat, as in New Mexico (Albert 1999; Albert and Trimble 2001). This restoration is inexpensive and self-supporting after only 2–3 years. A recent review of the ecology and conservation of southwestern willow flycatcher concludes that beavers should be left in place and monitored if they produce beneficial conditions, and that beaver reintroductions may be useful in creating conditions necessary for recolonization by the songbird (Finch and Stoleson 2000; p. 110).

Observations at Lake Skinner produced insufficient data to demonstrate that beavers harmed habitat for either least Bell's vireo or southwestern willow flycatcher. In general, vegetation ''managed'' by beavers favors songbirds, both by providing nesting opportunities and boosting insect populations as a food base, some examples of which are summarized by Müller-Schwarze and Sun (2003).

Tamarisk

While Resolution 80 listed the invasion of tamarisk as one of the major reasons for beaver removal, the existing literature did not support this model of ecosystem function. To the contrary, research on the topic indicated that beavers inhibit the spread of tamarisk (Baker 1995; Baker and others 1992).

Tamarisk consumes more water than do native trees in the southwestern United States. Its deep taproot allows it to access deeper water sources than are accessible to other vegetation. Furthermore, it can survive with little surface water, a condition that its water use helps to create (Cleverly and others 1997; Sala and others 1996; Smith and others 1998). Tamarisk can withstand greater drought conditions than native southern California trees (Cleverly and others 1997; Devitt and others 1997). The ecosystem consequences of tamarisk invasion and dominance are significant and negative (Zavaleta 2000). However, tamarisk is not as tolerant of inundation as native trees such as willow or cottonwood, and under flooded conditions, native riparian species outperform tamarisk (Vandersande and others 2001). Tamarisk seedlings can be killed by flooding (Roelle and Gladwin 1999).

Beaver dams collect water and raise the water table, which they were doing at Lake Skinner. They also capture and release water slowly through a hot summer season (Glausiusz 1996). Such conditions are superior for native riparian trees, which can avoid the seasonal droughts that would otherwise cause stress, and are unfavorable for tamarisk, which experiences increased stress from inundation (Baker 1995; Baker and others 1992; Glausiusz 1996). Indeed, tamarisk was killed by beaver impoundments in New Mexico (Albert and Trimble 2000). Nowhere in the literature is there any suggestion that beavers promote the spread of tamarisk in the arid southwest (but see Lesica and Miles 2004). Ironically, after removal of beavers at Lake Skinner, an internal Reserve report for November 1999 stated that, ''The dried up beaver ponds along Tucalota creek all have thousands of new tamarisk shoots sprouting up.'' Managers were subsequently reported to have attempted to maintain the beaver dams by hand to preserve the wetter conditions that they created. Had the Reserve Management Committee conducted a search of the literature before acting, they might have foreseen this ''unexpected'' result of beaver removal, and an Adaptive Resource Management approach would have provided a framework to better accommodate the remaining unforeseen eventualities.

Discussion

The beaver removal project conducted at Lake Skinner provides one example of how public lands can be managed for biodiversity. While the goal of the Reserve is to protect and manage for rare and endangered species, the actions taken ostensibly to protect endangered songbirds were simplistic and uninformed by the scientific literature. The decision to eradicate a species is complex and must consider feasibility and effects on other nontarget species (Myers and others 2000). Even if a decision to eradicate is made, an Adaptive Resource Management approach would increase knowledge of the ecosystem in the process.

The conservation planning processes that produce reserves such as the Southwestern Riverside County Multi-Species Reserve promise, and indeed require, a sophisticated management approach. These new public lands are to be managed for whole ecosystems, presumably with the best available science to elucidate the relationships between the parts. The Reserve Management Committee included resource agency members with the expertise to ask critical questions about the course of action. That none of the parties referred to the basic scientific research on the topic that they were adjudicating does not bode well for the protection of biological diversity on these newly established reserves. In this instance, the Reserve Management Committee undertook ''management by assertion,'' where decisions were made based on beliefs, ''common sense,'' and intuition, without consulting the scientific literature. If conservation and animal welfare groups had not questioned the decision to remove beavers, these actions would have gone unnoticed. Because agencies such as the U.S. Fish and Wildlife Service invoke scientific argument to impose restrictions on land use, these agencies must be thorough in their use of science as they make management decisions as well.

In a human-created system such as Lake Skinner, management choices that maximize habitat values for rare and endangered species are not necessarily obvious. The two reasons for beaver removal expressed by the Reserve Management Committee—elimination of exotic species and fighting invasion by tamarisk—do not stand up to scrutiny. The simplistic response that any exotic species should be removed may have done more harm than good for the endangered least Bell's vireo and likely promoted the truly destructive invasion of tamarisk. The Reserve Management Committee might have decided to remove beavers for other theoretically justifiable reasons, such as to reverse community shifts from lentic to lotic aquatic invertebrates. This was not, however, a stated reason for removal.

Funds to manage nature reserves are usually insufficient at best. They should, therefore, be used in a way that achieves management goals and increases knowledge in a cost-effective manner. At Lake Skinner, managers spent tens of thousands of dollars (Farwell 2001b) without gaining any appreciable knowledge of ecosystem function. Furthermore, the ''solution'' was temporary—we documented presence of beavers in Lake Skinner only a year after the removal program—ensuring that managers will face the same question again. While Resolution 80 suggested that the trapping would remove ''all beavers'' on the Reserve and at Lake Skinner, agency personnel not sitting on the Reserve Management Committee acknowledged at the time, off the record, that removal of all beavers would be impossible and that the action was futile. Two years later, Reserve biologists finally acknowledged that beavers remained in the area (Farwell 2001a).

We hope that ''management by assertion'' is the exception, but fear that it is not (see Pullin and others 2004). Rather, managers commonly make decisions based on their experience, and outside an experimental framework (Pullin and others 2004). Managers at Lake Skinner probably would characterize their management scheme as a ''common sense'' approach and they might even believe that they were implementing ''adaptive management'' because they were willing to respond to changing situations (e.g., trying to rebuild the beaver dams when tamarisk sprouted in the drying ponds). But at best these actions could be seen as trial and error management (Meffe et al. 2002). It seems most likely that neither the Reserve Management Committee nor the managers themselves actually had a formal approach to management, or that any of them were aware of the process of Adaptive Resource Management as described in the literature. Others have identified barriers to the successful implementation of the Adaptive Resource Management process: institutional complexity, difficult collaboration with stakeholders, lack of basic science, and difficulty modeling the subject system (Ladson and Argent 2002; Schreiber and others 2004; Gunderson and others 1995). None of these barriers applies here. Rather, managers and decision-makers simply did not commit fully to an Adaptive Resource Management approach for the new Reserve even though ''adaptive management'' was promised. The absence of an explicitly defined process for scientifically based management allowed staff and decision-makers to act based on preconceived notions and made them vulnerable to influence by unspoken political goals (e.g., the specter of disease or aesthetic concerns over loss of mature trees). While it is possible (even common) for sound scientific advice to be overruled by political considerations (e.g., Dustin and Schneider 2005), in our case study a thorough scientific assessment was never even conducted because an established framework for management that would have demanded it was missing. To avoid this result, managers and decision-makers should commit formally and substantially to an Adaptive Resource Management approach; conservation scientists and environmental advocates should accept no less.

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