

# Principles of Conservation Biology: Recommended Guidelines for Conservation Literacy from the Education Committee of the Society for Conservation Biology

We live in a world of diminished ecological diversity. We extract energy, materials, and organisms from nature and modify landscapes at rates that cannot be sustained. These activities have resulted in accelerated rates of extinction, degradation, and loss of ecosystems, and disruption of the natural systems in which our cultures are embedded. The Society for Conservation Biology (SCB) believes that conservation education is a necessary step toward correcting these problems. Its stated goals and objectives include “the education, at all levels, preparatory and continuing, of the public, of biologists, and of managers in the principles of conservation biology.”

What are these principles? What are the central concepts and values that underlie the professional interpretation of the field of conservation biology, an understanding of which represents what could be called “conservation literacy?” Although there have been occasional spotlights on education in the literature of conservation biology (Jacobson & Hardesty 1988; Fleischner 1990; Orr 1992, 1994; Trombulak 1993), no consensus has emerged on essential guiding principles. Here we attempt to provide a framework for such guidelines. This document is the result of a long-term project carried out by the Education Committee of the SCB. The principles we present here emerge from the large body of research in ecology and genetics, from the prac-

tice of conservation over the last century, and from a variety of emerging interdisciplinary perspectives in the social sciences. Thorough overviews of the theoretical and empirical bases for these guidelines have been given by Meffe and Carroll (1997), Massa and Ingegnoli (1999), García (2002), Primack (2002), and Hunter (2002).

Here we aim to describe the body of knowledge that we view as the hallmark of conservation literacy rather than to prescribe what any particular individual ought to achieve. It is our expectation that these principles will serve different purposes for different audiences. For example, conservation organizations may use them to develop educational programs for their members, where the emphasis might be on helping citizens better understand the basis for effective conservation policies. They may serve as a guide in the development of conservation biology courses for undergraduate students (major and nonmajor) or for natural resource professionals in continuing education programs. They may also serve as a guide in the development of graduate programs in conservation biology, where the emphasis is on acquisition of career skills.

Because this framework is designed as an educational tool for a variety of audiences, it is different in several ways from a list of important topics, such as the table of contents of the textbooks mentioned above. First, each item or entry is not a topic ti-

tle but rather a principle, a statement of concept or goal that stands on its own as an idea to guide teachers and engage learners. Each of these principles reflects the findings of a variety of research that is available in textbooks but perhaps may not be easily accessible to all groups of learners.

Second, the framework is a hierarchy of principles, each of which stands alone while contributing to the overall conceptual whole. We want to encourage people to use this material in as many different ways as possible. Users can build upon whichever principle or group of principles are appropriate to their application, without the need to investigate or understand them all.

Third, the three hierarchical levels—primary principles, secondary principles, and supporting principles—offer the principles of conservation biology in increasing detail. Some users might only want to use and understand the primary principle associated with each theme. It would also be both correct and useful if the material was used or studied at the greater level of detail of the secondary principles. A longer and more detailed course of study would be based upon the more specific supporting principles. The framework can even be used, in a scientifically correct manner and appropriate to local needs, in a “mixed-level” approach. For example, a legislative office interested in species protection and habitat restoration might examine the five

primary principles as well as all of the secondary principles and concepts of Theme V (Action).

It might be tempting to view conservation biology as just another specialized subject area, relevant to only a few and unimportant to everyday life. Given the magnitude of the impact that humanity is having on life on Earth, however, conservation literacy ought to be considered one of the cornerstones of good citizenship in any nation (Orr 1992, 2004). The development of conservation literacy guidelines by the Society for Conservation Biology is in line with the path taken by other professional societies for the development of literacy guidelines in their respective fields (Gilliard et al. 1988; Geological Society of America 1999; North American Association for Environmental Education 1999; American Chemical Society 2003).

In our view, depth of understanding in any subject entails knowledge of principles as well as the ability to use that knowledge to solve problems. This paper is about the principles of conservation biology. The ability to solve problems is necessarily developed to different degrees depending on an individual's level of education and experience. We do not address here the complex subjects of problem-solving skills or other related intellectual and scientific skills, important as they are. Those are topics for future discussions. At a practical level, we leave it to those responsible for curriculum development and implementation at individual institutions to flesh out examples of skills associated with each principle for different levels of education and experience.

