STUDY REPORT ON
ECONOMIC GROWTH AND FISH CONSERVATION

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INTRODUCTION

At its 2005 annual meeting, the American Fisheries Society (AFS) Governing Board asked its Resource Policy Committee, in partnership with the Water Quality Section and the Socioeconomics Section, to develop a study report summarizing the relationship between economic growth and fish conservation. The group of participants is referred to here as the "Joint Working Group on Economic Growth and Fish Conservation," or "Joint Working Group" for short. Ultimately, however, the participants representing the Socioeconomics Section decided not to co-author the study report, and instead prepared a minority opinion. Therefore, this study report should be viewed as a product of the Water Quality Section, with input from the Resource Policy Committee and the Socioeconomics Section.

The report will assist AFS in determining whether or not to prepare a policy statement on economic growth. The report addresses the nexus of human population growth, resource consumption, and fish conservation, with the latter including fish species, fisheries, and the ecosystems they depend on. The interdisciplinary approach to this report, reflecting AFS's vision and the membership's diverse skills, offers an opportunity to connect disparate efforts into a single analysis focused as much on economic theory as on fisheries and related natural resource issues such as environmental health. Understanding the implications of economic and ecological theory to economic policy making is paramount to effective natural resource conservation because economics is the dominant social science and is pre-eminent in governance and policy-making (Heilbroner 1999).

It is clear from the activities of various AFS units, AFS conference themes, publication titles, and policy statements that the AFS has considered economics for decades. However, the particular issue of economic growth has been a more recent concern (see chapter on "Addressing Economic Growth and Fish Conservation"). A series of articles in *Fisheries* in 2005 and symposia at the 2004 and 2005 annual meetings introduced the general subject to the AFS, its members, and the broader natural resource community.

The AFS Governing Board's charge on economic growth was to "develop a study report/background paper on economic development and fish. The document would be used to help inform a decision about whether or not to develop an AFS policy statement on the issue." In a later clarification, AFS leaders clarified that the intended subject was "economic growth and fisheries." The Joint Working Group further modified the title to reflect its emphasis on "fishery conservation" rather than commercial or recreational "fisheries." As used herein, the more inclusive "fish conservation" embraces fish populations and their habitats.

DEFINITIONS

To facilitate common understanding of concepts and principles presented in this report, we used Allaby (1994) and Ricklefs and Miller (2000) for ecological terms, and Pearce (1992) and Daly and Farley (2003) for economics terms, except where otherwise noted.

Allocation: the process of apportioning resources to the production of different goods and services via markets and cultural institutions.

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

Competitive exclusion: impossibility of coexistence of species with identical niches; proliferation of one species at expense of other species with overlapping niches.

Development: qualitative change, realization of potential, evolution toward an improved, but not larger, structure or system.

Ecological footprint: the amount of productive land needed to meet resource consumption and waste assimilation requirements of a defined human population or economy.

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; production and consumption of goods and services in a country, region, or community.

Fish conservation: conserving natural fish diversity and integrity, including the genetic diversity of stocks; conserving the aquatic and marine ecosystems that wild fish depend upon; maintaining commercially and recreationally harvestable fisheries.

Gross domestic product (GDP): 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.

Individual Transferable Quota (ITQ): a transferable share of a Total Allowable Catch (TAC) allocated to individual fishermen or fishing firms (Anderson 1995).

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

Macroeconomics: considers interactions in the economy as a whole, including such variables as aggregate employment, the average rate of price increases (inflation), and the foreign exchange rate. These are concepts which are familiar to the lay person from the daily news. Macroeconomists model the economy's behavior at this macroscopic scale.

Microenonomics: considers the allocative decisions taken by individual agents such as consumers and firms; microeconomists tend to focus on one particular aspect of these individuals as they examine the variables which determine why an individual demands any one commodity and why a firm supplies it.

Microeconomics thus considers the circular flow in the economy at a microscopic level.

Natural capital: stocks or funds provided by nature (biotic or abiotic) that yield a valuable flow into the future of either natural resources or natural services.

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.

Per capita consumption: consumption of goods and services by households, firms, and governments, expressed as a ratio of consumption in the aggregate to the number of people comprising the households, firms, and governments.

Pigouvian subsidy: a microeconomic policy tool to correct for a negative externality; a payment to each firm for each unit by which it reduces environmental costs.

Pigouvian tax: a microeconomic policy tool to correct for a negative externality; a tax equal to the external cost of an economic production activity.

Population: a group of organisms of the same species that occupies a particular area.

Scale: the physical size of the economic subsystem relative to the ecosystem that contains and sustains it; measured in its stock dimension of population and inventory of artifacts, or in its flow dimension of throughput required to maintain the stocks.

Steady state economy: the economy viewed as a subsystem in dynamic equilibrium with the parent ecosystem/biosphere that sustains it; quantitative growth is replaced by qualitative development or improvement as the basic goal.

Sustainable scale: the condition met when an economy is maintained within the capacity of the ecosystem to support it.

Technological (or *technical*) *progress*: a central element in economic growth that 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.

ECONOMIC GROWTH, TRENDS, AND POLICY

In its most basic form, an economy consists of producers and consumers. Firms acquire factors of production from households and produce goods and services. Households acquire and consume the goods and services. Economic growth is simply an expansion of that circular flow, resulting in an increase in cumulative production and consumption of goods and services (Abel and Bernanke 1994).

Economic growth also entails increasing population times per capita production and consumption, where "per capita" refers to the ratio of production or consumption in the aggregate to the number of people comprising households, firms, and governments. 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 may be classified as manufactured (e.g., machines), human (e.g., knowledge), or financial (e.g., money). Land is the aggregate of natural resources, to which value is added by labor and capital in the production of goods and services. The term "natural capital" is sometimes used synonymously with natural resources. More precisely, natural capital may be "stocks or funds provided by nature (biotic or abiotic) that yield a valuable flow into the future of either natural resources or natural services" (Daly and Farley 2003). The funds of "natural services," or "ecological services," are not typically associated with traditional concepts of land as a factor of production.

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" occurs (Pearce 1992). Technological progress via research and development is a function of economies of scale and, therefore, economic growth above that of pre-existing levels of technology (Czech 2003).

The fundamental identity of national income accounting is that total production = total income = total expenditure (Abel and Bernanke 1994). Therefore, the size of an economy may be measured by its production, income, or expenditures. In the U.S. and most other countries, the most typical measures of the size of an economy are gross national product (GNP) and gross domestic product (GDP). GNP is "the market value of final goods and services purchased by households, by government, and by foreigners (net of what we purchase from them), in the current year. Alternatively, it is the sum of all value added to raw materials by labor and capital at each stage of production, during the given year" (Daly and Farley 2003). GNP includes production by all citizens whether at home or abroad. GDP includes all production within the geographic borders of the country in question, whether by citizens or foreigners. When market value is adjusted for inflation, these indices of production reflect the size or scale of an economy and allow for monitoring trends in that size.

The U.S. economy has grown continually throughout its history, with few major exceptions. Beginning in 1929, national income accounting has been conducted by the U.S. 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 U.S., GNP and GDP have typically differed by less than 1% of GNP (Abel and Bernanke 1994), although the difference may be increasing due to corporate globalization and balance of payments. U.S. GNP has increased more than ten-fold since 1929. In recent decades, the economy was growing at a rate of about 2.5% per year (Abel and Bernanke 1994). By the end of 2005, U.S. GDP was $12.37 trillion, Canada's GDP was $1.077 trillion, and Mexico's GDP was 1.066 trillion (U.S. Central Intelligence Agency 2006). U.S. GDP ranks first in the world.

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

Economic growth has long been a primary, perennial, and bipartisan goal of the U.S. public and polity (Collins 2000). The Great Depression, the Keynesian revolution in economics (which gave birth to modern macroeconomics), and the material and fiscal exigencies of World War II were especially instrumental in making economic growth a foremost national effort. 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 the primacy of economic growth as a policy 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, and the Securities and Exchange Commission. Economic growth is the predominant goal for U.S. monetary policy (e.g., Federal Reserve System 2000). Canadian and Mexican macroeconomic policies are likewise concerned primarily with economic growth, as are those of the World Bank.

POPULATION GROWTH, CONSUMPTION, AND CONSUMER TRENDS

The U.S. is the third most populous country in the world, with approximately 296 million people (U.S. Central Intelligence Agency 2006). The populations of Canada and Mexico are approximately 33 million and 106 million, respectively (U.S. Central Intelligence Agency 2006). The U.S. population has grown steadily from approximately 75 million in 1900, increasing by more than 200 million during the past century. By 2050, the U.S. 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 U.S. comprises less than 5% of the world's population (Smith 1999), but consumes 30% of the resources used in the process of economic growth (Suzuki 1998). During the past 50 years, U.S. per capita resource use rose 45% overall, and its per capita use of paper, steel, aluminum, water, energy, and meat ranks first in the world (Suzuki 1998). The economy of the U.S. depends heavily on fossil fuel combustion, accounting for more than 25% of annual consumption worldwide (Suzuki 1998, Smith 1999).

Much of this consumption reflects 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 (1999) believes consumerism did not characterize the U.S. 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 U.S. workforce is employed in the production and sale of consumer goods (Rosenblatt 1999).

STATE OF GLOBAL FISH STOCKS: FISHERIES IN DECLINE

As shown in Figure 1 in Myers and Worm (2003), studies of fisheries abundance indicate that they are virtually everywhere in decline (Pauly and Palomares 2005, Christensen et al 2003, Myers and Worm (2003), especially preferred stocks. As one preferred species is fished beyond commercial viability, another less preferred species takes its place, only to be similarly depleted (Pauly and Palomares 2005). Myers and Worm (2003) reported that 90% of large predatory fish are gone from global oceans (see also Christensen et al. 2003). These losses can be attributed to two main causes, overfishing and habitat degradation and loss. A good example is the North Atlantic cod, once a mainstay of the economy of Northeast North America (Dybas 2006). Fisheries and Oceans Canada announced a closure of the Canadian cod fishery in nearly all of its waters (Science News 2003). A growing human population demands more fish for food (76% of world fisheries production) and other purposes (24%) (FAO 2004), causing more and more effort to be applied to continually decreasing stocks.

Moving from marine fisheries to those of the Laurentian Great Lakes, a precipitous decline of valuable commercial species began in the late 1800s as Europeans and European Americans settled in the area. They engaged in intensive commercial fishing and habitat modification including massive forest clearing, using rivers as tranportation conduits, and large scale killing of sturgeon as a “nuisance species” (Beattie Bogue 2000).

In the U.S., the leading factors currently contributing to fish species' listing under the federal Endangered Species Act are surface water diversion, invasive species, pollution and agriculture. Most species are listed due to multiple causes (Miller and Czech 2005). The five states with the most listings (Nevada, California, Tennessee, Arizona and Alabama) together account for 55 of the 117 species presently listed. Of these, Nevada and Arizona are the two fastest-growing states in the U.S.

