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Authors: TEAR, TIMOTHY H., KAREIVA, PETER, ANGERMEIER, PAUL L., COMER, PATRICK, CZECH, BRIAN, et al.

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How Much Is Enough? The Recurrent Problem of Setting Measurable Objectives in Conservation

TIMOTHY H. TEAR, PETER KAREIVA, PAUL L. ANGERMEIER, PATRICK COMER, BRIAN CZECH, RANDY KAUTZ, LAURA LANDON, DAVID MEHLMAN, KAREN MURPHY, MARY RUCKELSHAUS, J. MICHAEL SCOTT, AND GEORGE WILHERE

International agreements, environmental laws, resource management agencies, and environmental nongovernmental organizations all establish objectives that define what they hope to accomplish. Unfortunately, quantitative objectives in conservation are typically set without consistency and scientific rigor. As a result, conservationists are failing to provide credible answers to the question "How much is enough?" This is a serious problem because objectives profoundly shape where and how limited conservation resources are spent, and help to create a shared vision for the future. In this article we develop guidelines to help steer conservation biologists and practitioners through the process of objective setting. We provide three case studies to highlight the practical challenges of objective setting in different social, political, and legal contexts. We also identify crucial gaps in our science, including limited knowledge of species distributions and of large-scale, long-term ecosystem dynamics, that must be filled if we hope to do better than setting conservation objectives through intuition and best guesses.

Keywords: conservation, objectives, goals, biodiversity, planning

We all set goals or objectives: how much money we'd like to save, how much we'd like to weigh, or what our next job should be. Governments and organizations are no different: virtually every public and private institution sets goals or objectives, which are used as motivational and management tools. In the conservation arena, recovery goals for threatened and endangered species, and biodiversity protection goals for countries, play a central role in applying science to policy and translating policy into action. These goals and their application encompass a challenge that has plagued conservation scientists over the past several decades: providing credible answers to the question "How much is enough?"

Answering this fundamental question has not been easy. In the United States, the Endangered Species Act (ESA) of 1973 was instrumental in raising awareness about the dire needs of many species. In response, entirely new concepts, such as minimum viable populations (e.g., Shaffer 1981), became a focus of discussion. Although viability analyses have occupied research scientists for nearly two decades now, conservation practitioners are still typically at a loss when establishing a quantitative target. Furthermore, conservation objective setting must compete with other goals and objectives that have a more powerful influence on public policy. For example, economic growth—one of the highest priorities in the domestic policy arena—has been identified as posing a fundamental conflict with biodiversity conservation (e.g., Czech et al. 2000). In competitive political arenas, weak goals and objectives can be very costly to achieving biodiversity conservation.

On the global stage, initial attempts to establish goals for habitat protection have resulted in worldwide recommendations for the percentage of each nation's total area that

Timothy H. Tear (e-mail: ttear@tnc.org) is the director of conservation science for the Eastern New York Chapter of The Nature Conservancy, Troy, NY 12180. Peter Kareiva is a lead scientist for The Nature Conservancy, Seattle, WA 98101. Paul L. Angermeier is assistant leader for fisheries with the Virginia Cooperative Fish and Wildlife Research Unit, US Geological Survey, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061. Patrick Comer is chief terrestrial ecologist for NatureServe, Boulder, CO 80302. Brian Czech is a conservation biologist with the US Fish and Wildlife Service, Arlington, VA 22203. Randy Kautz is senior scientist for Breedlove, Dennis and Associates, Inc., 2625 Neuchatel Drive, Tallahassee, FL 32303. Laura Landon is the acting director for the Global Conservation Approach Team of The Nature Conservancy, Charlottesville, VA 22901. David Mehlman is an ornithologist for The Nature Conservancy, Albuquerque, NM 87104. Karen Murphy is an ecologist for the US Fish and Wildlife Service, National Wildlife Refuge System, Anchorage, AK 99503. Mary Ruckelshaus is a research biologist for the National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA 98112. J. Michael Scott is leader of the Cooperative Fish and Wildlife Research Unit, US Geological Survey, University of Idaho, Moscow, ID 83844. George Wilhere is a conservation biologist for the Washington Department of Fish and Wildlife, Olympia, WA 98501.

should be officially designated as protected (e.g., 12% [WCED 1987], 10% [IUCN 1993]). While such rules of thumb often quickly gain broad acceptance, probably due to their simplicity and ease of application, they are inevitably met later with harsh criticism (Pressey et al. 2003, Brooks et al. 2004, Svancara et al. 2005). For example, Soulé and Sanjayan (1998) concluded that the World Commission on Environment and Development's 12% goal was largely based on political expediency, and that an ecologically based goal would be much higher. Brooks and colleagues (2004) showed that even though global protected-area coverage nears 12%, biodiversity protection is still far from complete. Svancara and colleagues (2005) showed that, on average, policy-based approaches are very close (13.1%) to the well-known 10% to 12% goals cited above. However, these were significantly lower than evidence-based approaches, where conservation assessments and threshold assessments called for higher goals (30.6% and 41.6%, respectively).

Conservation objective setting often mixes scientific knowledge with political feasibility in such a way that one cannot tell where the science stops and the political pragmatism takes over. For example, Tear and colleagues (1993, 1995) found that for federally threatened and endangered species with recovery plans, over a quarter of the plans set quantitative recovery objectives at or below the species' existing population size or number of populations. How could the recovery plans for threatened and endangered species have objectives that did not promote increasing populations? Most likely these objectives were so low because they were politically palatable (Scott et al. 1995). Elphick and colleagues (2001) recently found that recovery goals for endangered birds reflected the species' population sizes at the time the plans were written more than they reflected the biotic traits that influence the species' capacities to recover. Another possible explanation for modest recovery objectives is the phenomenon of the "shifting baseline syndrome" first described for fisheries (e.g., Pauly 1995). In this scenario, successive generations of wildlife managers use as their baseline the conditions they experienced at the start of their careers, resulting in lower expectations with each new generation.

Inconsistent objective setting is not limited to federal agencies. As part of their ecoregional planning process (Groves et al. 2002, Groves 2003), The Nature Conservancy routinely sets quantitative objectives for each of its conservation targets (e.g., habitat types and selected species). A different team of scientists works on each ecoregional plan, resulting in a proliferation of methods (figure 1). Some of The Nature Conservancy's first ecoregional plans set "protecting all viable occurrences" as the objective for rare species, regardless of the number extant or the historical distribution, while others adopted a universal objective of 10 viable populations, regardless of the species' life history, dispersal ability, or habitat requirements (TNC 2001a, 2001b, 2001c). Other plans adopted a single percentage goal for selected habitat types (e.g.,

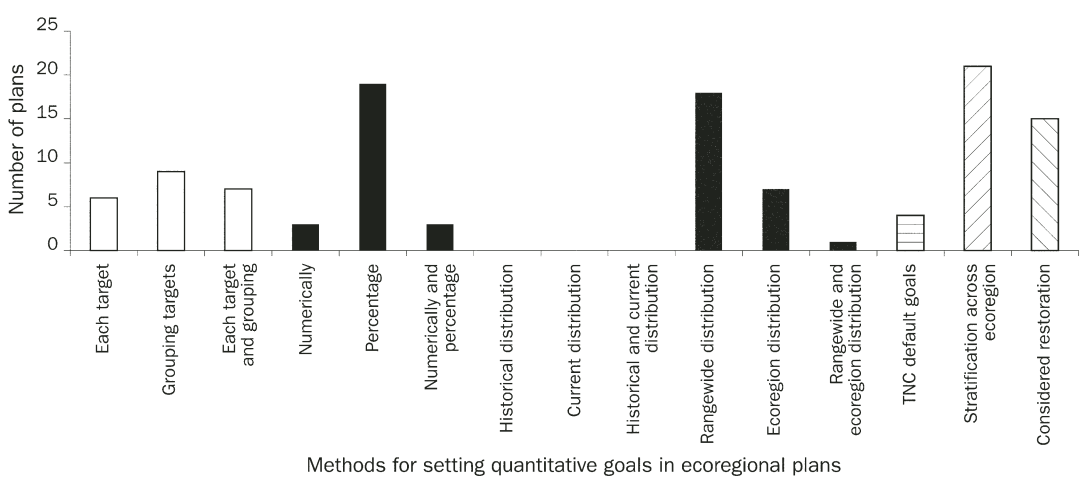

Figure 1. Different methods used to set quantitative objectives in The Nature Conservancy's (TNC's) ecoregional plans (based on a review of 44 plans). Quantitative objectives are referred to as "goals" in TNC's ecoregional plans. Goals for conservation targets (i.e., species, communities, or ecosystems) in each plan may be established for targets individually, for targets grouped together, or for a mixture of individual and grouped targets (unshaded bars). Metrics may be based on the number of targets, on a percentage of the total number or a distribution, or on a mixture of numerical and percentage-based calculations (black bars at left). Goals may be based on historical distribution patterns, on current distribution, or on a mixture of both (gray bars), depending on the target. Goals may consider the rangewide distribution of the target, its distribution within the ecoregion, or some mixture of ecoregion and rangewide distributions across all targets (black bars at right). The last three bars (with horizontal and diagonal lines) indicate how many goals are based on a set of default goals provided by TNC, how many reflect stratification across ecoregions, and in how many cases restoration was considered in the goal-setting process.

