Are We Conserving What We Say We Are? Measuring Ecological Integrity within Protected Areas

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Managers of protected areas are under increasing pressure to measure their effectiveness in conserving native biological diversity in ways that are scientifically sound, practical, and comparable among protected areas over time. The Nature Conservancy and its partners have developed a "Measures of Success" framework with four core components: (1) identifying a limited number of focal conservation targets, (2) identifying key ecological attributes for these targets, (3) identifying an acceptable range of variation for each attribute as measured by properly selected indicators, and (4) rating target status based on whether or not the target's key attributes are within their acceptable ranges of variation. A target cannot be considered "conserved" if any of its key ecological attributes exceeds its acceptable range of variation. The framework provides a rigorous basis not only for measuring success but for setting conservation objectives, assessing threats to biodiversity, identifying monitoring and research needs, and communicating management information to nonspecialists.

Keywords: monitoring, ecological integrity, protected area effectiveness, measures of success

Are we conserving what we say we are? This question is increasingly asked of and by protected area managers worldwide. The answers, unfortunately, remain ambiguous at best. Conservationists and protected area managers around the world spend millions of dollars each year to conserve biodiversity (Castro and Locker 2000, WRI 2000). Although efforts aimed at measuring the amount of conservation activity are increasing, the ability to measure the conservation impact of these investments and to document the true effectiveness of conservation actions has not greatly improved (Hockings et al. 2000, Salafsky et al. 2002). Without objective measurement, conservationists cannot claim successes, learn from failures, or work effectively and efficiently toward the conservation of the remaining biological diversity of the planet (Redford and Taber 2000, Salafsky et al. 2002).

For protected areas that focus on the conservation of biological diversity, the impact of conservation investment on biodiversity status is being questioned by donors and policymakers alike. Yet few parks have established systems to evaluate management effectiveness or to determine whether they are conserving the biodiversity they say they are (Brandon et al. 1998, Hockings et al. 2000). This widespread inability to measure progress, to learn through adaptive management, and to hold organizations accountable for conservation has led to a growing skepticism among policymakers and funding agencies about the long-term value of these conservation efforts (Senge 1994, Salafsky and Margoluis 1999a, Salafsky et al. 2001).

In response, several institutions have developed systems for measuring the efficiency and efficacy of protected area management (e.g., Hockings 1998, TNC 1998, Courrau 1999, Dudley et al. 1999, Hockings 2003). Most of these systems fit within an overall framework promoted globally by the IUCN (World Conservation Union) World Commission on Protected Areas (Hockings et al. 2000, Hockings 2003). This management effectiveness framework provides a system for identifying the information protected area managers should evaluate to determine whether management processes and conservation impacts are progressing as desired. The frame-

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work identifies six aspects of protected area management for evaluation: context, planning, inputs, process, outputs, and outcomes. This article focuses on the last of these six, the measurement of conservation outcomes.

Measuring what matters most in biodiversity parks

Though protected areas throughout the world have different purposes, we focus our attention on those areas with the principal purpose of biodiversity conservation. We propose that to assess conservation impact, management in these areas must address two primary outcome measures, namely, threat status and ecological integrity.

Threat status. Are the most critical threats that confront biological resources at a park changing in their severity or geographic scope as a result of conservation strategies (or lack thereof)? For example, has bushmeat poaching declined as a result of efforts to develop and improve contained domestic animal husbandry as a protein source for local communities? Measurement of threat status has gained increasing attention among practitioners and students of conservation (e.g., Salafsky and Margoluis 1999b, Hockings et al. 2001, Margoluis and Salafsky 2001, Ervin 2002). Clearly, without reduction in the threats to biodiversity, those species and ecosystems that are the focus of conservation investments will rapidly degrade and disappear. Yet, however important, measuring threat status is insufficient on its own for several reasons. Most significantly, a focus on threat status alone must assume that there is a clear, often linear, relationship between a threat and the status of biodiversity. This runs counter to recent evidence of the nonlinear dynamics of ecosystems and threshold effects (e.g., Scheffer et al. 2001). Also, a singular focus on threats can lead to a zero-tolerance approach to threat activities in human-influenced landscapes, and under most circumstances such an approach is unrealistic.

Ecological integrity. Do the ecological systems, communities, and species that are the focus of conservation efforts occur with sufficient size, with appropriately functioning ecological processes, and with sufficiently natural composition, structure, and function to persist over the long term? For example, is the riparian forest maintaining its natural range of species and patch composition, and is it resilient despite an increase in major flood events? Adapting the definition from Karr and Dudley (1981), we define *ecological integrity* as the ability of an ecological system to support and maintain a community of organisms that has species composition, diversity, and functional organization comparable to those of natural habitats within a region. An ecological system or species has integrity or is viable when its dominant ecological characteristics (e.g., elements of composition, structure, function, and ecological processes) occur within their natural ranges of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human disruptions.