Recent AFS and federal publications document marked declines in fish species and fish assemblages at regional and continental scales (Williams et al. 1989, Nehlsen et al. 1991, Hughes and Noss 1992, Musick et al. 2000, McCormick et al. 2001, Hughes et al. 2004, Rinne et al. 2005). Only 57% of the total stream and river length of the conterminous western USA supports least disturbed fish assemblages (Stoddard et al. 2005), while only 17% of mid-Atlantic Highland stream length contains least disturbed fish assemblages (USEPA 2000), and only 28% of wadeable stream length in the conterminous USA supports least disturbed macroinvertebrate assemblages (USEPA 2006). At least 364 North American freshwater fishes are endangered, threatened, or vulnerable (Williams et al. 1989, Nehlsen et al. 1991); at least 167 distinct population segments of marine North American fishes are so classified (Musick et al. 2000).

Focusing on habitat changes in the U.S., the Pew Oceans Commission (2003) reported that more than half of its citizens reside in the coastal zone and projected that 27 million more will live there within 15 years. Coastal zone population density is 5 times that of the country's interior. Typically wealthier, residents in coastal areas consume more land, boat more, drive more and generally consume at a higher level than other citizens, imposing greater burdens on fish habitat. Densely populated and rapidly expanding urban areas contribute significantly to aquatic habitat change (Paul and Meyer 2001, Brown et al. 2005). In addition to the obvious direct impact through alteration or removal of streams, growth in impervious surface area has repeatedly been implicated in aquatic habitat decline.

Economic activity causes significant water quality damage, negatively affecting fish. Agricultural runoff has and continues to degrade fish habitat. For example, phosphorous overload in the 1960s grossly enriched Lake Erie, wreaking havoc with fish stocks there. Judy et al. (1984) found that agriculture adversely affects 29% of all USA waters, and is a major concern in 17%. More recently, an 18,000 square kilometer hypoxic region in the Gulf of Mexico developed through the increased input of nitrogen-bearing chemicals in the Mississippi River watershed (McIsaac et al. 2001). Airborne pollutants from combustion increase mercury contamination of fish tissue (Peterson et al. 2002, Stoddard et al. 2005), contribute to surface water acifification (Baker et al. 1991), inhibit the growth of algae, reduce hatching success, increase egg and larval mortality and inhibit fish growth (National Wildlife Federation 1999).

At the same time, fish habitat is shrinking and degrading through expansion and intensification of human economic activities. For example, once the most productive estuary in North America, the Chesapeake Bay has experienced extensive eutrophication and populations of toxic microbes have exploded (Pauly and MacLean 2003) primarily from suburban and agricultural runoff. In 1997, mycobacteriosis was discovered in Bay rockfish and is believed to infect almost 75% (Washington Post 3/11/06). Although habitat losses have been inadequately quantified in most areas, they are likely to continue as human population growth, urban sprawl and climate change continue (McLaughlin and Mandrak 2003).

In the 1930s the alien sea lamprey entered the upper Great Lakes, apparently through the Welland Canal. In combination with overfishing its entry resulted in the crash of the lake trout population in 1948 (Smith 1968). Subsequent efforts to facilitate rebuilding of lake trout populations have achieved only modest success. Moreover, damaging alien species introductions from ship ballast water continue to threaten fish stocks and fish assemblages in the Great Lakes (NOAA-GLERL 2005). In a review of historical changes in large river fish assemblages, Hughes et al. (2005) concluded that flow and channel regulation plus alien species were key alterations, especially in the southwestern USA.

Description and analysis of the problem of fish decline and fish habitat degradation has recently intensified, but much remains to be learned.

Recognizing that federally-sponsored development programs have contributed to the habitat loss and degradation implicated in many species listings, the U. S. Congress has passed legislation such as the Northwest Power Act (PL 96-501, 1980) and the Central Valley Project Improvement Act (PL 102-575, 1992), which provide for comprehensive fishery restoration programs that include a doubling of local Pacific salmon populations. However, in the 26 years since the NPA and the 14 years since the CVPIA, these doubling goals have yet to be achieved, despite millions of dollars and untold hours of human effort invested, because they are unable to make sufficient progress against the underlying causes of the declines.

ECONOMIC GROWTH, ECOLOGICAL PRINCIPLES, AND FISH CONSERVATION

Two basic approaches may be used for ascertaining the relationship of economic growth to fish conservation: theoretical and empirical. In this section, we explore theoretical evidence using established principles of ecology and economics. We then provide an overview of the empirical evidence regarding the relationship between economic growth and fish conservation.

Theoretical Evidence

The most relevant principles of ecology that may be used to ascertain the relationship between economic growth and fish conservation are carrying capacity, niche breadth, competitive exclusion, and trophic levels.

Carrying Capacity

Carrying capacity is the principle that populations of all species are limited by environmental factors. Limiting factors were categorized by Leopold (1933) as welfare factors and decimating factors. Welfare factors include food, water, cover, space, and spawning sites. These factors comprise species' habitats. Decimating factors are external threats such as fishing, pollution, fires, storms, and floods. Fish management is largely an exercise of maintaining or providing welfare factors and preventing or mitigating decimating factors (Leopold 1933) (although natural floods constitute critical reset mechanisms for lotic ecosystems).

Some scholars have suggested that the concept of carrying capacity is not applicable to humans because humans are able to manipulate their environments and protect themselves from decimating factors (Simon 1996). When natural resources required for human population growth become scarce, humans may find or develop substitutable resources, natural or manufactured. Furthermore, invention and innovation lead to increasing efficiency in the production and consumption of goods and services. However, many ecologists (e.g., Ehrlich 1994, Pimm 2001) and economists (e.g., Daly 1996, Erickson and Gowdy 2000) deny that the substitutability of resources and increasing productive efficiency could result in an infinite expansion of production and consumption of goods and services or an infinite expansion of human population. Their assessment is based largely on the laws of thermodynamics, which establish limits to the availability of energy and materials and limits to the efficiency of economic production. More relevant to the relationship of economic growth to fish conservation, however, is that the ability of humans to increase carrying capacity, temporarily or even permanently if that is possible, does not necessarily preclude a fundamental conflict between economic growth and fish conservation. In assessing the relationship of economic growth to fish conservation, the term "economic carrying capacity" is useful because, especially for humans, carrying capacity is not only a function of population size but also of per capita consumption (Daly and Farley 2003). For nonhuman species, per capita consumption is fairly uniform across individuals of the same species, consisting largely of food. For humans, however, consumption covers a much broader set of goods and services and varies widely across cultures and individuals. Therefore, carrying capacity for humans is most appropriately discussed in terms of population times per capita consumption.

Niche Breadth

A species' niche pertains to the suite of habitat features used and the extent of interactions with other species (Hutchinson 1978). Factors indicating niche breadth include the variety of foods consumed, the species' range, and the variety of ecosystems occupied. Large body size usually offers a species a greater selection of prey, and intelligence enhances the individual's abilities to forage among a wide variety of food resources and habitats.

Competitive Exclusion

The principle of competitive exclusion establishes that two species cannot occupy an identical niche (Begon et al. 1996). Put in slightly different terms, 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. Populations of species with broad niches tend to grow at the competitive exclusion of numerous species. Clearly, the niche breadth of a species is correlated with the number of species affected by that species.

Trophic Levels

Trophic theory concerns the nutritional organization and resulting energy flows of an ecosystem (Ricklefs and Miller 2000). The basic trophic levels are producers and consumers. All fish are consumers and may be classified as primary, secondary, tertiary, or as higher-level consumers. Omnivorous generalists with broad niches are capable of consuming a wide variety of producers and consumers in multiple trophic levels, and they tend to thrive in highly disturbed environments (Karr 1981, Hughes and Noss 1992). The carrying capacity of an ecosystem for a given consumer is a function of the biomass and productivity of forage or prey species residing at lower trophic levels.

What do the above principles mean for humans? Humans are relatively large-bodied and possess the highest intelligence detected among species. In the global ecosystem, humans constitute the top trophic level. Humans are very effective competitors with other species. Their technological progress has resulted in unprecedented niche expansion (Kingdon 1993). They reside in all regions of the earth and in all types of ecosystems. As Czech (2002*a*) 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." By "wildlife," Czech (2002*a*) was referring primarily to nonhuman vertebrate species, including fish, but the same principles apply to invertebrates and plants. As evidence of this expansion, Vitousek et al. (1986) estimated that humans appropriated 40% of global terrestrial net primary production and 25% of global terrestrial plus marine net primary production, leaving the remainder for the other 5 million animal species. Based on ecological footprint analysis, if everyone on Earth lived like North Americans, three more Earths would be needed to do so sustainably (Wackernagel and Rees 1996), with 8-25 ha for each urban human.

Environmental Kuznets Curve

Thus far, basic principles of ecology tend to suggest a fundamental conflict between economic growth and fish conservation. However, there is a theoretical construct called the "environmental Kuznets curve" that would tend to suggest otherwise. A Kuznets curve represents the hypothesis that some aspect of welfare may be reduced in the early stages of economic growth but that, after a threshold level of wealth is attained, the aspect of welfare is increased thereafter. Normally, "economic growth" as used in the Kuznets curve literature has referred to GDP/capita (Barbier 1997, Yandle et al. 2004).

The logic of the environmental Kuznets curve is that, in the early stages of an economy, little attention is paid to environmental threats. The lack of attention may be due to the relatively small scale of the economy, which in its early stages exists within a relative plethora of natural resources. Alternatively, the lack of attention may be due to poverty, a condition in which people are more concerned with making a living than with environmental protection. As the economy grows, citizens begin to note the growing environmental problems and begin to divert some of their efforts to successfully solving environmental problems (Figure 1).

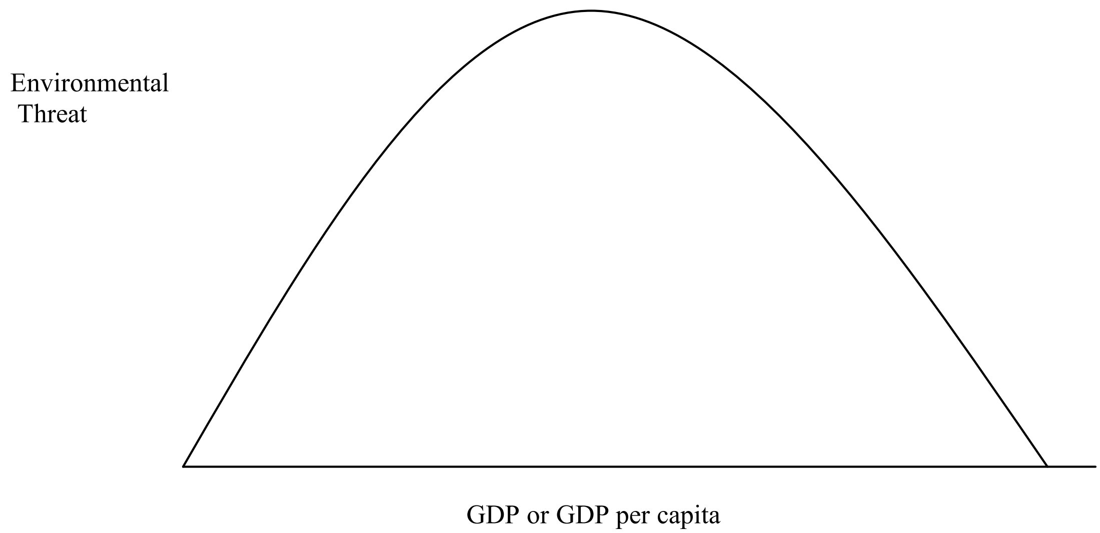

Figure 1. Hypothetical environmental Kuznets curve.