30% of historic extent), but provided limited scientific justification or rationale to support this decision (see case study by Neely and colleagues [2001] below).

What has led to the current situation, in which setting conservation goals and objectives remains so perplexing? Perhaps most important, the sheer complexity of conserving biological diversity cannot be overestimated. A variety of approaches are necessary for scientists to capture the continuum of biological organization, from genes to the entire biosphere, while addressing a variety of human needs (e.g., recreational and commercial harvest, ecosystem services, and intrinsic value of biodiversity). What is missing is an objective way to evaluate these different approaches that will facilitate improvement over time. To address this gap, we outline a few straightforward guiding principles and prescriptive standards to advance objective setting in conservation. We illustrate their application in three case studies.

Laying the foundation: Five principles for setting conservation objectives

We distinguish here between goals and objectives, although these terms are often interchangeable in common use. Our focus is on conservation *objectives,* which specify some quantifiable area, some number of individuals, or some number of populations that is identified as part of a conservation plan or vision. Conservation *goals,* as we use the term, are less precise and more conceptual. A conservation goal might refer to "a viable population" or "biodiversity protection," for example, without assigning specific numbers to the expression. The terms themselves are less important than the concept of defining clearly what is meant.

We propose five core principles that create a foundation for credible objectives: (1) state clear general goals, (2) define measurable objectives that science indicates will meet those goals, (3) separate science from feasibility, (4) follow the scientific method, and (5) anticipate change (table 1).

Principle 1: State clear goals. Goals are conceptual statements reflecting societal value and political or institutional intent. They need to be clear enough to direct the establishment of quantifiable objectives. Conservation goals may range from just enough resources for a species to survive 100 years to sufficiently abundant recovery that harvest of the species is allowed (box 1). If a minimal goal is set to "prevent extinction" of a species, then conservation might be achieved solely by maintaining the species in a zoo. If the much more ambitious goal of "historical levels sufficient to support commercial harvest" is selected, attaining this goal could require much larger numbers as well as vast areas of wildlands. What goals society selects is more a matter of values than it is of science, but the implications of different goals are profound.

While the need for better science to improve recovery planning has been repeatedly highlighted (e.g., Hoekstra et al. 2002), many debates surrounding the success and value of the ESA stem from different perspectives on the guiding goals, and not on the science applied in their pursuit. The act's stated purpose is "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved" (section 2[b]). This purpose gives considerable weight to the recent argument of Peery and colleagues (2003). They assert that salmon recovery goals for the Pacific Northwest should be more "ecologically defensible," emphasizing that salmon recovery should include the return of their role as a major nutrient source for aquatic and terrestrial ecosystems. Salmon populations required to sustain landscape-level nutrient dynamics would be much larger than the number required to avoid extinction.

Principle 2: Define measurable objectives. Whereas goals need to be broad and visionary, objectives must be measurable in order to ensure effective evaluation of progress (box 2). Systematic reserve selection has contributed substantially to advancing the application of this principle to identify priority areas for conservation (Margules and Pressey 2000, Pressey et al. 2003). The value of focusing on measurable objectives in conservation is receiving increased attention, due in part to a demand for accountability (Salafsky and Margoluis 2003, Parrish et al. 2003). Ideally, measurable objectives can be developed through a hierarchical process (figure 2). This would include a broad, visionary, long-term goal; a measur-

Table 1. The fundamental principles for advancing the science of objective setting in conservation.

Principle	Description
State clear goals	Well-defined, unambiguous statements that are brief, yet visionary, and are used as the basis for more specific objective setting.
Define measurable objectives	Measurable by some standard scale (e.g., number or percent) over time (e.g, months or years) and space (e.g., for a political or ecological region like a state or ecoregion).
Separate science from feasibility	Science alone must drive the process for setting objectives. Once set, feasibility may then be considered to evaluate the likelihood of achieving the stated objectives.
Follow the scientific method	Build on previous knowledge, conduct and document a transparent and repeatable process, document assumptions, quantify sources of error, and subject findings to peer review. In addition, thoroughly document sources of information, highlight weaknesses/information gaps, and suggest ways to improve through further research or improving the process in subsequent iterations.
Anticipate change	As objective setting is a science, expect objectives to change as knowledge and science change, and employ the concepts of adaptive management.

Box 1. Different societal viability goals to conserve individual populations.

Minimum viable population: The smallest isolated population that has a specified statistical chance of remaining extant for a given period of time in the face of foreseeable demographic, genetic, and environmental stochasticity and natural catastrophes (Meffe and Carroll 1994, p. 562; see also Soulé and Wilcox 1980, Shaffer 1981, Beissinger and Westphal 1998).

Ecologically viable population: Population that maintains critical interactions (e.g., behavioral, ecological, genetic) and thus helps ensure against ecosystem degradation. In general, these populations require population sizes much larger than estimated simply to persist over time (see Peery et al. 2003, Soulé et al. 2003).

Recreationally viable population: Population that supports recreational activities under specified conditions for a specified period of time (similar to criteria for minimum viable population above). Classic examples would be hunted populations, such as waterfowl and big game, and sport fisheries. For these populations, the impact of hunting or fishing can be manipulated through the use of different definitions of take, such as daily and seasonal bag limits to reduce the number of individuals taken, size limits (e.g., not allowing removal of fish larger than 18 inches to protect brood stock), or catch-and-release permits to limit incidental mortality resulting from no-take fishing (see Barnhart 1989).

Commercially viable population: Population that supports commercial activities under specified harvest levels for specified periods of time. Concepts such as maximum sustainable and optimally sustainable yields traditionally have been used to predict commercially permitted harvest levels (see Lovejoy 1996).

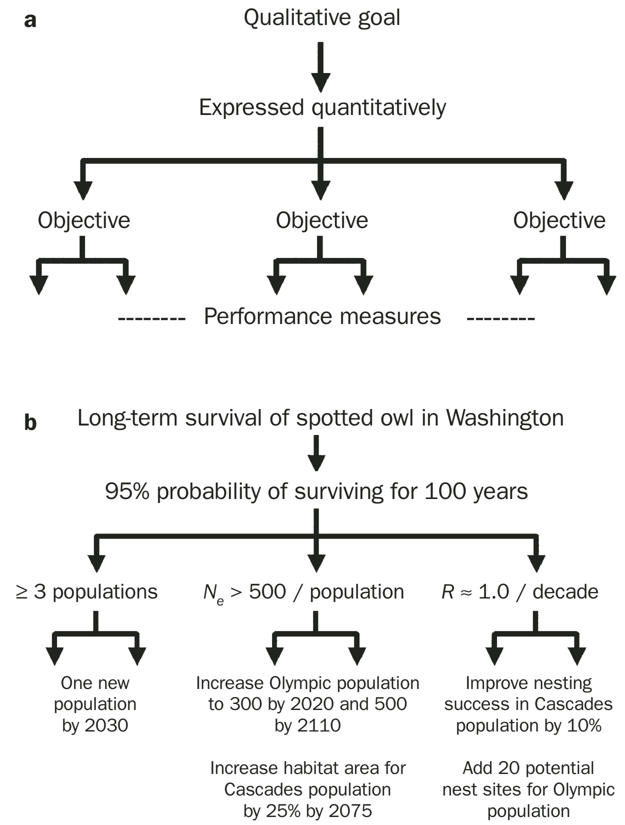

Figure 2. (a) Diagram showing a conceptual, hierarchical relationship among goals, objectives, and performance measures in conservation. The goal is likely to be expressed over the long term and is often, but not always, qualitative. Each objective should be measurable (quantitative measures are preferable, but qualitative measures are possible and often what is initially practical), with enough objectives to ensure completion of the goal. Performance measures are focused on a shorter time frame designed to demonstrate progress toward accomplishing the objectives. (b) An illustrative example for species conservation in Washington State shows how quantitative measures occur throughout the hierarchy.

able expression of that goal; multiple supporting objectives to meet the goal; and specific performance measures to track shorter-term progress toward accomplishing the objectives.