A framework for measuring conservation effectiveness

The native biological diversity of any area includes innumerable species unknown or at best poorly known to science, embedded in numerous ecological systems whose webs of biotic and abiotic interactions are only poorly understood. Where a protected area addresses only one or a few iconic species, the goals and criteria for success may be relatively easy to define. Where the focus of the protected area is native biological diversity itself, however, the challenge to setting goals and measuring success becomes more difficult, particularly if the measures are to be scientifically defensible, practical, comparable from one protected area to another, and replicable over time.

Tracking biological diversity in an area using species census data provides one potential avenue for measuring success; another lies in the use of indexes of biotic integrity that incorporate information on both taxonomic and functional composition of sampled communities (e.g., Noss 1990, O'Connell et al. 1998, Karr and Chu 1999, Sayre et al 2000, Stein et al. 2000). Such approaches face many challenges in protected areas, especially those that span large areas or incorporate combinations of terrestrial, freshwater, and coastal marine ecosystems. The costs of repeated, comprehensive biological censuses can be unsustainable. In addition, biotic responses to threats may lag behind the pace of the threats or be difficult to detect with sparse monitoring data. Further, different biotic measures may be difficult to compare or standardize within the same protected area over time, let alone across multiple protected areas. Finally, different biotic measures may be difficult to interpret for people who are not specialists in the particular taxa involved, and many conservation managers are, in fact, nonspecialists (e.g., Salafsky and Margoluis 1999b, Dale and Beyeler 2001).

An alternative approach to measuring conservation success pursued by a growing number of organizations, including The Nature Conservancy, involves the use of some form of ecological scorecard. Such scorecards tabulate and synthesize diverse scientific information about the focal biodiversity of an area into a small number of measurement categories, which are standardized for use across multiple areas and conservation projects. Examples include the frameworks developed by The Nature Conservancy (TNC 2000a) and the River Health Programme in South Africa (e.g., Angliss et al. 2001) and the framework advocated by Harwell, Young, and others (Harwell et al. 1999, Young and Sanzone 2002).

The Nature Conservancy and its global conservation partners have devoted significant resources to developing a practical framework for assessing conservation impact (Poiani et al. 1998, TNC 2000a, 2000b, Salafsky et al. 2002). This framework, called "Measures of Conservation Success," is being implemented by The Nature Conservancy and its partners in hundreds of large-scale conservation areas across the Americas, Asia, the Pacific Islands, and Africa. The Nature Conservancy has recently refined this framework to strengthen its scientific rigor and improve its use in adaptive management, incorporating innovations and advice from several programs and partner organizations (TNC 2003). This refined framework has been tested across dozens of field projects over the past 4 years, across a spectrum from data-rich to data-poor areas. The framework uses quantitative and qualitative data assembled by teams of partner institutions and experts to track important ecological characteristics and synthesize their status into a set of simple categorical ratings (e.g., poor, fair, good, very good) of biodiversity status in an area. These ratings are scientifically credible and readily interpreted by protected area managers. Through repeated measurement, managers can use the framework to determine whether the status of biodiversity is responding to conservation investments and strategies over time. The framework has the added advantages of providing a rigorous basis for setting conservation objectives, assessing threats to biodiversity, identifying monitoring and research needs, and communicating management information to nonspecialists.

The proposed ecological scorecard for assessing ecosystem integrity and species viability has four core components: (1) selecting a limited suite of focal biodiversity targets, the conservation of which is intended to serve as a coarse-filter/fine-filter framework for protecting the whole; (2) identifying a limited suite of key ecological attributes for each target, along with specific indicators for each, that provide the information for measuring target status; (3) identifying an acceptable range of variation for each key ecological attribute of the focal conservation targets, defining the limits of variation within which the key ecological attribute must lie for the target to be considered conserved; and (4) assessing the current status of each target, based on the status of its key ecological attributes with respect to their acceptable ranges of variation, and integrating the assessments of target status into a measure of the status of biodiversity overall. The Nature Conservancy and other organizations have also developed scorecard frameworks for tracking institutional capacity, threats to conservation targets, and other inputs into protected area management (e.g., Hockings et al. 2000, 2001, TNC 2000a), but this article focuses on a scorecard specifically for tracking the ecological outcomes of conservation activity.