Further, each teacher should develop examples of these principles that are relevant to her or his students in the context of developing an understanding of one's local environment and an appreciation for the condition of the entire biosphere. As such, this document covers principles that are applicable to any region of the world, while recognizing

that using them successfully in any specific region depends on familiarity with the biological characteristics and conservation realities of that region. While the principles represent a thorough survey of the discipline of conservation biology, we do not view this document as a final delineation of conservation literacy. Rather, we hope that publication of these guidelines will mark the onset of a dialog in the international conservation community on the goals, values, and concepts in conservation biology; threats to biological diversity, ecological integrity, and ecological health; and strategies for their protection—a dialog on conservation literacy. These five topics—goals, values, concepts, threats, and actions—form the framework for the five overarching themes of the principles. We specifically acknowledge that a significant number of the principles of conservation biology as presented here are not simply empirical facts or theoretical predictions, but are desired outcomes based on value-laden beliefs. This is not a departure from the norm for conservation biology but is in fact recognized as a key attribute of the discipline (Barry & Oelschlaeger 1996; Meine & Meffe 1996).

## The Principles of Conservation Biology

### Theme I. Goals of Conservation Biology

Conservation biologists seek to maintain three important aspects of life on Earth: the natural diversity found in living systems (biological diversity); the composition, structure, and function of those systems (ecological integrity); and their resiliency and ability to endure over time (ecological health) (Callicott et al. 1999).

(A) Biological diversity: Biological diversity is the variety of living organisms at all levels of organization, including genes, species, higher taxonomic levels, and the

variety of habitats and ecosystems.

- (1) There is an immense and often unmeasured variety of living organisms on Earth.
- (2) The diversity of nature can be measured in a variety of ways, including absolute numbers, relative abundance, and ecological distinctiveness.
- (3) Biological diversity is threatened with extinction when one of two related patterns is observed: when an element is rare or when it is in decline.
- (4) Biological diversity, even under conditions not altered by human actions, is not fixed over time but is influenced by both ecological and evolutionary processes.
- (5) Changes in biological diversity that are more rapid or more extensive than changes that would occur without the impacts of human actions are likely to negatively affect ecological integrity and ecological health.
- (6) All aspects of biological diversity potentially play a role in maintaining ecological health and, therefore, are considered of value in conservation biology.

(B) Ecological integrity: Ecological integrity is the degree to which an assemblage of organisms maintains its composition, structure, and function over time relative to a comparable assemblage that has been unaltered by human actions.

- (1) The integrity of an ecological system (e.g., population, ecosystem) can be measured in a variety of ways, including measures of its structure (what a system looks like in space and time), function (the relationships between components), and composition (what the component parts of the system are)

relative to that of the system were it unaltered by human actions.

- (2) Protecting and restoring the ecological integrity of an ecological system require conservation across all levels of the biological hierarchy and across all ecological aspects of structure, function, and composition.
- (C) Ecological health: Ecological health is a relative measure of the condition of an ecological system with regard to its resiliency to stress and ability to maintain its organization and autonomy over time.
- (1) Ecological health is evaluated through a combination of measures, none of which alone is an index of health. Pertinent variables include productivity (a system's ability to produce more biomass), complexity (the number of elements in the system, the number of connections among those elements, the strength of interactions among the elements), and resiliency (the ability of the system to return to a particular state following perturbation) and are assessed relative to that of the system were it unaltered by human actions.
- (2) Ecological health focuses on the processes underlying the observable patterns of biological diversity and ecological integrity.

### **Theme II. Importance of Biological Diversity, Ecological Integrity, and Ecological Health**

The conservation of nature is considered important for three reasons: nature's intrinsic values; its instrumental or economic values; and its emotional, spiritual, and psychological values. These values are not mutually exclusive, but different people may hold different values, which must be taken into account to achieve conservation (Norton 1987).

(A) Value systems and perceptions of nature: Value systems determine how we view nature, and these systems may vary both within and among cultures.