Principle 3: Separate science from feasibility. Social, economic, or political feasibility must not influence the use of ecological science in setting conservation objectives. Objective setting should be ecologically based and insulated from value-driven pressures. The place for other social and economic values—especially feasibility—is in the more conceptual goal-setting phase, or in the implementation of an action plan intended to achieve the goals and objectives. For example, if the goal is "sustainable fisheries," then we must be honest about what this goal means for harvest restrictions, and not alter our objectives simply because harvest reductions seem too unpopular. Alternatively, Czech (2002) argued that general, holistic land acquisition strategies could be informed by economic and political trends. The job of scientists is to make clear exactly what numerical objective is required to reach an associated goal. It is society's choice to revisit and modify conservation goals in light of scientific information.

Principle 4: Follow the scientific method. Objective setting for conservation needs to follow more closely the fundamentals of sound science. In particular, it needs to (a) have a transparent process that can be challenged or refuted by evidence, (b) state the assumptions used, (c) explain the relevant uncertainties, and (d) be subject to peer review. In our frame-

Box 2. Criteria for judging the quality of objective setting in regional-scale conservation plans.

Conservation goals and objectives should meet all of the criteria below (adapted from Margoluis and Salafsky 1998).

Criteria for goals

- Visionary: Inspirational in outlining the desired state of biodiversity in the conservation area.
- Relatively general: Broadly defined to encompass the sum of all activities.
- Brief: Simple and succinct so that all project participants can remember it.
- Measurable: Defined in quantitative or qualitative terms.

Criteria for objectives

- Impact oriented: Represents the desired status of specific ecological attributes.
- Measurable: Definable in relation to some standard scale (numbers, percentages, fractions, or all-or-nothing state).
- Time limited: Achievable within a specific period of time.
- Specific: Clearly defined so that all people involved have the same understanding of what the terms mean.
- Credible: Representing researchers' best scientific judgment as to what is necessary for conservation success.

Criteria for methods

- Accurate and reliable: Estimates sources of error and provides enough description so that the analysis can be repeated.
- Cost-effective: Estimates of the cost show that the method chosen is less expensive than other options.
- Feasible: Estimates the number of people or project teams that can use this method, and the resources available to conduct the work.
- Appropriate: The proposed methods make sense in the context of the key questions being addressed.

Criteria for indicators

- Measurable: Enables recording and analysis in quantitative and qualitative terms.
- Precise: Used or defined the same way by all people, with little variability.
- Consistent: Used or measured the same way, so that any results depict measurements of the same thing over time.
- Sensitive: Detects changes proportionately in response to actual changes in the condition being measured.

work, measurable objectives are hypotheses about what is needed to achieve the goals. To use these hypotheses correctly, the above components of the scientific process demand an approach and a commitment to follow-through that is rare in objective-setting processes to date. As the scientific method guides scientists, it should also guide conservation practitioners as they make decisions about objective setting.

Principle 5: Anticipate change. Scientists' ability to precisely answer the question "How much is enough?" for the majority of species, natural communities, and ecosystems is tenuous (e.g., Beissinger and Westphal 1998). Conservationists should recognize and admit key uncertainties, then design conservation actions that incorporate scientific monitoring to reduce those uncertainties (e.g., Holling 1978). If new knowledge indicates that established objectives will not achieve the current goal, then we must anticipate changing the objectives in an adaptively managed process.

Getting greater guidance: Six standards for setting measurable objectives

The previously described principles tell us in general terms how to go about setting conservation objectives. But they are too vague to tell us when conservation has been successful. Success can never be guaranteed, but we offer greater direction to practitioners through a set of more prescriptive, science-based standards to maximize the probability of success.

Standard 1: Use the best available science. The use of the concept "best available science" in the United States first appeared in legislation as part of the Marine Mammal Protection Act in 1972, and again later in the ESA; most recently, it has been reviewed in relation to reauthorizing the Magnuson-Stevens Act (OSB 2004). Numerous lawsuits have been filed surrounding the use of this term, and although there is no federal definition, there is legal precedent. For example, in the landmark case of *Daubert et al. v. Merrell Dow* (509 U.S. 579 [1993]), five criteria were defined for expert testimony to be admissible in court as representing the best available science:

1. The underlying reasoning or methodology is scientifically valid and can properly be applied to the facts at issue.
2. The theory or technique in question can be (and has been) tested.
3. It has been subjected to peer review and publication.
4. It has a known or potential error rate and the existence and maintenance of standards controlling its operation.
5. It has attracted widespread acceptance within a relevant scientific community.

Although debate about this ruling continues (see Faigman 2002), some states provide explicit guidelines for what constitutes best available science. For example, the Washington State Growth Management Act provides "a general indication of the characteristics of a valid scientific process typically associated with common sources of scientific information" (WAC 365-195-905) (table 2).

Standard 2: Provide multiple alternatives. The legal resolution of disputes over ecological and social conflicts often demands multiple alternatives. The US National Environmental Policy Act of 1969 requires that environmental impact statements provide multiple alternatives for evaluation. Presenting multiple alternatives is a sound way to accurately and fairly depict a full range of options that can incorporate varying degrees of societal risk and scientific uncertainty. For example, a goal may be to conserve a "viable population" of a particular species. The range of alternatives might include differing levels of risk (e.g., 75%, 95%, and 99% probability of persistence to 100 years), varying length of time for persistence (e.g., 80% probability of persistence to 10, 100, or 1000 years), or different strategies for persistence (e.g., many populations versus a few large populations). In fact, population viability analysis (PVA) is more appropriately used in this context for comparing the relative effects of differing management actions on population growth and persistence than for determining a specific minimum population size or extinction probability (Reed et al. 2002). For example, Czech (2005) assessed the capacity of the National Wildlife Refuge System to conserve federally listed animal species on the basis of an aggregated, three-tiered PVA approach that distinguished among genetic, demographic, and evolutionary viability. In addition, exploring multiple alternatives is a key component of systematic reserve selection (Pressey et al. 1993) and has been explicitly incorporated into reserve selection algorithms and software (Kerley et al. 2003).

Standard 3: Set objectives for both short and long time periods. It is commonly accepted that the further into the future scientists try to predict, the less confidence we have in our predictions. Many US planning horizons must be limited to political transitions, such as election years. However, many conservation goals currently require decades or even centuries to achieve. Consequently, we recommend that short-term, precise benchmarks accompany long-term, less precise targets for achievement. Short time frames (1 to 25 years) would span most planning horizons, whereas long-term predictions would cover those time frames greater than 25 years. Since PVAs typically emphasize a 95% probability of persistence to 100 years, conservation objectives relying solely on such analyses are inadequate without a set of complementary short-term objectives.

Table 2. Guidance for planners in Washington State on the relationship between the characteristics of a valid scientific process and common sources of scientific information from the Washington State Growth Management Act (WAC 365-195-905).

	Characteristics of a valid scientific process					
Sources of scientific information	**Peer review**	**Methods**	**Logical conclusions and reasonable inferences**	**Quantitative analysis**	**Context**	**References**
A. *Research.* Research data collected and analyzed as part of a controlled experiment (or other appropriate methodology) to test a specific hypothesis.	X	X	X	X	X	X
B. *Monitoring.* Monitoring data collected periodically over time to determine a resource trend or evaluate a management program.	—	X	X	Y	X	X
C. *Inventory.* Inventory data collected from an entire population or population segment (e.g., individuals in a plant or animal species) or an entire ecosystem or ecosystem segment (e.g., the species in a particular wetland).	—	X	X	Y	X	X
D. *Survey.* Survey data collected from a statistical sample from a population or ecosystem.	—	X	X	Y	X	X
E. *Modeling.* Mathematical or symbolic simulation or representation of a natural system. Models generally are used to understand and explain occurrences that cannot be directly observed.	X	X	X	X	X	X
F. *Assessment.* Inspection and evaluation of site-specific information by a qualified scientific expert. An assessment may or may not involve collection of new data.	—	X	X	—	X	X
G. *Synthesis.* A comprehensive review and explanation of pertinent literature and other relevant existing knowledge by a qualified scientific expert.	X	X	X	—	X	X
H. *Expert opinion.* Statement of a qualified scientific expert based on his or her best professional judgment and experience in the pertinent scientific discipline. The opinion may or may not be based on site-specific information.	—	—	X	—	X	X

X = characteristic must be present for information derived to be considered scientifically valid and reliable.

