An Accidental Resource: the Social Ecological System Framework Applied to Small Wetlands in Sierran Foothill Oak Woodlands[1]

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Abstract

An ongoing study of the small wetlands in the northern Sierra Nevada foothill oak woodlands that provide habitat for the state-threatened California black rail (*Laterallus jamaicensis coturniculus*) offers an example of the way that the social ecological systems (SES) framework can be used to analyze a natural resource problem. At the outset, it was hypothesized that the area's hydrology, West Nile Virus from wetland mosquitos, the population ecology of the bird, and the decisions of landowners would have important impacts on the wetlands and birds. A SES framework was applied to identify and understand the interactions among ecological and human factors. The case of irrigated wetlands in Sierra foothill woodlands turns out to be an example of a fractured SES. Actions within the social system are having profound impacts on the natural system, but these resulting changes in the natural system appear to have little or no feedback to the social system. Intervention points identified include education of landowners, influencing water districts, and incentivizing conservation.

Key words: California black rail, irrigation, pasture, water conservation, wildlife

Introduction: social ecological systems

Small wetlands in the northern Sierra Nevada foothill oak woodlands provide habitat for the state-threatened California black rail (*Laterallus jamaicensis coturniculus*). One ongoing study of the sustainability of the wetlands offers an example of the way that the social ecological systems (SES) framework can be used to analyze a natural resource problem. Fundamentally, a "social ecological system" is composed of an ecosystem and the people that interact with it. Such systems are complex and adaptive—society and environment are considered to "co-evolve" (Glaser and others 2008). Here we use the SES concept to assess the dimensions of sustainability for the rail and its wetlands, and at least some of the drivers that influence it.

The SES concept is most often used where society derives a stream of benefits from the natural system. The fact that society is dependent upon and in turn affects the surrounding environment has probably been known at least since early humans learned how to make fire. Despite this lengthy history, strategies in the academic literature for successfully managing SES and applying the SES framework have generally remained vague. Specific management recommendations are hindered by the diversity and complexity of the systems, and authors stress that there is no universal formula.

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Scientific understanding of the interaction between society and the environment has often been hampered by the fact that neither social nor ecological systems occur at only one spatial or temporal scale. Interactions between scales are common and may cause either gradual or sudden transitions across multiple scales (Gunderson and Holling 2002, Levin 1992). Studies or monitoring efforts focusing on only one scale, typical in natural resource management, are prone to failure.

Although the simultaneous interaction of processes at multiple scales is often included in the definition of SES as “nested, multilevel systems” (Binder and others 2013), monitoring or evaluating systems across scales is often beyond the budget and knowledge of natural resource managers or scientific researchers. For this reason, some authors have recommended concentrating analysis on interactions of specific sub-components (Roe 1998), while others have suggested that social-ecological interactions are typically determined by a small number of “controlling processes” that should be the analytic focal point (Holling 2001). In either case, the spatial or temporal scale of management is inadequate to address the scale of ecological processes, leading to bad, ineffectual, or no management (Cumming and others 2006). However, there are still a number of general guidelines and hazards to be aware of when thinking about how to apply the SES concept to management.

One strategy is adaptive management, which is a response to the realization that previous command-and-control-style management made unrealistic assumptions about the degree to which ecological systems could be understood and predicted (Walters and Hilborn 1978). In simplified form, adaptive management consists of establishing a goal, conducting management activities designed to achieve that goal, monitoring and evaluating the effects of those activities, and altering the management plan in response. The challenge with adaptive management is that, not only is it difficult to establish institutionally (Jacobson and others 2006), but adaptive management plans tend to focus on the ecological system without adequate consideration of the social system, including the limitations of the manager.