- (1) Human value systems determine how we view nature, including how we judge the value of individual aspects of nature, human effects on the environment, and changes to biological diversity, ecological integrity, and ecological health.
- (2) There exists a range of human value systems regarding nature, from the view that everything in nature has its own absolute right to exist to the view that nature exists solely for use by humans, with many shades in between.
- (3) A diversity of value systems exists both among human cultures (in that some cultures traditionally place a greater emphasis on one set of values than on others) and within human cultures (in that different people within a single culture may value nature in different ways).
- (4) Efforts to achieve conservation must be carried out with an awareness and understanding of these different values systems both among and within cultures.

(B) Intrinsic values of nature: Intrinsic values are those values of nature itself, independent of any usefulness to humans.

- (1) Humans may value nature and natural entities (e.g., individual animals or plants, ecosystems, mountains) owing to their intrinsic value. Attribution of intrinsic value is independent of any use value the entity has.
- (2) Destroying or interfering with entities that have intrinsic value may, in some views, be considered morally acceptable only to satisfy vital needs.

(C) Instrumental values of nature: Instrumental values are based on usefulness to humans, commonly measured in terms of economic or service value.

- (1) Some instrumental values can be measured in economic terms, such that a monetary value can be placed on a component or function of nature.
- (2) Instrumental values can be held even when it is not possible to assign an unambiguous market value if a component or function of nature has a recognized use or serves a function for society. Such values include the ecological services provided by nature, including maintenance of soil fertility and climate control.

(D) Psychological values of nature: Psychological values are those that contribute to the psychological (emotional, spiritual, aesthetic) well-being of humans.

- (1) Psychological values can be derived from an identification with and caring for ecological systems, which may expand a sense of self and increase the sense that one has realized his or her full potential (Naess & Rothenberg 1989).
- (2) Psychological values can be derived both from a direct experience with nature and indirectly from the knowledge that nature exists even if aspects of it are not experienced directly.

### **Theme III. Concepts for Understanding Biological Diversity, Ecological Integrity, and Ecological Health**

An understanding of the important components of nature that should be conserved is based on an understanding of many key biological concepts, including those within taxonomy, ecology, genetics, geography, and evolutionary biology.

(A) Taxonomic hierarchy: All organisms are related to each other to a greater or lesser degree, and the pattern of relationship can be described as a hierarchy of related groups.

- (1) Organisms can be grouped by degree of evolutionary relatedness to one another.
- (2) There is a hierarchy in the organization of these groups by relatedness, from evolutionarily significant or distinct units to species, and on up to higher levels of taxonomic organization (e.g., genus, family, order).

(B) Ecological hierarchy: The components of nature are grouped together in sets of nested and interacting levels of organization, ranging from very small (genes) to very large (ecosystems and landscapes).

- (1) There is a hierarchy in the organization of life (ecological hierarchy) from genes, subpopulations (demes), populations, metapopulations, communities, ecosystems, and landscapes.
- (2) An element of one hierarchical level can have an influence on levels both above and below it.

(C) Genetic diversity: The information for making an organism is coded in an individual's genes. Genetic information varies from one individual to another, making all individuals potential sources of important information.

- (1) The biological basis for many of the characteristics that make up an individual organism is determined by information coded in the individual's DNA.
- (2) The exact information coded in the genetic material may differ from one individual to another and from one group of individuals to another.
- (3) The differences among individuals and groups in the exact information coded in the

DNA are what is called genetic diversity.

(4) Genetic diversity may reflect different selective forces operating on populations in different environments and therefore represents an important mechanism whereby species can respond to environmental change.

(5) Genetic diversity can be reduced through the operation of chance events associated with the survival and reproduction of individuals in nature. Such chance events have a much greater probability of reducing genetic diversity when the number of individuals in a population is small (i.e., random genetic drift).

(6) Genetic diversity within species is influenced by gene flow among populations, which results from the movement of individuals and, in some species, the long-distance transfer of reproductive cells (gametes) such as pollen. Movement among subpopulations inhibits the fixation of alleles, which can alternatively be viewed as maintenance of diversity (no alleles are lost) or homogenization (subpopulations do not become genetically different).

(D) The species concept: The basic unit of organization for organisms is the species; however, there is substantial variation within species, making their subgroups evolutionarily distinct.

(1) There are a variety of definitions for species, but from the perspective of conservation, a species is considered a group of organisms that can actually or potentially interbreed with one another or a group of organisms that share common traits and common descent.

