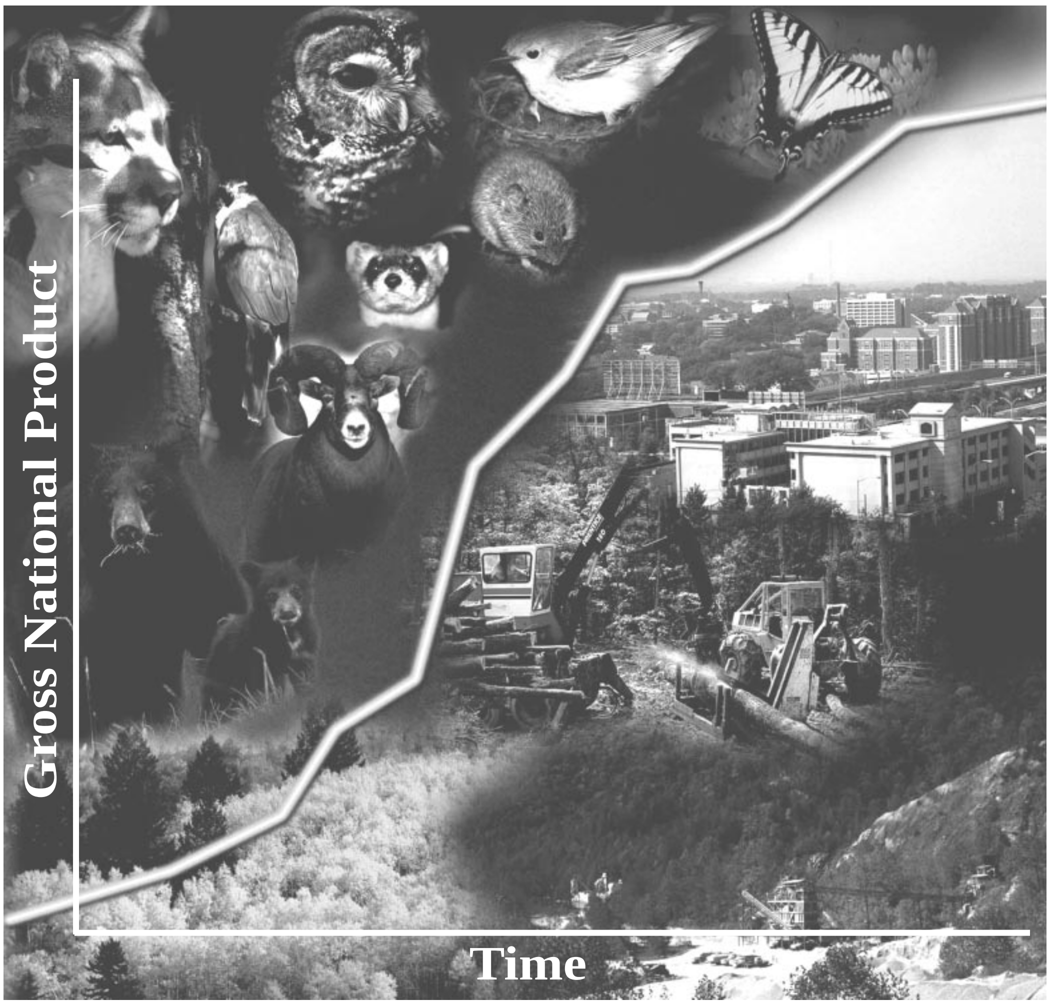
The Relationship of Economic Growth to Wildlife Conservation



THE WILDLIFE SOCIETY

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The Relationship of Economic Growth to Wildlife Conservation

The Wildlife Society

Members of the Economic Growth Technical Review Committee

David L. Trauger (Chair)
Natural Resources Program
Virginia Polytechnic Institute and State University
Northern Virginia Center
7054 Haycock Road
Falls Church, VA 22043

Brian Czech
National Wildlife Refuge System
U.S. Fish and Wildlife Service
4401 North Fairfax Drive, MS 670
Arlington, VA 22203

Jon D. Erickson
School of Natural Resources
Aiken Center
University of Vermont
Burlington, VT 05405

Pamela R. Garrettson
Division of Migratory Bird Management
U.S. Fish and Wildlife Service
11500 American Holly Drive
Laurel, MD 20708

Brian J. Kernohan
Boise Cascade Corporation
2010 South Curtis Circle
Boise, ID 83705

Craig A. Miller
Human Dimensions Research Program
Illinois Natural History Survey
607 East Peabody Drive
Champaign, IL 61820

Edited by Krista E. M. Galley

The Wildlife Society
5410 Grosvenor Lane, Suite 200
Bethesda, Maryland 20814

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Foreword

Presidents of The Wildlife Society occasionally appoint ad hoc committees to study and report on select conservation issues. The reports ordinarily appear as either a Technical Review or a Position Statement. Review papers present technical information and the views of the appointed committee members, but not necessarily the views of their employers. Position statements are based on the review papers, and the preliminary versions are published in *The Wildlifer* for comment by Society members. Following the comment period, revision, and Council's approval, the statements are published as official positions of The Wildlife Society.

The Wildlife Society
5410 Grosvenor Lane, Suite 200
Bethesda, MD 20814
(301) 897-9770
Fax: (301) 530-2471

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Acknowledgments

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Front Cover: The sigmoid curve, commonly used to represent the growth of wildlife populations, here portrays the human economy growing over time at the expense of the economy of nature. As natural resources are extracted to fuel the cash economy (measured by GNP), wildlife habitats and species are lost.

Design: **Mark Weaver** (mweaver228@aol.com).
Photos: Black bears, bighorn ram, northern goshawk, black-footed ferret, red-backed vole, and yellow warbler by **Milo Burcham** (milosphotos@yahoo.com). Cougar by **Carlyn Iverson**/Absolute Images (absolutesci@aol.com). Northern spotted owl by **Tim Christie** (tcphoto@iea.com). Tiger swallowtail butterfly and golden aspens by **Tom Barnes** (tbarnes@ca.uky.edu). Logging and quarrying scenes by **Bill Lea** (BillLea.com). Cityscape by **Nancy Anne Dawe** for American Forests (nadawe@bellsouth.net).

Table of Contents

Key Words

biological diversity, carrying capacity, consumerism, ecological economics, economic development, economic growth, economic productivity, economic prosperity, economics, economies of scale, economy, endangered species, gross domestic product, gross national product, human populations, per capita consumption, natural resources, resource consumption, social values, species endangerment, steady-state economy, sustainable development, technological progress, threatened species, wildlife conservation, United States.

SYNOPSIS

In 2001, The Wildlife Society appointed a technical review committee to investigate the relationship between economic growth and wildlife conservation. This comprehensive review encompassed human population growth, resource consumption, and human desires and aspirations. The economy has been growing steadily and sometimes rapidly throughout the existence of the United States. Economic growth, a function of population and per capita consumption, represents an increase in the production and consumption of goods and services. Economic growth is facilitated by technological progress, which tends to expand the breadth of the human niche. Such expansion increases the competitive exclusion of most wildlife species. Production and consumption of all goods and services ultimately require liquidation of natural capital, including habitats for wildlife. Habitats have generally declined in extent and quality, with corresponding declines in and endangerment of many wildlife species. There is a fundamental conflict between economic growth and wildlife conservation that is supported by sound theoretical and empirical evidence. Therefore, an alternative to economic growth, such as a steady-state economy with stable human population and per capita consumption, may be necessary to ensure wildlife conservation over the long term.

INTRODUCTION

Awareness of possible relationships between economic growth and wildlife conservation has increased within The Wildlife Society (TWS) over the past few years. Understanding the implications of economic theory is paramount to effective wildlife conservation because economics is the dominant social science and pre-eminent advisor to nearly all levels of governance and policy-making (Heilbroner 1999). A symposium at the 1998 TWS annual meeting demonstrated that many wildlife professionals viewed economic growth as a major challenge to wildlife conservation and management, and resulted in a special section, "The Importance of Ecological Economics to Wildlife Conservation," in the *Wildlife Society Bulletin* (Czech 2000*a*).

Following the 1998 annual meeting, a group of TWS members proposed that TWS adopt a position on economic growth (Czech 1999). In response, TWS Council appointed an ad hoc committee to ascertain whether the series of articles in the Spring 2000 edition of the *Wildlife Society Bulletin* was adequate to support a position on economic growth. The ad hoc TWS committee acknowledged that the *Wildlife Society Bulletin* articles provided an excellent starting point for development of a position statement on economic growth and its relationship to wildlife conservation, but concluded that broader issues needed to be included in relating economic growth to wildlife conservation (Baydack 2001). Subsequently, TWS Council appointed a committee to prepare a technical review that would broaden the information presented in the referenced *Wildlife Society Bulletin* articles. This broadened scope was to include information on human and social values. The committee was given a specific charge: Develop a technical review on the relationship of economic growth to wildlife conservation, including consideration of population growth, resource consumption, and human desires and aspirations.

In approaching this challenging assignment, the committee recognized that economic, social, and wildlife trends were intertwined and difficult to separate in terms of their influence on wildlife conservation. The fundamental threats to and/or successful strategies for wildlife conservation are inherently complex, overlapping, interdependent, and unpredictable. Economic growth is a driving quantitative force behind observed changes and documented trends within each of the economic, social, and environmental spheres. Rather than prepare a document for The Wildlife Society that only outlined trends resulting from economic growth and challenges facing the wildlife profession, we chose to address the complexity of some underlying forces in each sphere. Our primary objective, however, was to determine whether or not there is a conflict between economic growth and wildlife conservation. We also explore whether The Wildlife Society could contribute toward minimizing conflicts between economic growth and wildlife conservation by protecting wildlife and human welfare simultaneously in each of the three spheres (social, economic, and environmental) over the long term.

