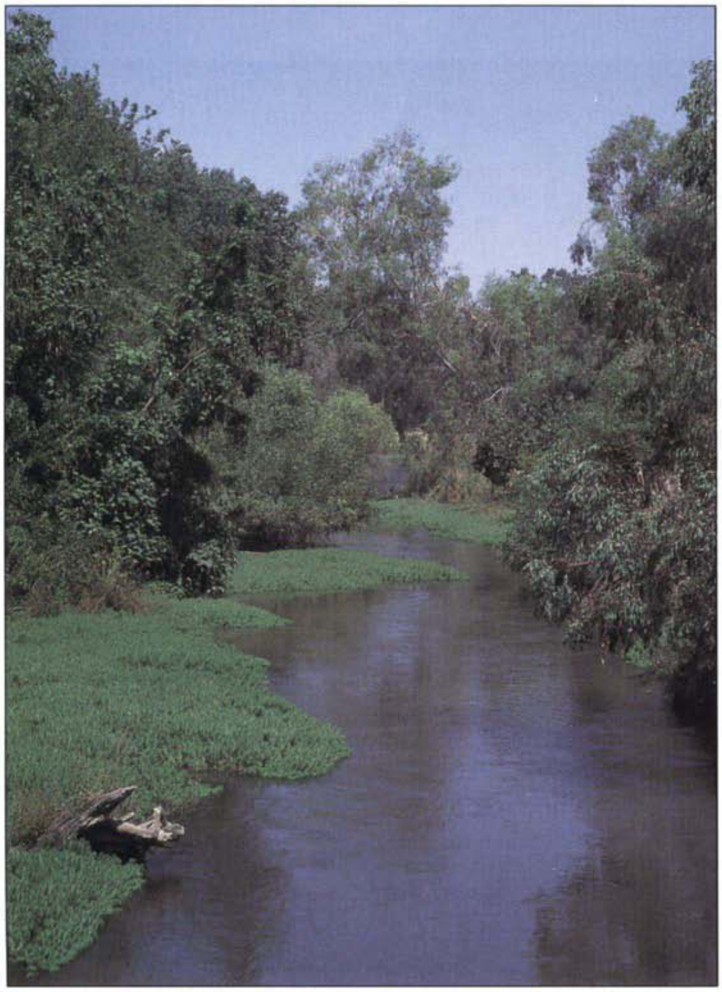

Jack Kelly Clark

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Biodiversity indicators in California: taking nature's temperature

Michael E. Soulé

Several habitats and ecosystems in California, including those that have been converted to agriculture, are severely threatened — the remnants of these disappearing communities constitute only 10% or so of their original extant. As a society we have begun a last-ditch effort to salvage and protect these remnants and the species that depend on them. To succeed, we must develop and agree on criteria for ecological integrity. These criteria must include "indicators" — ways to take nature's temperature. But more is needed than good science; saving this diverse living legacy also requires a moral consensus.

One must care about a world one will never see. — Bertrand Russell

What would you say if a friend from New Jersey asked you how wildlife was doing in California? Your answer, of course, would depend on what you both mean by "wildlife." In the broad sense, wildlife means all life that is wild, all the native species in a place from bugs to bears and from wild roses to giant redwoods. By this definition, wildlife is the same as the living components of nature or "creation." To be sure, dignified scientists rarely speak of creation these days — the term has too many emotional and religious connotations. Instead they write and talk about wildlife, natural resources and "biodiversity."

Perhaps the most objective word for living nature today is "biodiversity." Scientists would like to think that biodiversity is a value-free term, lacking political or cultural bias. Although many biologists equate biodiversity with species diversity, various international conservation organizations define it more widely. They encourage us to think about all of the levels of biological organization — from the DNA in individuals to entire ecosystems.

How to take nature's temperature?

Returning to our friend from New Jersey, how would we answer her question about the status of wildlife in California? I think that the answer would depend on many things. One of

◀ **About 90% of the Central Valley grasslands, riparian habitats *(left)*, old growth forests and wetlands of the state have disappeared. Irrigation canals, *right*, can harbor some aquatic species but cannot replace habitats created by rivers.**

these is perspective, or what scientists call "scale." From the window of a commercial jet, for example, one might guess that nearly all of the wetlands of the Central Valley have been replaced by the geometric pattern of modern agriculture. One might also be able to see that about 90% of the coastal habitat in Southern California has been converted to human uses.

