



UNIVERSITY OF
CALIFORNIA PRESS
JOURNALS + DIGITAL PUBLISHING

Social and Environmental Influences on Endangered Species: A Cross-National Study

Author(s): John P. Hoffmann

Source: *Sociological Perspectives*, Vol. 47, No. 1 (Spring, 2004), pp. 79-107

Published by: University of California Press

Stable URL: <http://www.jstor.org/stable/1389604>

Accessed: 20/01/2009 14:12

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at <http://www.jstor.org/page/info/about/policies/terms.jsp>. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at <http://www.jstor.org/action/showPublisher?publisherCode=ucal>.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

JSTOR is a not-for-profit organization founded in 1995 to build trusted digital archives for scholarship. We work with the scholarly community to preserve their work and the materials they rely upon, and to build a common research platform that promotes the discovery and use of these resources. For more information about JSTOR, please contact support@jstor.org.



University of California Press is collaborating with JSTOR to digitize, preserve and extend access to *Sociological Perspectives*.

<http://www.jstor.org>

SOCIAL AND ENVIRONMENTAL INFLUENCES ON ENDANGERED SPECIES: A CROSS-NATIONAL STUDY

JOHN P. HOFFMANN*
Brigham Young University

ABSTRACT: *Although there have been general social, economic, and environmental hypotheses developed to explain the distribution of endangered species across the globe, there is a paucity of social science literature designed to specify these hypotheses in more detail or test them with comparative, national-level data. This study draws on several models from environmental sociology to specify conceptually the relationship between social and economic factors and rates of endangered mammals and birds. Specifically, I developed hypotheses based on neo-Malthusian, ecological modernization, treadmill of production, and world-systems theory and analyzed data on endangered species, population, land use, economic size and growth, energy use, and industrial pollutants from one hundred twenty nations. The results support ecological modernization's position that there is an inverted U-shaped relationship between GDP per capita and endangerment rates, but they also indicate that GDP growth is associated with a monotonic increase in these rates, thus supporting a treadmill of production argument. Yet these relationships vary by world-systems position. Endangerment rates in peripheral nations are affected more by GDP growth, whereas rates in semiperipheral nations are affected more by deforestation, GDP per capita, and growth in energy use per capita.*

The impact of *Homo sapiens* on other species has begun to receive substantial attention from the sociological community. In particular, research has begun to ask whether human-controlled activities negatively affect the ability of other species to coexist and thrive in shared environments (Jokinen 2000; Machlis 1992). Moreover, the sociological lens has been directed toward philosophical issues involving fundamental relationships between human and nonhuman animals (Benton 1993; Franklin 1999; Tester 1991). Studies of the human effects on biodiversity have been primarily theoretical, historical, or regional, however, with little research on the issue from a global and comparative perspective. Those studies that have taken a global approach are limited in their conceptualization of biodiversity and

*Direct correspondence to: John P. Hoffmann, Department of Sociology, 844 SWKT, Brigham Young University, Provo, UT 84602-5409; e-mail: John_Hoffmann@byu.edu.

in their use of sociologically relevant theories that may help to determine the ways that human-controlled activities affect species diversity.

The objective of this article is to address cross-nationally the effects of a number of human-controlled activities on one measure of biodiversity: the rate of endangered mammal and bird species.¹ It extends previous social scientific research on biodiversity in several ways. First, it uses extensive data on the characteristics of nations across the globe that are linked to recently available data on endangered species. Second, it augments contemporary research on biodiversity by ecologists and other environmental scientists by systematically analyzing several explanatory mechanisms. Third, it draws on relevant sociological theories about the environment, in particular neo-Malthusian, ecological modernization, Schnaiberg's treadmill of production model, and world-systems theory, to develop a set of comparative hypotheses that predict rates of endangered species. Hence it provides a key test of several competing conceptual models of human effects on the environment. Fourth and more generally, it contributes to social scientific research on the impact of human factors on environmental changes (e.g., Buttel 2000; Buttel and Taylor 1994; Ehrhardt-Martinez 1998; Goldfrank, Goodman, and Szasz 1999; Mol 2001; Rudel 1998) while also answering the growing chorus of observers who argue that the global issues surrounding biodiversity are so intractable as to require interdisciplinary research from the social and natural sciences (Czech, Krausman, and Devers 2000; Goldman and Schurman 2000; Machlis 1992).

WHY BIODIVERSITY?

Human activities clearly affect biodiversity. For example, historical research establishes that humans have played a substantial role in the extinction of several large animal species (Crosby 1986; Roberts et al. 2001). There is also evidence that the rate of species extinction has accelerated in the past several decades (McNeeley 1992; Stork 1999). Recent estimates indicate that about 11 percent of mammal and bird species are designated as endangered (Stork 1997), with up to 10 to 15 percent expected to be extinct in the next fifty to one hundred years (Reid 1992; Smith et al. 1993). It is highly likely that human-controlled activities have affected the increasing rates of endangered and extinct species (Ehrlich 1985, 1995; Lawton and May 1995; Wilson 1999). Moreover, whereas activities such as excessive hunting and habitat destruction explained virtually all the impact of humans on endangerment and extinction in the prehistoric record (Alroy 2001; Roberts et al. 2001), there are several activities in the contemporary world that may play an even more consequential role.

Before describing these activities and linking them to extant sociological models, it is important to ask why biodiversity, in particular, animal species diversity, is a significant issue and what sociological implications it has for the contemporary world. There are several reasons that biodiversity is a crucial global issue. First, it is the main wellspring of food and medicine for humans. Although most of the attention in this area is directed toward plant life, animal species play an important role in ensuring the survival of many diverse plant species, are a key source of protein in the food supply, and provide essential pest control (Eldredge

1998). Second, species diversity is essential for the functioning of many of the earth's ecosystems. Biologically diverse ecosystems are more productive, stable, and responsive to disruption and thus enhance nature's ability to produce food and other vital products (Beattie and Ehrlich 2001; Reich, Knops, and Tilman 2001). Third, preserving biodiversity is important for historical, cultural, and aesthetic reasons (Alonso et al. 2001; Takacs 1996). Fourth, there are strong moral arguments that the rights of nonhuman animal species should be respected and protected (Benton 1993; Franklin 1999). Though these arguments range from greater or lesser protection of these rights vis-à-vis the rights of humans, a common thread is that humans should consistently consider the lives of other animal species when developing programs and planning activities that affect the environment.

Environmental sociology has responded to these points and now considers biodiversity a key research topic (Buttel 1998; McNeeley 1992). The presumed biodiversity crisis is a backdrop against which social scientific attention to the environment may find its strongest impetus (Grumbine 1995). Considering the impact of various social, economic, and cultural factors on biodiversity (Forester and Machlis 1996; Machlis 1992; Machlis and Forester 1996), it is clear that sociology can serve as an important source of research on this topic. Yet there has been little effort to use some of the more prominent conceptual models about human influences on the environment to explore the potential role that human-controlled activities have on animal diversity. The next section focuses these models on the issue of endangered species.

SOCIAL SOURCES OF ENDANGERED SPECIES

Environmental sociology and related subdisciplines have developed several conceptual models that may be trained on the issue of endangered species. These models have been used to examine a variety of environmental outcomes, from land use issues to industrial pollutants. However, with the possible exception of several studies by ecologists that have used variables captured by these models, they have not been directed in a systematic manner toward analyzing rates of endangered species. I examine four models that are useful for understanding human influences on the environment in general and on endangerment rates in particular: Neo-Malthusian, ecological modernization, Schnaiberg's treadmill of production, and world-systems theory.

Neo-Malthusian Models

Neo-Malthusian models of human pressures on the environment focus primarily on the effects of population growth and indirectly on the demand for land that usually accompanies it. The needs of a rapidly growing population are assumed to outpace the supply of natural resources such as timber and water and increase the demand for land (Ehrlich and Ehrlich 1981; Inman 1992). Deforestation is a prime example of what happens as populations increase and more land must be co-opted to house a greater number of people, produce subsistence crops, provide for energy needs (e.g., mining, power plants), build transportation

conduits, or develop other infrastructure components (Ehrhardt-Martinez 1998; Rudel 1998). This has an obvious impact on animal species: As human populations grow and make demands on the limited available land space, animal species are pushed out of their habitats and natural ecosystems are disrupted (Robinson et al. 1995). Given the fragile balance that exists between many species and their ecosystems, it is likely that rapid population growth and the accompanying land co-optation lead to more endangered species (Machlis 1992; Roberts et al. 2001). For example, recent studies indicate that deforestation and urbanization, two factors that usually accompany population growth, have significant negative effects on biodiversity in the United States and across nations (Czech, Krausman, and Devers 2000; Forester and Machlis 1996).

Ecological Modernization

A common observation is that industrialization and economic development negatively affect the environment. Yet an increasingly popular view is that as nations develop and become technologically sophisticated, they begin to improve their environmental conditions (Mol 1996; Mol and Spaargaren 2000). This model, labeled "ecological modernization," argues that advanced economies allow for flexible solutions to environmental problems. Technological sophistication permits more efficient conversion of raw products into finished materials (Buttel 2000) and promotes more efficient use of agricultural, forest, and other types of land (James 1999). Hence there is less need to appropriate land for human use. Moreover, information economies, which are supported primarily by technologically advanced nations, have less need for natural resource extraction and cultivate more efficient use of energy (Rosa, Machlis, and Keating 1988; Shove 1997). Ecological modernization proponents also contend that developed nations encourage legal protection of the environment primarily through the pressure that special interest groups are allowed to exert (Mol 1996, 2001). Hence one would expect that economic development leads to environmental degradation only up to a certain point, after which environmental improvement should take place.²

The empirical realization of ecological modernization theory is found in research on environmental Kuznets curves (EKC). Based on Kuznets's (1955) observation that economic growth (normally gauged by per capita GDP) and income inequality follow an inverted U-shaped curve, EKCs propose that per capita GDP and environmental problems also follow an inverted U-shaped pattern. In other words, environmental degradation occurs only as nations are industrializing, yet once they reach a certain asymptote further development is associated with improving environmental conditions, as would be predicted by ecological modernization theory.