Y = presence of characteristic strengthens scientific validity and reliability of information derived, but is not essential to ensure scientific validity and reliability.

Standard 4: Incorporate the "three R's": representation, redundancy, and resilience. It is often hard to know what scientists, managers, and policymakers mean by "conserve" or "protect." We suggest a simple trilogy of concepts we call the "three R's"—representation, redundancy, and resilience (after Shaffer and Stein 2000)—to bring more specificity to the use of these terms. *Representation* means capturing "some of everything" of the ecological element or target of interest (e.g., a population, species, or watershed type). *Redundancy* is necessary to reduce to an acceptable level the risk of losing representative examples of these targets. *Resilience,* often referred to as the "quality" or "health" of an ecological element, is the ability of the element to persist through severe hardships. These three concepts capture many of the other concepts and principles now considered important in conservation efforts, and provide a template for conserving evolutionary potential. Systematic reserve selection established the foundations and continues to advance the components of this standard. Complementarity-based methods of systematic reserve selection were born from the recognition that previous approaches inadequately represented all the biodiversity elements of interest (e.g., Kirkpatrick 1983). Representation and multiple representation (i.e., redundancy) were recognized early on and are widely used (Pressey et al. 1993). Resilience (or persistence) in reserve design continues to garner considerable research attention (e.g., Gaston et al. 2002).

Standard 5: Tailor objectives to the biological system of concern. In pursuit of consistency and expediency, there may be a tendency to establish generic quantitative objectives, so that the exercise need not be repeated for every species and every circumstance. For example, The Nature Conservancy at one time considered (and rejected) an organization-wide adoption of a "10 × 200" rule (i.e., 10 populations of 200 breeding individuals would be needed to be considered secure) for all species (plant and animal) in ecoregional plans in the absence of better information. This tendency toward generalization has to be tempered by the realization that what works for plants may not work for animals, and what works for populations may not work for ecosystems. Rules of thumb adopted across taxonomic groups are problematic, as they ignore the variability inherent among biota for the sake of simplicity. A variety of objectives will be needed depending on the suite of systems or species involved; this notion has been advanced in several studies (e.g., Davis et al. 1999, Pressey et al. 2003, Czech 2005).

Standard 6: Evaluate errors and uncertainties. Evaluating sources of error is a critical component of all scientific endeavors. There are at least three main types of common errors and uncertainties related to conservation: (1) occurrence related, including errors in estimates of presence/absence, abundance, or spatial extent; (2) dose-response (recovery) related, including uncertainties in limiting factors and in the shape of recovery trajectory relative to reduced impact; and (3) persistence (viability) related, including uncertainties in spatiotemporal dynamics, the influence of human impacts on those dynamics, and future human impacts. Although there is little precedent for reporting on error or uncertainty in any objective-setting process or product, we believe that all evolutionary or ecological estimates associated with objective setting should come with some description or measure of possible error.

Regional case studies

In the following three case studies, we compare how the principles and standards proposed above have been incorporated into a variety of conservation objective-setting environments (table 3). Key points are highlighted for each example below.

Table 3. Status of the science base behind objective setting in three case studies.

Objective-setting protocol	Single species—Pacific Salmon Federal Recovery Plan	Multiple species—Florida's Closing the Gaps	Ecosystems—southern Rocky Mountains ecoregional plan
Principles			
State clear goals	Yes	Yes	Yes
Define measurable objectives	Yes	Yes	Yes
Separate science from feasibility	Yes	Yes	Yes
Follow the scientific method	Yes	Yes	Mostly
Anticipate change	Yes	Yes	Mostly
Standards			
Use best available science	Yes	Yes	Yes
Provide multiple alternatives	Yes	No	No
Define short- and long-term objectives	In progress	No	No
Incorporate the 3 R's[a]	Yes	Mostly	Yes
Tailor objectives to the biological system of concern	Yes	Partially	Yes
Estimate Error	Yes	No	No

a. Representation, resilience, and redundancy (after Shaffer and Stein 2000).

Source: Single species: McElhany et al. (2000), Ruckelshaus et al. (2002a, 2002b, 2004a); multiple species: Cox et al. (1994), Kautz and Cox (2001); vegetation communities and ecosystems: Neely et al. (2001).

Single-species conservation: Salmon recovery in the Pacific Northwest. The recovery planning process for salmon in the Pacific Northwest is one of the most intensive efforts to recover endangered species to date. Two types of recovery goals for salmon have been highlighted: (1) ESA goals, pertaining to statutory requirements, and (2) broad-sense goals, concerned with a wider range of societal interests. ESA goals focus on delisting, while broad-sense goals have different meanings for different people. For example, some people advocate a goal of robust populations that can support different levels of harvest (i.e., tribal, commercial, and sport), whereas others embrace the goal of fully functioning aquatic and marine ecosystems. These broad-sense recovery goals are being identified separately in various recovery planning domains (figure 3).

The task of developing the quantitative objectives for salmon recovery planning goals was divided into two technical analyses: (1) setting viability criteria for populations and evolutionarily significant units (ESUs) and (2) evaluating the ability of proposed management actions to achieve viability criteria. Technical recovery teams (TRTs) established by NOAA Fisheries have identified the viability criteria for populations and ESUs. Watershed planning groups are identifying suites of actions they think will achieve the recovery objectives for their watersheds. The TRTs evaluate the technical basis for recovery actions identified in watershed plans and the likelihood that collective risk levels across populations will result in achieving ESU viability.

*Figure 3. Geographic domains of recovery planning used by NOAA Fisheries for Pacific salmon (***Oncorhynchus** *spp.) listed as threatened or endangered under the US Endangered Species Act. Each domain (in different shades of gray) contains between three and seven separate listed evolutionarily significant units, or ESUs, for which recovery plans are being developed.*

In preparation for establishing quantitative viability objectives for populations and ESUs, NOAA Fisheries scientists developed viability criteria to guide recovery planning. Four key biological parameters were identified: abundance, productivity, diversity, and spatial structure (McElhany et al. 2000). Each ESU has 1 to 30 historically independent populations of salmon within its geographic boundaries (Ruckelshaus et al. 2004a). Population viability criteria were subsequently developed specifically for each historical population within the ESUs, based on analytical methods tailored to the complex life histories of salmonids (PSTRT 2002, WLCTRT 2003). The TRTs also have identified the characteristics of viable ESUs (PSTRT 2002, WLCTRT 2003), based on basic conservation principles such as redundancy of populations and resilience of the ESU to changes in environmental conditions (Ruckelshaus et al. 2002b).

To evaluate the effects of management actions, the TRTs developed guidance defining the key questions that must be addressed by each watershed council responsible for recovering salmon populations within an ESU (PSTRT 2003). The document asks that each population-scale recovery plan outline the hypotheses for what ails the population; the integrated hatchery, harvest, and habitat management strategy used to address the hypothesized factors limiting recovery; and a set of recovery actions that are consistent with the strategy. Finally, the watershed planning groups are asked to translate the effects of their proposed actions on the four viability attributes for salmon. The intent is to develop a watershed-specific (i.e., population-specific) plan with measurable objectives for each of the four major threats to salmon recovery (i.e., habitat, hydropower dams, harvest, and hatchery management; see Ruckelshaus et al. 2002a).

The salmon recovery planning team is working in the context of a complex feedback loop between the two population- and ESU-wide recovery goals and objectives to sustain the separation of science and feasibility in its process. Criteria for biological viability are established at the beginning of the process, independent of feasibility or social constraints other than a policy judgment of what constitutes an "acceptable" risk to the ESU. Planners can use the ESU viability guidelines to develop several scenarios of population risk, each of which satisfies the biological criteria for a low-risk ESU. Policymakers then will choose their political, social, or logistical "favorite" among those scenarios.

The transparent process of salmon recovery planning and the list of peer-reviewed publications already available regarding the interim products of this process are testimony to its following the scientific method. The recovery planning team is also anticipating change in the objective-setting process. First, watershed planners are encouraged to propose alternative sets of actions, acknowledging the uncertainty in predicting the effects of actions on salmon populations, and allowing for the possibility that actions may change if they appear not to be working. Second, future-scenarios analysis will be used to quantify the sources of anticipated change in global climate (e.g., temperature and precipitation patterns), ocean productivity, patterns of human development, the presence and effects of nonindigenous species, and disturbance regimes so that recovery strategies can be chosen on the basis of their robustness to uncertain future conditions (Ruckelshaus et al. 2002a).