In view of the broad scope and complexity of the assignment, the committee based its research, analysis, and synthesis of documented trends largely on the United States of America. This decision was not dictated by professional bias, parochial interest, or political nationalism, but rather by recognition that comprehensive information on the broad dimensions of this issue was most available and best documented for the United States. Consistent with the TWS Council's directive, this review focuses on economic growth rather than economic development. *Economic development* is typically used in a qualitative sense, encompassing both economic and social dimensions and focusing most often on developing countries. In addition, ideology of *economic growth* permeates every corner of the globe with a concomitant broad range of environmental effects, including pollution, climate change, habitat loss, and overexploitation (Brown 1998, McNeill 2000). Naidoo and Adamowicz (2001) recently elucidated linkages of economic prosperity and threatened species from a global perspective, suggesting that the relationship between national economies and biodiversity conservation also applies elsewhere. Furthermore, as the world's leading economy (Knox and Agnew 1998), the United States provides leadership in many other social and environmental spheres of influence, including strategies to conserve biological diversity.

DEFINITIONS

Effective communication of complex ideas and technical information begins with accurate definitions of terms. To facilitate common understanding of concepts and principles presented in this review, we used standard, authoritative sources for defining crucial terms. For ecological terms we followed Allaby (1994) and Ricklefs and Miller (2000), and for economics terms we followed Abel and Bernanke (1994) and Pearce (1992), except where otherwise noted:

Carrying capacity: maximum population of a given organism that a particular environment can sustain.

Competitive exclusion: impossibility of coexistence of species with identical niches.

Ecological economics: a "transdisciplinary field of study that addresses the relationships between ecosystems and economic systems in the broadest sense" (Costanza et al. 1991:3). The major distinction of ecological economics relative to mainstream or neoclassical economics (including the subset of neoclassical economics called *natural resources economics* or *environmental economics*) is the incorporation of ecological principles not usually found in neoclassical (including environmental) economics.

Economic development: process of improving the standard of living and well-being of the population of developing countries by raising per capita income. This is usually achieved by an increase in industrialization relative to reliance on the agricultural sector.

Economic growth: increase in the real level of national product, income, and expenditure.

Economics: the study of the allocation of scarce resources among competing end uses. (*Resources* refers to the factors of production. *Scarcity* refers to the assumption that all people and all societies have more wants than resources.)

Economies of scale: reductions in the long-term average cost of a product due to an expanded level of output.

Economy: system or range of activity pertaining to allocation of factors of production and production and consumption of goods and services in a country, region, or community.

Gross domestic product: market value of final goods and services newly produced within a nation's borders during a fixed period of time.

Gross national product: market value of final goods and services newly produced by domestically owned factors of production during a fixed period of time.

Limiting factor: any environmental condition or set of conditions that approaches most nearly the limits of tolerance (maximum or minimum) for a given organism.

Natural capital or *natural resources* (synonymous)*:* freely given material phenomena of nature within boundaries of human activities (at present these boundaries extend to approximately 4 miles below the earth's surface and 12 miles above it): land, oil, coal or other cores or mineral deposits, natural forests, rivers that can produce hydroelectric power because of their location, wind if it can be usefully harnessed as a source of power, rainfall, etc. Some of these resources are nonrenewable and some will always continue however much they are utilized. (Some economists prefer to use the phrase *natural capital* instead of *natural resources* because macroeconomic textbooks typically include only capital and labor in the basic production function. Using the phrase *natural capital* emphasizes that natural resources are distinct from manufactured and human capital [Prugh et al. 1995:177].)

Neoclassical economics: a body of economic theory that uses the general approach, methods, and techniques of the original 19th-century marginalist economists. The term *neoclassical* is derived from the view that the originators of the "marginalist revolution" were extending and improving the basic foundations of classical economics. They emphasized market equilibrium or the confluence of prices (or wages), supply, and demand.

Neoclassical economic growth theory: models of economic growth developed in a neoclassical framework, in which the emphasis is placed on the ease of substitution between capital and labor in the production function to ensure steady-state growth.

Niche: ecological role of a species in the community; often conceived as a multidimensional space.

Niche breadth: variety of resources utilized and range of conditions tolerated by an individual, population, or species.

Niche overlap: sharing of niche space by two or more species; similarity of resource requirements and tolerance of ecological conditions.

Population: a group of organisms, all of the same species, which occupies a particular area.

Technological (or *technical*) *progress*: a central element in economic growth which enables more output to be produced for unchanged quantities of the inputs of labor and capital to the production process.

Trophic level: a step in the transfer of food or energy within a chain. There may be several trophic levels within a system: e.g., producers, primary consumers, and secondary consumers.

ECONOMIC GROWTH, TRENDS, AND POLICY

An economy consists of producers and consumers. In the basic model of a modern economy, firms produce goods and services, and households consume them. Economic growth is simply an expansion of that system, resulting in an increase in cumulative production and consumption of goods and services (Abel and Bernanke 1994).

Economic growth is a function of population and per capita consumption. If a population grows and per capita consumption remains constant, the economy grows at the same rate as the population. If per capita consumption grows and the population remains stable, the economy grows at the same rate as per capita consumption. If both grow, there is a multiplicative effect on economic growth (Rostow 1990).

Basic factors of production used to meet demands of increasing population and per capita consumption include land, labor, and capital. Capital is assumed to broadly include manufactured (e.g., machines), financial (e.g., money), social (e.g., knowledge), and natural (e.g., energy) sources. Natural capital and land are overlapping concepts. Specific factors that contribute to economic productivity include increases in knowledge, education, allocation improvements, and economies of scale (Denison 1985). When increases in knowledge and education result in invention and innovation that lead to more efficient production, *technological progress* or *technical progress* is said to have occurred (Pearce 1992).

In macroeconomics, the fundamental identity of national income accounting is that total production = total income = total expenditure (Abel and Bernanke 1994). Size of an economy may thus be measured by its production, income, or expenditures. In the United States and most other countries, the most typical measures of economic scale are gross national product (GNP) and gross domestic product (GDP). GNP measures monetary value of goods and services produced by a nation and its citizens and corporations abroad, and GDP measures the monetary value of goods and services produced within a nation's borders. When monetary value is adjusted for inflation, these indices of production reasonably reflect the relative scale of an economy (Abel and Bernanke 1994, Daly 1996).

Since the founding of the nation, the United States economy has grown continually with only a few significant exceptions. Beginning in 1929, national income accounting has been conducted by the United States government (U.S. Bureau of Economic Analysis 1998). GNP figures were emphasized until recent years, when GDP figures came into vogue for various reasons (Abel and Bernanke 1994). In the United States, GNP and GDP have typically differed by less than 1% of GNP (Abel and Bernanke 1994), although the difference may be increasing due to economic globalization.

GNP has increased more than ten-fold since 1929 (Figure 1). In recent decades, the economy was growing at a rate of about 2.5% per year (Abel and Bernanke 1994). By the end of 2001, GDP (more commonly used today) exceeded 10 trillion dollars (U.S. Bureau of Economic Analysis 2002). Overall, United States GDP ranks first in the world (Knox and Agnew 1998).

The economy has grown not only in aggregate but also in per capita terms. By 1900, the average real per capita income was about 3 times that of 1800, and by 1990, the average per capita consumption expenditure was about 4 times the level in 1900 (Madrick 1995). As the largest economy in the world, the United States accounts for nearly one-fourth of global gross product (Eves et al. 1998).

Economic growth has long been a primary, perennial, and bipartisan goal of the United States public and polity (Collins 2000). The Great Depression, the Keynesian

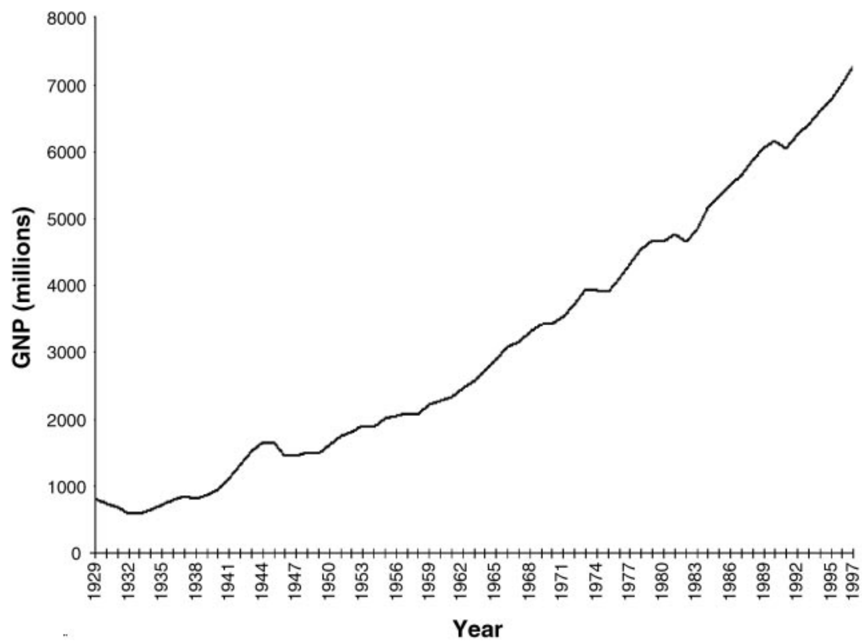

Figure 1. Growth (in millions of dollars) in the United States Gross National Product (GNP), 1929–1997 (U.S. Bureau of Economic Analysis 1998).

revolution in macroeconomics beginning in 1936, and the material and fiscal exigencies of World War II were especially instrumental in making economic growth a foremost national effort (Czech 2000*b*). The mission statements of key federal agencies—including the U.S. Department of Commerce (2002), U.S. Department of the Treasury (2002), and U.S. Agency for International Development (2002)—reflect economic growth as a primary goal.

In pursuing the goal to "promote domestic economic growth," the Department of the Treasury collaborates with other government departments including the departments of Commerce, Housing and Urban Development, and Health and Human Services (U.S. Department of the Treasury 2002). Other key partners include the Small Business Administration, the Federal Reserve Board, the Federal Deposit Insurance Corporation, the Securities and Exchange Commission, various advisory committees, and Congress. Economic growth is also central to the monetary policies of the Federal Reserve System, the central bank of the United States. A review of any recent annual report documents that economic growth is the driving force for the United States economy (Federal Reserve 2000). At the international level, the U.S. Agency for International Development advocates that "broad-based economic growth is the most effective means of bringing poor, disadvantaged, and marginalized groups into the mainstream of an economy" (U.S. Agency for International Development 2002).