There is substantial debate concerning the veracity of EKCs. Several studies indicate that an inverted U-shaped pattern exists across nations when examining industrial pollutants, agricultural land use, and deforestation (e.g., Liddle 2000; List and Gallet 1999; Mather, Needle, and Fairbain 1999). However, this research has been criticized because it has considered only a small number of environmental problems (Roberts and Grimes 1999). Others observe that the economic tipping point at which environmental problems begin to decrease is quite high and may

not be reached by most nations around the world (Ekins 1997). Finally, some empirical studies show that EKC operates only in nations that are already developed economically; in relatively poor nations, even when per capita GDP or income shifts upward, there is little improvement of environmental conditions (e.g., Roberts and Grimes 1997).

A question that remains is whether there is an EKC for endangered species. Assuming that the underlying logic of ecological modernization is correct, one might expect wealthier, more developed nations to implement protective measures to ensure species survival. The Endangered Species Act instituted in the United States in the early 1970s is one example of a policy step that a developed nation has taken to protect species threatened with extinction. Moreover, on average, nations designated as "high income" by the United Nations set aside a significantly greater percentage of their land for wildlife protection than nations designated as "low" or "medium" income (UNEP 2001). If land protection operates as expected, then species inhabiting wealthier, more developed nations should benefit from ecological modernization. In addition, assuming that ecologically sound policies and processes (e.g., more efficient land and energy use, less pollution) are more prevalent in developed nations (Mol 1996), animal species should reap the environmental benefits and be at lower risk of endangerment.

Treadmill of Production

A model that is at odds with ecological modernization theory is Schnaiberg's treadmill of production (Schnaiberg 1980; Schnaiberg and Gould 1994; cf. Mol 2001). The treadmill of production model, which precedes the introduction of the ecological modernization model by several years (Schnaiberg 1980), argues that economic growth in the modern world demands the maximization of profits and investments, thus requiring increases in both production and consumption. Although this typically leads to environmental degradation that must be addressed by governments at some point, continued growth takes precedence over environmental protection. In the short term economies may become more efficient, but over time the pressures of increasing production and consumption come at the expense of the environment.

The treadmill of production model has been used to criticize both neo-Malthusian and ecological modernization positions about the environment (Pellow, Schnaiberg, and Weinberg 2000; Schnaiberg 1997; Schnaiberg and Gould 1994). It views neo-Malthusian models as incomplete because they do not address the type of population growth that occurs in a society. In relatively poor nations, for example, population growth leads to malnutrition, disease, and death, yet little ability to extract natural resources. The most environmentally damaging nations are often industrializing, and frequently have negative population growth (Schnaiberg and Gould 1994). Ecological modernization theory is misguided because it mistakenly sees the ecological sphere of a nation as becoming emancipated from the economic sphere. Although there may be some movement toward economic efficiency that benefits the environment in developed nations, the typical course is for the economic sphere to subsume the ecological sphere and retain its dominant

position (Pellow, Schnaiberg, and Weinberg 2000). Environmental concerns remain subordinate to economic interests, with the ultimate result being the continuation of environmental degradation.

Empirical studies that have failed to show EKC usually demonstrate the negative impact of expanding economic development on the environment. For instance, several recent studies indicate that per capita GDP is positively associated with high levels of industrial pollutants, tropical deforestation, and other problems, with no downward tipping point as previous research on EKCs suggests (Ekins 1997; Hettige, Mani, and Wheeler 2000; Stern, Common, and Barbier 1996). This research is consistent with recent environmental studies of endangered species that indicate a monotonic positive relationship between measures such as energy use and commercial development and rates of endangered species (Forester and Machlis 1996; Wilcove et al. 1998). It is also compatible with the energy use hypothesis of species endangerment advanced by the ecologist Paul Ehrlich. Ehrlich posits that per capita energy use, both on a global and on a national basis, is highly correlated with rates of endangered and extinct species:

Energy use is involved in virtually all of humanity's most environmentally destructive activities. Energy powers the automobiles, airplanes, electric lights, heaters, airconditioners [*sic*], and household appliances of the rich, and is heavily involved in their manufacture, as well as in the construction of homes, office buildings, freeways, dams, and shopping malls. Mining and petroleum drilling are energy-intensive, as are production of plastics, pesticides, and fertilizers and production and distribution in intensive (industrial) agricultural systems. Over-harvesting of fuelwood and other biomass, which supplies an estimated 35% of energy consumed in poor nations, is a primary cause of deforestation and desertification. Chainsaws and bulldozers use energy, as does the modern transportation that makes it practical for rich nations to take easy advantage of natural resources of the entire globe and to transport invasive organisms from continent to continent. . . . Therefore, although not perfect, in part because of regional differences in energy efficiency, per capita energy use seems a reasonable surrogate for per capita impact [on the environment]. (Ehrlich 1995:220)

According to the treadmill model, a key problem with EKCs and the ecological modernization model is that they fail to consider that high levels of development and income are accompanied by high levels of consumption (Gould, Weinberg, and Schnaiberg 1995; Spangenberg 2001; cf. Spaargaren and van Vliet 2000). Thus extraction from and co-optation of the environment usually continue and often increase in highly developed nations, even though environmental programs tend to be high on policy agendas (Buttel 2000). Nevertheless, there has been little empirical research designed to ascertain whether EKCs or the treadmill of production are more determinative of endangered species rates across the globe.

World-Systems Theory

World-systems are defined as intersocietal networks in which the interactions (e.g., trade) are significant for the reproduction of the internal structures of the

composite units and affect local structures (Chase-Dunn and Hall 1997). World-systems theory takes the view that nations occupy particular structural positions in a global stratification system, with little relative movement of nations over time (Roberts and Grimes 1999). A recent focus of world-systems theory is on how interactions among nations affect environmental conditions within particular categories of developed and developing nations (Bartley and Bergesen 1997; Goldfrank, Goodman, and Szasz 1999; Smith 1994).

Although the world-systems perspective admits that many core nations have seen environmental improvement as ecological modernization predicts, it contends that the latter view fails to note that these nations do so at the expense of peripheral and semiperipheral nations. The most environmentally damaging industrial processes are often transplanted from core nations to peripheral and semiperipheral nations (Roberts and Grimes 1999). Moreover, semiperipheral nations frequently do substantial damage to their environments as they struggle to excise foreign debt and keep up with the world economy (Rudel and Roper 1997; Smith 1994). Extending the treadmill of production critique described above, the world-systems perspective regards ecological modernization as misguided because it fails to address key interactions among nations that lead to environmental improvement in core nations at the expense of ecological conditions in semiperipheral nations. However, the treadmill of production model is too myopic because it fails to address key stages of national development processes—and how these are linked to the global system—that dictate the waxing and waning of environmental degradation.

Early empirical research on world-systems and the environment finds that rapidly developing nations, especially those inhabiting the semiperiphery, produce the most industrial pollutants (Grimes, Roberts, and Manale 1993; Roberts and Grimes 1997), engage in the most intense deforestation (Burns et al. 1994), and, in general, deplete their natural resources at a higher rate than do nations that occupy core or peripheral positions in the world system (Burns, Kick, and Davis 1998). Moreover, intensive economic development has a stronger impact on environmental degradation in semiperipheral nations than in peripheral nations because the former have a greater ability to extract resources from the environment. Presumably, economic development also has a stronger effect on the environment in semiperipheral nations than in core nations because the latter can afford environmental protection measures; semiperipheral nations are wary of shifting resources away from development in order to protect their environments (Smith 1994).

Although world-systems theory appears to be useful for exploring biodiversity, it has rarely been used to assess this issue (Friedmann 2000). Yet, given its usefulness for understanding rates of pollution and deforestation (Bartley and Bergesen 1997), two factors that have been linked to declining biodiversity across the globe (Forester and Machlis 1996; McNeely 1992; Robinson et al. 1995), it is important to consider whether addressing the world-system position may help to contextualize the influence of human-controlled factors on endangered species. It is likely that nations in the semiperiphery, given their typically intense economic development, have the highest rates of endangered species. Moreover, according to this

view, these rates are more affected by human-controlled factors such as pollution, deforestation, and economic growth in semiperipheral nations as they struggle to keep up with core nations at the expense of their indigenous animal species (see Roberts and Grimes 1997, 1999). Core nations frequently have the ability to take environmental protective measures even when economic growth occurs. In contrast, peripheral nations do not normally have the industrial infrastructures to do as much environmental damage as semiperipheral nations.

Summary and Discussion

There are several models in environmental sociology that offer promising frameworks for understanding varying rates of endangered species among nations. The neo-Malthusian model predicts that population pressures and intensive land use increase rates of endangered species as natural habitats are disrupted. Ecological modernization posits that economic development leads to environmental damage such as species endangerment only to a certain developmental point, after which environmental conditions improve. Thus ecological modernization predicts that EKC exists for endangered species. The treadmill of production model disagrees with this position and proposes that economic development as gauged by per capita GDP and energy use have positive linear effects on rates of endangered species. Finally, world-systems theory suggests that core nations enjoy environmental benefits at the expense of semiperipheral nations. Semiperipheral nations are often the most environmentally unfriendly as they attempt to keep up in the world economy. Hence animal species are at greatest risk in semiperipheral nations, especially in those nations engaging in intense economic development.