Standards for salmon. The Pacific salmon recovery planning process uses the "best available science" in setting quantitative objectives by publishing peer-reviewed papers on the recovery planning team's PVA (Holmes and Fagan 2002). As the next set of peer-reviewed manuscripts is in preparation or review, the team's methods for other key analyses are documented in publicly available white papers on (a) habitat-based population dynamic models and (b) salmon's historical life history. Yet perhaps the most profound lesson learned from the planning process is the integral role that multiple alternatives have played in the quantitative objective-setting process. By embracing the principles described above, the recovery team applied scientific rigor while addressing societal needs.

The Pacific salmon recovery planning process incorporated the "three R's" in several ways. At its most basic level, the identification of 26 ESUs addresses appropriate representation and redundancy for the species, and ESU viability criteria require multiple populations with a representative sample of historical diversity for persistence. Resilience is addressed in part by using PVAs to ask how many fish are needed for population persistence, given the natural variability in abundance over time. Furthermore, diversity criteria are based on increasing resilience of populations and ESUs in the face of changing environmental conditions. Initial estimates of error in objective setting are well described for population viability, but they are not well described for ESU viability. Thus when Ruckelshaus and colleagues (2004b) attempted to give a range for the salmon population needed for ESU viability, their uncertainty was huge, and they had no good methods for producing rigorous confidence intervals. This uncertainty represents a large challenge for error assessment in conservation.

The salmon recovery planning effort is unusual in that it can draw on rich resources and quantitative acumen. Yet the distinction between short- and long-term objectives has been made only at the population (or watershed) scale. Planning groups acknowledge that because of the uncertainties in the effectiveness of recovery actions, shorter-term objectives are needed to guide their efforts. Comprehensive monitoring and adaptive management frameworks are just being developed. Furthermore, although general short-term objectives at the ESU level have been established (all populations must improve in status relative to their current state), no quantitative standards exist for how much improvement is necessary over the near term.

Multiple-species conservation: Closing the gaps in Florida. Perhaps no other US state has been as proactive at embracing quantitative objective setting as Florida. The Florida Forever Act of 1999 explicitly recognizes that measurable goals are central to successful conservation programs: "the Florida Forever program shall be developed and implemented in the context of measurable state goals and objectives" (Florida Statutes, chap. 259.105). In *Closing the Gaps in Florida's Wildlife Habitat Conservation System,* Cox and colleagues (1994) argued that Florida could not develop conservation plans for all 542 terrestrial vertebrates, 3500 vascular plants, and 44 terrestrial plant communities with the time and information available. Instead, they developed a transparent process to prioritize a subset of focal species and communities. We focus on Florida's series of PVAs that led to the selection of "10 populations of 200 breeding individuals on public land" as the criterion for considering all vertebrate species in Florida to be "adequately protected."

The overall goal was to identify lands in Florida that "at a minimum, must be conserved and managed in order to ensure the long-term survival of key components of Florida's biological diversity" (Cox et al. 1994). Measurable objectives followed from the PVAs and specified the need for 4.8 million acres (about 1.9 million hectares [ha]) of land acquisition. Despite public outcry that this was too much land for conservation, the objectives remained intact because of the defensibility of the process, independent of perceived feasibility. The planning team enhanced the credibility of the process by publishing its findings quickly as a publicly available agency report (Cox et al. 1994), later as a CD, and finally as a scientifically peer-reviewed document (Kautz and Cox 2001).

The Florida case study exemplifies the power of clearly articulated quantitative objectives (principle 2) and the need to anticipate evolution of objectives (principle 5). In 1990, Florida began a 10-year, $3.2 billion land acquisition program called Preservation 2000 to purchase lands for conservation and recreation. In 1999, the program was extended for another 10 years as "Florida Forever," and created the Florida Forever Advisory Council, which periodically reviews the program's goals and measures. A follow-up "Habitat Needs" report revealed that an additional 16 species were not adequately protected by the original "closing the gaps" approach, and that additional land acquisition was needed, although this additional area was very small (i.e., about 60,000 acres [24,000 ha] compared to the 4.8 million acres [1.9 million ha] originally identified). Despite repeated review and revision, the original 1994 goals and objectives have remained unchanged.

Following standards at the state level. The Florida team was progressive in its use of new technologies and tools to set quantitative objectives. First, instead of relying on existing recovery plans, the team used new models in the form of PVAs to set objectives. Second, habitat models were created from a database derived from Landsat imagery—one of the first such products ever completed at a state level. Third, the Florida team invoked available data, including more than 21,000 occurrence records, and a statewide breeding bird atlas. These factors led the state's land planning agency to declare that strategic habitats identified in the *Closing the Gaps* report were "best available science"—a declaration that played a critical role in updating county regulations pertaining to growth.

The Florida team established short- and long-term objectives, although these did not correspond with our proposed time periods. The team declared a "short-term" objective of achieving at least one viable population for each species. It built a universal viability objective for all vertebrate species based on 11 PVAs spanning three vertebrate groups (i.e., birds [6], mammals [4], and reptiles [1]). This was an extension of the existing guidance for short-term viability that called for an effective population size (i.e., N_e) of 50 (Soulé and Wilcox 1980). After evaluating multiple environmental scenarios (from favorable to harsh) for populations to exhibit a 90% probability of persistence to 200 years, they chose census populations of at least 200 breeding individuals to define the short-term goal of population viability (table 4). This is an important precedent, as Florida adopted into law a measurable objective using the "precautionary principle" (Groves 2003).

Although 200 years is not what we propose as "short-term," the Florida team considered this time frame as encompassing only "a few generations." In order to derive its long-term goal, the team relied on alternate modeling that estimated various probabilities of persistence (e.g., 15%–30%) for multiple populations (i.e., 1–10) (figure 4). This information was used by the Florida Game and Freshwater Fish Commission to choose 10 populations as their goal for long-term persistence. For species that exist as a single large, panmictic population (e.g., Florida sandhill crane) or are characterized by multiple isolated populations or loosely connected metapopulations, a single population of 2000 breeding individuals would be needed (i.e., 10 populations × 200 breeding individuals = 2000).

Despite its rigor and transparency, the Florida plan did not present multiple solutions (e.g., 75%, 90%, and 95% chance of persistence to 100, 200, and 300 years), nor did it consider the potential consequences of biases in objectives. The Florida effort lacked error rates associated with its key predictions (e.g., accuracy of land-cover data, accuracy of occurrence data, completeness of breeding bird atlas data, variability associated with demographic estimates used in PVA models). It did not explicitly consider rangewide species distributions, nor attempt to represent multiple populations across the state. Similarly, the objective for protecting rare natural communities was based on adequate representation in Florida over the long term, but not necessarily in proportion to original occurrences. However, as this was one of the first efforts of its kind, these shortcomings are understandable. More important, the official designation of the Florida results as "best available science" at the time secured these objectives as appropriate guides to conservation action.

Ecosystem conservation: Ecoregional assessment in the southern Rocky Mountains. The Nature Conservancy employs conservation planning at the scale of ecoregions to provide an ecological context for setting conservation priorities. Ecoregions are large areas of land and water with geographically distinct assemblages of species and natural communities, sharing similar environmental conditions and ecological processes (Bailey 1998, Ricketts et al. 1999). The Nature Conservancy intends to identify a network of conservation areas that could ensure the long-term survival and function of native species, vegetation communities, and ecosystems representative of each ecoregion (Groves et al. 2002).

The Southern Rocky Mountain (SRM) ecoregion covers approximately 40 million acres (16 million ha) from southern Wyoming to northern New Mexico (Neely et al. 2001). While objective setting for species was part of the SRM process, we focus here on terrestrial ecosystem representation. The Nature Conservancy's ecoregional goals are synonymous with quantitative objectives described in this paper.

Table 4. Estimates of census population sizes necessary to achieve an effective population size (i.e., N_e) of 50, and estimates of the smallest population sizes that have a 90% chance of persistence for 200 years based on computer simulations of populations experiencing favorable, moderate, and harsh environmental conditions.

Species	Viable population size			Census population
	Favorable	Moderate	Harsh	needed for N_e = 50
Florida panther	63	76	84	100–200
Florida black bear	46	82	114	71–126
Bobcat	113	169	239	156–190
Fox squirrel	216	285	365[a]	104–147
Bald eagle	57	114	126[a]	100–150
Sandhill crane	66	85	113	99–133
Wild turkey	63	134	229[a]	–
Florida scrub jay	121	132	179	65±[b]
Red–cockaded woodpecker	139	155	260	102±
Snowy plover	197	288	346[a]	130–170
Gopher tortoise	159	213	234[a]	90±
Range of values	46–216	76–288	84–365	65–200
Mean	112.7	157.6	208.1	

a. Population size was extrapolated.
b. Based on N_e=0.767(N) presented in Woolfenden and Fitzpatrick (1984).
Source: Used with permission from Blackwell Publishers.