POPULATION GROWTH, CONSUMPTION, AND CONSUMER TRENDS

Economic growth originates from either a growing population or growing consumption of products generated by the economic process. The United States is the third most populous country in the world (National Research Council 2000). Based on the 2000 census, the U.S. Census Bureau (2000) reported the nation's population at 281,421,906. The United States population has grown steadily from approximately 75 million in 1900 (Figure 2), increasing by more than 200 million during the past century. By 2050, the United States population is projected to increase to almost 400 million (U.S. Census Bureau 2002). This revised 2050 population exceeds by about 50 million an estimate of just a few years ago (National Research Council 2000).

The United States comprises less than 5% of the world's population (Smith 1999), but consumes 30% of its resources (Suzuki 1998). During the past 50 years, United States per capita resource use rose 45% overall, and its per capita use

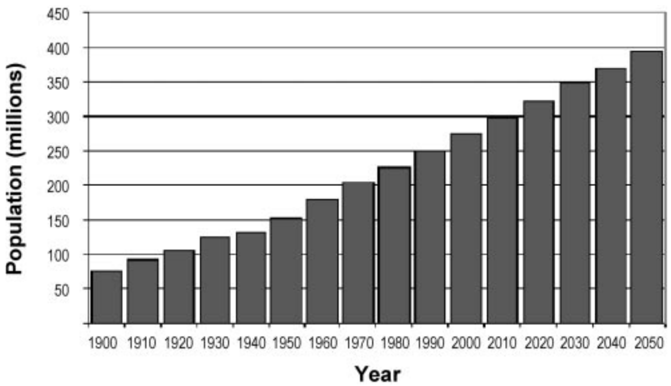

Figure 2. Population trends and projections in the United States, 1900–2050 (U.S. Census Bureau 2002).

of paper, steel, aluminum, water, energy, and meat now ranks first in the world (Suzuki 1998). The economy of the United States depends heavily on fossil fuel use, accounting for more than 25% of world annual consumption, and thus the United States is a leading producer of carbon dioxide thought to be responsible for global climate change (Suzuki 1998, Smith 1999).

Much of this consumption of resources and production of waste is a result of a "consumer society" that Schor (1997) characterizes as a society in which discretionary spending is a mass phenomenon, not just practiced by the rich or the middle classes. Schor believes United States consumerism as a mass phenomenon did not exist until the 1920s. Many scholars point to post-World War II as the time when trends in consumption of goods and services increased sharply, both in per capita terms and as a result of population growth (Collins 2000). Currently, approximately 90% of the United States workforce is employed in production and sale of consumer goods (Rosenblatt 1999).

Particularly relevant to a discussion of economic growth and resource consumption is Schor's (1997) view that consumer society is based on continuous growth of consumer expenditures and central to the economic system. She also described culture, ideology, and morality being interlinked with this economic system. In this context, social and political stability become dependent on the delivery of consumer goods.

Among scholars who study consumerism and consumer society, some stress the importance of biology and others stress the influence of culture. Apologists for and critics of consumer society have advanced evolutionary explanations of consumerism. Some, like Schor (1997), believe consumerism is culturally mediated, and often, a mere invention of those with commercial interests. Arguments based on evolutionary biology explain conspicuous consumption as a display that increases social status and may improve reproductive fitness, by enhancing perceived sexual attractiveness (e.g., clothing as plumage), by conveying an image of power, or by providing a measure of access to resources (Czech 2000*b*). Thus, resource consumption should not be surprising, but expected.

According to Frank (1999), consumption establishes a relatively better social position for the individual, consistent with evolutionary biology theory, but is bad for society as a whole, and ultimately for most individuals in it. However, Frank (1999) opposed conspicuous consumption on economic, not ecological, grounds. He viewed the high debt and low savings rate of the average United States citizen as economic weakness and recommended reductions in consumer spending and increases in saving as a temporary prescription that would lead to greater economic growth later, without discussing the potential ecological consequences of such growth.

Most scholarship on consumerism has examined its cultural roots, and because cultural hypotheses are easier to test, this scholarship has the quantitative support that evolutionary explanations lack. In a critical light, consumerism has been viewed as insatiable desire or yearning, often created by advertising or other media images such as television (McKibben 1992, Suzuki 1998, Lasn 1999). It has also been seen as an expression of individualism (McKibben 1992), a means of fitting in (Schor 1999), an expression of dominance (Czech 2000*b*), or as a substitute for emotional connections (McKibben 1992). Research suggests that consumer desires are very malleable.

As images of affluent, consumptive United States lifestyles have been increasingly exported via television, movies, and other mass media, economists predict increases in luxury spending and associated economic growth in developing nations (McKibben 1992, Schor 1997). In addition, an estimated 1.1 billion of the world's people live in abject poverty and need to increase their resource consumption to minimal standards set by the United Nations (Nebel and Wright 2000). In reality, their resource consumption aspirations likely extend beyond United Nations standards. Furthermore, although the United States has a higher population growth rate than most developed countries (National Research Council 2000), a baby born in the United States consumes approximately 20 times the resources as a baby born in a less developed country. Therefore, stabilizing or reducing the United States population is important for environmental sustainability (McKibben 1998). A small but growing "voluntary simplicity" movement, comprising secular and religious groups that oppose American-style consumption patterns for environmental, social justice, quality of life, and spiritual reasons may be a first step toward reversing patterns of increasing consumption.

ECONOMIC GROWTH, RESOURCES, AND SOCIAL VALUES

Societal debates concerning economic growth and natural resource use and allocation are not new to environmental protection and wildlife conservation. During the early 20th century, John Muir squared off against Gifford Pinchot over the dam project in California's Hetch-Hetchy valley (Muir 1901). More recently, protection for the northern spotted owl (*Strix occidentalis caurina*) was cast as pitting "owls versus jobs" (Schindler et al. 1993, Steele et al. 1994). Current conflicts regarding oil exploration and drilling in the Arctic National Wildlife Refuge on Alaska's North Slope contrast strategic sources of domestic oil with potential degradation from oil development. At the heart of these and similar issues lie conflicting individual and societal values toward wildlife and the habitats upon which they depend versus economic development and growth (Kellert 1984, Rudzitis 1999). Some members of our society believe natural resources only exist or have value for human consumption (Scherer and Attig 1983). The traditional forest management perspective is that national forests (and associated resources) are renewable resources to be utilized for the *greatest good for the greatest number* as espoused by Pinchot (1947). Others feel the same resources are there for individual human use as needed, including realization of personal financial profit. Still other individuals in our society believe natural resources, including wildlife, are held in public trust for their intrinsic values that are higher than values as economic commodities (Rolston 1988, Taylor 1993). Each of these beliefs is based on individual values shared collectively by members of our society, providing the context of the relationship between economic growth and wildlife conservation.

Discussions regarding value of natural resources generally focus on economic values of specific resources. Wildlife are not gauged in economic terms as often as forests, water, minerals, or range, yet economic amenities associated with wildlife (e.g., hunting license revenues, guide fees, hunting equipment) are often used in discussions of relative value of wildlife (Loomis et al. 1984, McDivitt 1987). Economic values are important, but are only part of the values assigned to wildlife (Kellert 1984). Social conflict over wildlife and their habitats rarely concerns actual economic values and benefits but rather centers on differing psychological values and beliefs held by individuals and groups within our society.

As part of this review, we considered the origins of values and beliefs in general, and how these values relate to natural resources and environmental values. We also examined the relationship between human values and wildlife in our society. In general, differing perceptions of economic growth and wildlife give rise to conflicting values concerning individual wildlife species (e.g., see Peterson et al. [2002]). These value orientations lead to beliefs and attitudes about the relative worth of particular species, importance of actions regarding wildlife, and outcomes of management practices. Values may compete with one another, giving way to the more deeply held of the conflicting values. Our values may predispose us to accept information that agrees with or reinforces these values, and to reject information that runs counter to our values.

Value orientations are very important in the discussion of economic growth and wildlife (Czech and Krausman 1999*a*). Several industries have altered their business practices to meet consumer demands for greater protection of wildlife. Examples of changes in business practices are "dolphin-safe" tuna, discontinuation of plastic 6-pack containers for canned beverages due to harmful effects on birds and other fauna, and development of "fake fur" for fashion apparel. Environmental values are important components of advertising and marketing for a multitude of products, including not only the product itself, but also positioning of the product as "environmentally friendly." Even product packaging has come under the scrutiny of environmental values. Extractive industries have used advertising that depicts their corporations as good environmental neighbors concerned about wildlife and a clean environment. Societal values regarding wildlife can have a profound effect on an industry if that industry is perceived as having a negative effect on wildlife and the environment in general. Wildlife professionals need to understand societal values regarding not only wildlife but also consumerism as a whole, if we are to address the issue of economic growth and its impact on wildlife conservation.

ECONOMIC GROWTH, POPULATION, AND CARRYING CAPACITY

Economists, mainstream media, and the United States public regularly make the tacit or explicit assumption that perpetual economic growth is possible and that such growth can occur without interfering with the needs of wildlife or people (Willers 1994, Czech 2000*b*). On the other hand, ecologists generally share the perspective that the world's resources are limited, and when certain limits are reached, both wildlife and people will suffer (Daily and Erhlich 1992; Meadows et al. 1974, 1992; Pulliam and Haddad 1994; Harrison and Pearce 2000). For wildlife professionals, *carrying capacity* is a well-known concept founded upon resource limits. Though developed to describe resource-based limits to wildlife populations, the concept applies to humans as well (Pulliam and Haddad 1994).

Nebel and Wright (2000) defined carrying capacity as the maximum population of an animal that a given habitat will support without degradation of the habitat over the long-term. Calculating an actual carrying capacity for wildlife can be difficult, and for humans, even more so (Trauger 2001). Useful carrying capacity estimates can be developed for most wildlife species provided there are estimates of population density in relation to habitat quality and availability. For wildlife, carrying capacity becomes simply a function of population size. The size of the human economy, however, is a function of population and per capita consumption (Czech 2000*b*).

We recognize the importance of population size on anthropogenic environmental impacts, yet we do not focus on it hereafter for two reasons. First, The Wildlife Society (1992) already has a policy statement on human population growth. Secondly, our paper is addressed mainly to biologists in industrialized nations, where excessive resource consumption is the greater problem.