(2) Species are not uniform, homogenous entities. They may contain diverse groups, each of which represents a unique set of genetic information and a unique evolutionary trend.

(3) Species are not unchanging over time; rather, they evolve in response to the forces of selection, gene flow, and chance.

(4) The classification of an individual organism into a particular species may change over time, reflecting our developing understanding of evolutionary and ecological relationships.

(E) Population growth: Populations tend to grow exponentially until limited by something in the environment. Small populations are more at risk of extinction and loss of genetic information than are large populations.

(1) The size of a population depends on the tradeoff between the tendency of a population to grow exponentially and the limitations imposed by biotic factors (e.g., density dependence, predation) and abiotic factors (e.g., climate) in the environment.

(2) The patterns of growth shown by populations when they are near the limit imposed on them by environmental factors may include a smooth approach to some intrinsic limit, oscillation around a limit, or population crash. Which pattern a population shows is influenced by several factors, especially the rate of recovery of food supplies and the behavioral and demographic responses of predators.

(3) The size of a population is, in general, inversely related to the probability of inbreeding, the loss of genetic information due to chance events

associated with survival and reproduction, and susceptibility to extinction. Therefore, small populations are, in general, at greater risk of extinction than large populations.

- (4) Metapopulations can occur when partly isolated subpopulations are connected by occasional dispersal of individuals from one subpopulation to another. Metapopulations can lead to a reduction in the risk of extinction of any of its component subpopulations.
- (F) Species distributions: Different species are distributed in different patterns over the earth based on their individual histories and biological characteristics. These patterns can change over time in response to changing conditions and human actions.
- (1) Each species has a distribution determined by evolutionary history, environmental factors (e.g., temperature, soil, rainfall), and historical events (e.g., colonization, extinction).
  - (2) The presence of any species in a given location is subject to change if the factors change that make the location suitable for the species.
  - (3) Distributions of many species have been affected by humans, both directly (through their local extirpation or transportation and release) and indirectly (through human alterations of habitats that make the movement or persistence of species more or less likely).
  - (4) Species with high local abundance also tend to have large geographic distributions, which can reduce the chance of extinction.
- (G) Communities and ecosystems: Communities and ecosystems are collections of individuals representing several to many species interacting with one another

in a particular area and with nonliving components of nature that are necessary for life.

- (1) The definition of a community or ecosystem depends on the context in which it is considered. For example, a community can be defined as the microfauna in the litter layer of a forest or as all the organisms in that forest.
  - (2) The composition of a community or ecosystem depends on the population growth processes of its constituent populations and on interactions among species (e.g., symbiosis, competition, and herbivory, parasitism, and predation).
  - (3) Community or ecosystem composition may change as a result of the responses by its constituent species to changes in environmental conditions. Thus, their composition is not static but shifts over time.
  - (4) Which species are potential members of a community or ecosystem will depend on the regional pool of species from which they can be drawn and on each species' dispersal and competitive abilities.
  - (5) The boundaries between communities or ecosystems may be relatively clear, such as between terrestrial and aquatic ecosystems, or they may be fuzzy. In no case is the division complete because there will always be interactions between species predominantly found in one community with those predominantly found in another.
- (H) Stochasticity: Stochasticity refers to the operation of chance in nature from one time period to another—for example, the chance that an individual will survive, the chance of having one offspring or two, or the chance of

experiencing a bad growing season.

- (1) Natural systems are constantly changing and are unpredictable over long periods. This applies equally to populations, communities, and ecosystems. The confidence in predictions about the future condition of natural systems decreases as the length of time over which the predictions are made increases.
  - (2) Stochastic changes caused by humans (e.g., an oil spill, destruction of a specific habitat fragment) are a distinct phenomenon superimposed on natural stochasticity.
- (I) Extinction: Extinction refers to the termination of an evolutionary line. It can occur as a result of both human and nonhuman causes; however, the rate of extinction due to human action today is far greater than the rate generally seen in the fossil record before humans.
- (1) Extinction is the long-term expectation for all populations—99.9% or more of all species that have ever existed have gone extinct.
  - (2) Lineages of a lesser rank than species (e.g., subspecies, stocks) go extinct more frequently than species, which contributes to the erosion of biological diversity.
  - (3) Extinction independent of the actions of humans results from stochastic events operating over long periods.
  - (4) Rates of extinction can vary over time. At infrequent times during Earth's history, extinction rates have been high relative to lower background rates. Some of these periods of high extinction rates—termed mass extinctions—were associated with extreme geological events, but the causes of others are unknown.