But this long-distance view might also be misleading. For example, while the forests of the Klamath or the Sierra Nevada mountains may appear pristine from such a height, they have been extensively clear-cut and little old growth remains at lower elevations. Further, one could not detect that grizzly bears are extinct and that many amphibian species have disappeared in these regions. Nor would one notice the absence of salmon from the rivers or the damage caused to riparian areas by mining and excessive grazing. In other words, the view from a plane allows the detection of some trends but not others.

But even a closer view, say from the passenger seat of an automobile, might also disguise reality. The screen of old-growth trees along the highway could lull us into believing that most of the forests were uncut. A more careful inspection, though, would reveal that clear-cuts lie just beyond, that many of the once-common animals such as tule elk, wolverine, fisher, and steelhead are rare or absent, and that soil erosion from road construction and logging was causing the silting in of salmon spawning habitat and was shortening the useful life of reservoirs. Moreover, such a roadside perspective would not reveal that the foothills of the Sierra Nevada are now being stricken by "ranchette pox," a diffuse outbreak of flammable houses on lots too large to supply fire protection economically, but too small to leave enough room for wildlife, such as mountain lions. In addition, we would need to be shown a time-lapse aerial view of the state to appreciate that the richest farmlands are being sold, subdivided, and smothered by black blankets of asphalt and grey slabs of concrete.

Without natural habitat, plants and animals cannot survive. And isolated remnants of habitat are usually too small or degraded to provide long-term protection. Due primarily to massive habitat destruction and fragmentation, about 100 kinds of creatures have been extirpated from California by humans during this century, more than in any other state except perhaps the Hawaiian Islands.

Besides having plowed or urbanized most of the coastal sage scrub in Southern California, we have lost about 90% of the Central Valley grasslands, riparian habitats, old growth forests and wetlands of the state. Organisms that depend on these habitats are nearing the end of the line.

How much habitat destruction is too much? How do we diagnose a sick land, and ecological disintegration? These are difficult questions. It is like asking the following: At what point do we say that a human society has become dysfunctional? Some people claim that the best indicators of civilization are its manners, civility, and the arts, and that the disappearance of these cultural values are signs of a society's dis-ease. Others claim that negative measures such as the crime rate, percentage of births out of wedlock, or numbers of incarcerated juveniles are the appropriate indicators of community health. But the question remains: where is the line to be drawn between healthy and sick, between a normal and a dysfunctional society?

Resolving the question of ecosystem health is even more difficult because most natural ecosystems are much more complex that human society. While society comprises only one species, *Homo sapiens*, a forest or lake may contain hundreds or thousands of species that all interact with each other. This complexity notwithstanding, ecologists have been assigned the task of setting the thresholds for ecosystem health and integrity to satisfy legislative and court mandates.

Indirect signs of integrity

What can we measure to determine the status of ecosystems? How do we take nature's temperature? First, we must distinguish biodiversity indicators from ecosystem services. Ecosystem services include water, timber and other natural resources that benefit humans directly. A production forester, for instance, might define the status of a forest in terms of the annual increase of board feet of wood. But what looks like a healthy forest from the forester's point of view might look pretty sick to a conservationist. The production forester may consider martens and woodpeckers to be superfluous because they play little or no role in the "important" resource services such as lumber production, whereas the conservationist wants to retain all the forest's original species as well as its majesty and wildness.

Second, we must distinguish between direct and indirect indicators. Direct indicators include determinations of species richness (number of species present) and the abundances of particular (target) species. Indirect indicators include measures of potentially harmful phenomena. The disappearance of many raptors and fish-eating birds, such as peregrine falcons, bald eagles and the California brown pelican, led ecologists to one indicator of ecosystem status or integrity — the concentration of chlorinated biphenyls like DDT, DDE and PCBs in the tissues of these predators and their prey. These contaminants are an example of an indirect, or "negative indicator," because they inform us about how bad things are likely to be without government regulations.

Indirect indicators also include herbicides, fertilizers and animal wastes that contaminate groundwater in many agricultural regions worldwide. In addition, atmospheric pollution is also a global concern. The acidic byproducts of mining, smelting and power generation are changing the chemistry of entire ecosystems, and the thinning layer of stratospheric ozone is allowing increasing amounts of DNA-damaging ultraviolet radiation to reach terrestrial plants and animals. Another indirect indicator is the atmospheric buildup of greenhouse gases such as carbon dioxide and methane. Not only are these changes affecting wildlands and wild waters, but there is concern about their impacts on the human economy and on human nutrition.