However, these competing hypotheses are based primarily on conceptual and empirical work on environmental outcomes such as deforestation, agricultural land use, industrial pollution, and energy use (e.g., Ehrhardt-Martinez 1998; Ekins 1997; James 1999; Roberts and Grimes 1999). The models from which they are drawn do not provide sufficient detail as to which specific variables affect environmental outcomes such as biodiversity (see Fisher and Freudenburg 2001 for a similar view). For instance, it is not clear based on current research and conceptual development whether variables such as population growth, land use, economic growth, energy use, and pollutants independently affect endangered species rates or affect them indirectly. Research by conservation biologists provides some guidance. For example, recent studies suggest that population growth and economic development indirectly affect biodiversity loss via habitat destruction and heightened energy use (Forester and Machlis 1996; Steadman 1997). Other research suggests that urbanization has a more direct effect on endangered species than other measures of land use (Czech, Krausman, and Devers 2000). Hence it is likely that measures of ecosystem threat such as deforestation, agricultural land co-optation, and pollution affect more directly rates of endangered animals than do variables such as economic growth, foreign debt, and increases in human populations. However, assuming that ecological modernization theory has merit, we should observe a tipping point at which the direct or indirect effects of economic

growth on these rates diminish. On the other hand, if rates are greater at higher levels of economic growth, then the alternative treadmill of production is supported. Finally, a key test for the world-systems hypothesis is whether semi-peripheral nations experience either the highest rates of endangered species or the strongest impact of variables such as economic growth, energy use, and land use on these rates. This suggests an interaction between the world-system position and several variables presumed to affect rates of endangered animal species.

DATA AND METHODS

The data used to examine the potential associations are drawn from a variety of international sources. Data on endangered species were obtained from the International Union for the Conservation of Nature and Natural Resources (IUCN) (1996) *Red List of Threatened Animals*. The *Red List*, a comprehensive listing of mammal, bird, reptile and other threatened or endangered species in most nations, is the most widely used source on threatened and endangered animals (Cole, Reeder, and Wilson 1994; Mace 1995; Pearman 2002). It is compiled by the Species Survival Commission (SSC) of the IUCN based on information provided by a network of more than seven thousand species conservation experts and their associated organizations from virtually every inhabited nation in the world (IUCN 2001). In this analysis, I use only the number of mammal and bird species. It is estimated that 98 percent of bird species and 95 percent of mammal species are documented (Wilson 1999; Wilson and Reeder 1993), so the IUCN (2001) considers its assessment of endangered mammals and birds complete. Data concerning other types of animal species are less reliable. I use the 1996 data only because in earlier years a different classification system was used and therefore these data are not directly comparable.³ Although this prevents the development of change scores or cross lagged effects, the use of 1996 endangered species data with anterior data on the proposed explanatory variables allows the temporal order in the models to be estimated more precisely than if only cross-sectional data were used.

The number of endangered species is influenced directly by the number of species and by the size of the landmass of a nation. Information on the total number of mammal and bird species in a nation is derived from the World Resources Institute (WRI) *Guide to Global Environment* (1996). Two approaches were used to validate this information. First, the data were compared to data on mammal species from Wilson and Reeder (1993) and on bird species from Monroe and Sibley (1993). There were minimal discrepancies.⁴ Second, considerable ecological research indicates that the number of species is a direct function of the size of the landmass. Known as area-species curves, these functions typically follow the form $S = CA^z$, where S is an estimate of the number of species, A is the size of the landmass, and C and z are constants derived empirically (May, Lawton, and Stork 1985; Reid 1992). Research suggests that C normally ranges from 35 to 65 and z ranges from 0.48 to 0.83 for most land areas (Leitner and Rosenzweig 1997). In the present data, the function $S = 55 \cdot A^{0.77}$ yielded a Pearson's correlation with the observed number of species of 0.88.⁵ However, recent studies suggest that area-species estimates are modeled more precisely using a Poisson or similar probability distribution

with a rapidly descending upper tail (Connor and McCoy 2001). I heed this suggestion in the empirical model (see below) by estimating the number of endangered species as a function of the number of species in a nation and other covariates while specifying land area (in 100,000 square kilometers) as the exposure variable. This allows the direct estimation of the rates of endangered birds and mammals in nations.

Both macrosociological and conservation biology research argue that structural effects on environmental outcomes take at least ten to fifteen years to develop (e.g., Ehrhardt-Martinez 1998; Forester and Machlis 1996). Therefore, I lagged the available data on the explanatory variables and also computed rates of change generally from the early 1980s to the early to mid-1990s.

Neo-Malthusian models argue that population growth engenders environmental pressure both directly and indirectly. Hence the first set of variables includes measures of human population and its growth, as well as land use. Population growth is measured as the average annual percent change in the total human population of the nation from 1980 to 1992. Urbanization is assessed by the percent of the population living in urban areas in 1980 and the average annual percent change in the urban population as a proportion of the overall population from 1980 to 1992. The natural logarithm of population density (1980) is also included to control for the fact that smaller, more densely populated nations are often judged urban by definition. Moreover, high population density may place particular pressures on animal species and thus lead to higher rates of endangerment (McKinney 2002; Robinson et al. 1995).

The land use variables include measures of deforestation and agricultural land. Rates of deforestation from 1980 to 1992 were derived from the Food and Agricultural Organization (FAO 1995) of the United Nations. This is a summary measure that provides the average annual rate of deforestation for each nation over the years specified. Moreover, for reasons described by Ehrhardt-Martinez (1998), I also include measures of the overall amount (in 100,000 square kilometers, logged to mitigate skewness) and percent of forest land in 1980 in each nation.⁶ As mentioned above, other types of land use, such as agricultural, have also been linked to rates of endangerment (Czech, Krausman, and Devers 2000). Hence the models include measures of the percentage of agricultural land in 1980 and the average annual percent change in agricultural land from 1980 to 1992. These data were also derived from the FAO (1995).

Treadmill of production and ecological modernization models debate the impact of economic growth on environmental outcomes (Mol and Sonnenfeld 2000). However, it is not clear whether differences among the sizes of national economies or economic growth within a nation are more consequential for environmental variables. Most studies of EKC's simply compare the relative sizes of economies based on per capita GDP (see Ekins 1997). Yet environmental degradation may be most prevalent when nations are developing rapidly. Hence I approach this issue in both ways, by examining the relative size of the economy and economic growth. Relative economic size is measured by the average per capita GDP from 1980 to 1992. Economic growth is gauged by average annual growth in per capita GDP across this time span. Per capita GDP is measured in constant

1987 international dollars. The GDP measures are found in the World Bank's *World Data 1995*. The per capita GDP measure is highly skewed, hence its natural logarithm is used. Moreover, because EKC's posit an inverted U-shaped association between per capita GDP or its growth and environmental outcomes (e.g., James 1999; Liddle 2000), quadratic terms for each GDP measure are also included in the models. Land use and economic growth are not independent (economic development often necessitates the use of land for producing food and energy), so I include a measure of the average annual percent change in food production from 1980 to 1992. This measure is provided by the WRI (1996).

Energy use and pollution are important aspects of economic development and key influences on endangered species and other environmental outcomes (Ehrlich 1995; McNeeley 1992; Shove 1997). Energy use is operationalized as the natural logarithm of average annual per capita energy consumption from 1980 to 1992 (in kilojoules) and the average annual percent change in energy consumption from 1980 to 1992. Pollution is measured by the natural logarithm of average industrial CO₂ emissions in 1,000 metric tons (1980–92) and the average annual percent change in industrial CO₂ emissions from 1980 to 1992. These data are derived from the WRI (1996).

Finally, to specify hypotheses derived from world-systems theory, a measure of core, semiperiphery, and periphery status is needed. However, there has been debate in the literature about the use of categorical or continuous variables to measure world-system position (cf. Bollen and Appold 1993; Roberts and Grimes 1999; Van Rossem 1996). Since the goal of the present analysis is to determine (1) if there are differences in rates of endangered species by world-system position and (2) if the independent variables affect the rates differentially across core, semiperiphery, and periphery, the most efficient approach is to stratify the sample into these groups and estimate subgroup models. Hence the world-system positions are categorized into periphery, semiperiphery, or core nation based on Bollen and Appold (1993), with supplementary information from Van Rossem (1996).⁷

Although the actual number of nations and independent states worldwide exceeds two hundred, complete data were available for only one hundred twenty nations. However, these nations occupy a wide variety of geographies and areas of the world (see Appendix A).⁸

Data Analysis

The distribution of the outcome variable, a measure of endangered mammal and bird species, is nonnegative and has a rapidly descending upper tail. Therefore, it is inappropriate to use a linear model such as OLS regression to analyze it statistically. There are two generally used alternatives that are appropriate for measuring this type of variable: Poisson regression and negative binomial regression. Both types of models are commonly used with rare events when they are measured as proportions or rates in areas or populations (Cameron and Trivedi 1998; Hoffmann 2003). As mentioned above, the number of species that an area can hold is a function of the size of the landmass (Connor and McCoy 2001). In a Poisson or negative binomial regression the unit over which the dependent

variable is observed is known as the "exposure." Spatial regression models use as a measure of exposure some indicator of the space over which the outcomes are observed (Best, Ickstadt, and Wolpert 2000). Hence the number of endangered species is the outcome variable with land area in 100,000 square kilometers as the exposure variable.

The choice of the Poisson or negative binomial model depends on assumptions about the distribution of the outcome variable. The Poisson model assumes that the distribution is equidispersed (mean = variance) (Hoffmann 2003). This is clearly not the case with the rate of endangered species among nations (see Table 1 below). Therefore, negative binomial regression models, which allow for overdispersion (mean < variance) in the outcome variable and therefore attenuate bias in the standard errors, are used in the following analyses (Cameron and Trivedi 1998). However, considering the relatively small sample size, the standard errors of the parameter estimates from the negative binomial model may still be biased. To attenuate this potential problem, all models are shown with bootstrapped standard errors.⁹

Since the link function for a negative binomial regression model is the log-link, its coefficients may be exponentiated and used to estimate predicted rates of change in the outcome variable that are associated with the independent variables. To determine the overall fit of the models, Akaike's Information Criterion (AICs) and pseudo-R² measures are computed based on the models' deviance statistics (Cameron and Trivedi 1988; Hoffmann 2003). A key property of AICs is that they may be used to compare nonnested models to determine which provides the best fit to the data.