Adaptive management to achieve the sustainability of a SES, as opposed to a natural resource system, would be sensitive to the different tiers of social actors, ranging from individuals to organizations and government agencies, as well as the governance structures that limit their behavior and the social and economic trends that motivate them (Folke and others 2005). Some authors have highlighted land tenure regimes and legal structures that enable resource users to self-organize as key components of successful ecosystem management, where organized groups can effectively and collaboratively manage a resource they all depend on (Adger and Luttrell 2000, Folke and others 2005, Ostrom 1990). Collective adaptive management is often difficult or impossible, however, in cases where social conflict (Galaz 2005), domineering government regulation, or tenure configurations or other institutions prevent resource users from collaboration and adaptation (Ostrom 1990). Collaboration between multiple tiers of stakeholders, combined with ongoing monitoring of the natural system, is the best way to ensure sustainability of a SES. While the sustainability of small wetlands may seem like a simple case of turning on some water, the SES framework gives us a fuller picture of how sustainability might work, and the management initiatives needed, in the situation of the black rail in foothill oak woodlands.

Case study: wetlands in a working landscape

The goal of the overall research on the rails and wetlands is to evaluate the sustainability of small wetlands within the bird's foothill distribution, given the potential impact of climate change on water accessibility and management. At the outset, it was hypothesized that the area's hydrology, West Nile Virus from wetland mosquitos, the population ecology of the bird, and the decisions of landowners would have important impacts on the wetlands and birds. A SES framework was applied to identify and understand the interactions among ecological and human factors. In this summation we focus on the results of a survey and interviews with landowners and water managers aimed at understanding management decisions affecting wetlands within the study area.

Wetlands in a social-ecological system

The secretive California black rail is a small ground-dwelling marsh bird, and was known only from large marshes in San Francisco Bay and along the lower Colorado River until it was "discovered" in the Sierra foothills of Yuba, Nevada, Placer and Butte Counties 20 years ago (Richmond and others 2008). First detected in 1994 at Sierra Foothill Research and Extension Center in Yuba County, the bird persists in small wetlands of 0.1 to 14 ha, where livestock grazing is a common use of local woodlands. Wetlands suitable for rails have shallow flowing water and short vegetation—open water is not of use to the birds. Wetlands used by rails may include densely vegetated marshes produced by springs, purposefully created wetlands, accidental leaks along canals and irrigation pipes, tailwater from irrigated pasture, and the marshy fringes of artificial ponds. Even apparently native springs in the area are likely influenced by extensive and leaky water transport systems that date from the Gold Rush. Water district managers have reported that the dirt-floored canals may lose 30 to 70 percent of their water through evaporation and seepage. An isotope study in Colorado found that ponds as far as 2 km from irrigation canals were fed primarily by irrigation water (Sueltenfuss and others 2013).

The SES framework allowed recognition that ecosystem services like the provision of rail habitat are a product of the interaction of humans and environment, rather than arising from the ecosystem alone (Huntsinger and Oviedo 2014). More than three-fourths of the bird's wetland habitat was found in recent studies to be created or influenced by irrigation and water use related to ranching and, to a lesser extent, other forms of agriculture (Richmond and others 2010). To better understand the "social ecological ecosystem service" of rail habitat provision, in 2013, landowners and water managers within the bird's habitat distribution were interviewed about their use of water. Based on these interviews, a mail survey was developed and administered in 2014 to a random selection of landowners stratified by property size in the study area using the Dillman Tailored Design Method with a multi-wave technique that included a cash incentive of two dollars in the first mailing (Dillman 1978, Dillman and others 2009) . Results were analyzed with SPSS with weighting to match property size distribution in the study area (Atlas Support 2014, Holt and Smith 1979). About 55 percent of the surveys sent to valid addresses were returned, resulting in a sample of 470 respondents with property sizes ranging from 1.2 to 3237.5 ha.