Indirect or "surrogate" indicators of biodiversity are like buoys on the sea, or one's pulse, because they provide clues about what is happening underneath the surface. Examples are the presence of toxics like DDT or the thinning of the ozone layer. The pH of a lake is an indirect indicator of the health of fish living there. However, the distinction between direct and surrogate indicators, often collapses on close inspection: they are two extremes of the same continuum.

Perhaps the best indirect indicator of future environmental destruction is roads. Even dirt tracks, seemingly insignificant intrusions into wildlands, can lead to major changes in the distributions and abundances of animals. It is well known that the more roads in an area, the fewer large carnivores, particularly females. Recent studies in Britain and the Netherlands suggest that the reproduction of birds living within two or three miles of major highways is affected by noise pollution; apparently the traffic roar drowns out the calls, chirps and coos that birds use to establish territories and maintain pair bonds. In addition, it has been shown that the frequency of bird nest predation can be higher than normal as far as 200 yards from roads or clear-cuts.

Roads also provide entry points for loggers, miners, hunters, poachers, vacationers, mountain bikers and dam builders. In some places, a few hunters can eliminate predators from large regions, and the absence of predators can entrain complex changes in their prey species and in entire ecosystems. Larger roads, of course, produce larger impacts. Logging roads are often the first industrial penetration of wildlands; they become conveyors of logs, wood chips and ores, and smooth the way for further development, including farming, natural resource extraction and subdivisions for summer cabins. Roads also encourage the spread of weedy plants as well as plant pests and diseases.

Moreover, even the most primitive and inconspicuous road develops a wide belt of disturbance along both sides. Ecologists use the term "edge effects" for these impacts. Edge effects can extend hundreds of meters from the road, diminishing in severity with distance from the road. Examples of edge effects that drop off with distance include vehicular noise, hunting and collecting rare plants. Other edge effects along roads include fire, which spreads more easily along roads, forest blowdown from storms (due to wind speed) and the acceleration of weed transport. Simply stated, one need only look at the plans for future roads to predict the future of wildlands: where roads go in, wildlife goes out.

Direct indicators of biodiversity

What are direct, immediate gauges — the biological indicators — that wildlife is really declining in diversity and abundance? Because we cannot measure everything, we have to select a few variables that we believe represent the life of the ecosystem. The direct indicators we choose reflect our values (what is important to us), the sophistication of our science (what we know), and our estimates about what is feasible and economical to measure (what is pragmatic).

Biodiversity indicators must be able to provide a basis for detecting change and for predicting future impacts. To measure changes in biodiversity, we must first gather "baseline" information to establish the normal fluctuations.

Unless there is some idea of normal fluctuations, we risk gathering data mindlessly. For example, it is often useless to census a population for a short period of time because populations fluctuate. One year's data on the number of elk on a wintering ground is not enough. It might take 10 years of monitoring to get an idea of the normal variability of that elk population.

The selection of indicators is as much an art as it is a science, but there are several guidelines that are obvious. First, the selected indicators should be relatively inexpensive and easy to monitor. For this reason, birds are often selected as opposed to relatively cryptic organisms like snakes and bats. Note, though, that there is a tradeoff between monitoring just a few things (it is economical) and monitoring many things (it is prudent because otherwise you might miss something important). Good experimental design and planning will help to assure an optimum solution.

Second, fads should not be permitted to drive the selection of indicators. New technologies periodically sweep up scientists and technicians in the coattails of scientific fashion. An expensive, current fad is the use of global positioning devices to map features and track wildlife. One must also be cautious about bandwagon species — organisms that are popular or easy to monitor but that may not indicate what we think they do. Recently, for example, much attention has been focused on certain insect groups such as butterflies and beetles or certain groups of vertebrates such as birds and mammalian carnivores. Yet some studies have shown that there is little correlation between the species richness of, say, birds or butterflies with that of other groups such as forest or aquatic plants.

Third, indicators should provide early warnings of ecological deterioration just as caged canaries used to warn miners when the air was bad. One example of a canary-type indicator is selenium levels in groundwater in the Central Valley. But animals don't have to be belly-up before we know something is wrong. Biologists are detecting early-warning signs of ecological stress by comparing the right and left sides of individual animals — the degree of subtle asymmetry in features like feather length in birds and numbers of scales in fish. Slight departures from the norm for such right-left differences are correlated with stress caused by pollutants, poor nutrition, and even noise.