RESULTS

Table 1 shows the distribution of the variables in the analysis. Population growth and land use are shown in the first set of distributions. Not surprisingly, there has been positive population growth and urbanization, on average, across these nations. This has been accompanied by increasing land co-optation as shown by the positive mean values for deforestation (0.61) and changes in agricultural land use (3.0). However, in some nations there has been negative deforestation, or reforestation (Rudel 1998). Similarly, most nations have, on average, been growing economically (mean percent change in GDP = 2.47), even though growth has been negative in some nations. Finally, it appears that energy consumption and industrial pollutant output have increased across the nations. Annual percent change in energy consumption averaged 2.29 and annual percent change in CO₂ emissions averaged 3.01 throughout the 1980s and early 1990s (cf. Roberts and Grimes 1997, 1999).

Table 2 provides the results of five negative binomial regression models that are designed to assess sets of variables derived from the conceptual models. The first is simply a baseline model that is appropriate for estimating the average rate of endangered mammal and bird species controlling for the number of species in a nation. The rate is derived by exponentiating the following equation: $4.03997 - (.00131 * 772)$. This results in $e^{3.029} = 20.68$, or the mean rate of endangered species

TABLE 1
Descriptive Statistics

| <i>Variable</i> | <i>Mean</i> | <i>S.D.</i> | <i>Minimum</i> | <i>Maximum</i> |
|--|-------------|-------------|----------------|----------------|
| Number of endangered mammal and bird species | 34.72 | 38.23 | 1.00 | 232.00 |
| Number of mammal and bird species | 772.39 | 412.96 | 85.00 | 2054.00 |
| Population density, 1980 (logged) | 3.43 | 1.54 | -0.34 | 8.24 |
| Annual population growth rate, 1980-92 | 2.18 | 1.18 | -0.33 | 5.24 |
| Percent urban, 1980 | 43.34 | 25.07 | 3.87 | 100.00 |
| Avg. annual % change urban, 1980-92 | 3.65 | 2.16 | 0.14 | 10.23 |
| Avg. annual rate of deforestation, 1980-92 | 0.61 | 1.27 | -4.49 | 7.25 |
| Forest cover in sq km, 1980 (logged) | 10.58 | 2.37 | 3.04 | 15.60 |
| Percent forest cover, 1980 | 31.51 | 24.40 | 0.03 | 94.47 |
| Percent agricultural land, 1980 | 39.16 | 23.18 | 0.43 | 86.86 |
| Avg. annual % change agricultural land, 1980-92 | 3.00 | 8.83 | -21.73 | 50.00 |
| Avg. GDP per capita, 1980-92 (logged) | 7.20 | 1.46 | 4.72 | 10.14 |
| Avg. GDP per capita, 1980-92 (logged) ² | 53.95 | 21.94 | 22.32 | 102.88 |
| Avg. annual % change in GDP, 1980-92 | 2.47 | 2.83 | -11.77 | 9.74 |
| Avg. annual % change in GDP, 1980-92 ² | 14.05 | 21.26 | 0.00 | 138.54 |
| Avg. annual % change in food production, 1980-92 | 0.00 | 2.26 | -7.94 | 14.68 |
| Avg. annual energy consumption per capita, 1980-92 (in kilojoules) (logged) | 1.15 | 1.02 | 0.03 | 4.33 |
| Avg. annual % change in energy consumption per capita, 1980-92 | 2.29 | 7.74 | -10.97 | 52.54 |
| Avg. annual CO ₂ emissions, in 1,000 MT, 1980-92 (logged) | 9.11 | 2.46 | 4.15 | 15.35 |
| Avg. annual % change in CO ₂ emissions, 1980-92 | 3.01 | 7.26 | -11.96 | 52.26 |
| World-systems classification of nation | | | | |
| Periphery | 0.58 | | 0 | 1 |
| Semiperiphery | 0.28 | | 0 | 1 |
| Core | 0.14 | | 0 | 1 |

Note: The data are from 120 nations (see Appendix). See the text for a description of the variables and their source documents.

per 100,000 square kilometers of land area (within rounding error). The dispersion parameter, which gauges statistically the overdispersion in the outcome variable (Hoffmann 2003), is significantly greater than one ($\chi^2 = 1385, p < .001$), thus providing evidence that the negative binomial model is preferred to the Poisson model.

The initial model that draws on previous conceptual work is model 2. It includes a set of variables drawn from neo-Malthusian theory that posits that population growth negatively affects environmental outcomes. In partial support of this position, we see that population density and population growth positively affect rates of endangered species. Each one percent increase in overall population growth is associated with a 44 percent higher rate of endangered birds and mammals. Considering that the mean population growth rate is 2.18, we may observe that this association is not uncommon.

TABLE 2
 Negative Binomial Regression Models of Rates of Endangered Mammal
 and Bird Species, 1996

| <i>Independent Variable</i> | <i>Model 1</i> | <i>Model 2</i> | <i>Model 3</i> | <i>Model 4</i> | <i>Model 5</i> |
|---|----------------|----------------|----------------|----------------|----------------|
| Intercept | 4.04 (.22)** | 1.01 (.48)** | 7.23 (.43)** | 4.00 (.27)** | 4.17 (.64)** |
| Number of mammal and bird species | -0.00 (.00)** | -0.00 (.00)** | 0.00 (.00) | -0.00 (.00)** | -0.00 (.00)** |
| Population density, 1980 (logged) | | 0.65 (.06)** | | | |
| Annual population growth rate, 1980-92 | | 0.37 (.17)* | | | |
| Percent urban, 1980 | | -0.01 (.01) | | | |
| Avg. annual % change urban, 1980-92 | | -0.11 (.10) | | | |
| Avg. annual rate of deforestation, 1980-92 | | | 0.19 (.06)** | | |
| Forest cover in square km, 1980 (logged) | | | -0.64 (.05)** | | |
| Percent forest cover, 1980 | | | 0.04 (.01)** | | |
| Percent agricultural land, 1980 | | | 0.01 (.00)** | | |
| Avg. annual % change agricultural land, 1980-92 | | | -0.01 (.01) | | |
| Avg. GDP per capita, 1980-92 (logged) | | | | 0.15 (.12) | |
| Avg. GDP per capita, 1980-92 (logged) ² | | | | -0.30 (.11)** | |
| Avg. annual % change in GDP, 1980-92 | | | | 0.75 (.13)** | |
| Avg. annual % change in GDP, 1980-92 ² | | | | 0.07 (.05) | |
| Avg. annual % change in food production, 1980-92 | | | | -0.14 (.06)* | |
| Avg. annual energy consumption per capita, 1980-92 (in kilojoules) (logged) | | | | | 0.27 (.14) |
| Avg. annual % change in energy consumption per capita, 1980-92 | | | | | 0.06 (.02)** |
| Avg. annual CO ₂ emissions, in 1,000 MT, 1980-92 (logged) | | | | | -0.09 (.05) |
| Avg. annual % change in CO ₂ emissions, 1980-92 | | | | | -0.01 (.03) |
| Dispersion parameter | 1.37 (.16)** | 0.85 (.10)** | 0.61 (.07)** | 1.22 (.14)** | 1.32 (.16)** |
| Pseudo-R ² | 0.03 | 0.10 | 0.13 | 0.05 | 0.04 |
| AIC | 10.01 | 9.35 | 8.97 | 9.88 | 9.98 |

Note: The outcome variable is the rate of mammal and bird species endangered per 100,000 sq km of land area. Bootstrapped standard errors are in parentheses.

N = 120.

*p < .05 (2-tailed); **p < .01 (2-tailed).

The second set of variables (shown in Table 2, model 3) continues the attention to neo-Malthusian conceptualizations about the environment but focuses on land use. Not surprisingly, deforestation, which is perhaps the most direct measure of habitat destruction available at the national level (Rudel 1998; Rudel and Roper 1997), is positively associated with rates of endangered species (cf. Forester and Machlis 1996). Although percent of agricultural land is also associated with endangerment rates, changes in the percent of agricultural land are not.

Model 4 is designed to explicitly compare hypotheses derived from the ecological modernization and treadmill of production models. As mentioned above, ecological modernization posits an inverted U-shaped association between economic development and environmental problems (i.e., an EKC), yet the treadmill of production model postulates a monotonic positive association (see Mol 2001; Schnaiberg and Gould 1994). The results, however, do not resolve the debate about which model is most accurate. They indicate that per capita GDP does not affect endangered species rates on average. Yet, at some point, GDP and these rates have a negative relationship. This partially supports the ecological modernization position, since it appears that at high levels of per capita GDP we may expect a lower rate of endangered species. This also suggests a tipping point in the association between GDP and endangered species rates. However, there is also a strong positive relationship between economic growth, as gauged by percent change in per capita GDP, and the outcome variable. Nations that grew quickly during the 1980s and early 1990s had higher rates of endangered species. Each one unit increase in GDP growth is associated with a 111 percent higher rate of endangered animals. This result is most consistent with the treadmill of production model.

Model 5 extends the concern about the impact of development but addresses energy use and pollution rather than GDP. The effects of overall energy consumption and industrial pollutants are not significant (cf. McNeeley 1992). Nevertheless, in support of Ehrlich's (1995; see also Machlis 1992) hypothesis, increases in energy consumption predict higher rates of endangered animals.