Results showed that about half the landowners purchased irrigation water from a water district and approximately a third have a canal or ditch on the property. About 40 percent had irrigated pasture for livestock production, found in previous studies to provide the most consistently used rail habitat through runoff (tailwater). Almost a third of respondents reported having a “wet area”, indicating that they might have rail habitat on the property. Few survey respondents reported any management of the wetlands, with 9 percent reporting draining some of them in the last 5 years, and 8 percent reporting that they created some during the last 5 years. About half said that they valued wetlands for wildlife, about a quarter thought the green forage was useful for livestock, but about a quarter reported not doing any management because the ponds simply did not “bother” them.

Water use and management by landowners

The most important reason to manage water for landowners in the study are was to reduce wildfire hazard, while of all the things asked about, concern about West Nile Virus was the least important reason. Interviewees, even those that had lost an animal to the disease, explained that they used vaccination to protect their horses and thought the risk to them was low. Enjoyment of the property, water saving, and water price were all relatively important to people in making decisions about water.

The most important reasons for creating or maintaining ponds for half or more of owners were wildlife watching, aesthetics, bird watching, and watering livestock. When respondents were asked what it would take to get them to create a wetland on their property, approximately a quarter said they would “do it for free if it benefitted birds and wildlife.” More than a third of landowners said they would do it in exchange for free water, and about a fifth said they would do it if it provided livestock forage in summer. Another third said they would “never create a wetland.” Property size made no difference in their responses.

Using a bivariate logistic regression analysis considering the relationship of water features with property size and purchasing water district water, the occurrence of springs on a property was found to be strongly related only to acreage ($p<.003$), while ponds were strongly related only to having water district water ($p<.000$). In contrast, the occurrence of wetlands like those used by the rail was found to be strongly related to property size ($p<.037$) and irrigation water purchases ($p<.003$). Both of these characteristics are strongly related to ranching.

Having water district water apparently changes the relationship of a landowner to water and the feedbacks from drought. Despite the fact that California is in the 3rd year of severe drought, irrigation water purchasers agreed at a higher rate than other landowners that they had plenty of water for their property. In fact, water districts have buffered the impacts of drought on their customers, maintaining existing flow without reductions until very recently, after the completion of the survey. Those purchasing water district water were more likely to agree that drought could have a big impact on their property, and that having less water would reduce their ability to use water. They also more strongly disagreed that they could adapt to a water shortage. Results indicate that while water is important to most respondents, those who purchase irrigation water from water districts are more dependent on the water they purchase (table 1) than are those using other sources, or not irrigating at all. About 80 percent of the land is owned by those purchasing irrigation water, and 63 percent of those landowners reported having irrigated pasture for livestock ($p < .000$).

Incorporating water districts into the SES hypothesized at the outset makes it clear that the feedbacks to water district decisions about water need further research. Water districts earn their funds through selling water—this makes them reluctant to cut back. It is also no doubt the case that landowners put political pressure on water districts to maintain water supplies. Other than that, water districts seem to operate independently from any consideration of small wetlands like those studied. At the state level, there is a strong push to conserve water, pushing water districts into efforts to line and pipe canals, and to fix leaks. The SES framework made clear the "weak links" (water districts and landowners have no reason to consider impacts on wetlands) and the "wetland-negative links" (pressure to conserve water) in the sustainability of the wetlands.

Table 1—Percent of landowners purchasing and not purchasing water district irrigation water within foothill California black rail habitat that agree with the following statements about water availability in 2013

Statement	% Agree or strongly agree		P ($\chi 2$)
	Irrigation water purchaser	No irrigation water purchased	
I have plenty of water for my property	80	64	.005
Drought can have a big impact on my ability to make a living	50	34	.002
Having less water will reduce my ability to use my property	94	85	.000
I can easily adapt to a water shortage	17	31	.024