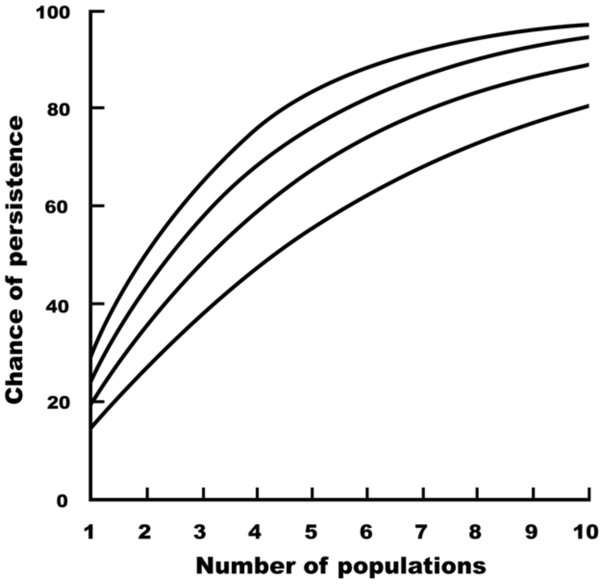

Figure 4. Relationship between the number of managed populations and the probability of persistence for vertebrate species in Florida. Four different persistence probabilities were investigated (e.g., 15%, 20%, 25%, and 30% probability of a single population persisting are shown at the starting point on the y-axis). Figure reproduced from Cox and colleagues (1994), courtesy of the Florida Game and Freshwater Fish Commission.

Pursuing principles in the private sector. The Nature Conservancy emphasizes the conservation of representative ecosystems to prevent species from imperilment, rather than focusing solely on recovering imperiled species. The National Wildlife Refuge System has also been exploring this approach to implementing its policy on biological integrity, diversity, and environmental health (USFWS 2001). This so-called coarse-filter/fine-filter approach (e.g., Groves et al. 2002) is built on the assumption that conserving the full array of natural habitats will adequately support the vast majority of species. Representation of all native ecosystem types and communities within conservation areas constitutes the "coarse filter" with types derived from a standard classification system (e.g., Grossman et al. 1998). A second assumption is that some rare and vulnerable species and natural communities would be inadequately protected by coarse filters. Therefore, a second "fine filter" is necessary to ensure conservation.

As with the above example in Florida, The Nature Conservancy faced the daunting challenge of establishing goals and objectives for each of the 500 or more target elements in the plan. Neely and colleagues (2001) started by setting goals differently for coarse- and fine-filter targets. The coarse-filter goal for ecosystems was to maintain (or restore) ecological processes to prevent additional species from imperilment. The fine-filter goal for species was to provide for their recovery and ensure their potential for evolutionary adaptation.

Incorporation of the "three R's" was explicit in the SRM plan's objectives for both filters, which were based on each target's level of biological organization and spatial distribution. In order to achieve resilience, knowledge of patch dynamics and disturbance regime was used to establish a minimum size criterion for each ecosystem type. For representation, models combining landform, substrate, and vegetation attributes were developed for all ecosystem types across the target's range of environmental settings and gradients.

Objectives varied depending on the spatial pattern of the conservation target (table 5). For ecosystems exhibiting "small-patch" characteristics (i.e., typically as discrete patches smaller than 10 acres [4 ha] each), objectives were expressed as a number of known occurrences, following assumptions and estimates similar to those of Anderson and colleagues (1999). Overall abundance objectives (for redundancy) were set for the entire ecoregion. Stratification (representation) across the ecoregion was set by requiring at least two occurrences of the conservation target (e.g., a species or vegetation community) within all portions of an ecoregion (called "sections" by the USDA Forest Service) that fell within the known range of the target.

For the remaining ecosystem types (i.e., matrix-forming, large-patch, and linear ecosystem types), Neely and colleagues (2001) established a generic objective expressed as 30% of an ecosystem type's historic extent (circa 1850, and approximated through various means to +/–10%). This percentage-based approach had been used elsewhere, based on the mathematical relationship between habitat area and the

Table 5. Conservation goals for terrestrial and aquatic ecological systems in the Southern Rocky Mountain ecoregion.

	Conservation goal		
	Matrix forming, large patch, and linear	Small patch	
Distribution relative to the ecoregion	Goal per section/ ecological drainage unit	Total number of occurrences	Goal per section/ ecological drainage unit
Endemic	Minimum of 30% of historic distribution (proportionally representing major gradients as expressed with ecological land unit and aquatic macrohabitat modeling)	25	2
Limited		15	2
Widespread		10	2
Peripheral		3	2

Note: See text for explanation.
Source: Modified from Neely et al. (2001).

number of species an area can support, generally referred to as the "species–area curve" (e.g., MacArthur and Wilson 1967). Considering this general relationship, the SRM team investigated to what degree conserving 10% and 30% of each ecosystem's historic extent might retain sufficient habitat to support the ecoregion's more common species at levels high enough to avoid the need for species-specific conservation actions. Exploratory analysis involved creating high-quality "ecosystems-only" portfolios (e.g., excluding targeted species). Analyzing occurrence data from 127 terrestrial species, the team concluded that conserving 10% or 30% of the historical extent of each ecosystem type in high-quality areas independently "swept in" (retained) approximately 10% or 30%, respectively, of the common species occurrences. Within this narrow range, a rough linear relationship existed between the percentage of high-quality habitat represented and the percentage of nontarget species occurrences that were captured independently.

The SRM team based its decision to select a 30% objective on a series of related assumptions. First, additional habitat for nontarget species and communities would exist outside the reserve design network. Currently there is extensive land area throughout the Rocky Mountain region that contributes significantly to long-term viability of many nontarget species and communities. Second, nontarget species and communities tend to occur across multiple ecoregions (usually two to four, but sometimes more). The SRM plan was geared to contribute only its proportion to the rangewide conservation of common species. For example, the representative portion within the SRM ecoregion might vary from 25% to 50%, depending on whether a species' range spanned four or two ecoregions, respectively. Third, published thresholds for vulnerable status provided an initial guide for numerical objective setting for nontarget species. For example, while criteria for establishing degrees of imperilment for species and communities vary (e.g., Mace and Stuart 1994, Master et al. 2002), they generally suggest numbers of discrete locations, or occurrences, ranging from 10 to more than 80 rangewide. For the coarse-filter concept to work, nontarget species and communities should be sustained at levels above such thresholds. These more common nontarget species and communities in the SRM ecoregion generally have more than 60 occurrences rangewide. On the basis of these assumptions and preliminary analyses, the SRM team settled on 30% of the historic habitat or area of these ecosystems as a preliminary objective for preventing the decline of the more common, nontarget species and natural communities (figure 5).

Will conserving 30% of the current extent of common species and communities within a network of reserves prevent imperilment? Answering this question definitely will require much additional research with many species and communities across diverse environmental conditions. Application of this concept faces significant challenges worldwide, as there remains a dearth of studies that explore this type of relationship.

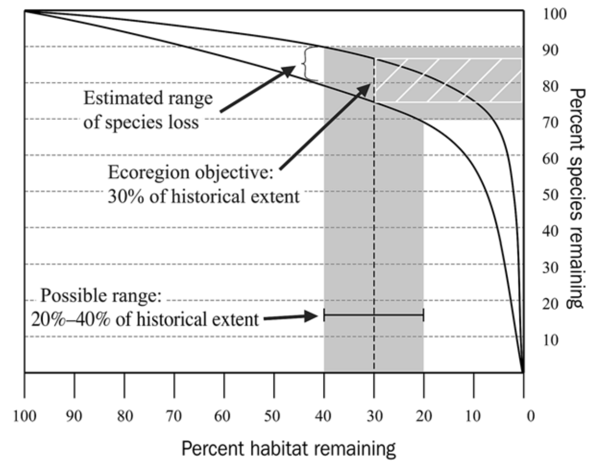

Figure 5. Estimated species loss with percent area of habitat loss over time, and its relationship to objective setting in the Southern Rocky Mountain (SRM) ecoregional plan. A single objective of 30% of the historical extent (circa 1850) of specified ecosystem types was selected by the SRM team, as shown by the single dotted vertical line. The white hatched rectangle connects the estimated range of species loss resulting from the 30% objective to the predicted percentage of species remaining in the habitat. A range of objectives could have been investigated, such as the gray zone representing 20%–40% of the historic range. Modified from Neely and colleagues (2001).