- (5) Rates of extinction caused by human action are greatly elevated over background rates and are thought to be comparable to or greater than rates during mass extinctions.
- (6) A given number of species can be maintained in a system if the extinction rate equals the speciation rate over evolutionary time but will decline if species lost to extinction outnumber those gained through speciation (as is the case with mass extinctions and human-induced extinctions currently taking place).

#### **Theme IV. Threats to Biological Diversity, Ecological Integrity, and Ecological Health**

Nature has faced and continues to face numerous threats from humans, including direct harvesting, habitat destruction, and introduction of non-native species. People's perceptions of the magnitude of a threat are strongly influenced by how much change they have seen occur, such that each generation develops a different standard for what is normal or natural.

- (A) Ecological economics: Recent developments in ecological economics correct past misconceptions in neoclassical economic theory, which have contributed to the loss of biological diversity, the degradation of ecological integrity, and the decline of ecological health (Costanza 1991; Daly & Farley 2003).
  - (1) Human activity is a subset of natural processes, not vice versa.
  - (2) Human economic activity encompasses services provided by natural ecosystems, yet not all of nature is available to be used as a resource for human economic activity.

- (3) Economic and physical constraints limit human economic activity and population growth, and not all of these constraints can be surmounted through technology.
- (B) Impacts of human colonization in ancient times: Human societies have a long history of causing extinctions and major changes in ecosystems.
  - (1) In the prehistoric (Martin & Klein 1984) and historic (Crosby 1993) past, arrival of humans to new areas led to extinctions of other species and large-scale changes in natural communities.
  - (2) Humans have caused extinctions and changes in natural communities in a variety of ways, including the cumulative impacts of direct exploitation for food, modification of natural vegetation, and introduction of exotic species.
  - (3) Human-caused changes in natural communities may be so pervasive yet poorly documented that contemporary human cultures may not be widely aware of how the biological conditions observed in the present have been altered by human actions in the past.
  - (4) Some human cultures may have developed a level of ecological knowledge or practice that supported the protection and restoration of biological diversity, ecological integrity, and ecological health.
- (C) Contemporary human impacts: Humans can affect species and ecosystems through the frequency and intensity of their actions as well as the area over which the actions are practiced. Varying these actions can modify their impact on nature.
  - (1) Ecosystems differ from one another in how they are af-

ected by a given type and magnitude of human impact. These differences are based, at least in part, on their own characteristics, such as rate of productivity.

- (2) As human activity changes an ecosystem, the altered system may be more susceptible to subsequent changes. That is, the system will lose resiliency.
- (3) All contemporary human impacts are amplified exponentially by the current growth rate of the human population; more people live now than ever before and the population is almost certainly committed to an increase over the next 50 years (Cohen 2003).
- (D) Patterns of extinction: Species are currently going extinct at a rate never before seen in human history and seen in the fossil record only during infrequent times of mass extinction.
  - (1) The pattern of extinctions among species we observe today is unprecedented in human history. These extinctions erode biological diversity, ecological integrity, and ecological health with long-term consequences.
  - (2) Currently, the extinction rate is exceeding the speciation rate. Thus, species are currently going extinct at a rate such that they cannot be replaced by evolution for millions of years.
- (E) Proximate causes of extinction: Humans bring about extinction through four primary actions: habitat destruction, habitat modification (such as through overhunting and overharvesting), and the introduction of non-native species.
  - (1) The effects of human activities on a species' extinction risk are influenced by the magnitude of the activities in both space and time.