Resource use by humans varies dramatically in quantity and quality, within and among cultures and socioeconomic groups (Durning 1992). Ehrlich and Ehrlich (1990) pointed out that for humans, technology also plays a role, both positive and negative, and proposed an equation to describe human impacts on the environment:

$$\text{Impact} = \text{Population} \times \text{Affluence (resource consumption)} \times \text{Technology},$$

or I = PAT. Relative to economic growth, the technology portion of the equation is particularly important, since "technological optimists" (e.g., Hawken 1993, Simon 1996) argue that improved technological efficiency will produce continued and even accelerated economic growth with vastly reduced damage to the environment. Freese (1998) plotted "global ecological sustainability" as an inverse function of the product of human population and per capita consumption.

Resource use is also important. Eating a meat-based versus a grain-based diet is generally more environmentally destructive due to greater energy demands at higher trophic levels and heavy use of pesticides and fossil fuel by modern agriculture. However, Kerasote (1997) and Shepard (1998) argue for hunting as the "least harm" alternative to mechanized agriculture.

Durning (1992) divided the world's people into three consumption categories: (1) the desperately poor (1.1 billion, who earn US$700/yr or less), who do not have access to clean water, eat a grain-based diet that provides inadequate calories, and walk for transportation; (2) the sustainable class (3.5 billion, who earn US$701–8,000/yr), who drink mostly clean, potable water, eat a nutritionally adequate diet based on grains and vegetables, and travel by bicycle, train, or bus; and (3) the consumer class (1.2 billion, who earn >US$8,000/yr), who generally drink at least some bottled beverages, eat a diet heavy in meat, and travel mostly by automobile. The latter description characterizes most social classes in the United States. Durning (1992) argued that both the desperately poor and the richest consumer class both tend to degrade the environment: the poor out of desperation (e.g., cutting wood for fuel or farming on marginal land) and the rich through overconsumption of resources. Consequently, he proposed policies to discourage consumption among the rich and to provide access to resources to the world's poorest citizens. The latter may be key to reducing population growth in developing countries, as nearly all decreases in birthrates have been preceded by decreases in infant mortality and increases in the education levels of women (Cohen 1995). However, increases in education lead to increases in quality of life fueled by greater resource consumption. The positive effects of decreased population growth may be offset by increased resource consumption.

Even if calculation of the earth's carrying capacity was a simple exercise, it is unlikely that a calculation of an actual carrying capacity, much less a maximum sustained yield, for human beings would be desirable. Values such as aesthetics, quality of life, and the preservation of other species may also play a role. Practically speaking, one might decide *a priori* to set aside habitat to meet these other needs, and subtract it from total available habitat used for calculations, thereby setting human carrying capacity "artificially low." This is a question of values, not mathematics, and must be done in community, not in isolation. Nonetheless, a review of estimates of the earth's carrying capacity may inform discussions about the feasibility of infinite economic growth. Neoclassical economics is based on the assumption that resources are limited only in the short term and that long-term sustainable growth is possible through technological progress. However, for more than 30 years, ecological economists have been questioning this assumption (Boulding 1966, Daly 1977, Costanza et al. 1997).

For wildlife professionals, there are at least three good starting points from which to explore the topic of global carrying capacity for humans. Cohen (1995) reviewed numerous estimates of human carrying capacity, including eight in detail. Vitousek et al. (1986), ignoring human population per se and focusing on habitat quality, calculated an estimate of Earth's primary productivity appropriated by humans. Wackernagel and Rees (1996) worked on *ecological footprints*—a more comprehensive approach focused on natural resource use and calculated estimates of amount of land needed to sustainably produce resources used by a person with a given lifestyle. The answers given by these three different approaches are not definitive, but all suggest limits to human use of the earth's resources.

Cohen's (1995) review found estimates of human carrying capacity ranging from less than 1 billion to more than 1,000 billion. Cohen debunked estimates at either extreme; the lowest most easily since they have long since been surpassed, and the highest because of far-fetched technological optimism. Disregarding extreme estimates, the median of the lower estimates was 7.7 billion and 12 billion for the high estimates (Cohen 1995). Compare these estimates with United Nations' projections of a probable world population of 8.9 billion by 2050, with various estimates ranging from a low of about 5 billion, a medium estimate of 11.5 billion, to the high figure of 28 billion.

Vitousek et al. (1986) provided several estimates of the percentage of global potential net primary productivity (NPP) appropriated by humans. Separate sets of calculations were made for terrestrial primary productivity and those that also include marine ecosystems. With a 1985 world population of about 4.5 billion, humans accounted for almost 40% of terrestrial NPP appropriation, and 25% of the global total if oceans are included.

Assuming conservative 1986 rates of resource exploitation and consumption, an increase of human populations to levels projected for 2025 could result in the consumption of considerably more than half of the world's total productivity (Vitousek et al. 1986). Nevertheless, the Brundtland Report (World Commission on Environment and Development 1987), widely considered a pioneer document on sustainable development, recommends growth of the world's economy on the order of five- to ten-fold, in order to provide for basic human needs and to bring the world's poorest to a decent standard of living. Such growth may be an ecological impossibility, based on the findings of Vitousek et al. (1986).

A comprehensive evaluation of the concept of *sustainable development* is beyond the scope of this review. Sustainable development continues to be a poorly defined and understood concept (Daly 1996), but one of the most widely cited definitions was provided by the World Commission on Environment and Development (1987): development that meets the needs of the present without compromising the ability of future generations to meet their needs. Implementation of this concept is controversial, particularly with respect to environmental protection and resource conservation, largely because of disagreements among economists about what may or may not compromise the ability of future generations (Daly 1996).

The *ecological footprint* (Wackernagel and Rees 1996) is an estimate of the amount of productive land needed to meet resource consumption and waste assimilation requirements of a "defined human population or economy." The waste assimilation component is a change from previous carrying capacity estimates that considered only resources limits, particularly in terms of nonrenewable ones (Meadows et al. 1974, Vitousek et al. 1986, Cohen 1995), and is important, as ecologists increasingly consider waste "sinks" to be limiting factors (Kendall and Pimentel 1994, Costanza et al. 1997). Global climate change is taken seriously by Wackernagel and Rees (1996), whereas it was not a concern for many earlier researchers, and footprints include estimates for carbon sequestration when fossil fuels are used. This assumption results in a lower estimate of global carrying capacity. However, uncertainty about the effects of global climate change would surely be a focus for criticism.

Values favoring preservation of wildlife habitat are built into this version of footprint analysis by Wackernagel and Rees (1996). The presence of these values also results in a lower estimate of carrying capacity than would be otherwise. Wackernagel and Rees subtracted approximately 607 million hectares that are currently wilderness from their global estimate of 3.6 billion hectares of ecologically productive land, arguing that it should remain as undeveloped as possible. Most wildlife professionals likely favor such an assumption, but a footprint analysis lacking this assumption would have a higher calculated global carrying capacity.

Wackernagel and Rees (1996) calculated per capita footprints for a number of countries. They compared a country's total footprint with its available land area, along with an accounting of where the country obtains its resources, its "ecological trade imbalance" to determine whether a country has exceeded its national carrying capacity. By this accounting, the Netherlands exceeds its carrying capacity by more than 15 times, whereas the United States, with more available land area, is below its carrying capacity, even though its per capita footprint is almost twice that of the Netherlands, and higher than any other country in the world. From a global perspective, however, if everyone on Earth lived a typical North American lifestyle, three more Earth-like planets would be needed to do so sustainably (Wackernagel and Rees 1996, Raven 2000).

It is also possible to calculate per capita footprints for different lifestyle choices, such as commuting by car versus by bicycle. This may guide people, particularly in industrialized nations, in reducing their resource consumption. Footprint analysis could also aid in forming policies that favor sustainability. If one accepts footprint analysis and other estimates of human carrying capacity, then it is easy to argue that economic growth occurs at the expense of natural resources, including wildlife. Use of the GDP alone as a measure of economic welfare has come under criticism for not counting depletion of natural capital as depreciation (Daly and Cobb 1989, Cobb et al. 1995). Depletion of our natural capital stocks is akin to living off capital rather than income. A GDP/footprint unit (e.g., dollars/hectare or dollars/acre) could be used as a more ecologically informative accounting measure. Other alternatives such as the Index of Sustainable Economic Welfare (Daly and Cobb 1989) and the Genuine Progress Indicator (Cobb et al. 1995) have also been suggested. These measures count depletion of resources and pollution as negatives, and take crime, unemployment, income distribution, and other social factors into account.

Such broad policy measures of human welfare would partly sidestep the question about whether it is economic growth per se or resource consumption that contributes most to resource depletion and loss of wildlife habitat. Some authors (Simon 1996, Hawken et al. 1999) have argued that technological advances resulting in more efficient use of resources will allow for increased economic growth without negative ecological consequences. However, even with the increased efficiency that a higher GDP/footprint unit would represent, overall scale of the human economy relative to available resources (Daly and Cobb 1989) remains important. For instance, increases in efficiency of resource use can be more than offset by increases in economic growth. The relationship of technological progress to economic growth is further explored below.

This review suggests that the world's current human population of 6 billion is at or approaching carrying capacity levels suggested by a majority of experts. At current rates of growth (population and resource use, and by extension, growth of the world's economy), we are at best approaching the limits and at worst beyond the limits (Meadows et al. 1992). Informing the general public about the relationship between economic growth and subsequent effects on natural resources could be a useful outcome of this review. People may readily understand the environmental effects of per capita resource use and population size (Trauger 2001), yet fail to relate these factors to economic growth (Czech 2000*c*).

ECONOMIC GROWTH, ECOSYSTEMS, AND WILDLIFE TRENDS

As reviewed above, economic growth is a function of increasing population growth and/or per capita consumption.

To examine effects of economic growth on wildlife conservation, we explored national trends in ecosystem loss and species endangerment. Unfortunately, few studies of ecosystem and/or species trends are available at a national scale for North America. A recent report by the Commission for Environmental Cooperation (2001) provided valuable information on biodiversity trends for Canada, United States, and Mexico. LaRoe et al. (1995) summarized existing information on the status of living resources of the United States, including the distribution and abundance of animals, plants, and ecosystems. Mac et al. (1998) reviewed a range of factors affecting biological resources and reported regional trends of biological resources in the United States. One of the major findings of these national assessments was that the paucity of scientifically credible information limited definitive statements about the status and trends of many biological resources. Consequently, the limited focus of this section on ecosystem loss and species endangerment is by default, rather than one of convenience.