The results shown in Table 3 extend the empirical models by asking whether the statistically significant associations persist once we introduce all the key variables into a single regression model. High population density continues to affect the outcome, but population growth does not. An auxiliary analysis indicates that the association between population growth and the outcome variable is fully attenuated once controls are introduced for per capita GDP (population growth and per capita GDP are negatively correlated). Moreover, the relationships among deforestation, forest cover, and endangered species are reduced to insignificance in the full model. Additional analyses indicate that once population density and growth are included in the model, deforestation and forest cover no longer significantly affect the outcome. Hence, as predicted by the neo-Malthusian perspective, there is evidence that population pressure in the form of high density of human habitation negatively affects animal species (McKinney 2002) and that this pressure explains the putative association between one form of land co-optation and endangered species (cf. Forester and Machlis 1996; Steadman 1997).

A key finding is that the associations involving economic size and growth continue to support the arguments of both the ecological modernization and tread-

TABLE 3
 Negative Binomial Regression Model of Rates of Endangered Mammal
 and Bird Species, Full Model, 1996

| <i>Independent Variable</i> | <i>Coefficients (Standard Errors)</i> |
|--|---|
| Intercept | 1.32 (0.76) |
| Number of mammal and bird species | 0.00 (0.00) |
| Population density, 1980 (logged) | 0.84 (0.07)** |
| Annual population growth rate, 1980–92 | –0.01 (0.08) |
| Percent urban, 1980 | 0.01 (0.01) |
| Avg. annual % change urban, 1980–92 | 0.07 (0.05) |
| Avg. annual rate of deforestation, 1980–92 | 0.00 (0.03) |
| Forest cover in sq km, 1980 (logged) | –0.05 (0.07) |
| Percent forest cover, 1980 | 0.02 (0.00)** |
| Percent agricultural land, 1980 | 0.00 (0.01) |
| Avg. annual % change agricultural land, 1980–92 | 0.00 (0.01) |
| Avg. GDP per capita, 1980–92 (logged) | 0.29 (0.13)* |
| Avg. GDP per capita, 1980–92 (logged) ² | –0.20 (0.05)** |
| Avg. annual % change in GDP, 1980–92 | 0.18 (0.06)** |
| Avg. annual % change in GDP, 1980–92 ² | –0.00 (0.02) |
| Avg. annual % change in food production, 1980–92 | –0.03 (0.02) |
| Avg. annual energy consumption per capita, 1980–92 (in kilojoules) (logged) | 0.29 (0.09)** |
| Avg. annual % change in energy consumption per capita, 1980–92 | 0.03 (0.01)** |
| Avg. annual CO ₂ emissions, in 1,000 MT, 1980–92 (logged) | –0.30 (0.05)** |
| Avg. annual % change in CO ₂ emissions, 1980–92 | –0.01 (0.01) |
| Dispersion parameter | 0.24 (0.04)** |
| Pseudo-R ² | 0.22 |
| AIC | 8.42 |

Note: The outcome variable is the rate of mammal and bird species endangered per 100,000 sq km of land area. Bootstrapped standard errors are in parentheses.

N = 120.

p* < .05 (2-tailed); *p* < .01 (2-tailed).

mill of production models. If one considers the relative size of the economy, an EKC emerges: The rate of endangered species is positively associated with per capita GDP up to a certain point, after which the association is negative. An additional analysis indicates that this tipping point occurs at approximately \$9,000 per capita GDP. Note, however, that only about 15 percent of the nations in the analysis have per capita GDPs that exceed this level; 11 percent are core nations. Moreover, the positive linear effect of changes in GDP supports the treadmill of production presumption that rapid economic growth damages the environment. Here we see its persistent statistical association with rates of endangered species.

The results shown in Table 3 also demonstrate that the positive relationship

between high energy consumption and rates of endangered species continues after controlling for other variables, including economic growth. Moreover, changes in energy use also emerge as a significant predictor of endangerment rates. These positive associations support Ehrlich's (1995) argument that high energy use has an especially pernicious effect on the environment. Yet even after controlling for the impact of energy use and economic growth, CO₂ emissions are negatively associated with the outcome. It is worth observing, however, that many of the nations with the highest CO₂ output (e.g., Canada, the United States, Germany, France) are highly industrialized, core nations that fit into EKC's downward sloping curve. Hence it is important to consider what world-systems theory can tell us about the variable rates of endangered species among peripheral, semiperipheral, and core nations.¹⁰

World-Systems Analysis

Figure 1 provides the average rate of endangered species by world-systems position. As expected, the highest rates occur in semiperipheral nations, which, as world-systems theory contends, often develop economically at the expense of their environments. It is important to note, however, that the relative difference in rates between peripheral and semiperipheral nations is not statistically significant. Moreover, since there is likely a ceiling effect of species decline in core nations—many have already lost larger or more environmentally sensitive birds and mammals (Ehrlich and Ehrlich 1981)—it is important to not put too much stock in the lower average rate found in core nations.

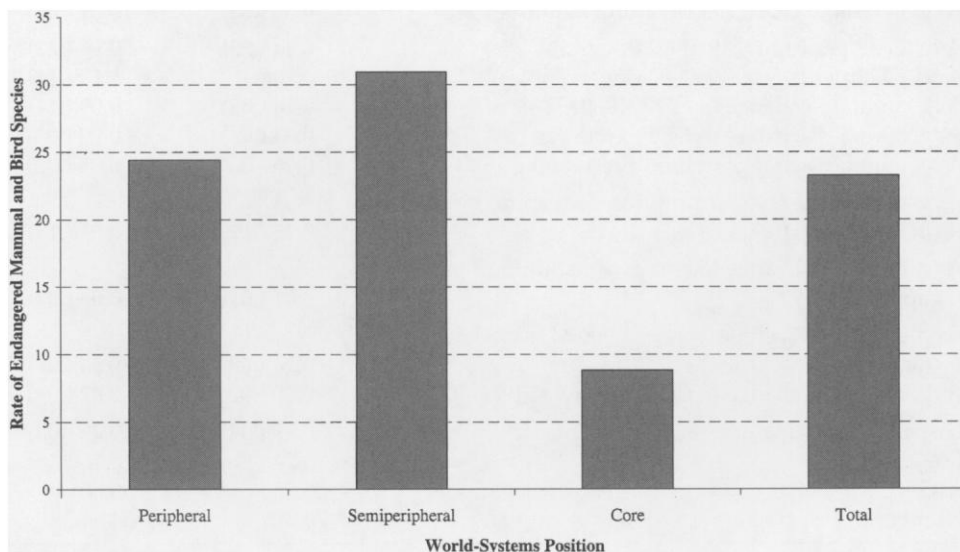


Figure 1
Rate of Endangered Mammal and Bird Species per 100,000 Square Kilometers
of Land Area, by World-Systems Position, 1996

Table 4 provides models that are similar to the model shown in Table 3 but that are stratified by world-system position. Unfortunately, the number of core nations was too small to provide suitable estimates, so the table provides the results only for semiperipheral and peripheral nations. Yet this focus is appropriate given world-systems theory's key concerns about semiperipheral nations and the environment (Goldfrank, Goodman, and Szasz 1999).

The results of the analysis suggest that in general the variables affect rates of endangered animals similarly among peripheral and semiperipheral nations.

TABLE 4
Negative Binomial Regression Models of Rates of Endangered Mammal and Bird Species,
Full Model by Periphery and Semiperiphery Status of Nation, 1996

| <i>Independent Variable</i> | <i>Periphery</i> | <i>Semiperiphery</i> |
|--|----------------------|----------------------|
| Intercept | 1.77 (.99) | 2.32 (.51)** |
| Number of mammal and bird species | 0.00 (.00) | 0.00 (.00) |
| Population density, 1980 (logged) | 0.80 (.10)** | 0.97 (.08)** |
| Annual population growth rate, 1980–92 | –0.18 (.15) | –0.16 (.17) |
| Percent urban, 1980 | 0.01 (.01) | 0.01 (.01) |
| Avg. annual % change urban, 1980–92 | 0.09 (.07) | 0.05 (.11) |
| Avg. annual rate of deforestation, 1980–92 | –0.02 (.04) | 0.19 (.06)* |
| Forest cover in sq km, 1980 (logged) | –0.08 (.11) | 0.03 (.09) |
| Percent forest cover, 1980 | 0.02 (.01)** | 0.00 (.01) |
| Percent agricultural land, 1980 | 0.00 (.00) | –0.00 (.01) |
| Avg. annual % change agricultural land, 1980–92 | 0.01 (.01) | 0.01 (.01) |
| Avg. GDP per capita, 1980–92 (logged) | 0.24 (.23) | 0.55 (.22)* |
| Avg. GDP per capita, 1980–92 (logged) ² | –0.22 (.10)* | –0.19 (.14)** |
| Avg. annual % change in GDP, 1980–92 | 0.20 (.08)* | 0.09 (.14) |
| Avg. annual % change in GDP, 1980–92 ² | –0.04 (.06) | –0.07 (.03)* |
| Avg. annual % change in food production, 1980–92 | –0.06 (.06) | –0.05 (.02) |
| Avg. annual energy consumption per capita, 1980–92 (in kilojoules) (logged) | 0.25 (.12)* | 0.51 (.15)** |
| Avg. annual % change in energy consumption per capita, 1980–92 | 0.01 (.01) | 0.03 (.01)* |
| Avg. annual CO ₂ emissions, in 1,000 MT, 1980–92 (logged) | –0.24 (.08)** | –0.53 (.07)** |
| Avg. annual % change in CO ₂ emissions, 1980–92 | –0.00 (.02) | 0.07 (.04) |
| Dispersion parameter | 0.17 (.04)** | 0.07 (.03)* |
| Pseudo-R ² | 0.24 | 0.36 |
| AIC | 8.05 | 8.66 |
| Number of cases | 70 | 34 |

Note: The outcome variable is the rate of endangered mammal and bird species per 100,000 sq km of land area. Bootstrapped standard errors are in parentheses. Significant differences (at $p < .05$) between the coefficients from the periphery and semiperiphery models (in bold) are based on significance tests of interaction terms from a pooled negative binomial regression model and are based on bootstrapped standard errors.