Identifying focal conservation targets

Biodiversity conservation targets (hereafter *conservation targets, sensu* Noss 1996, TNC 2000b, Salafsky et al. 2002) are a limited number of species, natural communities, or entire ecological systems that are chosen to represent the biodiversity of a conservation landscape or protected area. These targets serve as the foci of conservation investment and measures of conservation effectiveness. The reasoning behind such use of reduced numbers of elements of biodiversity for conservation planning is richly addressed in the literature (e.g., Noss and Cooperrider 1994, Christensen et al. 1996, Schwartz 1999, Poiani et al. 2000, Carignan and Villard 2002, Sanderson et al. 2002).

What elements of biodiversity should be chosen as conservation targets? Individual species work well as conservation targets for an area when their health and population dynamics vary in response to the full range of critical environmental factors and biological processes of the ecosystem in which they are embedded. Examples include species that play critical trophic or landscape-shaping roles in an ecosystem; require large ranges to sustain their populations or accommodate migratory patterns; require a broad spectrum of habitat conditions, from recently disturbed to long-undisturbed successional stages; or are highly sensitive to human interference. Yet the very qualities that make a species sensitive to changes in some features of an ecosystem often make it insensitive to others and therefore less suitable as a conservation target. For example, predators may eat either native or exotic prey without harm, and riparian forests may thrive even along rivers that have lost all their native fishes. Further, the dynamic environmental regimes and constraints that are critical for any one species may operate at different spatial and temporal scales than those that affect others (Holling 1992). As a result, conserving the conditions that best suit only a few native species will often not ensure the right conditions for the long-term survival of all native species and communities. We therefore recommend the selection of ecological communities or systems at the outset as "coarse-filter" conservation targets (Noss and Cooperrider 1994, Poiani et al. 2000), followed by the selection of species with unique ecological requisites not captured in the conservation of the communities or ecological systems in which they are embedded. The combined species, community, and ecological system targets—preferably a small and practical number—must create a safety net for the ecosystem as a whole, meaning that their conservation will help ensure that suitable environmental conditions exist for the persistence of all native species within a conservation landscape or protected area.

Identifying the key ecological attributes for conservation targets

To identify what is most important to manage for the conservation of biodiversity in protected areas, we must first synthesize our best understanding of the ecology of the conservation target, a process greatly aided by the development of ecological models. An ecological model for a conservation target (a species, community, or ecological system) identifies a limited number of biological characteristics, ecological processes, and interactions with the physical environment—along with the critical causal links among them—that distinguish the target from others, shape its natural variation over time and space, and typify an exemplary reference occurrence (Maddox et al. 2001). Some of these characteristics are especially pivotal, influencing a host of other characteristics of the target and its long-term persistence. We label such defining characteristics of a target its *key ecological attributes* (see figure 1). For example, consider a riparian ecosystem located within the foothills of a montane ecoregion. It is possible to identify enormous suites of species and describe numerous biotic and abiotic interactions that typify this system. Yet the spring flooding regime would clearly qualify as a key ecological