Kuznets curves for some aspects of environmental protection have been reported, for example regarding sulfur dioxide emissions in the U.S. However, critics of such findings note that these assessments have often failed to account for the effects of globalization and the "exporting" of polluting industries to less-developed nations, which then produce goods that are imported by wealthier nations (Stern 2004). Critics also note that many 2-variable relationships are not curvilinear but instead entail multiple thresholds. For example, an environmental threat may increase in the early stages of economic growth, decrease in intermediate stages, and increase again as an economy approaches carrying capacity. Critics also question the validity of a "macroecological," environmentally encompassing Kuznets curve, noting that some environmental problems may be addressed (e.g., ozone depletion) while others proliferate (e.g., biodiversity loss, cumulative greenhouse gas emissions, desertification). Of primary relevance here is the prospect of an environmental Kuznets curve for fish. Naidoo and Adamowicz (2001) sought evidence for an environmental Kuznets curve for vertebrate species in a cross-section of nations and found no evidence except possibly, they emphasized, for birds in some nations.

Fundamental Conflict

Taken together, the principles of carrying capacity, niche breadth, competitive exclusion and trophic levels suggest a fundamental conflict between economic growth and fish conservation. The conflict is illustrated theoretically by the allocation of natural capital among human and nonhuman species (Figure 2). In the absence of humans, all natural capital comprises habitats for nonhuman species, including fish. Economic growth entails the re-allocation of natural capital from nonhuman uses, or the "economy of nature," to the human economy.

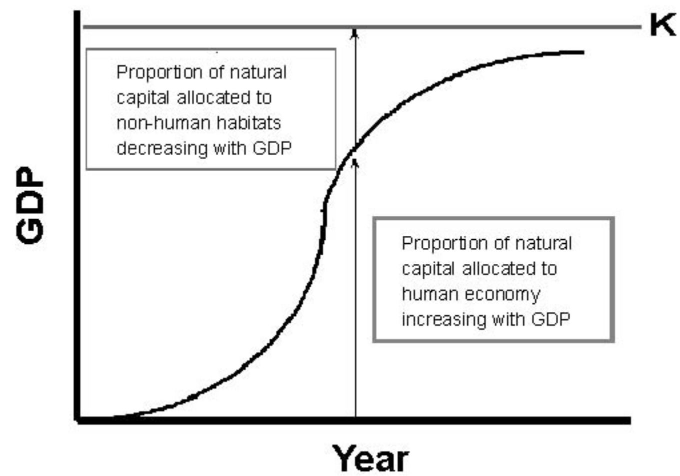

Figure 4. Allocation of natural capital as modified from Czech (2000a). GDP = Gross Domestic Product; K = carrying capacity.

Figure 2. Re-allocation of natural capital. (Reprinted from TWS 2003.)

Empirical Evidence

The causes of fish species endangerment and related trends in aquatic ecosystem loss offer the clearest empirical evidence for a conflict between economic growth and fish conservation. Miller and Czech (2005) focused on the causes of fish endangerment in the U.S. and found that the causes of fish endangerment reflected the structure of the American economy (Table 1). Agricultural and extractive sectors (i.e., water diversions, logging, mining, ranching, and harvesting of fish and wildlife) constitute the economy's foundation. Water, agricultural, and extractive surpluses aid the establishment of manufacturing and service sectors (Quesnay 1968, Smith 1976).

Table 1. Causes of fish species endangerment in the U.S. There are 17 causes, with two pairs (rankings 2 and 8) tied in frequency. (Modified from Miller and Czech 2005).

Ranking	Cause of Endangerment	# of Species	% of Listed Fish
1	Surface water diversions	84	73.0%
2	Non-native Species	56	48.7%
2	Pollution	56	48.7%
3	Agriculture	47	40.9%
4	Aquifer Depletion and Wetland Conversion	27	23.5%
5	Urbanization	26	22.6%
6	Mining, Oil, Gas Activities	24	20.9%
7	Grazing, Other Ranching Activities	16	13.9%
8	Logging	14	12.2%

8	Roads	14	12.2%
9	Genetic Problems	13	11.3%
10	Recreation and Tourism	9	7.8%
11	Industrial, Military Activities	6	5.2%
12	Native Species Interactions	5	4.3%
13	Harvest	4	3.5%
14	Modified Fire Regimes, Silviculture	3	2.6%
15	Vandalism	1	0.9%

Urbanization represents not only the proliferation of infrastructure, residential housing, and light manufacturing plants but also of the many service-providing businesses (e.g., restaurants, clothing stores, banks) that operate in urban areas. Pollution is an inevitable by-product of producing goods and services (Daly and Farley 2003). Roads and reservoirs constitute economic infrastructure. The proliferation of nonnative species is largely a function of international trade and interstate commerce (Ericson 2005). Activities such as firefighting and silviculture are conducted largely for economic purposes.

Rose (2005) analyzed the threats to freshwater fish species in Canada (Table 2). The most common threats were habitat loss or degradation, pollution, and non-native species. Rose (2005) found that the 69 fishes in the study were endangered by 2.4 causes each. Rose (2005) identified climate change, most notably global warming, as a threat to fish conservation in Canada, noting that global warming was "an indirect consequence of the energy, transportation and the manufacturing sectors (i.e., mainly an effect of our dependence on fossil fuels)." Rose (2005) concluded that global warming and all of the other identified threats to fish conservation in Canada would increase in severity with the growth of the Canadian economy.

There is a strong correlation ($r^2 = .984$) between economic growth and the number of listed species (Figure 3). Correlation does not prove causality, but when the causes of species endangerment are considered, as above, evidence for causality emerges because the causes of endangerment correspond with sectors of the human economy (Czech et al. 2000).

Table 2. Causes of freshwater fish species endangerment in Canada (from Rose 2005).

Ranking	Source of Endangerment	Number of Species	% of Listed Species
1	Habitat Loss/Degradation	49	71.0%
2	Pollution	27	39.1%
3	Non-native Species	22	31.9%
4	Barriers/Dams	14	20.3%
5	Water Management	13	18.8%
6	Urban Development	13	18.8%
7	Over Exploitations	9	13.0%
8	Natural Habitat Change	3	4.3%

9	Climate Change	3	4.3%
10	Aquaculture	1	1.4%

Source: Canadian Wildlife Service 2004 (http://www.speciesatrisk.gc.ca/)

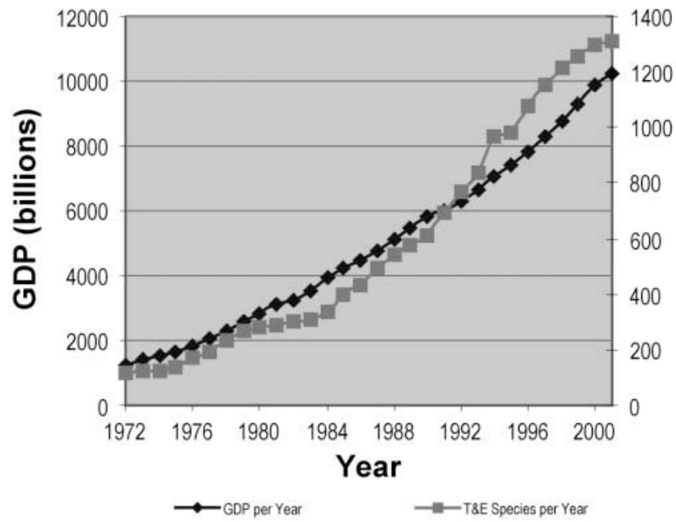

Figure 3. GDP and federally listed threatened and endangered species in the U.S. (Reprinted from TWS 2003).

Other empirical evidence for a conflict between economic growth and fish conservation includes the reduction in extent and integrity of ecosystems and habitats that support fish species. Noss et al. (1995) identified 30 critically endangered, 58 endangered, and 38 threatened ecosystems of the U.S., 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). Some of these ecosystems are to a large extent aquatic, many include substantial aquatic components, and all the non-aquatic ecosystems are upstream of aquatic ecosystems.

Noss et al. (1995) did not analyze the relationship of the economy to the decline of ecosystems but noted that ecosystem decline was most pronounced in the South, Northeast, Midwest, and California, or regions characterized by large regional economies. Ecosystem decline was minor only in Alaska, which is characterized by a relatively small population and economy. Noss et al. (1995) also noted that European settlement was the beginning of widespread ecosystem decline, although Martin (1971) argued that Pleistocene hunters altered ecosystems in the present-day Americas by eliminating more than 100 large mammal species. In any event, European settlement led to an American industrial revolution, which the economic growth theorist Rostow (1990) referred to as "take-off," which in turn is stylized as the steepest slope in Figure 2.

Other authors who have noted the economic causes of wildlife and habitat loss include Pletscher and Schwartz (2000), who posited that such loss "can ultimately be attributed to increases in human population and per capita consumption," and Barbier et al. (1994), 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 biodiversity 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).

Although lacking explicit reference to the human economy, many other assessments of ecosystem decline and species endangerment are consistent with the findings reported here (e.g., Chadwick 1995, Dobson et al. 1997, Foin et al. 1998, Wilcove et al. 1998). For example, assessments of species endangerment have invariably revealed habitat loss to be the primary cause of species endangerment or extinction (Miller et al. 1989). Such habitat loss is typically attributed to "human activities." These activities, in turn, tend to be predominantly economic and not, for example, spiritual or intellectual activities. (Military activities also exact a significant toll on ecosystems and species, but even these activities are strongly linked to economies because national security and economic security have historically been considered intertwined goals and because warfare is often the result of resource shortages and resulting economic competition.) The typical lack of explicit reference to economic growth as a driver of biodiversity loss can result from oversight, an impression that the point is too obvious to mention, lack of economic background among ecologists, lack of ecological background among economists, or political pressure (Czech 2002*b*; Song and M'Gonigle 2001).