Scale and feedbacks

Research on the black rail illustrates the importance of scale when looking at ecosystem service production from a social-ecological systems perspective. At the pasture scale, grazing can reduce the suitability of rail breeding habitat in spring if vegetation height and density are greatly reduced (Richmond and others 2012). At the regional scale, water districts have impacts. Focusing on the landscape, the persistence of the working landscapes that foster rail habitat is critical, including maintenance of the livestock enterprises that support semi-natural grasslands, and the use of water for irrigation and stockponds. One important feedback to consider is that if protecting rail habitat is costly to the landowner, the ranching operation may be less profitable and less able to sustain itself. Instead, the land may be sold and parcelized, or placed into alternative land uses that are less rail-friendly. On the other hand, landowners reported that knowing that they were benefiting wildlife, or provision of the needed water for free, would motivate them to create a wetland. This willingness indicates that creation of wetlands on private land could be initiated through the right education or incentive programs.

Learning from irrigated wetlands

It was initially hypothesized that the specific factors likely to influence management of wetlands included landowner concerns about the recently-arrived West Nile Virus (as mosquitos live in wetlands), drought and/or rising water costs, water conservation initiatives, changes in landowner management practices, the land ethic of the landowner, and land use change. A series of interviews revealed the following as important factors supporting habitat persistence and led to changes in our hypotheses and survey questions: availability of inexpensive water, the need to maintain a water district water allocation by using the allocation each year, the high cost of labor and repairs for irrigation and water transport systems, owner indifference to grassy hillside or sloping wetlands, and the limited funds for water districts to implement water conservation technologies and to improve water transport. The central importance of water districts to the future of small wetlands was not anticipated in the original hypotheses, nor was landowner indifference to West Nile Virus (though the impact of West Nile on rail populations has now been documented).

The landowner survey revealed that landowners have limited direct effect on either rails or wetlands, either positive or negative. Far more important to wetlands, and thus to rails, are the actions of water districts. The continued provision of abundant water at relatively low prices will probably ensure that landowners will continue to spread water on their land in patterns similar to present. Severe hikes in water prices or decreases in supplies would likely result in less irrigation, with negative implications for wetlands. Perhaps even more important, water seepage from unlined irrigation canals appears critical to the maintenance of rail habitat. If water districts continue to line irrigation ditches with concrete or convert them to pipes, the amount of persistent water on the landscape will decline, in turn decreasing the size and number of wetlands. Current concerns over water shortages and efficiency in California suggest that pressure to decrease canal leaks and seepage will continue. Preliminary interviews with water districts suggested that there is little regulation to protect existing wetlands from being dried up by improvements to irrigation canal infrastructure. It is possible that such regulations might either be enforced or created in the future, however.

Studying the case of irrigated wetlands in an SES framework reveals several challenges for sustainability of the system. First and foremost, key components of the natural system are functionally invisible to key components of the social system. Water districts neither monitor wetlands or rails, nor do they make any attempt to manage them (except to dry them up if an irrigation leak is found to be the cause). Landowners rarely manage wetlands directly either, and many seem unaware that small, shallow wetlands offer wildlife benefits.

Secondly, linkages between tiers of the social system are missing, leading to little communication or collaboration. Wetlands typically occur on private lands but are fed by water from irrigation canals. Water districts line or pipe irrigation canals regardless of whose land is affected by the decline of water seepage, and landowners have little or no input in this process. State water regulators, if they are aware of the relation between irrigation water and wetland habitat at all, have so far made no mention of this connection when pushing for water conservation efforts and curtailing some legal rights held by water districts to collect surface water for later distribution.

In essence, the case of irrigated wetlands in the Sierra foothills is an example of a fractured SES. Actions within the social system are having profound impacts on the natural system, but these resulting changes in the natural system appear to have little or no feedback to the social system. This disconnect is due at least in part to the fact that irrigated wetlands are a largely unintended consequence of a different resource system, that of irrigation water, which is being actively managed on all tiers of social organization. Completing the feedback circuit for irrigated wetlands is not impossible, but education of the social actors about their presence and cause is a necessary first step. Shoring up connections between landowners, water districts, and state/federal regulators will be necessary if these wetlands are to be sustained into the future.

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