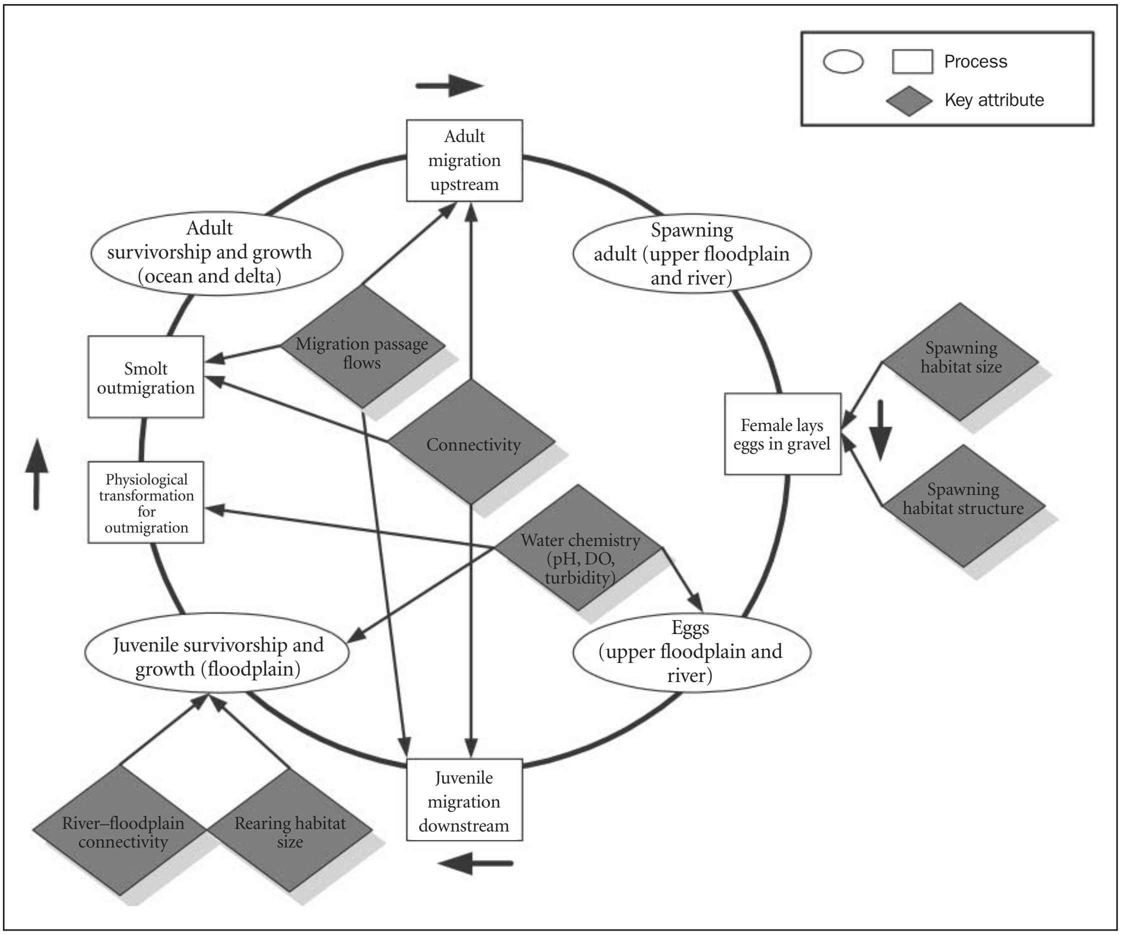

Figure 1. Conceptual ecological model of the key ecological attributes for a species-level conservation target, chinook salmon* (Oncorhynchus tshawytscha), *for the Cosumnes River Protected Area, California. (DO stands for dissolved oxygen.)

attribute of this ecosystem, because its magnitude, spatial extent, timing, and duration can play a pivotal role in a cascade of biological dynamics, such as seed dispersal for native riparian vegetation, variation in soil composition and fertility, elimination of invasive species that compete with native species, and patterns of succession.

The Nature Conservancy's Measures of Success framework rests on the premise that key ecological attributes must be managed and conserved to sustain each conservation target. By explicitly identifying such attributes, protected area managers can specify what is important to manage and monitor about individual conservation targets and, through monitoring these targets, can assess conservation success. Conservation targets and their key ecological attributes, therefore, are the essential currency for conservation management at any scale.

The key ecological attributes of any conservation target include not only its *biological composition* (and crucial patterns of variation in this composition over space) but also the *biotic interactions and processes* (including disturbance and succession dynamics), *environmental regimes and constraints* (again including disturbance dynamics), and attributes of *landscape structure and architecture* that sustain the target's composition and its natural dynamics (Noss 1990, 1996, Noss et al. 1995, Christensen et al. 1996, Schwartz 1999, Poiani et al. 2000, TNC 2000a, Young and Sanzone 2002). Identifying key attributes that address more than just biotic composition is important for two reasons. First, the abundance and composition of a target may lag in their responses to environmental impairments, and data on biotic interactions, environmental regimes, and landscape structure can help ensure the early detection of threats and changes resulting from human activities. Second, conserving the focal targets is not the ultimate goal but a means for conserving all native biodiversity in an area. Consideration of these additional types of key ecological attributes will further ensure that crucial aspects of ecological integrity are managed for the conservation of all native biodiversity.

Key attributes of a target's biological composition and spatial variation will differ, depending in part on whether the target is an individual species, an assemblage of species, or a natural community or ecological system. These attributes include the abundance of species and the overall spatial extent (range) of the target. Noss (1990) and Karr and Chu (1999) summarize the types of key attributes of composition relevant to these different scales of biological organization.

Key biotic interactions and processes are those that significantly shape the variation in a target's biological composition and its spatial structure over space and time. These may include not only interactions among specific species and functional groups but also broad ecological processes that emerge from the interactions among biota and between biota and the physical environment. Examples include productivity, nutrient cycling, distribution of biomass among trophic levels, biological mediation of physical or chemical habitat, and potential for trophic cascades (e.g., Pace et al. 1999, Scheffer et al. 2001).

Key environmental regimes and constraints (including both normal and extreme variation) shape physical and chemical habitat conditions and thereby significantly shape the target's biological composition and structure over space and time. Examples include attributes of (a) weather patterns; (b) soil moisture and surface and groundwater regimes; (c) fire regimes; (d) water circulation patterns in lakes, estuaries, and marine environments; (e) soil erosion and accretion; and (f) geology and geomorphology.