ECONOMIC GROWTH, TECHNOLOGICAL PROGRESS, AND FISH CONSERVATION

In the vernacular, "technological progress" refers to invention and innovation, especially that which is useful for purposes of economic production. Some observers expect technological progress to reconcile the conflict between economic growth and biodiversity conservation (e.g., Lomborg 2001), presumably including fish conservation. Others expect technological progress to result in the liquidation of additional natural capital and therefore the loss of more nonhuman biodiversity (e.g., O'Connor 1994). The argument has focused largely on the types of technological progress available.

Three major types of technological progress may be identified (Wils 2001). The first two are explorative and extractive technological progress. Explorative technological progress enables producers to locate natural resources that would otherwise have not been located, and extractive technological progress enables producers to obtain located resources that would otherwise not have been obtainable. These two forms of technological progress may work in conjunction or independently. Explorative and extractive technological progress enable the reallocation of natural capital from nonhuman species to the human economy except in cases where explorative technological progress results in the discovery of resources that remain unobtainable.

The third type of technological progress, or end-use technological progress, allows for more efficient use of inputs; i.e., more output per unit input (Wils 2001). In other words, this form of technological progress results in increasing "productive efficiency" or "technical output efficiency" (Marklund 2004). An example is increasing efficiency of electric motors. In theory, end-use technological progress can result in economic growth without the reallocation of natural capital from non-human species to the human economy. 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 may just as readily be 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 a motor uses less electricity per revolution because of end-use technological progress, the result may simply be more revolutions of the motor. Alternatively, money saved on electricity may be spent on other exploitative and/or consumptive activities. The result is technological progress leading not to natural resources conservation but rather to increased re-allocation of natural capital from non-human species to the human economy. This phenomenon is referred to as "Jevons paradox," after Jevons (1906): "the very economy of its [coal's] use… leads to its extensive consumption. It has been so in the past, and it will be so in the future. Nor is it difficult to see how this paradox arises….If the quantity of coal used in a blast-furnace, for instance, be diminished in comparison with the yield [i.e., technological progress has occurred], the profits of the trade will increase, new capital will be attracted, the price of pig-iron will fall, but the demand for it increase; and eventually the greater number of furnaces will more than make up for the diminished consumption of each. And if such is not always the result within a single branch, it must be remembered that the progress of any branch of manufacture excites a new activity in most other branches and leads indirectly, if not directly, to increased inroads upon our seams of coal."

The application of Jevons paradox to fish conservation has occurred in two ways. First, as fishing fleets have become more efficient at harvesting, or "producing" fish for the market, the price of fish has fallen, thus increasing demand for fish and the resultant harvest. While the technological progress of the fishing industry may continue, the population dynamics of fish species are rooted in evolutionary ecology. There is no rational expectation that reproduction or recruitment rates would increase, or that (non-fishing) mortality rates would decrease, significantly as a function of technological progress. We would expect, then, that technological progress in the fishing sector would result in more, not fewer, fish caught and brought to market, and that expectation is consistent with the technological development and expansion of fishing fleets and the concomitant decline of fisheries (Myers and Worm 2003).

Second, technological progress in the various other economic sectors results in lower prices of goods and services in the aggregate, thus increasing demand in the aggregate. All economic sectors are part of an integrated whole (Boulding 1993), a trophic structure that expands at the competitive exclusion of non-human species in the aggregate (Czech 2005). Many of these sectors reallocate fish habitat directly into raw materials, construction sites, manufactured capital, and consumer goods, while the effects of other sectors are largely indirect. Production in all sectors, for example, entails co-production of wastes, many of which degrade fish habitat because fish tend by nature to inhabit areas that are downslope and downstream of production sites and facilities.

Developing a hypothesis complementary to the Jevons paradox, Czech (2003) reviewed the sources of technological progress and noted that, especially in the current political economy of developed nations, technological progress is as much a product of economic growth as vice versa. For example, American corporations in 2000 spent $199.2 billion on research and development (Payson and Jankowski 2000). Corporations conduct research and development as a function of profit. In the absence of technological progress, such profit stems primarily from economies of scale (Denison 1985). Because economies of scale are achieved via increased production and consumption, regardless of the level of technology, obtaining technological progress from corporate research and development has had either a neutral or negative effect on fish and other natural resource conservation. Czech (2003) also hypothesized that the effect has been negative, rather than neutral, because some of the corporate research is focused on marketing which is designed to increase demand, again regardless of the level of technology. Although an indirect effect of marketing research may be to promote economies of scale (because marketing increases demand), marketing research does not increase productive efficiency.

Most technological progress not achieved by corporations stems from governmental (especially federal) research and development (Payson and Jankowski 2000). Governmental revenue for financing research and development is derived from income and corporate taxes (Stein and Foss 1995). Research and development is itself a service produced and consumed and constitutes about 2.8% of American GDP (Payson 1999).

Economists of all persuasions agree that, in competitive economies with free markets in labor and capital, profits tend to dry up and wages tend to be pushed down to subsistence levels. Technological progress and economies of scale are depended upon to maintain profits and surplus income, which helps to explain why some believe a capitalist economy cannot exist without economic growth and without a perpetually greater impact on the environment (e.g., O'Connor 1994). However, that hypothesis does not acknowledge the prospect for the establishment of a steady state, capitalist democracy with stabilized population and per capita consumption (Daly and Farley 2003, Czech and Daly 2004).

The empirical evidence of fish and other biodiversity declines suggests that technological progress is used primarily for purposes of increased production and consumption rather than purposes of conserving natural capital, including fish and fish habitats. This is to be expected because technological progress and economic growth are tightly linked when economic growth is a national goal and when government research and development policies are motivated by that goal. If technological progress were a successful approach to conserving natural capital and facilitating economic growth at the same time, biodiversity decline and habitat deterioration would be subsiding rather than worsening.

Threats to fish conservation are not posed by technological progress in and of itself but by the economic growth facilitated by technological progress.

ADDRESSING ECONOMIC GROWTH AND FISH CONSERVATION

The theoretical and empirical evidence presented in this report reveals a fundamental conflict between economic growth and fish conservation. The AFS and the fisheries profession in general is concerned primarily with fish conservation. Therefore, it behooves the fisheries profession to help educate the public and policy makers on the tradeoffs between economic growth and fish conservation, as well as potential alternatives to economic growth that would improve society's performance in the fish conservation arena. Thus far, however, the fisheries profession and, natural resource professions in general, have been relatively silent on the topic of economic growth. This silence may be attributed to several factors. Perhaps the most obvious is that criticism of economic growth is often avoided or curtailed for political and personal reasons. Economic growth has long been a primary goal of governments, and most natural resource professionals are employed by or funded by governments.

Other factors are less obvious and may generally be categorized as ambivalence. One potential source of ambivalence is the incidental, beneficial effects that economic growth has had for some fish species in some locations. For example, the construction of hydroelectric dams has created reservoirs and tailraces that often support highly productive fisheries, including non-native game and native species highly valued by humans, such as trout, striped bass, largemouth bass and channel catfish. Therefore, many fish biologists who work with these species may not recognize the conflict between economic growth and fish conservation without considering a broader context. However, while reservoir and tailrace habitats may be good for many game species in some areas, reservoirs and other surface water diversions also contribute to the endangerment of 84 fish species in the U.S., or 73% of federally listed fish species in the U.S. (Miller and Czech 2005). Anything that modifies the environment, unless it results in total annihilation, will benefit some species and harm others, but the net effect of economic growth is biodiversity decline in the aggregate.

Another potential source of ambivalence is the importance of funding for conservation programs, in and out of government. Natural resource professionals are often faced with insufficient budgets. All else equal, if the economy stopped growing, so would many conservation programs. More importantly, given the structure of the human economy, increased monetary funding in the aggregate (i.e., across all programs, including conservation) ultimately entails the liquidation of natural capital. If funds for purchasing, restoring, or managing fish habitat entail activities that liquidate natural capital, which prior to liquidation had comprised fish habitat, a net loss of fish habitat should be expected. This implies that a net gain in fish habitat via additional funding is likely to occur only if the additional funding comes from a reallocation from other sources (including government and non-government programs) rather than increased funding for all programs in the aggregate.

Yet another potential source of ambivalence is the feeling that the alternatives to economic growth are undesirable or even impossible in a capitalist system. For example, Marxists sometimes claim that a capitalist economy cannot function in the absence of economic growth (O'Connor 1994). However, other scholars posit that, in a capitalist democracy, economic growth can be curtailed if the majority of citizens deem it necessary (Daly and Farley 2003). It also seems relevant to note the expansive literature on business cycles, which has established that economies alternate between stages of growth and recession while maintaining their capitalist structure (Rostow 1990).

Whatever the reasons may be, there has been little published discussion of the implications of economic growth to fish conservation by fisheries professionals. Until the "Economic Growth Forum" was published in *Fisheries* during 2005 and 2006, references to economic growth in fisheries publications were rare. Most economics-oriented papers pertaining to fisheries have been limited entirely to fish (or fish habitat) valuation and microeconomic case studies (e.g., Strange et al. 2004).

Using the AFS Online Journals search engine, we found that, prior to the Economic Growth Forum, the phrase "economic growth" had been used in only 21 articles published in AFS journals, mostly in passing. Economic growth was a prominent enough subject to be included in the abstracts of only two of these articles (both in *Fisheries*). In one article, Smith (1994) noted that "Salmon problems in the Pacific Northwest have an important cultural as well as biological dimension. Economic growth is a dominating cultural goal. Social and political units do not match well with ecosystems." The article goes on to imply that salmon conservation conflicts with economic growth in the Pacific Northwest.

In the other article, Schweitzer (1992) noted, "Countries richest in biological diversity ironically are often the poorest economically. In these countries, in which humans struggle daily to meet urgent basic needs, efforts to protect the environment will succeed only if implemented in the context of promoting economic growth. Yet economic growth itself depends on the normal functioning of ecosystems and on a sustainable supply of natural resources." This quote merits further analysis, because "promoting economic growth" (or at least pursuing economic growth) would indeed seem an appropriate policy for countries in which humans struggle daily to meet urgent basic needs. Likewise, few would deny that economic growth depends on the normal functioning of ecosystems and on a sustainable supply of natural resources. Schweitzer (1992) did not proceed to explore the potential for reconciling continual economic growth with normal functioning of ecosystems and a sustainable supply of natural resources. Our summary indicates that economic growth alters ecosystem function and structure and depletes natural resources. The implication is that financially wealthy countries are better suited to undertake a transition from economic growth to a stabilized population and per capita consumption, and that poor countries should be expected to pursue the goal of economic growth, but cannot expect perpetual economic growth. Rich and poor countries alike can be expected to lose biodiversity and eventually breach ecological and economic carrying capacity in the perpetual pursuit of economic growth.