- (2) Different species and groups of species may go extinct or be threatened with extinction as a result of a combination of different human activities.
- (3) Different species and groups of species may be more susceptible to extinction from one type of human activity than another.
- (4) Human activity might alter species' interactions, leading to extinctions of multiple species in a system (e.g., trophic cascades).
- (F) Global climate change: The earth is currently experiencing an increase in average temperature caused by human addition of greenhouse gases into the atmosphere. This change in temperature will have severe consequences for life on Earth through rapid changes in climate, geographic range, and ecological processes, increasing the risk of extinction (McCarthy et al. 2001).
- (1) Fossil fuel use during the past century has resulted in an increase in greenhouse gases, particularly carbon dioxide, in the atmosphere. The increased presence of these greenhouse gases in the environment has already resulted in an increase in the global average temperature over the last century that is greater than that of any century in the past 1000 years.
- (2) Uptake of carbon by plants offers only a temporary solution because most of this carbon will be released back into the atmosphere during decomposition; current conditions on Earth do not permit accumulation of new fossil fuel deposits.
- (3) The effects of continued increases in greenhouse gas concentrations will inevitably continue to affect climate for centuries, resulting in regional and seasonal changes in temperature and precipitation. Even assuming no further additions of greenhouse gas to the atmosphere, our climate will continue to change as a result of the additions already made.
- (4) Regional and seasonal changes in climate will have many effects on species, including changes in geographic distributions, risk of extinction, community composition, and ecosystem function.
- (5) It is not possible to halt completely the effects of these inevitable changes in climate on species. It may be possible, however, to reduce the magnitude of the effects by changing human resource consumption behaviors and land-use policies.
- (G) Cascading effects: The extinction of one species can cause the unpredictable extinction of other species as a result of their interactions in nature; these subsequent extinctions can in turn affect other species, causing a ripple effect throughout an ecosystem.
- (1) The degradation of biological diversity, ecological integrity, and ecological health at one level of biological organization may have subsequent impacts on biological diversity, ecological integrity, and ecological health at other levels.
- (2) Extinction or habitat degradation may in turn cause additional impacts, leading to a series of changes cascading through an ecosystem.
- (3) The ways in which cascading effects will occur are difficult, if not impossible, to predict in advance of their occurrence, but their effects can be large and long-lasting.
- (H) Historical condition of ecosystems: The present-day condition of most ecosystems is dramatically different from that of the past because of the actions of humans.
- (1) The actions of historical and current human societies have resulted in dramatic modifications of most present-day terrestrial and aquatic ecosystems.
- (2) Humans as individuals and societies have made value-based choices about how much the condition of an ecosystem can or should be modified, and these choices have determined and continue to determine the condition and composition of the natural world.
- (I) Changing standards: People's ideas about what constitutes the normal condition of nature are strongly influenced by what they have experienced in their own lifetime, regardless of whether those conditions were already altered by humans in the past.
- (1) As biological diversity, ecological integrity, and ecological health decline, each generation views the new lower level as "normal," and this affects value judgments that people make about the natural world and therefore affects the land-use decisions they make.
- (2) As people's firsthand exposure to natural systems declines, as a result of cultural changes and lack of accessibility, their perceptions of "normal" conditions of nature change.

#### **Theme V. Protection and Restoration of Biological Diversity, Ecological Integrity, and Ecological Health**

The conservation of nature requires a combination of strategies, including the protection of endangered species, ecological reserves, control of human actions that hurt ecosystems, ecosystem restoration, captive

breeding, control of non-native species, and conservation biology education.

(A) Endangered species protection: Species at risk of extinction require protection from exploitation and loss of habitat.

(1) Single-species protection activities focus on identifying the factors that led to the decline in population size and on remediation of those factors.

(2) Individual species may be helped by protection activities that target a species alone, or they may be helped by protection activities that include multiple species or entire communities.

(3) Given the stochastic effects on population sizes from both natural and human causes, species-protection activities must necessarily take place in a climate of uncertainty.

(B) Ecological reserve systems: Areas that are designated for conservation need to be established in such a way that they collectively cover the full range of ecosystem types and can protect the species present there from premature extinction.

(1) Ecological reserve systems are sets of areas managed in such a way that their primary function is to protect a species or group of species from extinction and to promote natural ecological and evolutionary processes.

(2) Such reserve systems are designed to include area sufficient for the target species to be viable with limited human intervention and for natural processes to occur.

(3) The effectiveness of reserve systems is influenced by their context, including the stresses placed on them by actions taking place outside of the system, actions taking place inside of the system,

and the degree to which the organisms present in the reserves perceive them to be connected.