Fourth, some indicators should be educational, assuming that one objec-

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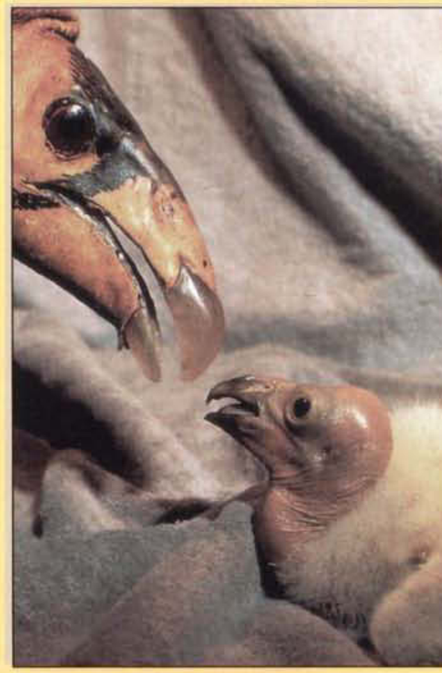
Setting priorities for conserving endangered species

Katherine Ralls

Conservation funds often go to endangered species that enjoy vocal public support, such as condors. (Courtesy of the Los Angeles Zoo)



While the Endangered Species Act requires us to try to save every listed species, many argue that this is not feasible from an economic standpoint. The argument goes that because there is a limited amount of money for conservation, we need to decide which species are the most important to save.

The letter of the law notwithstanding, it may come as a surprise that there is a federal system for setting conservation priorities. The current system for setting conservation priorities considers how unique, how threatened and how recoverable a species is as well as the economic impact of listing the species as endangered. The system is hierarchical: the first factor is weighted the most and the last is weighted the least.

While this system sounds good in theory, in practice it does not work as well as it could. For one thing, although economic impact is supposed to be the least important factor in setting conservation priorities, when the impact is serious this factor tends to dominate the discussion, as in the case of the spotted owl. In addition, such protracted public debates drain limited resources from other endangered species that need protection.

Another problem with the current system is that a species' distinctiveness is defined in terms of taxonomy — biologists' method for classifying species. For example, species are given higher priority than subspecies. However, the standards for classification as a species or a subspecies vary across groups of organisms. In other words, what botanists might classify as a species, mammalogists might classify as subspecies. Moreover, this limited definition of distinctiveness overlooks the fact that a species' uniqueness is also reflected by its role in the ecosystem. Some species are interdependent on other rare species, for example, key pollinators of endangered plants. Some species live only in rare habitats such as vernal pools and serpentine soil. Also, so-called "umbrella species" such as the San Joaquin kit fox populate such large habitats that saving them also means saving some of the other rare species that live there.

These shortcomings are often moot, however, because the U.S. Fish and Wildlife Service has little opportunity to use its system for setting conservation priorities. One reason is that most of the money budgeted for saving endangered species goes to condors, black-footed ferrets and a few other species that enjoy vocal public support. People who care about a particular species lobby Congress, which then attaches a provision earmarking funds for that species to an appropriations bill.

Another reason that the Fish and Wildlife Service does not always conserve species according to their priority is that lawsuits distort the conservation system. Many regulators hardly get to consider the relative importance of saving a given species because they are so busy responding to lawsuits. Petitions to list and delist species must be responded to within statutory time limits, which consumes regulators' time and energy.

Even if regulators did not face these obstacles, priority-setting would be in trouble because the current system needs improvement. While many have criticized the current system for setting conservation priorities, few have suggested concrete ways of improving it. At one extreme, we could divide the money equally among the listed species. Another approach would be to save as many species as possible by focusing on those that can be recovered the most inexpensively. Or we could decide that large animals like the grizzly bear are worth more to us than a few beetles. None of these approaches, however, addresses the real problem: how to save functional ecosystems.

Resolving the issue of setting priorities for conserving endangered species is very difficult in our diverse, democratic and litigious society. However, we should try to base the priority-setting process on sound science so we can conserve as much as possible for future generations.