Using the AFS Fisheries Archive website, we found three additional references to economic growth in AFS publications. The AFS (2004) found that "The tremendous economic growth in the U.S. since the early 1990s has been supported by a plentiful and reliable supply of water. Water availability in the U.S. is considered high (10,000-20,000 cubic meters per year per capita), but supply is predicted to drop to 5-10,000 cubic meters per year per capita by 2015 due to a combination of population increase and water consumption rates." The context was the availability of water supplies for fish habitat vis-à-vis competing demands for water.

Angermeier et al. (2004) posited, "More explicit recognition of the relation between road building and urbanization and of the effects of urbanization on aquatic biota is crucial to comprehensive assessment of road impacts". Roads, especially highways, are necessary but not sufficient for economic growth (TRB 1995). Although specific effects of new highways on land development patterns are poorly understood (TRB 2002), roads unquestionably facilitate urbanization, including more road building, through their strong influence on the distribution of development (TRB 1995). Although roads are not the sole determinants of economic growth, many highways are built for the express purpose of promoting it. For example, the U.S. Congress authorized building the Appalachian Development Highway System, a 5,535-km network of major highways, to promote economic development in Appalachia. This network has contributed substantially to the region's economic growth (Wilbur Smith Associates 1998). In rural areas, where new highways tend to be built, economic growth is tantamount to urbanization. In some mountainous areas of the eastern U.S., roads and urban sprawl generally follow stream valleys (Wear and Bolstad 1998), resulting in especially severe impacts on aquatic biota."

Finlayson et al. (2000) noted, "In the U.S., the National Environmental Policy Act (NEPA) sets forth a systematic approach for evaluation of the environmental impacts of federal actions. Many states and provinces have similar review processes, some of which tend to place a higher value on environmental protection than on economic growth or other social considerations. For proposals subject to NEPA, an agency must evaluate and consider all reasonable alternatives and must suggest appropriate mitigation measures, but is not bound to them." The implication was a trade-off between environmental protection and economic growth. Similar trade-offs are evident in the USEPA's water quality standards regulation, whereby standards may change if attaining them "would result in substantial and widespread economic and social impact" (USEPA 1983), and in the "God Squad" provision (Section 7(e)) of the Endangered Species Act, which allows the federal government to exempt specific species from protection if economic conditions warrant.

AFS publications are not unique among natural resource publications in providing little coverage on economic growth. Searching the literature for the most recent decade (at the time), and focusing on wildlife conservation, Czech (2000) found 97 citations containing the key-phrase "economic growth" in BIOSIS© for the period 1992–1998 and Biological Abstracts© for the period 1989–1991. Only one was about wildlife conservation, and it focused on large carnivores (Rasker and Hackman 1996). Since that literature search was conducted, several more articles have been published in natural resource journals that describe or imply the conflict between economic growth and wildlife or biodiversity conservation (e.g., Hall et al. 2000, Naidoo and Adamowicz 2001, and Song and M'Gonigle 2001). A special section on "The Importance of Ecological Economics to Wildlife Conservation" was also published in the *Wildlife Society Bulletin*, Volume 28, Issue 1 (2000), and several articles in that series described or implied the conflict between economic growth and biodiversity conservation.

In explaining the conflict between economic growth and fish conservation, the fisheries profession will be expected to suggest an alternative to economic growth. There are not many alternatives to economic growth per se, yet there are many alternative economic growth rates that would differentially affect aquatic habitats, the fish that depend on a healthy environment, and industry sectors that depend on fish. The range of alternative growth rates most conducive to fish conservation spans from economic recession (negative economic growth) to a stabilized or "steady state" economy. As with economic growth, neither recession nor a steady state economy is without its problems (Czech and Daly 2004).

The alternative of a steady state economy with stabilized population and per capita consumption has been touted at least since the classical era of economics, when John Stuart Mill referred to it as the "stationary state." In recent decades, the steady state economy has received renewed attention by economists, most notably Herman Daly, who advocated steady state economics during (and prior to) his work as a senior economist at the World Bank (e.g., Daly 1973, Daly 1977, Daly and Cobb 1994). A stable or steady state economy would, by definition, stabilize the balance between the natural capital allocated to humans and the natural capital allocated to nonhuman species including fish. The need to establish or approach a steady state economy for purposes of biodiversity or fish conservation has therefore been noted by Hughes and Noss (1992), Hughes (1997), Winter and Hughes (1997), Czech (2000, 2001, 2002*a*, 2003, 2005, 2005*b*), Daly and Farley (2003), Pergams et al. (2004), and Czech and Daly (2004). Czech and Krausman (2001) likened the Endangered Species Act to an implicit prescription for a steady state economy.

Economic growth culminating in a steady state economy resembles the population growth of a "K-selected" species, which is graphically represented by a sigmoid curve. As the growth of the economy tapers off, so does the reallocation of natural capital from the economy of nature to the human economy (Figure 2). The further below economic carrying capacity the steady state economy is established, the more natural capital is retained as fish habitat. If the steady state economy were established at human economic carrying capacity, natural capital stocks, and therefore fish habitats, would be minimized.

Policies with the explicit goal of stopping economic growth may not seem feasible in the current political climate. Policies aimed at slowing resource extraction, population growth, or the consumption of certain goods and services (policies which, taken together, would slow economic growth) would be more feasible. However, if citizens become better informed about the conflict between economic growth and a wide array of social and environmental goals, including fish conservation, policies conducive to a steady state economy would be more politically acceptable. Relating the steady state economy to increased human welfare, especially for human descendants, is the key for social acceptance and fish conservation.

The fisheries profession cannot depend upon other professions to educate the public on this issue. A thorough understanding of the relationship between economic growth and fish conservation requires the knowledge of many fields, including the fields of fisheries science and economics, and especially fish ecology and macroeconomics. Therefore, an appropriate approach to this issue cannot be left entirely to ecologists, or to economists, or to the practitioners of any other discipline. Fortunately, efforts to integrate natural and social sciences have proliferated in recent decades. One highly relevant effort is the development of the field of ecological economics, which prioritizes issues of scale (the size of the economy relative to its sustaining, containing ecosystem). This report, for example, has been informed by conventional ecologists, conventional economists, and transdisciplinary practitioners including ecological economists.

Not all representatives of these disciplines (including contributors to this report) will concur with each and every point herein; for example, some economists will not advocate the goal of a steady state economy, and believe that only microeconomic policies are effective for fish conservation. Some ecologists believe that microeconomic policies cannot suffice for fish conservation because of the inherent, ecological properties of fish species and because of the ecological integration of economic sectors. Ecological economists tend to promote both microeconomic and macroeconomic policies for the conservation of fish and all other natural resources (Daly and Farley 2003). Ultimately, this report represents a good-faith effort to include all perspectives and to synthesize them consistent with a holistic understanding of this issue. The synthesis may be summarized as follows:

> **There is a fundamental conflict between economic growth and fish conservation, a conflict that is founded in ecological principles and revealed by empirical evidence. Therefore, a goal other than economic growth is required for the sake of fish conservation, and the least problematic alternative to economic growth is a steady state economy.**

Other approaches to fish conservation offer a blend of reduced growth with pragmatic acceptance that fish and fish habitat will never be the driving forces behind economic and political decisions beyond the local level. That realization leads to a range of alternatives based on reduced growth rather than no growth, and to reduced impacts to fish and their habitats rather than no impacts. Indeed, that shift reflects the decision-making arena of most natural resource decisions, where efforts to avoid harm often evolve into efforts to minimize harm.

EMERGING RESPONSIBILITY FOR FISHERIES PROFESSIONALS

Our interdisciplinary analysis concludes that economic growth has direct implications to fish, fish harvest, and associated environmental issues. While that relationship is logical and easily anticipated, the options for AFS action are more complicated and limited. AFS has limited opportunities to influence national economic policy or individual decisions such as construction or development proposals. Between those extremes are numerous roles related to policies, technical information, and education or communications strategies that influence decisions with secondary implications to the resources and issues within the interests of the AFS. AFS, its members, and the broader fisheries profession are positioned to address different roles along that continuum.

Fisheries professionals and their organizations need not work independently as we educate the public on these issues. Indeed, our toils would be more reasonable and the power of our efforts would increase if we partner with others throughout. This is true with the economics, water quality, general environment, and fisheries sectors that are central to the Society's efforts to make full use of this report and encourage the implementation of the resulting policy statement. Collaborative efforts with The Wildlife Society on global warming could offer a useful template. Balancing competing views without discounting minority opinions is also likely to be a major issue as there are many possible roles for AFS in the debate about economic growth and fish conservation.

As AFS shapes its role in this debate, the organization and its members are best positioned to offer professional wisdom. Interdisciplinary knowledge, experience, and perspectives on fisheries, the environment, and socioeconomic implications of human actions are vital to sound decisions. AFS must join discussions within the confines of the fisheries community, in the broader arena of natural resource management, and in the turf of related fields such as economic policy, the social sciences, and politics. 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 conflicts between ecological and economic goals, which he characterized as an important challenge in the 21st century. The AFS has the opportunity to be at the forefront of that charge, leading by example in some arenas and providing vital support elsewhere.

ECONOMIC POLICIES FOR FISH CONSERVATION

Daly and Farley (2003) presented a set of six policy design principles for developing economic policy pertaining to ecological issues. Each principle may be applied to fish conservation as follows:

1. Economic policy always has more than one goal.

If a problem or an issue is narrow enough to be addressed with only one policy goal, it may be classified as a "technical" issue and handled with technical policies. For example, if the issue is salmon access to spawning grounds, and the primary barriers are hydroelectric dams, then a technical policy of providing effective fish ladders at hydroelectric dams will be conducive to salmon conservation.

With broader, more complex issues encompassing a plethora of ecological and economic situations, more than one policy goal will be identified. However, there are limited means with which the various goals may be addressed. This calls for an economic approach to policy making, in the broadest sense of the term "economic," and it also calls for economic policies per se.

At least three general goals of the fisheries profession may be identified: 1) conserving natural fish diversity, including the genetic diversity of stocks; 2) conserving the aquatic and marine ecosystems that wild fish depend upon; 3) maintaining commercially and recreationally harvestable fisheries. Taken together, these goals may be referred to as "wild fish conservation" or simply "fish conservation." These are broad, sweeping goals that require more than technical policy. They entail a broad suite of technical and economic policies.

As with virtually all environmental or natural resource conservation issues of national, continental, or global scope, three economic policy goals are appropriate for fish conservation: 1) sustainable scale, or the maintenance of an economy, all sectors of which affect fish conservation, within the capacity of the ecosystem to support it, and preferably at a size that comes close to optimizing (as opposed to maximizing) the amount of fish conservation; 2) equitable distribution of the goods and services provided by fish species and their ecosystems, and; 3) efficient allocation of fish and fisheries-related services among producers and consumers of fish products. Separate economic policies are required for each distinct economic goal (Tinbergen 1952).

2. Policies should strive to attain the necessary degree of macro-control with the minimum sacrifice of micro-level freedom and variability.