Key attributes of landscape structure and architecture comprise a special subset of environmental constraints, including connectivity and proximity among biotic and abiotic features of the landscape at different spatial scales (e.g., Holling 1992). Such constraints, for example, may affect the ability of that landscape to sustain crucial habitat requirements of individual species, sustain processes that transport habitat-forming matter (nutrients, sediment, plant litter) across the landscape, and permit recolonization of disturbed locations and demographic sinks.

The identification of key ecological attributes also requires the identification of the specific kinds of information, or *indicators,* that can be measured to inform managers of changes in the status of those attributes. Protected area managers should select for each attribute one or more indicators that meet several well-established criteria (Noss 1990, Margoluis and Salafsky 1998, Dale and Beyeler 2001).

Figure 1 and table 1 identify key ecological attributes and indicators for a sample conservation target, in this case the population of a species, chinook salmon *(Oncorhynchus tshawytscha),* in the Cosumnes River, California. The ecological model for this species illustrates several critically important characteristics in the species' life cycle. These include the size of unfragmented floodplain habitat for rearing young of the year; the connectivity between ocean, delta, floodplain, and river; and the river bottom (riffle) structure during spawning. Research and expert opinion confirm that these ecological attributes, if degraded, would rapidly result in the loss of ecological integrity to an extent that could make recovery substantially more difficult. With explicit documentation of data sources and decisions, managers can identify these characteristics as the key ecological attributes for the salmon population within the protected area and make them the focus of conservation management and measurement.

Defining when a target is conserved: The acceptable range of variation

The proposed scorecard framework defines a conservation target as *conserved* when all of its key ecological attributes are maintained or restored within some explicitly delineated range of variation over space and time, the limits of which constitute the minimum conditions for persistence of the target. We suggest calling this range of conditions the *acceptable range of variation* for a target's key ecological attributes.

Species, natural communities, and ecological systems all evolve over time within dynamic environments, and most of their ecological attributes have some temporal variation (Landres et al. 1999). For example, there is natural variation in the age and species composition of a forest canopy and in the frequency and intensity of fires or flooding regimes. This variation is not random; rather, it is limited to a particular range that is recognized as either (a) natural and consistent with the long-term persistence of each target or (b) outside the natural range because of human influences (e.g., fire suppression in fire-maintained systems) or other drastic environmental change. Further, the natural variation of the physical environment and biotic interactions within that environment create a dynamic template that shapes how species evolve and what species may (or may not) be able to persist in any given area. Managing conservation targets based on the concept of an acceptable range of variation, therefore, is important both for ensuring the persistence and integrity of a protected area's biological diversity and for safeguarding species' evolutionary potential (Christensen et al. 1996, Holling and Meffe 1996, Poff et al. 1997).

The distinction between an acceptable and a natural range of variation is important. Although there has been some theoretical and practical debate over the concept of a natural range of variation, it has proved a useful construct for setting benchmarks for conservation practice (Landres et al. 1999, Swetnam et al. 1999, Allen et al. 2002). However, what is "natural" is difficult to define, given the limited knowledge of many species and systems and the extent of human involvement in, and disturbance to, biodiversity around the globe (Hunter 1996). Indeed, in some areas current ecological systems have no historic counterparts, because the ecological systems in these areas have been so thoroughly transformed by direct human alterations such as anthropogenic chemicals and introduced species. Further, scientific knowledge of most ecological systems and species has a relatively short history, as does the preserved record of most environmental regimes (e.g., weather, fire, hydrology). As researchers begin to understand the ways in which ecosystems can be naturally dynamic on time scales not only of years and decades but also of centuries (e.g., Holling 1992, Swetnam et al. 1999) and millennia, it becomes apparent that human knowledge of the natural range of variation in populations, communities, and ecological systems arises from only a small sample of time.

Table 1. Format for the assessment of key ecological attributes for a conservation target, in this case a species target, chinook salmon (**Oncorhynchus tshawytscha**), *for the Cosumnes River Protected Area, California, as illustrated in figure 1.*

		Rating				
Key ecological attribute	**Indicator**	**Poor**	**Fair**	**Good**	**Very good**	**Current rating**
Habitat size: rearing	Areas of floodplain rearing habitat	0 acres of floodplain habitat	0–100 acres of habitat	101–1000 acres of habitat	> 1000 acres of habitat	Good
Habitat size: spawning	River miles of spawning habitat with at least one functional spawning riffle (with young-of-year production)	Latrobe Falls to Granlees Dam (5.5 miles)	Latrobe Falls to Highway 16 (7 miles)	Latrobe Falls to Schneider property (8 miles)	Latrobe Falls to Meiss Road (14 miles)	Fair
Migration: passage flows	Magnitude and timing of fall flows	No connectivity between the delta and spawning habitat	Periods of flow of 60 cfs at Michigan Bar during migration season; at least 10 days of duration	Periods of flow 60–200 cfs during migration season; at least 25 days of duration	Periods of flow > 200 cfs during migration season; > 25 days of duration	Fair
Habitat structure: spawning	Substrate composition of riffles	> 50% fine sediment	10%–50% fine sediment, 50%–90% gravel and cobble	Approximately 80% gravel, 20% cobble, some fine sediment	80% gravel, 20% cobble, no fine sediment	Fair
Recruitment: juvenile abundance	Abundance of juveniles	0–0.10 catch per hour in a rotary screw trap	0.11–0.25 catch per hour	0.26–1 catch per hour	> 1 catch per hour	Fair