K. Ralls is Research Zoologist, National Zoological Park, Smithsonian Institution

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tive is to involve the public. For example eagles and other "flagship" species that the public understands and appreciates make excellent indicators. In turn, information about the status of flagship species can provide opportunities for educating the public about less charismatic species and ecological processes.

Fifth, some indicators should be "umbrella" species. These are species such as wolverines and mountain lions that require large areas of relatively undisturbed habitat in order to maintain a viable population. By protecting the habitat that these species require, we also protect many other less visible and less space-demanding species.

Sixth, the list of indicators should include elements from all levels of biodiversity including genes, species and ecosystems. This means consulting with a broad range of experts from population geneticists and aquatic ecologists to local natural history experts and geographers.

Seventh, indicator monitoring should be a component of a long-range master plan designed by all parties, including managers and policy makers. Without participation, there is no commitment, and without commitment there will be little or no action when a danger flag is raised.

Finally, the objectives of monitoring the indicators should be clear to everyone. It is not enough to state that the goal is to monitor biodiversity. Explicitly stated objectives are especially helpful because they bridge the gap between policy decisions and management actions. The following statements provide clear monitoring objectives:

1. Our objective in monitoring large predators is to determine if they are being over-harvested.

2. Our objective in monitoring forest-floor beetles is to assess when and where forest fragmentation is beginning to affect invertebrate faunas.

3. Our objective in monitoring water quality (sediment and nutrient loads, pH, coliform bacteria count, species diversity of protozoans and diatoms, etc.) is to determine where and when positive and negative incentives limiting pollution and development need to be introduced.

Everyone should realize that conflicts are unavoidable where human beings have already converted almost all of a particular ecosystem to their own economic uses.

Agribusiness and indicators

Until early this century, most agriculture in this state was subsistence farming and ranching, and agriculturalists had little tangible support from government. Since the 1930s, however, there have been major changes in food production. Nowadays, local, state and federal governments subsidize agriculture and ranching with large-scale irrigation projects, flood control structures and their maintenance, below-cost grazing on public lands, price supports, roads, below-cost water and electricity, various tax subsidies, price supports and other programs. Consequently, farming and ranching now have the potential to generate large amounts of capital, and food production and marketing have become attractive to large, publicly owned corporations.

How do these revolutionary changes in the food industry affect the way we care for the remnants of creation? Now that most grasslands and floodplains are laser-leveled and plowed from fence to fence, the surviving native species hang on precariously in isolated patches that are too poor to plow. And now that most of the rivers and streams have been dammed, channelized, herbicided or grazed, the surviving aquatic species often must persist in polluted wetlands or canals.

Alien species from other parts of the world often deal the final blow. In California, native red-legged and yellow-legged frogs are eaten and replaced by introduced bullfrogs, game fish and mosquito fish. Native kit foxes and clapper rails retreat before alien red foxes. Kangaroo rats and California mice are displaced by house mice and Norway rats. Quail and roadrunners vanish as feral housecats become more abundant. And native meadow plants are overwhelmed by exotic thistles and dozens of other weedy plants.

Should we throw up our hands and admit defeat? Should agricultural regions necessarily become biodiversity sacrifice zones? I hope not. Small changes in management can make big differences in the survival of native species and ecosystems. For example, the use of chemicals (i.e., pesticides, fertilizer) should be minimized as part of the transition to benign forms of agriculture.

Habitat is critical. Unplowed strips should be left along fences and water courses, to provide wildlife with both habitat and corridors to move along. If such measures are considered undesirable for economic reasons, then local farmers could agree to set aside the equivalent acreage in fenced, interconnected blocks. Tax incentives should reward such patriotism.

Most of the actions that threaten nature are little ones. Nature is nibbled to death by people like you and me, on our private and public lands. In other words, nature is subject to the tyranny of small decisions. Just as thousands of little acts of subdivision gradually overwhelm our richest agricultural lands, so do thousands of indifferent management decisions gradually overwhelm and destroy our wildlands, wild waters, and wild creatures. If we wish to cover our eyes and ears, blaming the messenger for our woes, then we will repeal the environmental laws that protect creation from our economic activities. But if we want to know what is happening we must survey and monitor, trusting that we, as a people, have the generosity of spirit and the inventiveness of mind to find ways to coexist with the remnants of California's natural legacy.

M.E. Soulé is Chair, Board of Environmental Studies, UC Santa Cruz.

For further reading:

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