Some forms of "macro-control" are well-known among fish biologists who help to formulate harvest regulations. For example, placing a cap on an annual fish harvest is a form of macro-control; the enforcement of fishing seasons and creel limits are designed to ensure the cap is not exceeded. "Micro-level freedom and variability" refers to the ability of fishers, commercial and recreational, to access, catch, sell and consume fish. The objective is that the cumulative fishing effort within a particular fisheries falls within the established cap, yet is undertaken with as much freedom and variability among fishers as the cap will allow for.

Simply ensuring that the catch for an individual fisheries is kept within a sustainable cap is a necessary condition but not a sufficient condition for fulfilling the policy goals of conserving natural fish diversity, conserving their ecosystems, and maintaining harvestable fisheries. Nor is it a sufficient condition for fulfilling the associated economic policy goals of sustainable scale, just distribution and efficient allocation. For example, the conservation of fish species, taken one at a time, entails the application of microeconomic policy tools that serve the objective of efficient allocation among producers and consumers of fish products. These policy tools are not sufficient for fulfilling the policy goals of sustainable scale and just distribution (Daly and Farley 2003). However, a wide application of these tools is essential for efficient allocation.

Primary among the microeconomic policy tools for efficient allocation are those that help to provide fish with the characteristics of market goods. The most important characteristics of market goods are excludability and rivalness. An excludable good "is one for which exclusive ownership is possible; that is, a person or community must be able to use the good or service in question and prevent others from using it, if so desired. Excludability is virtually synonymous with property rights. If a good or service is not owned exclusively by someone, it will not be efficiently allocated or produced by market forces" (Daly and Farley 2003). Excludability is established via legal institutions, most notably property laws.

As McWhinnie (2006) noted, "Historically, all capture fisheries have proven hard to manage due to their common property nature." In other words, fish are difficult to make excludable with legal institutions. In the North American nations, wild fish are state property. However, the waters they occupy may be found on state property or private property. Fish often cross property boundaries during the course of a life cycle, seasonal migrations, and even daily movements. However, institutions can be established to add the characteristic of excludability to some extent. For example, coastal nations have established 200-mile zones of exclusion along their coastlines, in which the fleets from foreign nations are prohibited from fishing. In the United States, the zone of exclusion has been institutionalized via the Magnuson-Stevens Fishery Conservation and Management Act (Public Law 94-265). This institution of excludability provides more incentive to conserve the fisheries within the zone of exclusion. Legal institutions that help to make fish more readily excludable should be encouraged and tailored to the fisheries in question.

A rival good is one "for which use of a unit by one person prohibits use of the same unit at the same time by another. Rivalness may be qualitative, quantitative, or spatial in nature" (Daly and Farley 2003). Fish are rival goods, and no policy tools are needed to enhance their rivalness.

3. Policies should leave a margin of error when dealing with the biophysical environment.

Daly and Farley (2003) cite fish as a prominent example of the margins of error inherent to the conservation of biotic resources. Many fish populations have been managed for "maximum sustainable yield," or the maximum annual harvest that will yet ensure the maintenance of the population. However, population models used to calculate maximum sustainable yield are often static, assuming a fixed population size in the absence of fishing or in the context of maximum sustainable yield. Fish populations are not static in nature, but rather are subject to fluctuations resulting from weather events, floods, and a host of terrestrial habitat succession and disturbances that affect downstream waters

(Haddon 2001). When a fish population is subject to a non-fishing-related decline and a harvest corresponding to maximum sustainable yield ensues, the result is a decline in the fish population that will not support maximum sustainable yield thereafter, unless a different non-fishing variable results in a population increase. Consistent allowance of maximum sustainable yield systemically leads to protracted declines in fish populations. The Atlantic cod is a well-known example.

Applying standard economic objectives to fish harvesting entails adjusting the prescribed yield to account for the costs of fishing efforts and the revenues obtained as a result. In general, the objective of a commercial fishing interest is to maximize annual profit. For a fisheries at large, annual profit is maximized when the difference between total costs and total revenues is maximized. Annual profit maximization may occur at a harvest level equal to, above, or below maximum sustainable yield. For example, liquidation of stock may allow the harvester to invest in alternative ventures with higher rates of revenue than fish harvesting can provide. Therefore, the enforcement of a cap is often required to ensure a sustainable harvest.

Margins of error in optimizing fish harvests result from the complexities of ecological systems (Brodziak and Link 2002). For example, recovery efforts for the Atlantic cod have proven elusive, and fisheries ecologists hypothesize that the demise of the cod fishery in the 1990's resulted in trophic disruptions that may preclude recovery. The cod occupied a high trophic level in the Atlantic ecosystem, feeding upon small species including capelin, shrimp and herring,. With the demise of cod and other large, predatory competitors, prey populations have grown dramatically and are now important predators, feeding upon young Atlantic cod, which do not spawn for the first six or seven years of life (O'Brien 1999).

Another margin of error associated with optimizing fish harvests is the incidental effect of harvesting on ecosystem services that are non-rival and non-excludable, and therefore not efficiently allocated via the market (Daly and Farley 2003). For example, a fisheries may serve as a food source for numerous other wildlife species that are valued by humans, such as bald eagles, grizzly bears, or whales. The decline of a fish population resulting from fishing may lead to a reduction in the value to society provided by the predatory wildlife species. Therefore, the costs to society of fishing are greater than the monetary costs to the fishing industry in question. It behooves the appropriate polity to account for the social costs of fishing and to adjust harvesting caps accordingly. The various efforts to estimate values of ecosystem services are helpful to derive an appropriate accounting (e.g., Costanza et al. 1997).

4. Policies must recognize that we always start from historically given initial conditions.

This principle highlights the importance of conditions that exist prior to the development of new policies. Such conditions, which comprise the immediate (albeit evolving) context within which a policy must operate, may be ecological, economic, cultural, political, or legal (Schneider and Ingram 1997). With regard to economic growth and fish conservation, highly relevant, pre-existing conditions include native fish species, introduced fish species, ecosystems from relatively pristine to dramatically modified, the market system, fish supply and demand, private property, public property, and government regulation. For example, there is a long-held tradition in North American nations that native fish and wildlife shall not devolve to the private property of those who hold title to land and the habitat components supporting fish and wildlife species (Bean and Rowland 1997). This is a problem (in addition to the inherent, mobile characteristics of fish) for providing the characteristic of excludability to fish, and is therefore a barrier for engaging the efficiencies of the market in allocating wild fish.

There are also many institutions, including agencies, policies, and programs, devoted to the goal of economic growth in North America. This too is problematic for fish conservation. The fishing sectors are part of an integrated economy (Boulding 1993), and virtually all other sectors impact fish to a degree ranging from large (e.g., mining) to small (e.g., computer manufacturing) (Miller and Czech 2005). When the economy is encouraged to grow as a result of institutionalized goals and programs, natural capital is reallocated from the ecosystems where fish reside to the human economy, where the natural capital is transformed to manufactured capital and consumer goods, and pollutants degrade fish habitats.

The primary implication of this "initial conditions principle" is the appropriateness of a certain temperance, or gradualism, in economic policy development. It behooves the fisheries profession to seek and assist in the development of policies that gradually engage the efficiencies of the market for fish and other forms of natural capital, while respecting long-held cultural norms and institutional arrangements that help to ensure a reasonably just distribution of fish, fish products, and fishing opportunities. It also behooves the fisheries profession to seek and assist in the development of policies that gradually temper economic growth, while respecting other cultural norms and institutional arrangements. If institutional change is required for fish conservation, the fisheries profession cannot expect immediate or absolute institutional reform, even if fish conservation reaches the highest levels of public priority. However, the fisheries profession may participate with the polity in formulating a gradual evolution of institutional arrangements conducive to fish conservation and other facets of sustainable scale, just distribution, and efficient allocation.

5. Policies must be able to adapt to changed conditions.

As Daly and Farley (2003) pointed out, "Human impacts on the ecosystem are enormous, and are likely to cause new problems over time. Ecosystems themselves naturally show considerable variation over time - where time can be measured in seasons, years, or eons. Human knowledge is increasing, leading to a new awareness of previously unrecognized problems, as well as new solutions to old ones. The economic system is also continually evolving, and policies that work well now may not work as the system changes."

Daly and Farley (2003) also cited the concept of adaptive management, whereby management practices and the policies that guide them are informed by the successes and failures of past practices and policies. If a policy of maximum sustainable profit has continually led to the decline of a particular fisheries, it is time to reassess and modify that microeconomic policy, at least to the extent that fish conservation is the objective. If the economic policy tools applied for purposes of fish conservation have been purely microeconomic, and fish species have continued to decline, it is time to reassess the sufficiency of microeconomic policy tools to conserve fish. If a policy of economic growth has continually resulted in the reallocation of natural capital from the ecosystems that support fish, it is time to reassess and modify that macroeconomic policy; again, at least to the extent that fish conservation is the objective.

6. The domain of the policy-making unit must be congruent with the domain of the causes and effects of the problem with which the policy deals.

This principle, also known as the "principle of subsidiarity," is that policies, and the polities that implement them, should fit the dimensions of the policy goal. For example, policies to increase the efficiency of traffic flow are inherently associated with the municipalities experiencing traffic congestion. Therefore, state or national policies on traffic control would tend to violate this principle. Policies on national defense are inherently associated with the nation-state to be defended. Therefore, local policies on national defense would tend to violate this principle.

If the policy goal is to conserve a particular fish species or fisheries found within a state, then the principle of subsidiarity entails that the state of jurisdiction would have the responsibility to formulate and implement policies, including microeconomic policies, for conservation of that fish species or fisheries. (Exceptions include fish species listed as threatened or endangered pursuant to the Endangered Species Act, in which case federal jurisdiction applies and entails state cooperation and partnership.) For example, if the construction of a dam would eliminate a fish species or fisheries, then an appropriate policy to conserve the fish would be to forego the construction.

If the policy goal is to conserve fish species or fisheries in the aggregate, then the principle of subsidiarity entails that the aggregate of polities (federal and state) would be engaged in formulating and implementing policies, including macroeconomic policies, to conserve the aggregated fish species and fisheries. For example, if the causes of fish species endangerment and fisheries decline in the aggregate are sectors, insfrastructure, and byproducts of the economy, then an appropriate policy to conserve fish would be the pursuit of an alternative to economic growth, such as a steady state economy.

Policy Tools for Fish Conservation

Given the policy design principles described above, we conclude this section with a basic list of policy tools conducive to fish conservation. These policy tools may also be conceptualized in terms of sustainable scale, just distribution, and efficient allocation. In more conventional economic terms, some of these policy tools would be classified as "macroeconomic;" most would be classified as "microeconomic." Just distribution and efficient allocation are straightforward, traditional policy goals, but sustainable scale is a relatively new concept that deserves further consideration prior to listing the policy tools.