cfs, cubic feet per second; DFG, Department of Fish and Game; TNC, The Nature Conservancy; USFWS, US Fish and Wildlife Service.

Therefore, defining what is natural may be infeasible for many, if not all, conservation targets.

Direct knowledge of the natural range of variation, therefore, is merely one source of information for developing hypotheses about the desired status for key ecological attributes. Other sources of such information include ecological models, expert knowledge, and comparisons among other examples of the same or similar species, communities, or ecological systems. Particularly where such examples have been affected by human impacts of varying types and magnitudes, comparisons can be especially informative about where the limits may lie beyond which the persistence of the target may be at risk.

The term *acceptable range,* unlike *natural range,* draws attention to the idea that it is not necessary to characterize all the details of an attribute's hypothesized range of variation. Instead, researchers need only to characterize certain outer limits that define the envelope of conditions within which the target should be expected and allowed to vary over time (e.g., Christensen et al. 1996, Holling and Meffe 1996). The resulting acceptable range of variation, while most likely not replicating prehuman conditions, will ensure the long-term persistence of the target (Swetnam et al. 1999, Egan and Howell 2001).

The concept of an acceptable range of variation for key ecological attributes establishes the minimum criteria for identifying a conservation target as conserved. Additional gradations are possible, helping to set more precise conservation objectives and measure their progress over time. For example, a target for which considerable effort is needed to keep one or more key attributes within their acceptable ranges of variation should be considered less well conserved than a target for which less active management is required. Similarly, among targets that do not meet the minimum criteria for being conserved, those for which one or more key attributes are trending further away from, rather than back toward, their acceptable ranges of variation would typically be considered more imperiled than those for which this is not the case. And targets for which one or more key attributes are approaching or have exceeded some threshold of recoverability altogether—or require a massive effort to prevent such failure—would be considered more imperiled than those whose key attributes are all within the recoverable range. We recommend using a hierarchical, four-part rating scale to capture these distinctions in conservation status and to represent the quantitative ecological data behind the assessment in a way that is intelligible to nonspecialists (figure 2).

Assessing conservation target status

Assessing the status of each conservation target involves assembling information on the indicators for all of its key ecological attributes and determining the appropriate status rating for each attribute (figure 2). The ratings for the individual attributes can be combined to generate an overall

Table 1. (continued)

Goal	Basis for indicator rating	Management objective	Current status (date)	Basis for current rating	Comments
Good	TNC knowledge of floodplain connectivity; area based on run size data (Yoshiyama et al. 1998; Peter Moyle, University of California–Davis, personal communication, 2000)	Rearing habitat provided for the young-of-year produced in the river (given the current low numbers, 100–1000 acres is adequate)	Approximately 750 acres (November 2001)	TNC data	Reflects ecological health. Monitoring information needs can be determined during the course of other duties.
Good	TNC comparison of historical spawning range to current spawning range (Keith Whitener, Consumes River Preserve, Galt, CA, personal communication, 2000)	Some spawning occurrences in full historical range	Seven miles of good spawning habitat (2000)	TNC data	Reflects ecological health. Monitoring information needs can be determined during the course of other duties.
Good	TNC ground-truthing of passage conditions on an annual basis (Keith Whitener Consumes River Preserve, Galt, CA, personal communication, 2000)	No passage restrictions during migration season	Good (1999), fair (2000); variable conditions year to year	TNC data	Reflects threat abatement. Approximately 4 half-days to ground truth for both migration factors.
Good	Evidence that fine sediment deposition causes damage to incubating eggs and disrupts the food web (USFWS species profiles)	80% gravel, 20% cobble, some fine sediment (in an undammed river some fine sediments are expected, as there is no trap)	Fine sediment dominant; waiting for DFG 2000 data report	TNC and DFG data	Reflects ecological health and threat abatement.
Very good	Numbers calculated from limited DFG data for the Cosumnes River; calculations based on target numbers for adults	Number of juveniles increased to at least 1 per hour by 2010	0.12 catch per hour (1998); waiting for recent data	DFG data	Reflects ecological health. DFG has not committed to monitoring beyond 2001.

conservation status rating for each target. The ratings for all targets, in turn, can be combined to generate an overall rating for the protected area. At each step in this tabulation, the definition of what it means for a target to be conserved must be maintained. That is, if any attribute for a target lies outside its acceptable range of variation, then that target itself cannot be considered conserved. If any target is considered not to be conserved, then challenges still persist for the adequate management of the protected area, and resources should be redirected as feasible toward restoring the conservation target to conserved status.