(4) The design and management of ecological reserves must address the predicted effects of global climate change on the system or species they are intended to protect.

(C) Human uses of nature: Human uses of nature can be modified so that the impacts on ecological systems are lessened.

(1) Human enterprises should be more harmoniously integrated within the context of their natural environments, rather than segregated from them.

(2) Modifying ways in which humans use nature so that they more completely mimic natural ecological processes can lessen the impact of these uses on biological diversity, ecological integrity, and ecological health.

(3) The impact of human uses of nature on biological diversity, ecological integrity, and ecological health can be lessened by a reduction of the magnitude of human impacts in both space and time.

(4) Although biological reserves and national parks are often an essential component of conservation strategy, the ultimate success of conservation depends on refashioning human activities to coexist with biological diversity and ecological systems.

(D) Ecosystem restoration: Ecosystems that have been degraded through changes in function and species composition need to be restored to as close to their natural (as contrasted to culturally modified) conditions as possible.

(1) Ecosystems that have been degraded through human modification can, in some cases, be restored through

elimination of the external stresses, reintroduction of native species, removal of exotic species, and restoration of ecological processes.

(2) The extent to which a restoration effort is considered "successful" depends on the goals identified. No effort can ever restore exactly the natural ecosystem in its composition, structure, and function.

(3) An ability to promote restoration should not be seen as a justification for promoting habitat destruction elsewhere.

(E) Augmentation of natural populations: Species at risk of extinction can, in some cases, benefit from having their populations increased through the introduction into the wild of individuals bred in captivity.

(1) Species and subspecies on the brink of extinction in the wild may be helped through breeding in facilities such as zoos, aquaria, botanical gardens, and captive breeding facilities.

(2) Care must be taken to maintain genetic diversity from generation to generation and to mimic selective pressures the organisms would encounter in nature. For animals, habituation to humans should be minimized.

(3) Captive breeding programs for conservation are expensive and therefore are not practical for all species. For some species, they may be biologically unfeasible. For some endangered species, however, captive breeding may be the only strategy available to prevent immediate extinction.

(F) Management of harvests: The numbers of individuals from species that are harvested in nature need to be controlled so that the harvest does not significantly

**Table 1. A summary of the themes and primary and secondary principles of conservation biology presented in this paper.\***

<i>Themes</i>	<i>Primary principles</i>	<i>Secondary principles</i>
Goals: the goals of conservation biology	Conservation biologists seek to maintain three important aspects of life on earth: biological diversity, ecological integrity, and ecological health.	Biological diversity is a measure of the diversity of all life at all levels of organization. Ecological integrity is a measure of the composition, structure, and function of biological systems. Ecological health is a measure of a biological system's resiliency and ability to maintain itself over time.
Values: why biological diversity, ecological integrity, and ecological health are important	The conservation of nature is important for nature's intrinsic values, its instrumental values, and its psychological values.	Value systems determine how we view nature, and this may vary within and among cultures. Intrinsic values are those of nature itself, separate from a usefulness to humans. Instrumental values are based on the usefulness of nature to humans. Psychological values are those that contribute to the psychological wellbeing of humans.
Concepts: concepts for understanding biological diversity, ecological integrity, and ecological health	An understanding of conservation is based on key concepts in taxonomy, ecology, genetics, geography, and evolution.	All organisms are related to one another. The components of nature are grouped together in sets of levels of organization, from small (genes) to large (landscapes). Genes contain the information for making an organism, and this information varies from one organism to another. The basic unit of biological organization is the species. Populations grow exponentially unless limited by the environment; small populations are more at risk than large ones. Species are distributed in different patterns over the earth based on individual histories, characteristics, and responses to human action. Communities and ecosystems are collections of interacting species and the components of their physical environment. Nature may behave stochastically, in that conditions and outcomes may be unpredictable. Extinction is the termination of an evolutionary line and can occur as a result of both to human and nonhuman causes.
Threats: threats to biological diversity, ecological integrity, and ecological health	Nature has faced and continues to face numerous threats from humans, including direct harvesting, habitat destruction, and introduction of non-native species.	Principles of ecological economics correct oversights in neoclassical economic theory, which have contributed to conservation threats. Human societies have a long history of causing extinctions and making major changes to ecosystems. Human actions affect nature through their frequency, intensity, and spatial extent. Species are currently going extinct at a rate faster than at any time in human history and at a rate comparable to mass extinction events seen only in the fossil record. Humans cause extinction through habitat destruction and modification, over-exploitation, and introduction of non-native species. Humans are currently causing the earth's climate to warm, which will have severe consequences for natural systems. Extinction of a species can cause extinctions of other species. The present condition of most natural systems is changed from the past as a result of human actions. Ideas about the "normal" condition of nature are influenced by what a person experiences in his or her own lifetime.