"Scale" refers to the size of an economy relative to its containing, sustaining ecosystem (Daly and Farley 2003). Increasing scale is synonymous with economic growth, entailing increasing population, increasing production of manufactured capital and consumer goods, increasing consumption of goods and services, and increasing throughput of materials and energy, all of which are facilitated by technological developments. Scale is limited by finite natural resources, including biotic and abiotic resources, energy flows, and the capacity of the environment to assimilate wastes. Limits to scale is consistent with the ecological principle of carrying capacity.

Scale is a crucial issue to consider for the goal of conserving natural fish diversity, fisheries, and the aquatic and marine ecosystems that wild fish depend on. Fish and their ecosystems are inextricably interwoven with the other structures, functions, and composition of the environment. As scale increases, natural capital is reallocated from non-human species and natural ecosystems to the human economy. Therefore, fish conservation entails limiting scale. A society and its polity must decide which level of scale provides the most desirable balance of natural capital allocated to fish and other nonhuman species relative to structures and composition of the human economy. In slightly different terms, it must decide what level of scale optimizes the "macro-allocation" of natural capital between the economy of nature and the human economy. In North American nations, this may be accomplished via democratic processes, assisted by the allocative efficiency of the market, based upon cultural norms and consumer preference, and informed by natural and social sciences. Citizens must be informed of the relationships among economic growth and parameters of ecological integrity, including fish conservation, to optimize scale.

A great many policy tools are available for managing scale, most notably including economic and environmental policies. For example, in the first sentence of the Endangered Species Act of 1973 (ESA), "The Congress finds and declares that- (1) various species of fish, wildlife, and plants in the United States have been rendered extinct as a consequence of economic growth and development untempered by adequate concern and conservation." The ESA goes on to prohibit actions that jeopardize the existence of species. Czech and Krausman (2001) described the Endangered Species Act as an implicit prescription for a stabilized, steady state economy, one in which a large suite of endangered species would be maintained at the margins of population viability. They also noted the inconsistency of this implicit prescription with a highly prioritized goal of economic growth, thus helping to explain efforts to weaken the ESA and the increasing political difficulties of implementing it. Only a public with a firm understanding of the conflict between economic growth and biodiversity conservation would be capable of the political support necessary for upholding and implementing the ESA and many other environmental policies.

Here we are concerned with economic policies for sustainable scale (as well just distribution and efficient allocation) for purposes of fish conservation. Given limits to economic growth, policies for sustainable scale are also policies that lead to the establishment of a steady state economy. Among such economic policy options are a vast array of microeconomic and macroeconomic tools.

Individual Transferable Quotas (ITQs)

An ITQ is a transferable share of a Total Allowable Catch (TAC) allocated to individual fishermen or fishing firms (Anderson 1995). The share may be sold or leased. An ITQ/TAC system falls under the general category of "cap-and-trade" systems. Cap-and-trade systems conform with policy principle 2 described above: Policies should strive to attain the necessary degree of macro-control with the minimum sacrifice of micro-level freedom and variability.

An ITQ/TAC system also conforms to policy principle 1: Economic policy always has more than one goal. The TAC is a cap instituted by a polity and formulated via fisheries and economic science. It helps to address one component of scale within the broader economy and ecosystem; i.e., the size of a fishing sector relative to the ecosystem that contains and sustains the fish population. Given the TAC, the ITQ helps to incorporate the powers of the market to efficiently allocate fish among fishers. This is an advantage of an ITQ/TAC system over individual quota programs, in which each fisher is allocated an Individual Fishing Quota (IFQ) by the polity (Copes 1986). In other words, an ITQ/TAC system helps to address the goals of sustainable scale and efficient allocation.

An ITQ/TAC system is conducive to the sustainability of a fisheries, but is not a sufficient condition for that sustainability. Fisheries are affected by a wide variety of variables, including the various economic sectors operating upstream. Broader approaches to sustainable scale are required, both for fish in the aggregate and for an individual fisheries.

Pigouvian Taxes

Pigou was one of the first to describe the existence of "externalities" in economic systems. An externality is "an unintended and uncompensated loss or gain in the welfare of a party resulting from an activity by another party" (Daly and Farley 2003). Because they are not captured in prices, externalities prevent the establishment of a market equilibrium whereby marginal social costs equal marginal social benefits. Pigou conceived of a policy tool to correct for negative externalities: a tax equal to the value of the cost of the external cost. Pigouvian taxes are especially well-suited to fulfilling the goals of efficient allocation and just distribution.

Environmental economists have built upon the concept of Pigouvian taxes, applying it most prominently to the issue of pollution. Polluters may be taxed to compensate for the costs to society of the pollution. Pollution is a major threat to fish conservation, and the fisheries profession should support all efforts to establish taxes that "internalize" the social costs (including degradation of fisheries and their ecosystems) of pollution. (Pollution may also be addressed with cap-and-trade systems, in which total pollution is capped and polluters receive an allocation of tradable permits.)

Pigouvian taxes are also relevant to the loss of ecosystem services that result from the depletion of natural capital stocks. For example, if a waterfront development will destroy a portion of the spawning habitat of a fisheries, fisheries biologists and economists may collaborate in developing an estimate of the associated costs to society. Environmental and ecological economists have been especially active in recent years in the field of natural capital accounting, and the fisheries profession should encourage the application of their efforts in the form of Pigouvian taxes.

Pigouvian Subsidies

A subsidy is the opposite of a tax. It is a payment that provides an incentive to a producer of goods and services to perform or modify a certain operation. An environmental Pigouvian subsidy "is a payment to each firm for each unit by which it reduces environmental costs." It is another way of avoiding negative externalities or compensating the producer who would otherwise have provided a positive externality. Ridding the economy of externalities serves the goal of efficient allocation and of achieving a more just distribution of wealth. However, subsidies, now matter how well-intended, are notorious for producing unpredictable, perverse incentives, so care should be taken by the fisheries profession in encouraging environmental Pigouvian subsidies.

Fiscal policy

Fiscal policy refers to government expenditure and the financing thereof, most notably via taxes. Distinctive expenditures and taxes have different microeconomic or microecological effects. For example, increasing expenditures on fish conservation programs is normally conducive to fish conservation. Increasing taxes on gasoline is also conducive to fish conservation, much less directly. With fiscal policy, however, the concern is expenditures and taxes in the aggregate.

Total expenditure and total taxes influence the scale of an economy, albeit in a very blunt manner. In general, increased expenditure has an expanding effect on scale, and increased taxes has a contractionary effect. These are basic precepts of Keynesian economics (Keynes 1936) or, more generally speaking, macroeconomics.

Given the conflict between economic growth and fish conservation, the goal of fish conservation entails an economic goal of something other than growth. The two basic alternatives to economic growth are recession or a steady state economy, which is an economy "viewed as a subsystem in dynamic equilibrium with the parent ecosystem/biosphere that sustains it. Quantitative growth is replaced by qualitative development or improvement as the basic goal" (Daly and Farley 2003).

Although neither of the two alternatives to economic growth may appear desirable at first glance, one or the other is eventually in the offing regardless of public policy because of the limits to economic growth imposed by nature. That eventuality has traditionally been viewed as far off in the future, but in recent years many scholars have been questioning whether or not the current global economy is within its long-term carrying capacity

(Meadows et al. 2004). The most notable scholarship in this regard is that pertaining to the "ecological footprint," or the amount of land required to support each individual on earth at current levels of consumption (Wackernagel and Rees 1996), and that pertaining to "Peak Oil," or the prospect that the peak in global per capita oil production is imminent (Deffeyes 2001).

The question of carrying capacity is important for society to address, but for the purpose of fish conservation, the more immediate issue is the conflict with economic growth regardless of carrying capacity. Nevertheless, the issue of economic carrying capacity is relevant because if limits to economic growth are imminent (for example, resulting from a severe oil supply shock), then perhaps there are no policy alternatives that will result in anything but recession.

Facing a conflict between economic growth and fish conservation, yet acknowledging the severe hardships that could accompany a long-run recession and uncertainty about economic growth, an appropriate approach for the fisheries profession is to support policy reforms conducive to a steady state economy. These should be advocated in a way that makes it clear that an immediate transition from a growing economy to a steady state economy is both virtually impossible and highly undesirable. Pursuant to policy principle 4 (policies must recognize that we always start from historically given initial conditions), the fisheries profession should advocate a cautious and gradual transition toward a steady state economy.

For accomplishing a cautious and gradual transition to a steady state economy, the same set of economic tools that are currently used to influence scale may be used, along with others. In general and up to a point, the fisheries profession should be supportive of cautious and gradual decreases in government expenditure and cautious and gradual increases in taxes. The goal should be stabilization of population, production and consumption, and pollution, not recession. It cannot be overemphasized that these recommendations pertaining to expenditures and taxes apply in the aggregate, and that, for governmental fish conservation programs, increased expenditures would result only from budgetary reallocation and not from larger government budgets in the aggregate.

Monetary policy

Monetary policy refers to the manipulation of the money supply and interest rates, which in turn affect each other. Along with fiscal policy, monetary policy is a blunt tool for affecting the scale of the economy. In general, expanding the money supply and decreasing interest rates have the general effect of expanding scale. These actions tend to stimulate spending and, especially in the case of lowering interest rates, investment, which stimulates the establishment and expansion of housing, infrastructure, and industry. The money supply may be expanded by reducing reserve requirements (i.e., the fraction of bank deposits that must be held on demand), selling government bonds on the open market, and lowering the interest rate.

For all of the reasons mentioned in the section on fiscal policy, the fisheries profession should support cautious and gradual adjustments in monetary policy that are conducive to a steady state economy. In the most basic terms, this means cautiously and gradually reducing the rate of monetary expansion and increasing interest rates. Ultimately, a steady state economy connotes a stabilized money supply.

Population Stabilization

Population stabilization is not an economic policy per se, yet no credible set of economic policy recommendations for sustainable scale would be complete without addressing population growth. All else equal, population growth results in economic growth and is, along with economic growth, unsustainable. As with fish conservation, population growth may be addressed with economic tools. For example, certain aspects of the tax code provide marginal incentives for having children. The most obvious example in the United States is a per-dependent tax break for parents. Tax breaks could be provided for the first two children, and eliminated for further children. A more stringent approach would entail progressively taxing parents for each child. The fisheries profession should encourage tax code reforms that would provide disincentives for having children.

Boulding (1993) proposed a market-oriented solution to population growth. He noted that, given child mortality rates and other factors of population dynamics, stabilized population entailed an average of approximately 2.1 children per woman in developed countries. He therefore suggested institutionalizing a property right to 2.1 children per woman, issued in tradable permits. This is essentially an application of the cap-and-trade mechanism to childbearing, and is conducive to sustainable scale and efficient allocation.