* $p < .05$ (2-tailed); ** $p < .01$ (2-tailed).

However, there are several interesting discrepancies. First, deforestation has a significant positive impact on the outcome in semiperipheral nations but not in peripheral nations (cf. Ehrhardt-Martinez 1998; Rudel 1998). This is a bit surprising since peripheral nations have had higher rates of deforestation than semiperipheral nations (cf. Burns et al. 1994; Ehrhardt-Martinez 1998).

Second, both sets of nations experience traditional EKC, although the linear impact of per capita GDP is larger among semiperipheral nations. Moreover, the linear effect of GDP growth is significant only among peripheral nations. Hence rapid economic development affects species primarily in the poorer nations of the world. Third, changes in energy consumption significantly affect endangerment rates only in semiperipheral nations. In sum, it appears that animal species in semiperipheral nations are affected more by deforestation, per capita GDP, and energy consumption, but those in peripheral nations are affected more by changes in GDP over time. This supports the world-systems contention that different factors affect environmental issues in peripheral and semiperipheral nations (Roberts and Grime 1999). Both types of nations, though, have significantly higher rates of endangered species than do core nations.

DISCUSSION

The goal of this article has been to determine cross-nationally which human-controlled activities influence the rate of endangered mammal and bird species. A key feature of my analyses is that they allowed a direct test of competing hypotheses drawn from ecological modernization theory and the treadmill of production model. The former proposes that highly developed nations often improve their environments; the latter disagrees and argues that high levels of consumption virtually require the continuance of environmental degradation (cf. Mol 2001; Mol and Spaargaren 2000; Pellow, Schnaiberg, and Weinberg 2000; Schnaiberg and Gould 1994).

The results inform this debate by showing that both arguments have merit. Similar to research on other environmental outcomes (e.g., List and Gallet 1999), the findings indicate that there is an environmental Kuznets curve for endangered species: At low to medium per capita GDP, rates of endangered species follow a positive linear trend, but at high levels of per capita GDP this association flattens out and becomes negative. However, as some observers have argued (Buttel 1998; Roberts and Grimes 1997; Stern, Common, and Barbier 1996), the level at which the relationship turns negative is quite high (>\$9,000 per capita), and reaching it is out of the grasp of many developing nations. So it is unwise at this stage to argue that ecological modernization applies to developing nations as well as it seems to apply to highly developed nations (Mol and Sonnenfeld 2000). On the other hand, the analysis also supports the notion that there is an EKC for endangered species even in peripheral and semiperipheral nations (see Table 4). Yet per capita GDP has a particularly strong linear relationship with the outcome in these latter nations. Thus the world-systems theory assertion that nations in the semiperiphery often experience the most environmental damage as they seek to catch up with wealthier core nations has merit (Roberts and Grimes 1999).

That hypotheses from both models are supported reinforces recent arguments that reject the either/or nature of the debate about ecological modernization versus treadmill of production. Fisher (2002; Fisher and Freudenberg 2001; see also Buttel 1998), in particular, contends that inconsistent empirical support for the theories points to weaknesses in both that need to be overcome. Research that considers multiple nations from across a developmental spectrum is needed to determine the particular complementary or competing aspects of ecological modernization or treadmill of production that will help us to understand environmental problems. A key goal for these theories, as suggested by the present analysis, is to become more sensitive to the demographic, political, and economic dynamics of nations (Fisher 2002); to consider further the structural positions and intersocietal networks of nations (Goldfrank, Goodman, and Szasz 1999); and to be developed sufficiently so that logically consistent hypotheses may be derived from each or from some synthesis of the two theories.

Nonetheless, even if we accept the argument that wealthy nations offer significant environmental protections to nonhuman species, the results also suggest that rapid development continues to do damage (cf. Schnaiberg and Gould 1994). Nations that underwent rapidly increasing per capita GDPs throughout the 1980s and early 1990s experienced the highest rates of endangered species. The analysis showed little evidence for a downward tipping point (one exception, surprisingly, is found among semiperipheral nations). Hence the treadmill of production prediction that economic growth continues to damage the environment with little abatement is supported. Rapid development is frequently accompanied by poor environmental planning, and this frequently leads to substantial biodiversity loss in many nations.

In addition, recent arguments that development may also be gauged as increasing energy use and that this may be a more important marker for environmental damage than other dynamic measures (Ehrlich 1995) are supported. The two indicators of energy use, average energy consumption per capita and changes in energy consumption, both significantly predict rates of endangered species. Hence, even after controlling for GDP growth, this is still a residual impact of development on one form of environmental degradation. An interesting result that supports world-systems theory's observations about the environment is that increasing energy consumption has its most substantial impact in semiperipheral nations. Rapid development in terms of energy use in these nations has a unique impact on species endangerment. These findings suggest that research on EKC is shortsighted and should be expanded to consider other forms of development beyond simple measures of per capita GDP.

There is only modest support for the neo-Malthusian position that rapid population growth affects land use patterns and ultimately does damage to mammal and bird species. Although several ecological studies indicate that population growth, urbanization, deforestation, and agricultural land co-optation have the most immediate effects on endangered species (Czech, Krausman, and Devers 2000; Forester and Machlis 1996; Stork 1999), such a position is not generally supported in the present analyses. A key exception, however, involves population density. Even after controlling for the effects of development and land use, nations with high population densities have higher rates of endangered species (Robinson et al. 1995). Nevertheless, it appears that the most immediate influences

on endangered species are economic development factors such as GDP growth and energy use (cf. Machlis and Forester 1996; Wilcove et al. 1998), and these, along with population density, explain much of the putative effects of land use and population growth (cf. Tables 2 and 3).

An important qualification to this conclusion emerges from the world-systems analysis that compares peripheral and semiperipheral nations. Deforestation, which, it was argued above, may provide the most direct measure of habitat destruction, is significantly associated with rates of endangered species in semiperipheral nations but not in peripheral nations. Some semiperipheral nations have begun the process of reforestation, although this varies dramatically across the globe (Bhattari and Hammig 2001; Rudel 1998). Yet deforestation in these areas has a significant impact on biodiversity loss.

To summarize, there are clear effects of development and production on endangered mammals and birds. Rapid economic development and heightened energy use, in particular, are harmful to global biodiversity. Peripheral nations that have experienced increasing per capita GDP and semiperipheral nations that have undergone growth in energy use tend to have the highest rates of endangered species. Yet attenuating or halting these deleterious effects is often quite difficult. Especially in peripheral and semiperipheral nations, there has been a profound lack of attention or ability to address environmental concerns (Buttel 2000). Much of this is because developing nations understandably argue that the industrialized world should accept blame for most of the environmental degradation seen throughout the world, and they should not have to sacrifice their economic development to benefit developed nations' emerging sense of duty to the environment (Buttel 1998; DeSombre 2000; Redclift and Sage 1998). Moreover, environmental movements, most of which emerge from wealthier nations (Buttel 2000), are often perceived by the developing world as stemming from imperialist ideals, and thus these movements have little influence on issues such as biodiversity conservation in peripheral nations (Bartley and Bergesen 1997). The discord between developing and developed nations, which has historically involved the Southern Hemisphere trailing the Northern Hemisphere in level of industrialization and modernization, takes on a thorny edge in these environmental conflicts (Giampietro and Mayumi 1998). Unfortunately, it appears that nonhuman species and their natural habitats are among the victims of this conflict.

In conclusion, it is not surprising that the increasing loss of global biodiversity has begun to capture the attention of many disciplines, including sociology. Assuming that the estimates that 10 to 15 percent of mammal and bird species will be extinct in the next fifty to one hundred years (Reid 1992; Smith et al. 1993) are even marginally accurate, there is clearly an environmental crisis that calls for new ideas and approaches. Moving beyond simplistic models of biodiversity loss requires the development of a research agenda and policy considerations that draw on the conceptual and empirical strengths of a variety of disciplines (Goldman and Schurman 2000). Recognizing that habitat destruction and other forms of land degradation that affect animal species are often overt yet unintended results of rapid economic growth and that decisions about growth are principally the result of world-systems relations and global market pressures is a key contribution that sociology can make to research on the biodiversity crisis.

APPENDIX
LIST OF NATIONS INCLUDED IN ANALYSIS

| | | |
|--------------------------|---------------|------------------------|
| Algeria | Guinea-Bissau | Panama |
| Angola | Guinea | Papua New Guinea |
| Australia | Guyana | Paraguay |
| Austria | Haiti | Peru |
| Bangladesh | Honduras | Philippines |
| Belgium | Hungary | Poland |
| Belize | Iceland | Portugal |
| Benin | India | Romania |
| Bhutan | Indonesia | Rwanda |
| Bolivia | Iran | Saudi Arabia |
| Botswana | Iraq | Senegal |
| Brazil | Ireland | Sierra Leone |
| Bulgaria | Israel | Singapore |
| Burkina Faso | Italy | Solomon Islands |
| Burundi | Jamaica | Somalia |
| Cameroon | Japan | South Africa |
| Canada | Jordan | South Korea |
| Central African Republic | Kenya | Spain |
| Chad | Laos | Sri Lanka |
| Chile | Liberia | Sudan |
| China | Libya | Suriname |
| Colombia | Madagascar | Swaziland |
| Congo (Brazzaville) | Malawi | Sweden |
| Costa Rica | Malaysia | Switzerland |
| Cote d'Ivoire | Mali | Syria |
| Denmark | Mauritania | Tanzania |
| Dominican Republic | Mauritius | Thailand |
| Ecuador | Mexico | Togo |
| Egypt | Mongolia | Trinidad and Tobago |
| El Salvador | Morocco | Tunisia |
| Ethiopia | Mozambique | Turkey |
| Fiji | Myanmar | Uganda |
| Finland | Nepal | United Kingdom |
| France | Netherlands | United States |
| Gabon | New Zealand | Uruguay |
| Gambia | Nicaragua | Venezuela |
| Germany | Niger | Viet Nam |
| Ghana | Nigeria | Zaire (Congo Kinshasa) |
| Greece | Norway | Zambia |
| Guatemala | Pakistan | Zimbabwe |

Acknowledgments: Earlier versions of this article were presented at the 2001 annual meeting of the American Sociological Association, Anaheim, California;

and the Orem Elementary School Science Fair, Orem, Utah, March 2001. I thank Christine Horne, Mikaela Dufur, Robert Hoffmann, Don Wilson, Craig Hilton-Taylor, Duke Rogers, Tim Heaton, and especially Brian Hoffmann for helpful advice and assistance.