Table 1. (continued)

<i>Themes</i>	<i>Primary principles</i>	<i>Secondary principles</i>
Actions: protection and restoration of biological diversity, ecological integrity, and ecological health	Conservation requires a combination of many different strategies.	Protect species at risk of extinction. Designate ecological reserves. Lessen the magnitude of human impacts on natural systems. Restore ecosystems that have been degraded. Augment populations with individuals raised in cultivation or captivity. Control the number of individuals harvested in nature. Prevent the establishment of non-native species, and eliminate non-native species that have become established. Understand and participate in the policy-making process. Educate others about the importance of conservation.

\*Complete descriptions of the supporting principles associated with each secondary principle are presented in the text.

- increase the probability that the species will go extinct.
- (1) Indiscriminate harvesting can accelerate or cause extinction.
- (2) Control of harvesting, through outright bans in the case of rare, threatened, or endangered species; through controls of harvest of vulnerable age or stage classes; through limits on the number of individuals harvested; through limits on the length of time over which harvesting can occur; and through establishment of "no-take" reserves, may promote species persistence.
- (3) To prevent extinction through over-harvesting of species, societies must be willing to regulate harvesting guided by a biological understanding of population demography.
- (G) Management of non-native species: Efforts must be made to decrease the probability that non-native species will become introduced or successfully established, and efforts need to be made to eliminate established non-native species whenever possible.
- (1) Non-native species are one of the prime threats to native species and ecosystems worldwide.
- (2) Non-native species can be spread either accidentally or intentionally.
- (3) Most introductions of non-native species are probably unsuccessful, but a few have had devastating consequences both ecologically and economically.
- (4) After a non-native species becomes established, it is difficult if not impossible to completely eradicate it.
- (5) The ability of a non-native species to establish itself is influenced both by its own characteristics (e.g., reproductive biology) and the condition of the natural community into which it is being introduced (e.g., ecologically healthy communities tend to be less vulnerable to invasion).
- (H) Political participation: Understand and participate in the realm of human politics and policy, making sure to insert the importance of maintaining native biodiversity into public discourse.
- (1) Understand the processes and structures by which public policy is established—including laws, administrative regulations, and channels for lobbying.
- (2) Be familiar with the people who play key roles at a variety of geographic levels, from local to international.
- (3) Share knowledge and expertise of conservation biology with policy makers whenever opportunities arise or can be created.
- (I) Education: Conservation education needs to occur at all levels in all societies so that humans can better learn to coexist with nature.
- (1) Conservation education programs seek to develop in people a deeper understanding of the importance and tools of conservation biology.
- (2) Education is most successful when it focuses on developing knowledge, skills, and attitudes in a way that gives people extended direct experience.
- (3) Conservation biologists have a unique set of knowledge, skills, and concerns to share with others.

## Conclusions

We set out to describe hierarchically the central principles of conservation biology, summarized in Table 1, to facilitate development of conservation education programs at various levels and a general appreciation by all persons of what conservation biologists have found to be important for the discipline. Mastering the appropriate principles and the skills to apply them constitutes conservation literacy. Our belief is that if citizens, decision makers involved in

conservation, and conservation practitioners become fully conservation-literate, then our collective societies will be able to live more harmoniously with nature.

We welcome discussion of these guidelines; an electronic gateway to that dialog ([http://conbio.net/scb/services/education/docs/conservation\\_literacy.cfm](http://conbio.net/scb/services/education/docs/conservation_literacy.cfm)) is provided on the SCB web site. We look forward to assimilating input from the broader international community of conservation biologists based on their experience with teaching and mentoring conservation-literate citizens, decision makers, and conservation practitioners.

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