While the SRM team followed several principles and standards, the separation of science from feasibility was less clear. For example, the need to develop one initial vision, or conservation "blueprint," brought with it the risks and weaknesses of not developing multiple alternatives. Alternatives could have been created to explore a wide range of representation objectives (e.g., 20%–40%, as displayed in figure 5) and to facilitate discussion of the trade-offs between various risks. Consideration of multiple alternatives is highly feasible using optimization algorithms such as those available in SITES (Andelman et al. 1999), which was used in the SRM plan. Ambiguity surrounding the selection of the 30% areal objective is a weakness, as is the failure to evaluate error or uncertainty. This highlights the importance of recognizing that explanations of decisionmaking rationales should not be shortchanged by the desire to report results and begin implementation. The SRM team generated a readily available public plan in printed and electronic formats similar to those in the Florida example above. However, although multiple reviews of all aspects of the plan occurred at multiple times during its development, little substantive feedback on objective setting was offered by reviewers during this process.

To date, these shortfalls have been relatively inconsequential for nongovernmental organizations (NGOs), which are free to innovate and establish objectives for habitats and ecosystems without the threat of litigation. However, without formalized review, acceptance of such plans by government agencies may suffer because of their perceived inability to meet legal burdens of proof. The lack of critical review of the coarse-filter/fine-filter approach is largely a function of the lack of data and research necessary to test key assumptions, as well as a lack of guiding principles and standards for evaluating the objective-setting process.

Conclusions

The problem of how to credibly address the question "How much is enough?" has plagued conservation for decades (e.g., Beissinger and Westphal 1998, Svancara et al. 2005). In the United States, the ESA of 1973 raised awareness about the dire needs of many species, and demanded that science specify when a species is safe enough that it does not need federal protection. Thirty years later, a haphazard mix of science and societal values continues to drive biodiversity conservation (Czech and Krausman 2001), and setting quantitative objectives for imperiled species remains contentious, even for well-studied species like Pacific salmon (Peery et al. 2003).

One challenge to credible objective setting is the increasing emphasis on considering conservation of biological diversity across multiple spatial scales (e.g., Poiani et al. 2000) and at larger, regional scales such as states and countries (e.g., Groves et al. 2002, Groves 2003). These larger, more complex political, social, and ecological units present tremendous hurdles to answering the question "How much is enough?" The simple truth is that the more conservation biologists expand the spatial and temporal frames under consideration, the less confidence we have in the answers. These questions cannot be answered by theory alone, but require an empirical, target-by-target approach if the field of conservation is ultimately to improve the accuracy of its answers and sustain a commitment to monitoring and continual reevaluation over the long term (Soulé and Sanjayan 1998).

Another difficulty is that framing this discussion as the question "How much is enough?" has placed an inordinate and potentially detrimental emphasis on finding a single, absolute answer. Instead, answers should be communicated as hypotheses, with much more attention devoted to the relative amount of risk and uncertainty associated with the answers provided. Conservation biologists and natural resource managers know that they cannot preserve every acre of habitat or every individual of an imperiled species. They understand that sustaining species and ecosystems will require conserving at least some minimum amount—whether it is a number of individuals, a number of populations, or an area. The harsh reality is that for the vast majority of species, communities, or ecosystems, these minima are unknown. Lack of critical information on species and ecosystem distributions constrains conservation biologists' ability to test the underlying assumptions of conservation objective setting.

Conservation biologists need to improve the rigor of the science behind measurable objective setting. Through establishing a set of principles and standards, we begin making objective setting a legally defensible process. Measurable goals and objectives for successful conservation are needed if we are to clarify local, regional, and national ecological and social needs. Our case studies show that sound principles and standards for objective setting can be developed and applied effectively in federal, state, and NGO efforts with diverse visions for success (table 3). We propose that a set of general principles and prescriptive standards provides a much-needed foundation for objective evaluation. Without a method for effective and fair assessment of objective-setting processes, conservation has not been able to improve substantially our ability to assess whether answers to "How much is enough?" are credible. With a foundation for evaluation in place, it is now possible to advance objective setting in an adaptive process.

It is worth noting that although all three of our examples were blessed with larger budgets and scientific staff than most, some major gaps in setting credible conservation objectives were apparent. For example, although relatively simple in concept, it is remarkably difficult in practice to justify appropriate thresholds for representation, resilience, and redundancy (the three R's)—a problem central to quantitative objective setting. In many areas, it may also be necessary to incorporate a fourth "R"—restoration—to achieve even modest levels of representation, resilience, and redundancy. Similarly, the principles and standards described here apply specifically to setting objectives to establish the status, viability, or health of biological entities. However, there is an equally important set of conservation objectives that address reducing threats to biological diversity. Some of the standards we have listed, such as the three R's, do not apply to threat abatement objectives. Practitioners developing these objectives should apply only those principles and standards that are relevant to threat abatement.

One of the remaining challenges in conservation objective setting is to document the benefits of successful efforts and the consequences of mistakes. Currently, we have few examples that can verify either. Conservation biologists must advance the science of objective setting so that we can objectively assess the outcomes of these efforts. This is critical if we are to effectively link science with government policy in a way that can survive the tests of the courts. We propose that the principles and standards laid out here should be broadly applied. If objective setting falls short in many attributes, then appropriate managers or scientists should be asked to revise accordingly. A clear vision of the ideal objective-setting process can help guide us to conservation success.

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References cited

Andelman S, Ball I, Davis F, Stoms D. 1999. SITES V1.0: An analytical toolbox for designing ecoregional conservation portfolios. A manual prepared for The Nature Conservancy. (10 September 2005; *www.biogeog.ucsb.edu/projects/tnc/toolbox.html*)

Anderson M, Comer P, Grossman D, Groves C, Poiani K, Reid M, Schneider R, Vickery B, Weakley A. 1999. Guidelines for Representing Ecological Communities in Ecoregional Plans. Arlington (VA): The Nature Conservancy.

Bailey RG. 1998. Ecoregion Map of North America: Explanatory Note. Washington (DC): USDA Forest Service. Misc. Publication no. 1548.

Barnhart RA. 1989. Symposium review: Catch and release fishing, a decade of experience. North American Journal of Fisheries Management 9: 74–80.

Beissinger SR, Westphal MI. 1998. On the use of demographic models of population viability in endangered species management. Journal of Wildlife Management 62: 821–841.

Brooks TM, et al. 2004. Coverage provided by the global protected-area system: Is it enough? BioScience 54: 1081–1091.

Cox JR, Kautz M, MacLaughlin M, Gilbert T. 1994. Closing the Gaps in Florida's Wildlife Habitat Conservation System: Recommendations to Meet Minimum Conservation Goals for Declining Wildlife Species and Rare Plant and Animal Communities. Tallahassee (FL): Florida Game and Fresh Water Fish Commission.

Czech B. 2002. A transdisciplinary approach to conservation land acquisition. Conservation Biology 16: 1488–1497.

———. 2005. The capacity of the National Wildlife Refuge System to conserve threatened and endangered animal species in the United States. Conservation Biology 19. Forthcoming.

Czech B, Krausman PR. 2001. The Endangered Species Act: History, Conservation Biology, and Public Policy. Baltimore: Johns Hopkins University Press.

Czech B, Krausman PR, Devers PK. 2000. Economic associations among causes of species endangerment in the United States. BioScience 50: 593–601.

Davis FW, Stoms DM, Andelman S. 1999. Systematic reserve selection in the USA: An example from the Columbia Plateau ecoregion. Parks 9: 31–42.

Elphick CS, Reed JM, Bonta JM. 2001. Correlates of population recovery goals in endangered birds. Conservation Biology 15: 1285–1291.

Faigman DL. 2002. Is science different for lawyers? Science 297: 339–340.

Gaston KJ, Pressey RL, Margules CR. 2002. Persistence and vulnerability: Retaining biodiversity in the landscape and in protected areas. Journal of Biosciences 27: 361–384.

Grossman DH, et al. 1998. International Classification of Ecological Communities: Terrestrial Vegetation of the United States. The National Vegetation Classification Standard, vol. 1. Arlington (VA): The Nature Conservancy.

Groves C. 2003. Drafting a Conservation Blueprint: A Practitioner's Guide to Planning for Biodiversity. Washington (DC): Island Press.