Ecosystem Loss

According to the Commission for Environmental Cooperation (2001), humans are reshaping the environment and using up many parts of North America faster than nature can renew itself. Over the past few decades, transformation of the landscape, including habitat loss and alteration, has become the primary threat to biodiversity (Commission for Environmental Cooperation 2001). Half of North America's most diverse ecoregions are now severely degraded (Ricketts et al. 1999). Human use of the environment is the largest contributor to habitat modification and ecosystem loss (Goudie 2000, Harrison and Pearce 2000, World Resources Institute 2000). Considering the critical effects of land use change on wildlife habitats, we examine the most pertinent causes of those activities that result in fragmentation and destruction.

A nationwide summary of ecosystem loss was compiled by Noss et al. (1995). Using a classification of endangered ecosystems for the United States, they further classified each ecosystem type as critically endangered (>98% decline), endangered (85%–98% decline), or threatened (70%–84% decline). Identification of endangerment focused on reduction in area or degradation in quality due to human activities (Noss et al. 1995). They identified more than 30 critically endangered, 58 endangered, and more than 38 threatened ecosystems (Noss et al. 1995). Specific examples include loss of 60%–68% of Long Island pine barrens, 98% loss of longleaf pine (*Pinus palustris*) communities, 70%–90% decline in coastal sage scrub in southern California, and 99.9% loss of the Palouse grasslands of the interior Pacific Northwest.

Although Noss et al. (1995) focused their evaluation on those ecosystems reduced or degraded primarily due to human activities, a discussion of the types of activities was not presented. However, three broad types of land-altering human activities are generally recognized as contributing most to ecosystem loss: (1) urbanization, (2) agriculture, and (3) resource extraction, including forest management. In this context, deforestation for purposes other than providing for a sustainable harvest of trees is not considered forestry (e.g., deforestation for agriculture). Urbanization and agricultural practices endanger ecosystems by replacing them directly, whereas forest management generally endangers ecosystems when severe modification (i.e., degradation) occurs.

Total urban area as defined by the U.S. Census Bureau (2002) has more than doubled over the last 40 years from 25.5 million acres in 1960 to 55.9 million acres in 1990. As urban areas continue to expand, a more recent trend toward larger lots for individual houses has emerged. According to the U.S. Census Bureau (2002), only about 16% of the acreage used by houses built between 1994 and 1997 was in existing urban areas. These compounding trends of urban sprawl will continue to create conflict between wildlife conservation and population growth.

Approximately one-fifth of the United States is used for cropland (U.S. Department of Agriculture 1992). One of the major agricultural areas is within the Great Plains ecoregion. Here, crop cultivation in some states occupies more than 30% of the land area (Commission for Environmental Cooperation 2001). The original ecosystem degradation caused by agricultural conversion is subject to continued degradation due primarily to erosion, desertification, and salinization as a result of growing and harvesting techniques (Commission for Environmental Cooperation 2001). According to the Commission for Environmental Cooperation (2001), two trends in agriculture during the 20th century have been to substitute machines for humans and to become more reliant on synthetic chemical fertilizers. While amount of lands devoted to agriculture has remained stable since 1960, a steady rise has occurred in agricultural production, aided by increased irrigation, increased use of fertilizers and pesticides, and increased use of fossil fuels to power machinery.

Forested lands as defined by the National Resource Inventory cover approximately 160 million hectares, and represent 20% of land in the United States (U.S. Department of Agriculture 1992). The overall quantity of North American temperate forests has stabilized in recent years as natural regeneration and replanting make up for harvesting losses (Hall et al. 1996, Food and Agriculture Organization

1997). However, forest degradation can result if sustainable forest practices are not implemented. The United States committed itself to the sustainable management of forests in the *Forest Plan for a Sustainable Economy and a Sustainable Environment* (Council on Environmental Quality 1996). The American Forest & Paper Association, whose members hold about 90% of the industrial land in the United States, adopted the Sustainable Forestry Initiative in 1994 (American Forest & Paper Association 1994). These efforts reflect a desire to reduce the pressures on forested lands, thus reducing the threat of human-induced forest degradation.

Species Endangerment

Although North America has a number of major public and private agencies, organizations, programs, and initiatives to maintain biological diversity, the region has experienced some of the most dramatic reductions in species abundance of any part of the world (Commission for Environmental Cooperation 2001). The United States provides habitat for the largest number of known species of any temperate country (Wilson 2000). According to *Precious Heritage* (Stein et al. 2000), the United States contains the widest span of biome types, ranging from rain forest to arctic tundra and from coral reefs to great lakes, of any country in the world. The more than 200,000 described United States species constitute more than 10% of all known on Earth (Wilson 2000).

The United States is experiencing a loss of biological diversity as is occurring throughout the world (Trauger and Hall 1992, Stein et al. 2000). Relative to populations inhabiting the North American continent at the time of European contact, most populations of native species have declined, some dramatically (Matthiessen 1959). Several species have gone extinct in the United States, including the Labrador duck (*Camptorhynchus labradorius*), heath hen (*Tympanuchus cupido cupido*), Steller's sea cow (*Hydrodamalis gigas)*, passenger pigeon (*Ectopistes migratorius*), and Carolina parakeet (*Conuropsis carolinensis*). Numerous other less noticeable and economically irrelevant species have probably gone extinct in various parts of the country (Czech and Krausman 2001). The U.S. Fish and Wildlife Service (2002) suggests that approximately 216 species could go extinct within 5 years unless immediate conservation measures are taken.

Widespread wildlife conservation efforts began during the late 1800s and gained momentum during the 1900s (Trefethen 1975). In response to state and federal wildlife management programs, a variety of game species have increased in the United States (Moulton and Sanderson 1999). For example, today white-tailed deer (*Odocoileus virginianus*) are commonly observed in most eastern states, and resident Canada geese (*Branta canadensis*) are widely abundant, especially in urban areas. Although large predators are limited primarily to the West, black bears (*Ursus americanus*) and coyotes (*Canis latrans*) are increasing in a number of eastern states (LaRoe et al. 1995, Moulton and Sanderson 1999). Also, populations of numerous nonnative vertebrate species (e.g., Norway rats [*Rattus norvegicus*], house sparrows [*Passer domesticus*], cattle egrets [*Bubulcus ibis*], nutria [*Myocastor coypus*], wild boar [*Sus scrofa*], European starling [*Sturnus vulgaris*]) have risen dramatically since they were introduced to the North American continent via international travel and trade. However, improvement in population status of some intensively managed game species (e.g., wild turkey [*Meleagris gallopavo*], wood duck [*Aix sponsa*], elk [*Cervus elaphus*], pronghorn antelope [*Antilocapra americana*]), a few threatened and endangered species (bald eagle [*Haliaeetus leucocephalus*], gray wolf [*Canis lupus*], Aleutian Canada goose [*Branta canadensis leucopareia*], sea otter [*Enhydra lutris*]), and a number of nuisance wildlife species (beaver [*Castor canadensis*], snow goose [*Chen caerulescens*], raccoon [*Procyon lotor*]) should not divert our primary focus on the pervasive and accelerating endangerment and extinction of flora and fauna on local to global scales (Wilson 1988, Trauger and Hall 1992, LaRoe et al. 1995, Moulton and Sanderson 1999, Harrison and Pearce 2000, Stein et al. 2000).

According to the Commission for Environmental Cooperation (2001), a significant proportion of the plant and animal species of North America are threatened. With an increasing number of species becoming imperiled during the 20th century, the U.S. Congress enacted the Endangered Species Act of 1973 (ESA). Similar legislation was enacted in Canada. As a result of the requirements of the ESA, listing data since 1973 provide some measure of the progression of species endangerment, although there have been many fiscal and political deterrents to consistent listing practices. In general, listings of threatened and endangered species have steadily increased from 119 to 1,308 over the past 3 decades (Figure 3).

Understanding the causes of species endangerment is subject to the same dilemma as describing ecosystem loss. There have been few studies of national scope (Czech and Krausman 1997, Wilcove et al. 1998). Czech and Krausman (1997) found that at the national scale, nearly all species listed by the U.S. Fish and Wildlife Service as threatened or endangered have declined because of human economic activity (Table 1). Categories of economic activities used in their study included urbanization, agriculture, mineral extraction, outdoor recreation, logging, and industry, among

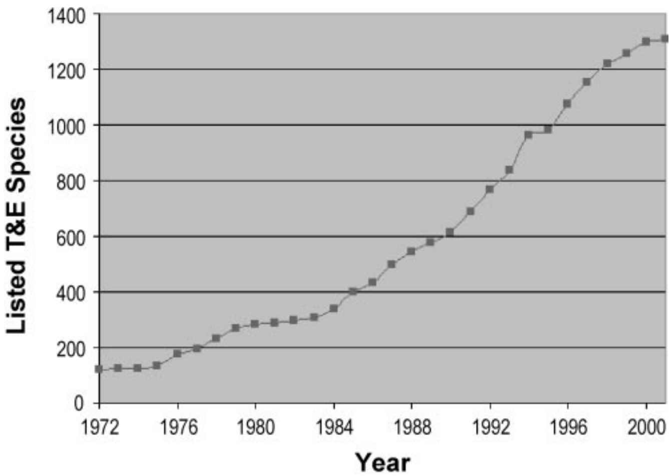

Figure 3. Cumulative numbers of threatened and endangered (T&E) species in the United States listed pursuant to the Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 2001).

others. Categories indirectly related to economic activity included interactions with nonnative species and disease. These findings were consistent with those of Wilcove et al. (1998, 2000), identifying agriculture and land conversion for development as leading causes of species endangerment. Czech and Krausman (1997) acknowledged that most endangered species are impacted by several causes and that it is rarely possible to determine relative importance of each. Subsequent investigation focused on "associations of species endangerment" whereby multiple causes of endangerment could be combined to produce a more integrated analysis (Czech et al. 2000). In proportion to the number of species endangered, for example, roads (i.e., their construction, presence, and maintenance) were found to be associated with more other causes of species endangerment than any other cause. Roads are often required for urbanization, mining, agriculture, and other causes of endangerment, which likely explains their high level of association. Urbanization and agriculture are associated with each other in more cases of endangerment than any other pair of causes (Czech et al. 2000). As in the case of ecosystem loss, urbanization and agriculture contribute to species endangerment due to habitat destruction. Although some species coexist with agriculture, long-term effects (e.g., soil erosion) often result in the loss of even these species.