Unlike the production and consumption of most goods and services, childbearing is an issue of enormous ethical, spiritual, and religious import. It is viewed among some cultures as a sacrosanct right beyond the pale of a polity's interference. On the other hand, today's population growth threatens the quantity and quality of posterity's childbearing, including the fisheries and ecosystems posterity will inherit. To the extent that we extend the policy goal of just distribution to future generations, it is ethical for a polity to address the issue of population growth. The fisheries profession should support recommendations for market-oriented regulations on family size, such as Boulding's proposal, and should exercise the utmost caution in doing so.

ALTERNATIVES TO A STEADY STATE ECONOMY FOR ADDRESSING THE CONFLICT BETWEEN ECONOMIC GROWTH AND FISH CONSERVATION

Lower Rates of Economic Growth

Given the fundamental conflict between economic growth and fish conservation, the steady state economy may be identified as an ultimate, long-term goal. However, it is unrealistic to expect the public and policy makers to immediately embrace the steady state economy as a policy goal. Therefore, it is also important to consider a range of policy options that may be viewed as more realistic, short-term approaches, or "stepping stones" from the current prioritization of economic growth to the long-term goal of a steady state economy.

A steady state economy occurs when there is a stable or mildly fluctuating product of population times per capita consumption (where consumption refers to the economic activities of households, firms, and governments, all of which require the use or consumption of natural capital). A steady state economy is not a particular kind of political or economic system. Theoretically, a steady state economy may be achieved in a capitalist democracy, a socialist democracy, a communist dictatorship, a theocracy, or virtually any form of political economy. The concern of the AFS is about economic growth, not the type of political economy.

The most basic alternatives to a steady state economy are economic growth and economic recession. Economic recession is not a practical policy target for many reasons. Therefore, the only realistic, basic alternative is economic growth.

Compromise between current or historic economic growth and a steady state economy entails a rate of economic growth between the current or historic rate (e.g., approximately 3% in the U.S. in recent decades) and the rate associated with a steady state economy (i.e., 0%). Noting that economic growth entails the reallocation of natural capital from the economy of nature (where it comprises fish and wildlife habitats) to the human economy, a lesser rate of economic growth entails a slower reallocation. A lesser rate of economic growth also entails a slower rate of pollution and, all else equal, a slower rate of invasive species introductions as a function of international trade and interstate commerce.

In general, it behooves the fisheries profession and other natural resources professionals to support a downward trend in the rate of economic growth. As the rate of economic growth decreases, the rate of natural capital depletion will also decrease and the decline of fish species and other biodiversity will be slower.

Unlike a steady state economy, a gradually declining rate of economic growth is something that may occur immediately, and is not politically out of the question. To the contrary, it is the normal course of affairs in American economic policy-making to debate and negotiate preferred rates of economic growth among such policy-relevant entities as the Council of Economic Advisors, Federal Reserve System, and Department of Commerce (Collins 2000). What the AFS has to offer such debates is that a slower rate of economic growth will give the public and policy makers more time to think about pending limits to economic growth and how large of an economy to strive for.

"Green Growth"

The phrase "green growth" has been used to refer to the potential for economic growth to become more environmentally benign. Some suggest that, if economic growth can become green enough, the conflict between economic growth and environmental protection will no longer exist. However, the phrase "economic growth" as used in this study report, among the public, and by policy makers, simply means the production and consumption of more goods and services. Basic principles of ecology and physics establish that increasing production and consumption of goods and services does not occur without a concomitant increase in energy and material flow. In other words, economic growth requires the use of more natural capital.

If production and consumption is currently occurring in a very "non-green" fashion, for example with the use of environmental toxins that could be substituted for by less damaging technology, then production and consumption at the same level will be less environmentally damaging if the less damaging technology is switched to. This would constitute an example of "economic development" conducive to environmental protection (or at least a lesser rate of environmental damage), because the quantity of goods and services produced would remain constant and different technology would be employed, in this case with environmental benefits.

Theoretically, providing the alternative form of technology would allow for some greater amount of economic growth up to a level whereby the environmental damage using the new technology would be equivalent to the environmental damage caused using the older technology. This is the type of scenario that is generally implied with the phrase "green growth." However, the phrase "green growth" should be used very carefully, and in the context that no form of production and consumption is "pure green." In the example, even using the newer, greener technology, economic growth may still proceed to a point whereby the environmental damage exceeds that incurred by the use of the older technology at lower levels of production and consumption. All else equal, economic growth conflicts with environmental protection, including fish conservation, and regardless of how green the growth becomes, more of it conflicts with environmental protection, including fish conservation. This is what is meant by the phrase "fundamental conflict between economic growth and fish conservation."

Furthermore, it is unrealistic to expect that, in a competitive economy, producers will opt for the greenest form of technology without substantial governmental intervention. Rather, a realistic hope is that, through somewhat higher consumer preference for green products, along with some degree of governmental stimulus, producers will opt for somewhat greener technologies, processes, and products. All else equal, the ultimate goal of a steady state economy could be larger, with no more environmental damage, if based on a greener technological regime, than a steady state economy based on a less green technological regime.

Alternative Indicators to GDP and GNP

A common critique of GDP and GNP (heretofore referred to interchangeably as GDP) is that these are not good indicators of economic welfare, much less overall human welfare, yet are often assumed to be indicators of welfare by some economists and many policy makers. Despite the weakness of GDP as an indicator of welfare, GDP is a very good indicator of the size of an economy. It reflects the amount of economic activity taking place, and given the trophic structure of the human economy, it also reflects the amount of natural capital re-allocated from the economy of nature to the human economy. That explains the tight connection of GDP growth with energy and material throughput (Daly and Farley 2003, Nørgård 2006), and with environmental impacts such as biodiversity decline (The Wildlife Society 2003, Czech et al. 2005).

It is not in the interests of the fisheries profession or other natural resources professions to advocate abolishing GDP as a calculation of the federal government. Rather, GDP is a valuable tool. GDP is a widely recognized model of consistency that allows scholars and policy makers to develop time series data for monitoring trends in the size of the economy. It is akin to a scale for measuring the weight of a person. (A weight problem is not addressed by throwing away the scale, but by using the scale to monitor weight.) However, it does behoove the fisheries profession to consistently and frequently note that a bigger economy is not necessarily a better one and, for the sake of fish conservation, tends to be worse.

In recent years, a number of alternative economic indicators, or indicators of broader social welfare, have been developed and advocated, and some of them are highly relevant to issues of natural capital conservation and therefore fish conservation. Alternative indicators generally fall under two categories. One category includes those indicators for which the "score" or the indication is expressed in monetary units. These are economic indicators per se, albeit not necessarily of size or scale. The other category includes indices that are not expressed in monetary terms, but rather involve a non-monetary "scoring" of variables. These indicators vary widely in their foci but are not generally referred to as "economic" indicators.

A notable example of an economic indicator that is an alternative to GDP is the Index of Sustainable Economic Welfare (ISEW), developed by Daly and Cobb (1994). The ISEW incorporates GDP and also accounts for various aspects of economic welfare not represented by GDP, such as the estimated costs of pollution to society, and the value of natural capital depleted in the process of economic production. The ISEW is not an indicator of economic growth, but rather an indicator of economic sustainability. As such, it is not so much an "alternative" to GDP, which measures the size of the economy, but a complement to GDP which measures sustainability.

An equally notable example of an economic indicator of social welfare is the Genuine Progress Indicator (GPI). The GPI considers the value, in monetary estimation, of non-marketed services such as housework, caring for children and the elderly, and volunteerism. Such activities can be viewed as good for society, despite no associated market transactions. As with the ISEW, the GPI is not an indicator of economic growth and is not so much an "alternative" to GDP, which measures the size of the economy, but a complement to GDP which measures social welfare.

The tracking of indicators such as the ISEW and GPI suggest that, while the economy has continued growing over the past few decades, economic welfare has not, and ecological and economic sustainability has been declining (Daly and Farley 2003, Venetoulis and Cobb 2004). Alternative economic indicators such as these should be advocated, as long as care is taken not to conflate trends in such indicators with trends in economic growth.

An example of a non-monetary indicator of social welfare is the Human Development Index (HDI). The HDI incorporates poverty, literacy, education, life expectancy, childbirth, and other factors. It is a standard means of measuring social well-being, with a focus on child welfare. Since 1993, the HDI has been used by the United Nations Development Programme in its annual report. The HDI and other non-monetary indicators of welfare should be advocated as better representing the status of nations with regard to overall well-being. As with alternative monetary indicators such as the ISEW and the GPI, these non-monetary indicators of welfare are not indicators of economic growth.

PROPOSED POLICY STATEMENT

Given the findings presented in the study report, the WQS proposes that the following position on economic growth (preceded if necessary by a preamble) be adopted by the AFS:

Whereas,

1) Economic growth is an increase in the production and consumption of goods and services, and;

2) Economic growth occurs when there is an increase in the product of population multiplied by the per capita production and consumption of households, firms, and government entities, and;

3) Economic growth is indicated by increasing real gross domestic product (GDP) or real gross national product (GNP), and;

4) Economies grow as integrated wholes consisting of agricultural, extractive, manufacturing, and services sectors that require physical inputs and produce wastes, and;

5) Based upon established principles of physics and ecology, there is a limit to economic growth, and;

6) A steady state economy is an economy with stabilized (or mildly fluctuating) production and consumption of goods and services, and with a stabilized (or mildly fluctuating) product of population multiplied by per capita consumption, and;

7) A steady state economy is generally indicated by stabilized (or mildly fluctuating) real gross domestic product (GDP) or real gross national product (GNP).

Therefore,

1) There is a fundamental conflict between economic growth and fish conservation based on ecological principles including niche breadth, carrying capacity, and competitive exclusion, and;

2) Technological progress occurs via research and development that requires funding and the use of natural resources, has many positive and negative ecological and economic effects, and may not be depended upon to reconcile the conflict between economic growth and fish conservation, and;

3) A steady state economy is a viable, sustainable alternative to a growing economy, especially in the larger, wealthier American economies, and;

4) The long-run sustainability of a steady state economy requires its establishment at a size that does not breach ecological and economic capacity during expected or unexpected supply shocks such as droughts and energy shortages, and;

5) A steady state economy does not preclude economic development, a qualitative process in which different technologies may be employed and the relative prominence of economic sectors may evolve, and;

6) A steady state economy is ultimately required for the conservation of fish, the ecosystems they depend upon, and harvestable fisheries, and;

7) Macroeconomic and microeconomic policy tools may be used in tandem to gradually reduce rates of economic growth pursuant to the long-run goal of a steady state economy, and;

8) Economic policy tools for human population stabilization may be carefully and gradually introduced for purposes of achieving sustainable, healthy economies including sustainable, healthy fish populations and fisheries.

An AFS policy statement on economic growth need not be explicit on which policy tools would be used to temper economic growth and to establish a steady state economy. However, in the previous two sections we have offered several observations on policy tools that could be incorporated in the statement if necessary.

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