Table 1 shows the rating information for a sample of the key ecological attributes of the salmon target presented in figure 1. It illustrates a simple format for recording the information used to develop a scorecard. Maintaining such a record is invaluable for documenting management outcomes and maintaining institutional memory as conditions change and monitoring data accumulate over time.

Why use this framework?

The measurement framework presented here provides not only a standardized basis for

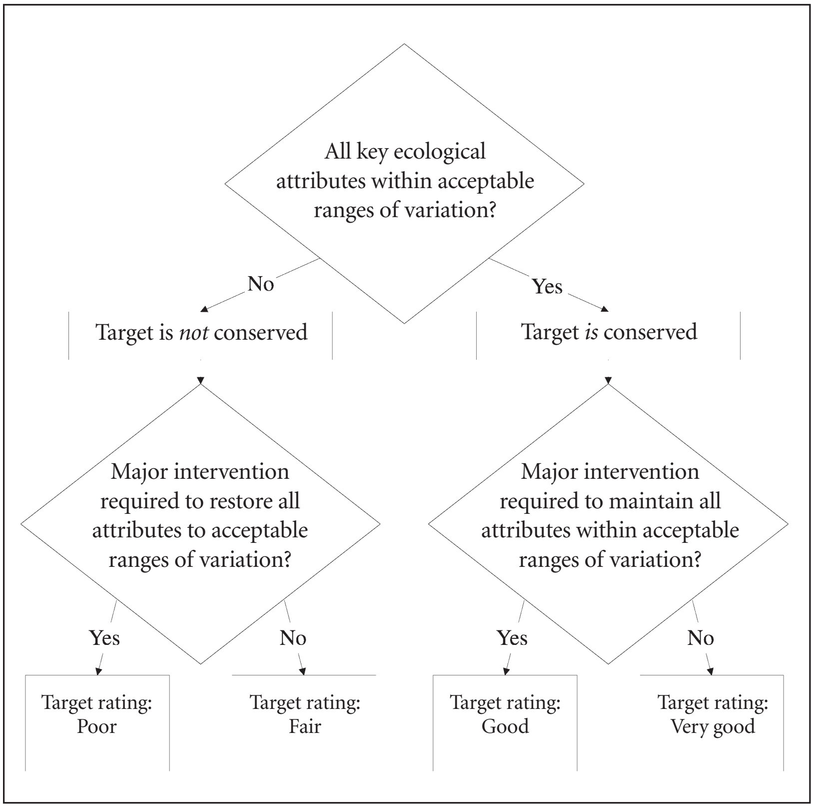

Figure 2. Basic decision tree for rating the status of a conservation target.

measuring the effectiveness of protected area management but several additional benefits for parks management.

It focuses strategy development along ecological, rather than jurisdictional, boundaries. Protected area management often focuses on implementing strategies only within the protected area boundaries, failing to consider issues of landscape connectivity and ecological processes that extend outside the park. Such strategies can achieve only limited success in reaching the park's ultimate objectives of conserving its ecological integrity. The proposed framework can help identify the true spatial scales at which each target's key ecological attributes function, irrespective of jurisdictional boundaries, so that conservation investments can take these scales more fully into account.

It provides consistency and specificity in setting conservation objectives. Setting clear, specific, measurable objectives for both threats and target integrity is essential for effective conservation management (Noss 1990, Margoluis and Salafsky 1998). The proposed framework helps set these benchmarks consistently across all targets, establishing what attributes of the target need to be managed, how much change is needed to achieve conservation success, and how to measure progress toward that end. Without such a framework, it is only too easy to adopt vague objectives such as "conserve the southern sea otter, *Lontra felina*." With the framework, managers can establish a more specific, scientifically defensible objective, such as "by 2010, double prey quantity and diversity for *L. felina* as compared to 2003 baselines in order to achieve a minimum viable population size of 5 to 10 individuals per square kilometer of protected coastline."

It enhances the identification and anticipation of threats to biodiversity. For every key ecological attribute of a target that is altered beyond its acceptable range of variation (e.g., insufficiently frequent flooding cycles in a riparian system), there is a cause that must be addressed. The proposed framework provides a means of systematically identifying and rating the status of possible threats. It therefore provides a means of ensuring that protected area management does not focus only on highly visible but not necessarily significant threats (such as conversion of native grassland to exurban development on a portion of the reserve) and overlook other less visible yet potentially more destructive threats (e.g., invasive species that affect the composition of a grassland community across an entire park).