Groves CR, Jensen DB, Valutis LL, Redford KH, Shaffer ML, Scott JM, Baumgartner JV, Higgins JV, Beck MW, Anderson MG. 2002. Planning for biodiversity conservation: Putting conservation science into practice. BioScience 52: 499–512.

Hoekstra JM, Clark JA, Fagan WF, Boersma PD. 2002. A comprehensive review of Endangered Species Act recovery plans. Ecological Applications 12: 630–640.

Holling CS, ed. 1978. Adaptive Environmental Assessment and Management. New York: John Wiley and Sons.

Holmes EE, Fagan WF. 2002. Validating population viability analyses for corrupted data sets. Ecology 83: 2379–2386.

[IUCN] The World Conservation Union. 1993. Parks for Life: Report on the IVth World Congress on National Parks and Protected Areas. Gland (Switzerland): IUCN.

Kautz RS, Cox JA. 2001. Strategic habitats for biodiversity conservation in Florida. Conservation Biology 15: 55–77.

Kerley GIH, Pressey RL, Cowling RM, Boshoff AF, Sims-Castley R. 2003. Options for the conservation of large and medium-sized mammals in the Cape Floristic Region hotspot, South Africa. Biological Conservation 112: 169–190.

Kirkpatrick JB. 1983. An iterative method for establishing priorities for the selection of nature reserves—an example from Tasmania. Biological Conservation 25: 127–134.

Lovejoy TE. 1996. Beyond the concept of sustainable yield. Ecological Applications 6: 363.

MacArthur RH, Wilson EO. 1967. The Theory of Island Biogeography. Princeton (NJ): Princeton University Press.

Mace GM, Stuart SN. 1994. Draft IUCN Red List Categories, Version 2.2. Species 21–22: 13–24.

Margoluis R, Salafsky N. 1998. Measures of Success: Designing, Managing, and Monitoring Conservation and Development Projects. Washington (DC): Island Press.

Margules CR, Pressey RL. 2000. Systematic conservation planning. Nature 405: 243–253.

Master LL, Morse LE, Weakley AS, Hammerson GA, Faber-Langendoen D. 2002. Heritage Conservation Status Assessment Factors. Arlington (VA): NatureServe.

McElhany P, Ruckelshaus M, Ford MJ, Wainwright T, Bjorkstedt E. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. US Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42. (25 August 2005; *www.nwfsc.noaa.gov/publications/techmemos/tm42/tm42.pdf*)

Meffe GK, Carroll CR, eds. 1994. Principles of Conservation Biology. Sunderland (MA): Sinauer.

Neely B, et al. 2001. Southern Rocky Mountains Ecoregion: An Ecoregional Assessment and Conservation Blueprint. Boulder (CO): Nature Conservancy of Colorado.

[OSB] Ocean Standards Board. 2004. Improving the Use of the "Best Scientific Information Available" Standard in Fisheries Management. Washington (DC): National Academies Press. (25 August 2005; *www.nap.edu/catalog/11045.html*)

Parrish JD, Braun DP, Unnasch RS. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. BioScience 53: 851–860.

Pauly D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10: 430.

Peery CA, Kavanagh KL, Scott JM. 2003. Pacific salmon: Setting ecologically defensible recovery goals. BioScience 53: 622–623.

Poiani KA, Richter BD, Anderson MG, Richter H. 2000. Biodiversity conservation at multiple scales: Functional sites, landscapes, and networks. BioScience 50: 133–146.

Pressey RL, Humphries CJ, Margules CR, Vane-Wright RI, Williams PH. 1993. Beyond opportunism—key principles for systematic reserve selection. Trends in Ecology and Evolution 8: 124–128.

Pressey RL, Cowling RM, Rouget M. 2003. Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. Biological Conservation 112: 99–127.

[PSTRT] Puget Sound Technical Recovery Team. 2002. Planning Ranges and Preliminary Guidelines for the Delisting and Recovery of the Puget Sound Chinook Salmon Evolutionarily Significant Unit. (15 September 2005; *www.sharedsalmonstrategy.org/resources.htm*)

———. 2003. Draft Integrated Recovery Planning for Listed Salmon: Technical Guidance for Watershed Groups in Puget Sound. (*www.sharedsalmonstrategy.org/resources.htm*)

Reed JM, Mills LS, Dunning JB, Menges ES, McKelvey KS, Frye R, Beissinger SR, Anstett MC, Miller P. 2002. Emerging issues in population viability analysis. Conservation Biology 16: 7–19.

Ricketts TH, et al. 1999. Terrestrial Ecoregions of North America: A Conservation Assessment. Washington (DC): Island Press.

Ruckelshaus M, Levin P, Johnson J, Kareiva P. 2002a. The Pacific salmon wars: What science brings to the challenge of recovering species. Annual Review of Ecology and Systematics 33: 665–706.

Ruckelshaus M, McElhany P, Ford MJ. 2002b. Recovering species of conservation concern: Are populations expendable? Pages 305–329 in Kareiva P, Levin S, eds. The Importance of Species: Perspectives on Expendability and Triage. Princeton (NJ): Princeton University Press.

Ruckelshaus M, Currens K, Graeber B, Fuerstenberg B, Rawson K, Sands N, Scott JM. 2004a. Independent Populations of Chinook Salmon in Puget Sound. US Department of Commerce, National Oceanic and Atmospheric Administration. (25 August 2005; *www.nwfsc.noaa.gov/trt/index.html*)

Ruckelshaus M, McElhany P, McClure M, Heppell S. 2004b. Chinook salmon in Puget Sound: Effects of spatially correlated catastrophes on persistence. Pages 208–218 in Ackakaya R, Burgman M, Kindvall O, Wood CC, Sjogren-Gulve P, Hatfield JS, McCarthy MA, eds. Species Conservation and Management: Case Studies. Oxford (United Kingdom): Oxford University Press.

Salafsky N, Margoluis R. 2003. What conservation can learn from other fields about monitoring and evaluation. BioScience 53: 120–121.

Scott JM, Tear TH, Mills LS. 1995. Socioeconomics and the recovery of endangered species: Biological assessment in a political world. Conservation Biology 9: 214–216.

Shaffer ML. 1981. Minimum population sizes for species conservation. BioScience 31: 131–134.

Shaffer ML, Stein BA. 2000. Safeguarding our precious heritage. Pages 301–321 in Stein BA, Kutner LS, Adams JS, eds. Precious Heritage: The Status of Biodiversity in the United States. New York: Oxford University Press.

Soulé ME, Sanjayan MA. 1998. Conservation targets: Do they help? Science 279: 2060–2061.

Soulé ME, Wilcox BA. 1980. Conservation Biology: An Evolutionary-Ecological Perspective. Sunderland (MA): Sinauer.

Soulé ME, Estes JA, Berger J, Del Rio CM. 2003. Ecological effectiveness: Conservation goals for interactive species. Conservation Biology 17: 1238–1250.

Svancara LK, Brannon R, Scott JM, Groves CR, Noss RF, Pressey RL. 2005. Policy-driven versus evidence-based conservation: A review of political targets and biological needs. BioScience. Forthcoming.

Tear TH, Scott JM, Hayward PH, Griffith B. 1993. Status and prospects for success of the Endangered Species Act: A look at recovery plans. Science 262: 976–977.

———. 1995. Recovery plans and the Endangered Species Act: Are criticisms supported by data? Conservation Biology 9: 182–195.

[TNC] The Nature Conservancy. 2001a. California North Coast Ecoregional Plan. San Francisco: TNC. (25 August 2005; *www.conserveonline.org/2002/07/m/NorthCoast_ERP*)

———. 2001b. Central Appalachian Forest Ecoregional Conservation Plan. Arlington (VA): TNC.

———. 2001c. East Gulf Coastal Plain Ecoregional Plan. Arlington (VA): TNC. (25 August 2005; *www.conserveonline.org/2003/08/s/egcp_ERA_june03*)

[USFWS] US Fish and Wildlife Service. 2001. Policy on maintaining the biological integrity, diversity, and environmental health of the National Wildlife Refuge System. (31 August 2005; *www.fws.gov/policy/library/66fr9593a.html*)

[WCED] World Commission on Environment and Development. 1987. Our Common Future. New York: Oxford University Press.

[WLCTRT] Willamette–Lower Columbia Technical Recovery Team. 2003. Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids. (22 September 2005; *www.nwfsc.noaa.gov/trt/viability_criteria.htm*)

Woolfenden GE, Fitzpatrick JW. 1984. The Florida Scrub Jay: Demography of a Cooperative-Breeding Bird. Princeton (NJ): Princeton University Press.