NOTES

1. Although the term “biodiversity” has been used to identify a variety of hierarchical components in the environment, from ecosystems to species and genetic variability (Dobson 1998), this study focuses on the number of animal species in a nation, in particular mammal and bird species. The conceptualization of biodiversity is limited for three principal reasons. First, of the data on the variety of endangered species in a nation, those on mammal and bird species are the most reliable (IUCN 1996; Wilson 1999; WRI 1996). Second, because most mammal and bird species are land dwelling, matching species to specific nations is more reliable than attempting to match them to the number of, say, fish or amphibian species. Third, much of the social scientific attention to nonhuman species has addressed mammal and bird species, perhaps for historical reasons and because these species have economic, agricultural, and recreational use for humans.
2. Ecological modernization theory was initially developed to explain the environment-economic development relationship in western European nations (Mol 2001). However, it has been used recently to examine, with varied success, numerous environmental issues in developing nations as well (Mol 2001; Mol and Sonnenfeld 2000).
3. I thank Craig Hilton-Taylor, IUCN Red List Programme Officer, for providing extremely useful information about the *Red List* data.
4. Wilson and Reeder (1993) and Monroe and Sibley (1993) do not map species directly to nations but to regions. However, the regions are specific enough so that one may infer whether or not a mammal or bird species is found in a particular nation. I thank Don E. Wilson and Robert S. Hoffmann of the Smithsonian Institution for very helpful discussions about the regional distribution of mammal species.
5. Because there is no straightforward or generally accepted method for arriving at particular values of C and z , I ran a series of simulations to obtain reasonable values. However, since these values are likely to vary by nation or region, I opted to model the rate of endangered species using land area as an exposure variable in the empirical model. This modeling approach is discussed below.
6. Briefly, Ehrhardt-Martinez argues that rates of deforestation are affected by the abundance of forestland in a nation and by the perception in nations with more forest and woodlands that they can afford to clear more land.
7. Van Rossem (1996) uses international data from the 1980s to estimate each nation’s network prominence in international trade and relations. Prominence is measured from 0 to 1. I used cutpoints similar to those used by Van Rossem to classify nations that were not classified by Bollen and Appold (1993).
8. An astute reviewer of an earlier draft of this article pointed out that several studies have found that economic dependency contributes to environmental problems, especially in developing nations, since a heavy debt burden forces some nations to ignore the environment and expand agricultural production, deforestation, and industrialization (Bradshaw and Schafer 2000; Bryant and Bailey 1997; Rudel and Roper 1997). I included a measure of the average annual percentage change in debt per capita, 1980–92

(see Rudel and Roper 1997), in several of the models. A key limitation of this and other similar measures is that they are available for the time period of interest mainly for peripheral nations. For example, annual percentage change in debt per capita (based on data published by the World Bank 1994) was available for 69 of the 70 peripheral nations but for only 24 of the 36 semiperipheral nations and for only 2 of the 17 core nations. Nonetheless, I estimated the models shown in Table 4 with average annual percent change in debt per capita as an additional covariate. It was not significant in either model ($p > .30$), nor did its inclusion appreciably change the magnitudes of the other coefficients. Therefore, it is not included in the models. Given the data constraints mentioned, this auxiliary analysis cannot show conclusively that foreign debt dependency has no effect on rates of endangered species. More finely detailed data and analysis of peripheral nations should be conducted in future research to explore the potential association between debt dependency and endangered species.

9. I allowed 250 replications of the bootstrap for each model. This is normally sufficient to attenuate bias in standard errors resulting from small sample analyses (Chernick 1999). To further check the model for violations of assumptions, I conducted a residual analysis for each model using deviance residuals designed for negative binomial regression models (Cameron and Trivedi 1998). Two outliers emerged for the full model (Table 3): Belgium and El Salvador. Both cases had large negative residuals (-4.69 , -4.68), indicating that the model overestimated the number of endangered species in these nations. According to a Q-Q plot, their inclusion forced the residuals to depart from a Gaussian distribution. I subsequently conducted two auxiliary analyses to determine the effect of these outliers. First, I deleted the two cases and reestimated the models. Second, I reestimated the models using robust (sandwich) estimates of the standard errors. Both sets of models agreed closely with the original negative binomial models, so the tables present these original models with bootstrapped standard errors.
10. As I have intimated throughout this article, economic growth is not the only developmental variable that may affect environmental outcomes in a nonlinear fashion. Since per capita GDP has a quadratic association with endangerment rates, it is reasonable to argue that energy use and industrial emissions may have similar associations. In other words, if ecological modernization's position about development is correct, then there may also be EKCs that involve energy use and industrial emissions. However, tests for these quadratic effects provided no evidence to support these other potential forms of EKCs.

REFERENCES

- Alonso, Alfonso, Francisco Dallmeier, Elise Granek, and Peter Raven. 2001. *Biodiversity: Connecting with the Tapestry of Life*. Washington, DC: Smithsonian Institution Monitoring and Assessment of Biodiversity Program.
- Alroy, John. 2001. "A Multispecies Overkill Simulation of the End-Pleistocene Megafaunal Mass Extinction." *Science* 292:1893-96.
- Bartley, Tim and Albert Bergesen. 1997. "World-Systems Studies of the Environment." *Journal of World-Systems Research* 3:369-80.
- Beattie, Andrew and Paul Ehrlich. 2001. *Wild Solutions: How Biodiversity Is Money in the Bank*. New Haven: Yale University Press.
- Benton, Ted. 1993. *Natural Relations: Ecology, Animal Rights and Social Justice*. London: Verso.
- Best, Nicola G., Katja Ickstadt, and Robert L. Wolpert. 2000. "Spatial Poisson Regression for Health and Exposure Data Measured at Disparate Resolutions." *Journal of the American Statistical Association* 95:1076-88.

- Bhattari, Madhusudan and Michael Hammig. 2001. "Institutions and the Environmental Kuznets Curve for Deforestation: A Crosscountry Analysis of Latin America, Africa, and Asia." *World Development* 29:995–1010.
- Bollen, Kenneth A. and Stephen J. Appold. 1993. "National Industrial Structure and the Global System." *American Sociological Review* 58:283–301.
- Bradshaw, York W. and Mark J. Schafer. 2000. "Urbanization and Development: The Emergence of International Nongovernmental Organizations Amid Declining States." *Sociological Perspectives* 43:97–116.
- Bryant, Raymond L. and Sinéad Bailey. 1997. *Third World Political Ecology*. London: Routledge.
- Burns, Thomas J., Edward L. Kick, and Byron L. Davis. 1998. "Theorizing and Rethinking Linkages between Population and Environment." Paper presented at the annual meeting of the American Sociological Association, San Francisco, CA, August.
- Burns, Thomas J., Edward L. Kick, David A. Murray, and Dixie A. Murray. 1994. "Demography, Development and Deforestation in a World-System Perspective." *International Journal of Comparative Sociology* 35:221–39.
- Buttel, Frederick H. 1997. "Social Institutions and Environmental Change." Pp. 40–54 in *The International Handbook of Environmental Sociology*, edited by M. Redclift and G. Woodgate. Cheltenham, UK: Edward Elgar.
- . 1998. "Some Observations on States, World Orders, and the Politics of Sustainability." *Organization & Environment* 11:261–86.
- . 2000. "World Society, the Nation-State, and Environmental Protection: Comment on Frank, Hironaka, and Schofer." *American Sociological Review* 65:117–21.
- Buttel, Frederick and Peter Taylor. 1994. "Environmental Sociology and Global Environmental Change: A Critical Assessment." Pp. 228–55 in *Social Theory and the Global Environment*, edited by M. Redclift and T. Benton. New York: Routledge.
- Cameron, A. Colin and Pravin K. Trivedi. 1998. *Regression Analysis of Count Data*. New York: Cambridge University Press.
- Chase-Dunn, Christopher K. and Thomas B. Hall. 1997. *Rise and Demise: Comparing World-Systems*. Boulder, CO: Westview Press.
- Chernick, Michael R. 1999. *Bootstrap Methods: A Practitioner's Guide*. New York: Wiley.
- Cole, F. Russell, DeeAnn M. Reeder, and Don E. Wilson. 1994. "A Synopsis of Distribution Patterns and the Conservation of Mammal Species." *Journal of Mammalogy* 75:266–76.
- Connor, Edward F. and Earl D. McCoy. 2001. "Species-Area Relationships." *Encyclopedia of Biodiversity* 5:397–411.
- Crosby, Alfred W. 1986. *Ecological Imperialism: The Biological Expansion of Europe, 900–1900*. Cambridge: Cambridge University Press.
- Czech, Brian, Paul R. Krausman, and Patrick K. Devers. 2000. "Economic Associations among Causes of Species Endangerment in the United States." *BioScience* 50:593–601.
- DeSombre, Elizabeth R. 2000. "Developing Country Influence in Global Environmental Negotiations." *Environmental Politics* 9:23–42.
- Dobson, Andrew P. 1998. *Conservation and Biodiversity*. New York: Scientific American Library.
- Ehrhardt-Martinez, Karen. 1998. "Social Determinants of Deforestation in Developing Countries: A Cross-National Study." *Social Forces* 77:567–86.
- Ehrlich, Paul R. 1985. "Extinctions and Ecosystem Functions: Implications for Humankind." Pp. 157–73 in *Animal Extinctions*, edited by R. J. Hoage. Washington, DC: Smithsonian Institution Press.
- . 1995. "The Scale of Human Enterprise and Biodiversity Loss." Pp. 214–26 in *Extinction Rates*, edited by J. H. Lawton and R. M. May. New York: Oxford University Press.
- Ehrlich, Paul R. and Anne Ehrlich. 1981. *Extinction: The Cause and Consequences of the Disappearance of Species*. New York: Random House.