It promotes the development of comprehensive conservation strategies. Conservation strategies based on *ad hoc* perceptions of threats to protected areas almost inevitably focus all resources on threat abatement (Bryant et al. 1998, Salafsky and Margoluis 1999b). Yet frequently the abatement of a threat will not improve the status of a conservation target, because it ignores the need to restore other crucial ecological attributes. For example, curbing the conversion of native temperate forest to industrial forest plantations of alien species may leave only remnants of the original forest that are too small to support adequate populations of the pollinators and seed dispersers needed for successful regeneration. The identification and assessment of key ecological attributes thus provides a means for identifying not only what threats require abatement but what altered attributes require restoration in order to achieve conservation goals.

It helps identify crucial research needs. Knowledge of the key ecological attributes of conservation targets will always be limited at best. This uncertainty may lead to the abandonment of conservation strategies for poorly understood targets or to a desperate quest for information on the target, without a clear sense of the questions that must be answered to improve conservation management effectiveness (Feinsinger 2001). The proposed framework helps identify the most critical questions and knowledge gaps for protected area management by specifically challenging management teams to identify the key ecological attributes and their acceptable ranges of variation for each target (Sayre et al. 2000).

It promotes focused and efficient monitoring programs. Monitoring programs to support the measurement of biodiversity and threat status are globally recognized as crucial elements of any protected area management program (Noss 1990, Brandon et al. 1998). Yet most monitoring programs are opportunistic rather than strategic, because it is unclear what should be monitored, where, and why (Dale and Beyeler 2001). The proposed framework helps identify exactly which of a target's ecological characteristics need to be monitored, encourages the identification of measurable indicators, and helps park managers answer logistical questions concerning where and when an indicator should be monitored, given its likely spatial distribution, natural fluctuations, and susceptibility to change.

Implementing the framework

Implementing the proposed framework may appear to be a daunting task. Conservation planners are likely to have little confidence in quantitative descriptions of the acceptable range of variation for a key ecological attribute, and they may possess no information at all on a target's ecology, let alone specific data for rating a target's status. Nevertheless, the framework challenges researchers and planners to advance their conservation work with hypotheses based on the best available information and to guide conservation management while documenting all assumptions and information gaps. Even where local scientific data are thin, it will be possible to find experts who are familiar with the general composition, structure, and function of the biodiversity in question or with similar systems for comparison. Such expert knowledge can serve as the basis for moving forward with hypotheses toward the goals of a rigorous assessment of ecological integrity and a thoughtful program of adaptive management. The data gaps, in turn, can serve as a menu for motivating and directing research toward the most pressing conservation questions. With such a framework in hand, park managers can ensure scientific rigor in their planning and management, promote consistency in the evaluation of management effectiveness, and begin to track the impacts of management actions. With sound measures of ecological integrity and species viability, managers of protected areas can begin to say with greater confidence whether or not they are conserving what they say they are.

Acknowledgments

This article reflects the innovative work and experience of thousands of conservation practitioners and protected area managers within The Nature Conservancy and its conservation partners. It specifically rests on the work of The Nature Conservancy's Ecosystem Integrity Working Group, whose members included Mike Beck, Jenny Brown, Pat Comer, Jeff Hardesty, Shirley Keel, Ricardo Soto, Tim Whittier, and the authors. We thank The Nature Conservancy's Freshwater Initiative for serving as a laboratory for the new framework. We are grateful to members of The Nature Conservancy's Conservation Measures and Audit Team, including Doria Gordon, Alex Mas, Wendy Millet, Brad Northrup, Nick Salafsky, Dan Salzer, M. Sanjayan, Stacey Solie, Tim Tear, and Steve Watkins, for their promotion of and improvements to the framework. We thank M. Sanjayan and Bradford Northrup for their leadership in supporting the development of these concepts within the organization. The conservation team at the Cosumnes River landscape in California, under the direction of Ramona Swenson, generously provided the salmon example herein. Richard Margoluis, Nick Salafsky, Tim Tear, Doria Gordon, Peter Kareiva, John Wiens, Jeff Baumgartner, Jamison Ervin, and our anonymous reviewers provided extraordinarily helpful reviews of this paper. We greatly appreciate Nicole Rousmaniere's assistance in preparing the final figures for this paper, and we are grateful for the support of the Colorado chapter of The Nature Conservancy (J. D. P.), Lisa Mickley (J. D. P.), and The Nature Conservancy's Freshwater Initiative (D. P. B.) and Rocky Mountain Division (R. S. U.).

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