Observations made by many researchers suggest a relationship between species endangerment and ecosystem (or habitat) loss. For example, Wilcove et al. (1998) concluded that destroyed and degraded ecosystems were the most pervasive threats to biological diversity, contributing to endangerment of 85% of species studied. However, more important to this review is the relationship between human economic activities and loss of both species and ecosystems as described by Czech and Krausman (1997) and Czech et al. (2000). Behind pressures impinging on ecosystems are two major drivers: human population and resource

Table 1. Causes of endangerment for American species classified as threatened or endangered by the U.S. Fish and Wildlife Service (Czech and Krausman 1997).

Cause	Number of species endangered by cause	Estimated number of species endangered by cause
Interactions with nonnative species	305	340
Urbanization	275	340
Agriculture	224	260
Outdoor recreation and tourism development	186	200
Domestic livestock and ranching activities	182	140
Reservoirs and other running water diversions	161	240
Modified fire regimes and silviculture	144	80
Pollution of water, air, or soil	144	140
Mineral, gas, oil, and geothermal extraction or exploration	140	140
Industrial, institutional, and military activities	131	220
Harvest, intentional and incidental	120	220
Logging	109	80
Road presence, construction, and maintenance	94	100
Loss of genetic variability, inbreeding depression, or hybridization	92	240
Aquifer depletion, wetland draining or filling	77	40
Native species interactions, plant succession	77	160
Disease	19	20
Vandalism (destruction without harvest)	12	0

consumption (World Resources Institute 2000). As we have established earlier in this report, economic growth is the synthesis of population and consumption.

ECONOMIC GROWTH, ECOLOGICAL PRINCIPLES, AND WILDLIFE CONSERVATION

There are two general approaches to assessing the relationship of economic growth to wildlife conservation: theoretical and empirical. Theoretically, a conflict between economic growth and wildlife conservation could be identified based upon established principles of ecology and economics. Empirical evidence should support this theoretical construction. In this section, we explore theoretical and empirical evidence concerning this relationship, as well as consider some counterarguments.

Theoretical Evidence

Theoretical evidence for a fundamental conflict between economic growth and wildlife conservation rests upon principles of carrying capacity, niche breadth, competitive exclusion, and trophic levels. *Carrying capacity* is the principle that populations of every species have limits. Factors that limit populations were categorized by Leopold (1933) as welfare factors and decimating factors. *Welfare factors* are habitat components: food, water, cover, space, and special species-specific needs. *Decimating factors* are extrinsic threats such as hunting, pollution, and severe weather. Wildlife conservation requires the identification of limiting factors.

As noted above, some economists (e.g., Simon 1996) have posited that there is no carrying capacity imposed upon humans because humans have the ability to modify their environments and to protect themselves from decimating factors. As resources become scarce, humans find substitutes for those resources, and invention and innovation lead to increasing efficiency in the economic production process. However, ecologists are often critical of the notion that substitutability of resources and increasing productive efficiency could result in an infinite expansion of production and consumption of goods and services (e.g., Ehrlich 1994). In addition, ecological economists, who integrate principles of ecology with principles of economics, increasingly criticize theories of unlimited economic growth (e.g., Daly 1996, Erickson and Gowdy 2000). More relevant to the relationship of economic growth to wildlife conservation, however, is that human ability to increase carrying capacity (whether the increase be temporary or permanent) does not preclude the potential conflict between economic growth and wildlife conservation. Explanation for this is based upon principles of niche breadth and competitive exclusion.

In assessing the relationship of economic growth to wildlife conservation, the term *economic carrying capacity* is useful because carrying capacity is not only a function of population size but also of per capita consumption (Daily and Ehrlich 1992). For nonhuman species, per capita consumption is primarily of food and is fairly uniform across individuals of the same species. For humans, however, consumption includes a much wider set of goods and services and varies tremendously among individuals. Thus carrying capacity for humans is most appropriately discussed not solely in terms of population size but in terms of economic scale.

A species' niche pertains to the breadth of habitats used and the extent of interactions with other species (Hutchinson 1978). Prominent traits reflecting niche breadth include the variety of food items consumed, extent of geographic distribution, and variety of ecological communities occupied. Species with broad niches are generalists, those with narrow niches are specialists. Niche breadth is generally correlated with intelligence and body size (Czech and Krausman 2001), both of which determine options a species has in exploiting its environment. Hummingbirds, for example, are relatively small-bodied specialists of limited intelligence, while baboons are relatively large-bodied, intelligent generalists. Hummingbirds have relatively narrow niches, while baboons have broad niches.

Competitive exclusion is the principle that if two species compete for the same resources, then one species can succeed only at the expense of the other (Ricklefs and Miller 2000). Populations of species with narrow niches tend to grow at the competitive exclusion of few other species. For example, a hummingbird species will compete primarily with hummingbirds (of similar beak size), bees, bats, and other pollinators that feed on the nectar of flowering plants. Populations of species with broad niches tend to grow at the competitive exclusion of many other species. For example, baboon troops will consume a wide variety of foods and drive off species of small- and medium-sized predators and omnivores. The "amount" of competitive exclusion per species excluded may vary, but the niche breadth of a species is clearly correlated with the number of species affected by that species.

Trophic levels refer to the nutritional organization of an ecosystem (Ricklefs and Miller 2000). Basic trophic levels are producers and consumers. *Producers* are plants that produce their own food via photosynthesis. *Consumers* may be primary or secondary. Primary consumers consume producers, and secondary consumers consume other consumers. Omnivore generalists with broad niches are capable of consuming a wide variety of producers and consumers. The carrying capacity of a habitat for a particular species depends largely upon the biomass and productivity of consumable species residing at lower trophic levels.

Humans are a large-bodied species with the highest intelligence known. They reside at the top of the trophic structure and are most capable of defending themselves from the competition of other species. Their technological progress has resulted in unprecedented niche expansion. They reside in all regions of the earth and in all types of ecosystems. As Czech (2002*a*:1489) noted, "due to the tremendous breadth of the human niche and the technologically boosted rate of its expansion, the scale of the human economy expands at the competitive exclusion of wildlife in the aggregate."

The fundamental conflict between economic growth and wildlife conservation is illustrated by a consideration of the allocation of natural capital (Figure 4). In the absence of humans, all natural capital is available as habitat for nonhuman species. As the scale of the human economy expands, natural capital is re-allocated from nonhuman uses to the human economy.

Empirical Evidence

Perhaps the most compelling empirical evidence for a fundamental conflict between economic growth and wildlife conservation lies in the trends and causes of species endangerment and ecosystem loss. As the economy grows, species are becoming endangered at an increasing rate (Figure 5). A strong relationship (R^2 = 98.4%) exists between species endangerment and economic growth in the United States.

Although Canada has a very different collection of species and a very different listing process, examination of similar data from Canada appears to conform to the same general relationship between GDP and species endangerment. Canada's GDP in 2001 was US$1,084,000,000, roughly the GDP of the United States in the early 1970s. Currently, there are 197 listed species in Canada, which is in the same range as the number of listed species in the United States during the early 1970s.

Likewise, causes of species endangerment correspond with sectors of the human economy (Table 1). These sectors interact in a manner similar to trophic levels in the "economy of nature" (Czech 2000*b*:55). Agriculture and extractive sectors (i.e., logging, mining, ranching, and harvesting of wildlife) constitute the economy's foundation or its producer trophic level. Consumer trophic levels are represented primarily by the manufacturing sector. Services sectors are represented by recreation and by urbanization, which represents not only the proliferation of dwellings but also of the many service providers that operate in urban areas. Pollution is a by-product of the economic production process. Economic infrastructure includes roads, pipelines, reservoirs, etc. A major cause of species endangerment—nonnative species—is largely a function of international and interstate commerce. Activities such as firefighting and silviculture are conducted largely for economic purposes. Other causes of species endangerment such as genetic problems and diseases become threatening after populations have been decimated by the preceding causes of endangerment. Czech and Krausman (2001) found that only a few species were endangered primarily by natural causes,

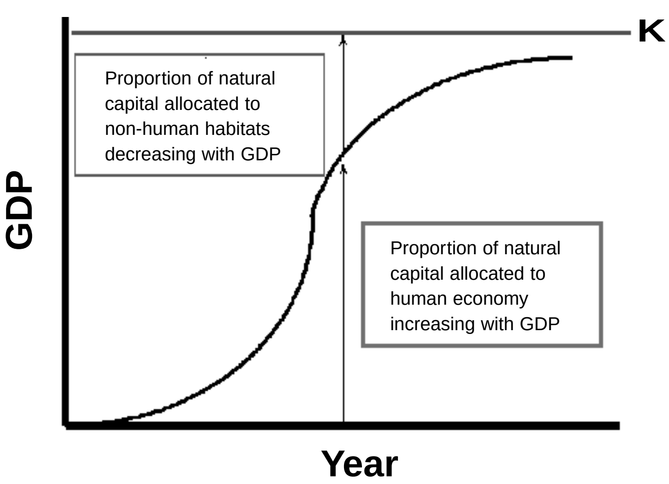

Figure 4. Allocation of natural capital as modified from Czech (2000a). GDP = Gross Domestic Product; K = carrying capacity.

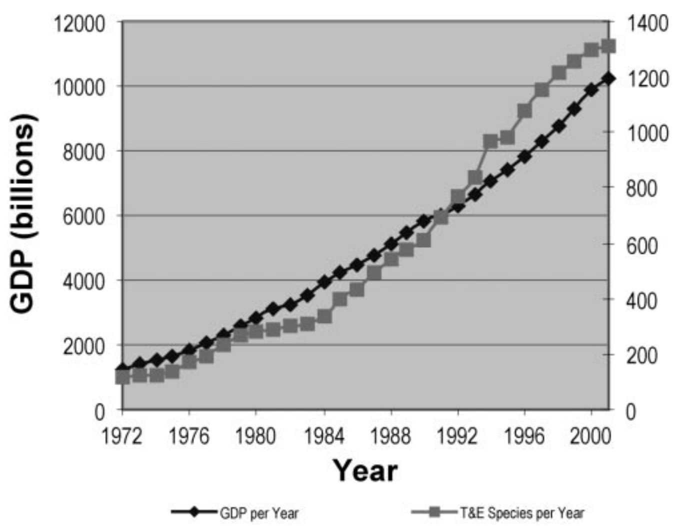

Figure 5. Comparison of Gross Domestic Product (GDP) value (in billions of dollars) and the number of threatened and endangered (T&E) species in the United States listed pursuant to the Endangered Species Act of 1973 (R^2 = 98.4%).

and that the recovery of even these species was curtailed by economic growth activities that degraded their erstwhile habitats.

Other empirical evidence for the fundamental conflict between economic growth and wildlife conservation may be found in reduction of ecosystems and habitats because these habitats provide welfare factors required for wildlife conservation. Noss et al. (1995) identified 30 critically endangered, 58 endangered, and 38 threatened ecosystems of the United States, ranging from 70% decline to 98% decline. Decline was defined as "destruction, conversion to other land uses, or significant degradation of ecological structure, function, or composition since European settlement" (Noss et al. 1995:50). Noss et al. (1995:3) did not elaborate upon economic causes of decline, but noted, "Inadequate protection can be put in perspective by the extent of lost biodiversity at the ecosystem level and by the correlation of these losses with losses at other levels of biological organization." They pointed out that ecosystem decline was correlated with the decline of wildlife species which, as Czech et al. (2000) noted, was a function of human economy. They also pointed out that ecosystem decline was most pronounced in the South, Northeast, Midwest, and California (regions characterized by large economies replete with economic sectors) and minor only in Alaska (characterized by a relatively small population and small economy dominated by extractive exports). Their premise—that European settlement was the beginning of widespread ecosystem decline—reflects the fact that such settlement rapidly engaged in an industrial revolution, which the economic growth theorist Rostow (1990) referred to as "take-off."

Freese and Trauger (2000) stated that economic interests lead to loss of wildlife populations and biodiversity in four basic ways: (1) over-harvesting of wild populations of plants and animals; (2) conversion of habitat to alternative uses of the land; (3) economic specialization in production of wild species, leading to habitat change and biodiversity loss; and (4) negative environmental externalities, particularly contaminants. While Czech et al. (2000) have been the only researchers to assess species endangerment in the context of economic sectors, other assessments of endangerment are consistent with their findings (e.g., Chadwick 1995, Dobson et al. 1997, Foin et al. 1998, Wilcove et al. 1998). Each of these studies has revealed habitat loss to be the primary cause of endangerment. Such habitat loss is typically attributed to "human activities," where the point that these human activities are economic (and not, for example, spiritual or intellectual activities) is implied. Other authors have come somewhat closer to explicating the economic nature of wildlife and habitat loss. For example, Pletscher and Schwartz (2000:1918) noted that such loss "can ultimately be attributed to increases in human population and per capita consumption" (i.e., the two components of economic growth) and proceeded to address population and to a lesser extent consumption without using the word *economic* and therefore leaving the economic implications implied. One of the rare explicit references to the economy was provided by Barbier et al. (1994:60), who referred to "the economic activities that lead to the direct depletion of species, and the destruction and degradation of their habitat." The conflict between economic growth and wildlife conservation has also been noted with variable degrees of explicitness by Freese (1998), Erickson (2000), Gowdy (2000), Hall et al. (2000), Naidoo and Adamowicz (2001), and Song and M'Gonigle (2001).

The usual lack of explicit reference to the economic nature of species endangerment and habitat loss can result from oversight, an impression that the point is too obvious to mention, lack of economic background, or political pressure (Czech 2000*b*,*c*,*d*; Song and M'Gonigle 2001). Czech (2000*b*) described disincentives that dissuade scholars from revealing perils of economic growth. These and other disincentives apply in management and policy circles, too, in and out of government.

ECONOMIC GROWTH, TECHNOLOGICAL PROGRESS, AND WILDLIFE CONSERVATION

The form, pace, and timing of economic growth can each have an effect on wildlife conservation. In particular, many people expect technological progress to reconcile the conflict between economic growth and wildlife conservation (e.g., Lomborg 2001). Others expect technological progress to result in liquidation of more natural capital and therefore wildlife (e.g., O'Connor 1994). The argument has focused largely on types of technological progress available.

Pertaining to natural resources conservation, three major types of technological progress may be identified (Wils 2001). The first two types are *explorative* and *extractive technological progress*, which allow for locating and attaining natural resources theretofore unavailable. Technological progress of these types results in reallocation of natural capital to the human economy. The third type, *end-use technological progress*, allows for more efficient use of inputs (Wils 2001). An example is increasing efficiency of internal combustion engines. In theory, end-use technological progress can result in economic growth without reallocation of natural capital. Calls for a "natural capitalism" are focused on this type of technological progress (Hawken et al. 1999).

As Wils (2001) pointed out, however, end-use technological progress can be just as readily used for increased consumption as opposed to conservation, especially in a society where economic growth (i.e., increased production and consumption) is a national goal. For example, when less gasoline is used per mile because of end-use technological progress, the result may simply be more miles driven. Alternatively, money saved on gasoline may be spent on other exploitative and/or consumptive activities. Because the economy is powered primarily by fossil fuel consumption, proximate consumption of other goods and services enabled by more efficient engines entails distal consumption of fossil fuels required to produce the goods and services. In any event, all economic sectors are part of an integrated trophic structure that grows as a whole and at the competitive exclusion of wildlife in the aggregate (Czech 2000*c*).

In addition to the propensity for technological progress to result in more reallocation of natural capital and therefore liquidation of wildlife habitats, Czech (2003) investigated the sources of technological progress and hypothesized that, especially in the current political economy of the United States, technological progress is as much a product of economic growth as vice versa. For example, in 2000 United States industry performed research and development worth about $199.2 billion (Payson and Jankowski 2000). Industry conducts research and development as a function of profit. Prior to technological progress, such profit stems mostly from economies of scale. Because economies of scale are achieved only via increased production and consumption, the derivation of technological progress from industrial research and development has a neutral or negative effect on natural resources, including wildlife conservation. Czech (2003) also hypothesized that the effect tends to be negative rather than neutral because much of industrial research and development (e.g., marketing research) is designed to increase gross production and consumption.

Most of the remaining technological progress comes from federal government research and development, which in turn is derived from income taxes and corporate taxes (Stein and Foss 1995). Other federal receipts are dedicated to social security or insurance or are otherwise earmarked. With federal research and development constituting a function of surplus income and corporate profits, technological progress is premised upon economic expansion. Income and profits are tightly integrated, and their growth is dependent upon increased production and consumption of goods and services (i.e., economic growth) at current levels of technology (Blanchard 1986).

Finally, empirical evidence of biodiversity decline suggests that technological progress is used primarily for further economic growth rather than for conservation. This is not surprising because economic growth is a national goal. If technological progress was used primarily for conservation purposes, species endangerment and other signs of wildlife decline and habitat deterioration would presumably be subsiding rather than worsening. As long as technological progress is used for economic growth, competitive exclusion is engaged. The challenge to wildlife conservation, therefore, is not posed by technological progress itself but by economic growth, whether or not such growth is based upon technological progress. Technological progress in the context of a conservation agenda, designed to reduce consumption of natural capital, could be an important tool in reducing economic growth and its impact on wildlife conservation.

ADDRESSING ECONOMIC GROWTH AND WILDLIFE CONSERVATION

Chiras et al. (2002:28) provided a concise overview of issues related to economic growth and the environment. They stated that "another dominant societal myth is that economic growth is good, indeed essential. Without a doubt, economic growth has made our lives better than our predecessors'." They point out, however, that the higher standard of living has come at a cost, i.e., "some of the most significant costs are the excessive consumption and depletion of natural resources, the loss of countless species, the pollution of lakes and rivers, and the fouling of the air."

The perceived conflict between economics and ecology is not a new one (O'Neill et al. 1998). Resource managers, policy makers, and the public have historically viewed resource-management decisions as requiring a tradeoff between the economy and the environment (Niemi 2002). Although ecology and economics ironically share a common etymological root—the Greek word *oikos,* house—economics and ecology are often presented as opposing disciplines (Leefers and Castillo 1998). Various renewed calls have been expressed for détente between ecology and economics (O'Neill et al. 1998) and for bridging the gap between economics and ecology (Leefers and Castillo 1998). The emerging field of ecological economics appears to be making progress toward this end (Costanza et al. 1997, Erickson 2002). This review constitutes yet another call for recognizing the fundamental conflict between economic growth and wildlife conservation, as well as the need for identifying potential solutions.

Aside from the reality that language critical of economic growth is often avoided or curtailed for political reasons, ambivalence toward the conflict between economic growth and wildlife conservation may result from the incidental, beneficial effects that economic growth has had for some species (Czech 2000*c*). Any ecosystem modification short of annihilation will benefit some species and harm others. For example, construction of hydroelectric dams has created reservoirs that often support highly productive fish populations, and logging can improve habitat for elk and other species that benefit from edge effect, primary succession, and late regeneration (e.g., ruffed grouse [*Bonasa umbellus*], cottontail rabbit [*Sylvilagus floridanus*]). On the other hand, reservoirs and logging contribute to endangerment of 161 and 109 federally listed species in the United States, respectively (Czech and Krausman 1997).

Another source of ambivalence is the importance attached to agency funding for conservation programs. Wildlife professionals in government agencies have perennially been faced with insufficient budgets (Clarke and McCool 1996). Therefore, funding from private sources has been welcomed. Land trusts, for example, are sometimes established in the private sector (Endicott 1993). Corporate landowners administer substantial wildlife management programs. Wealthy entrepreneurs are depended upon to purchase expensive big game permits, with the proceeds going to state and tribal wildlife management programs (Czech 1995, International Association of Fish and Wildlife Agencies 1997, Czech and Tarango 1998). If the economy stopped growing, so would the profits for these types of private expenditures, placing many such well-intended endeavors and programs in jeopardy.

However, to argue that economic growth is prerequisite to wildlife conservation is to commit the "fighting fire fallacy" (Czech 2000*d*:194). This fallacy takes the form "Failure to perform A causes B," when A constitutes the original threat to B. For example, one may assert that cause of a disastrous fire is failure to perform a backfire or the failure to "fight fire with fire." However, while one may stop a fire from consuming grass by employing a backfire, backfires consume grass. Ultimately, if grass is to stop burning, fires must be kept from starting. Likewise, one may assert that cause of habitat-liquidating economic growth is failure to purchase habitat, but if funds for purchasing habitat come from habitat-liquidating economic growth, a net loss of wildlife habitat should be expected. This implies that only if increased funding comes from a reallocation of funds from other government programs or private sources in the context of a steady-state economy (discussed below) can a net gain in wildlife habitat be achieved.

Another source of ambivalence is a supposed lack of alternatives to economic growth. Some theorists of political economy claim that a capitalist economy cannot function in the absence of economic growth (O'Connor 1994), while others assert that, in a capitalist democracy, economic growth can be curtailed if the majority of citizens deem it necessary (Czech 2000*b*). In any event, there are two major alternatives to economic growth: economic stability and economic recession.

Pursuant to principles presented thus far, a stable or steady-state economy would be expected to result in equilibrium of natural capital allocation among human and nonhuman species. Theoretically, economic recession should result in the re-allocation of natural capital from human to nonhuman species. However, economic stability appears to be the most reasonable and prudent alternative to economic growth at the present time because a planned long-term economic recession would entail serious hardships and would not be politically viable. Furthermore, economic recession often undermines existing conservation efforts, resulting in more political support for exploiting protected resources and eliminating important programs.

A nongrowing, steady-state economy has been touted at least since the classical era of economics. John Stuart Mill referred to it as the *stationary state*, where attention would shift from economic production to political and cultural development. The stationary state lost favor among the neoclassical economics movement that began approximately with the tenure of Alfred Marshall at Cambridge University from 1885 to 1908, especially when economic growth theorists began to espouse theories of unlimited economic growth in the mid-20th century (Rostow 1990). Neoclassical economists have continued to tout one version of a "steady-state economy," but inevitably in terms of "steady-state growth." This type of steady-state economy has constant ratios of various parameters (e.g., capital:labor) but continues to grow in size (Abel and Bernanke 1994).

In final decades of the 20th century, however, a general dissatisfaction with neoclassical economics proliferated. Among its early detractors was the "ecological economics" movement assembled from the work of Nicholas Georgescu-Roegen (1971), Kenneth Boulding (1966), and Herman Daly (1973, 1977). This alternative included a realization of biophysical principles that limit economic activities, the evolution of natural and social systems together through time, and an abandonment of the myth of progress through growth (Erickson 1999). Early ecological economists noted that neoclassical economics had lost its ecological moorings and that neoclassical economic growth theory had therefore become based upon a fallacious set of assumptions (Costanza et al. 1997, Gowdy and Erickson 2002). A prominent participant in the ecological economics movement is Herman Daly, who was largely responsible for resurrecting discussion of the nongrowing steady-state economy in 1973 with his book *Toward a Steady-State Economy* and an article in *American Economics Review* (Daly 1973, 1974). Since then, Daly has written extensively on the steady-state economy (e.g., Daly 1977, 1996). Herein, *steady-state economy* refers to the nongrowing version as consistent with ecological economics.

With the possible exception of Freese (1998), macroeconomic issues have been largely ignored by the wildlife profession (Czech 2000*a*). In recent years, however, relevance of the steady-state economy to wildlife conservation has been noted repeatedly by Czech (2000*a,b,c,d*, 2001*a,b*, 2002*a,b*), Czech and Krausman (1997, 1999*a,b*, 2001), Czech and Borkhataria (2003) and Czech et al. (1998, 2000). For example, noting that causes of species endangerment reflected the structure of the United States economy, Czech and Krausman (2001) likened the Endangered Species Act to an implicit prescription for a steady-state economy. Aforementioned articles by Erickson (2000), Gowdy (2000), Hall et al. (2000), Naidoo and Adamowicz (2001), and Song and M'Gonigle (2001) also demonstrate conflict between economic growth and wildlife conservation and thus tend to imply that the steady-state economy may offer a solution.

Growth of population × per capita consumption (as roughly gauged by GDP) in a steady-state economy resembles population growth of K-selected wildlife species (Figure 4). As growth of the economy tapers off, so does reallocation of natural capital from the economy of nature to the human economy. The further below economic carrying capacity the steady-state economy is established, the more natural capital is retained as wildlife habitat. If the steady-state economy were established at human economic carrying capacity, natural capital stocks, and therefore wildlife habitats, would be minimized.

Policies with the explicit goal of slowing or stopping economic growth may not be feasible in the current political climate. Policies aimed at slowing resource use or population growth might be more palatable, particularly if citizens are more widely informed about estimates of global carrying capacity and reductions in resource use and population needed to avoid overshoot and collapse. Shifting taxes away from payroll and income and onto resource consumption (Durning et al. 1998), eliminating income tax deduction for dependents or limiting it to one or two children (Ehrlich and Ehrlich 1990), and eliminating or placing a cap on tax deduction for mortgage interest payments are some examples of public policy actions (Constanza et al. 1997), the first of which has been tried in a few states. Making manufacturers responsible for the entire life cycle of their product, including its reuse, recycling, or disposal has been tried with some success in Europe (Costanza et al. 1997). These policies may slow economic growth, but that effect would be secondary and not the explicit goal of the policy.

Without question there are many technically complex and politically challenging questions about establishing and maintaining an environmentally sustainable economy (e.g., Meadows et al. 1992, Brown 2001). Such questions deal especially with employment and standard-of-living issues during the transition from a growing to a steady-state economy. These questions are beyond scope of this paper, but will continue to be addressed in the ecological economics literature (e.g., Daly 1996). The purpose of this paper was to assess the relationship between economic growth and wildlife conservation. Finding a fundamental conflict between economic growth and wildlife conservation, we developed this section to show that at least one potential alternative exists.

EMERGING RESPONSIBILITY FOR THE WILDLIFE PROFESSION

Our findings are that economic growth and wildlife conservation are conflicting societal goals and that economic growth is a primary goal in the United States. Wildlife conservation is also a societal goal but is not nearly as high a priority as economic growth. Yet there has been little published discussion of the implications of economic growth to wildlife conservation by wildlife professionals. Until the special section on ecological economics in the *Wildlife Society Bulletin* (Czech 2000*a*), references to economic growth in the *Bulletin* were nonexistent or not substantial enough to be registered in *Bulletin's* index. Economic topics were limited entirely to wildlife valuation and microeconomic case studies (e.g., Wallace et al. 1991). The *Bulletin* is representative of a general paucity of macroeconomic discussion in natural resources journals. Czech (2000*b*) found 97 citations containing the keywords "economic growth" in BIOSIS® for the period 1992–1998 and Biological Abstracts® for the period 1989–1991. Only one publication was about wildlife conservation in the United States.

Admittedly, there are publications that escape notice using Czech's (2000*b*) keyword approach to literature searching. One periodically encounters publications in which negative impacts of economic growth on wildlife conservation are clearly identified (e.g., Smith 1994). However, such publications are the exception; the more common approach is to relegate statements on economic growth to passing comments in the discussion section.

For wildlife conservation to be achieved and sustained over the long term, economic growth should be reduced with the goal of establishing a more stable, sustainable economy. Because the public values wildlife, this is an achievable goal if the public fully understands the fundamental conflict between economic growth and wildlife conservation. Realistically, the public values human welfare more than wildlife conservation. Relating the steady-state economy to increased human welfare is the key for societal acceptance and wildlife conservation.

The wildlife profession cannot depend upon other professions to educate the public on this issue. Concerns about the fundamental conflict between economic growth and wildlife conservation are especially unlikely to emanate from the economics profession (Czech 2002*c*). A very small percentage of economists specialize in economic growth, and those that do begin with a set of assumptions that run contrary to principles of wildlife ecology (Erickson 2000, Gowdy 2000, Hall et al. 2000). Furthermore and unsurprisingly, the economics profession has long been subject to political pressures that tend to work in favor of wealthy and corporate interests (Gaffney and Harrison 1994). Today, many mainstream economists in and out of academia are under intense pressure to serve the corporate interests that fund them by promoting economic growth, which tends to benefit all corporations in the short term (Korten 2001).

Partly because of the politicization of economics, there are various movements intent on reforming or replacing neoclassical economics (O'Connor 1994) and advancing ecological economics (Krishnan et al. 1995). While the latter, especially, recognizes the conflict between economic growth and wildlife conservation, its position outside of the mainstream economics profession puts it at a disadvantage for entering into discourse on this issue. The ecological economics movement is one of the most developed of the alternative economic paradigms, but it is not as defined, organized, or professionally acknowledged as the wildlife profession and might never be.

Furthermore, in developing an appropriate approach to any issue involving two major aspects, expertise pertaining to both aspects is required. In developing an appropriate approach to the relationship between economic growth and wildlife conservation, a professional knowledge of wildlife ecology is just as important as a professional knowledge of economics. Wildlife professionals will increasingly face the challenge of balancing ecological systems with economic needs, which will require building bridges among competing groups and especially fostering cooperation with economists (Niemi 2002). Trauger and Hall (1992) emphasized that conservation demands the best efforts of many disciplines working together, not only for wildlife but also for people. O'Neill et al. (1998) suggested convening joint meetings or interdisciplinary symposia to develop solutions to the conflict between ecological and economic goals, which he characterized as an important challenge in the 21st century.

Given the fundamental conflict between economic growth and wildlife conservation, cross-disciplinary initiatives are essential for the future success of the wildlife profession. Therefore, the wildlife profession should be expected to provide leadership in addressing the issue. At stake are not only the conservation of wildlife species but also the sustainability of ecosystems that provide wildlife habitats and ecosystem services for the sustainability of human societies.

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5410 Grosvenor Lane, Suite 200, Bethesda, Maryland 20814

The Wildlife Society is the association of wildlife professionals dedicated to excellence in wildlife stewardship through science and education. The goals of The Wildlife Society are to: develop and maintain professional standards for wildlife research and management; enhance knowledge and technical capabilities of wildlife managers; advance professional stewardship of wildlife resources and their habitats; advocate use of sound biological information for wildlife policy and management decisions; and increase public awareness and appreciation of wildlife management. The Wildlife Society, founded in 1937, is a nonprofit organization whose members include research scientists, educators, resource managers, administrators, communications specialists, conservation law enforcement officers, and students from more than 70 countries.