- Ekins, P. 1997. "The Kuznets Curve for the Environment and Economic Growth: Examining the Evidence." *Environment and Planning A* 29:805–30.
- Eldredge, Niles. 1998. *Life in the Balance: Humanity and the Biodiversity Crisis*. Princeton, NJ: Princeton University Press.
- Fisher, Dana R. 2002. "From the Treadmill of Production to Ecological Modernization? Applying a Habermasian Framework to Society-Environment Relationships." *Research in Social Problems and Public Policy* 10:53–64.
- Fisher, Dana R. and William R. Freudenburg. 2001. "Ecological Modernization and Its Critics: Assessing the Past and Looking Toward the Future." *Society and Natural Resources* 14:701–9.
- Food and Agricultural Organization (FAO). 1995. *Forest Resources Assessment 1990: Global Synthesis*. New York: FAO.
- Forester, Deborah J. and Gary E. Machlis. 1996. "Modeling Human Factors That Affect the Loss of Biodiversity." *Conservation Biology* 10:1253–63.
- Franklin, Adrian. 1999. *Animals and Modern Cultures*. Thousand Oaks, CA: Sage.
- Friedmann, Harriet. 2000. "What on Earth Is the Modern World-System? Foodgetting and the Territory in the Modern Era and Beyond." *Journal of World-Systems Research* 6:480–515.
- Giampietro, Mario and Kozo Mayumi. 1998. "Another View of Development: Ecological Degradation and North-South Trade." *Review of Social Economy* 56:20–36.
- Goldfrank, Walter L., David Goodman, and Andrew Szasz, eds. 1999. *Ecology and the World-System*. Westport, CT: Greenwood Press.
- Goldman, Michael and Rachel M. Schurman. 2000. "Closing the 'Great Divide': New Social Theory on Nature and Society." *Annual Review of Sociology* 26:563–84.
- Gould, Kenneth, Adam Weinberg, and Allan Schnaiberg. 1995. "Natural Resource Use in a Transnational Treadmill: International Agreements, National Citizenship Practices, and Sustainable Development." *Humboldt Journal of Social Relations* 21:61–93.
- Grimes, Peter E., J. Timmons Roberts, and Jody Manale. 1993. "Social Roots of Environmental Damage: A World-Systems Analysis of Global Warming." Paper presented at the annual meeting of the American Sociological Association, Baltimore, MD, August.
- Grumbine, R. Edward. 1995. "Using Biodiversity as a Justification for Nature Protection in the U.S." *Humboldt Journal of Social Relations* 21:35–59.
- Hettige, Hemamala, Muthukumara Mani, and David Wheeler. 2000. "Industrial Pollution in Economic Development: The Environmental Kuznets Curve Revisited." *Journal of Developmental Economics* 62:445–76.
- Hoffmann, John P. 2003. *Generalized Linear Models: An Applied Approach*. Boston: Pearson.
- Inman, Katherine. 1992. "Fueling Expansion of the Third World: Population, Development, Debt, and the Global Decline of Forests." *Society and Natural Resources* 6:17–39.
- International Union for the Conservation of Nature and Natural Resources (IUCN). 1996. *1996 Red List of Threatened Animals*. Cambridge: IUCN.
- . 2001. *The SSC Red List Programme*. Cambridge: IUCN.
- James, Alexander N. 1999. "Agricultural Land Use and Economic Growth: Environmental Implications of the Kuznets Curve." *International Journal of Sustainable Development* 2:530–53.
- Jokinen, Pekka. 2000. "Europeanisation and Ecological Modernisation." Pp. 138–67 in *Ecological Modernisation around the World: Perspectives and Critical Debates*, edited by A. P. J. Mol and D. A. Sonnenfeld. London: Frank Cass.
- Kuznets, Simon. 1955. "Economic Growth and Income Inequality." *American Economic Review* 45:1–28.
- Lawton, John H. and Robert M. May, eds. 1995. *Extinction Rates*. New York: Oxford University Press.

- Leitner, Wade A. and Michael L. Rosenzweig. 1997. "Nested Species-Area Curves and Stochastic Sampling: A New Theory." *Oikos* 79:503–12.
- Liddle, Brantley. 2000. "Population Growth, Age Structure, and Environmental Impact." *Population and Environment* 21:385–411.
- List, John A. and Craig A. Gallet. 1999. "The Environmental Kuznets Curve: Does One Size Fit All?" *Ecological Economics* 31:409–23.
- Mace, Georgina. 1995. "Classification of Threatened Species and Its Role in Conservation Planning." Pp.197–213 in *Extinction Rates*, edited by J. H. Lawton and R. M. May. New York: Oxford University Press.
- Machlis, Gary E. 1992. "The Contribution of Sociology to Biodiversity Research and Management." *Biological Conservation* 62:161–70.
- Machlis, Gary E. and Deborah J. Forester. 1996. "The Relationship between Socio-Economic Factors and the Loss of Biodiversity: First Efforts at Theoretical and Quantitative Models." Pp. 121–46 in *Biodiversity in Managed Landscapes: Theory and Practice*, edited by R. C. Szaro and D. W. Johnston. New York: Oxford University Press.
- Mather, A. S., C. L. Needle, and J. Fairbain. 1999. "Environmental Kuznets Curves and Forest Trends." *Geography* 84:55–65.
- May, Robert M., John H. Lawton, and Nigel E. Stork. 1995. "Assessing Extinction Rates." Pp. 1–24 in *Extinction Rates*, edited by J. H. Lawton and R. M. May. New York: Oxford University Press.
- McKinney, Michael L. 2002. "Urbanization, Biodiversity, and Conservation." *BioScience* 52:883–90.
- McNeeley, Jeffrey A. 1992. "The Sinking Ark: Pollution and the Worldwide Loss of Biodiversity." *Biodiversity and Conservation* 1:2–18.
- Mol, Arthur P. J. 1996. "Ecological Modernisation and Institutional Reflexivity: Environmental Reform in the Late Modern Age." *Environmental Politics* 5:302–23.
- . 2001. *Globalization and Environmental Reform: The Ecological Modernisation of the Global Economy*. Cambridge, MA: MIT Press.
- Mol, Arthur P. J. and David A. Sonnenfeld, eds. 2000. *Ecological Modernisation around the World: Perspectives and Critical Debates*. London: Frank Cass.
- Mol, Arthur P. J. and Gert Spaargaren. 2000. "Ecological Modernisation Theory in Debate: A Review." *Environmental Politics* 8:17–49.
- Monroe, Burt L. and Charles G. Sibley. 1993. *A World Checklist of Birds*. New Haven: Yale University Press.
- Pearman, Peter B. 2002. "Developing Regional Conservation Priorities Using Red Lists." *Biodiversity and Conservation* 11:469–85.
- Pellow, David N., Allan Schnaiberg, and Adam S. Weinberg. 2000. "Putting the Ecological Modernisation Thesis to the Test: The Promises and Performances of Urban Recycling." Pp. 109–38 in *Ecological Modernisation around the World: Perspectives and Critical Debates*, edited by A. P. J. Mol and D. A. Sonnenfeld. London: Frank Cass.
- Redclift, Michael and Colin Sage. 1998. "Global Environmental Change and Global Inequality: North/South Perspectives." *International Sociology* 13:499–516.
- Reich, Peter B., Jean Knops, and David Tillman. 2001. "Plant Diversity Enhances Ecosystem Responses to Elevated CO₂ and Nitrogen Deposition." *Nature* 410:809–12.
- Reid, Walter V. 1992. "How Many Species Will There Be?" Pp. 55–73 in *Tropical Deforestation and Species Extinction*, edited by T. C. Whitmore and J. A. Sayer. London: Chapman & Hall.
- Roberts, J. Timmons and Peter E. Grimes. 1997. "Carbon Intensity and Economic Development 1962–1991: A Brief Exploration of the Environmental Kuznets Curve." *World Development* 25:191–98.
- . 1999. "Extending the World-System to the Whole System: Toward a Political Economy

- of the Biosphere." Pp. 59–86 in *Ecology and the World-System*, edited by W. L. Goldfrank, D. Goodman, and A. Szasz. Westport, CT: Greenwood Press.
- Roberts, Richard G., Timothy F. Flannery, Linda K. Ayliffe, Hiroyuki Yoshida, Jon M. Olley, Gavin J. Prideaux, Geoff M. Laslett, Alexander Baynes, M.A. Smith, Rhys Jones, and Barton L. Smith. 2001. "New Ages for the Last Australian Megafauna: Continent Wide Extinction about 46,000 Years Ago." *Science* 292:1888–92.
- Robinson, Scott K., Frank R. Thompson, Therese M. Donovan, Donald R. Whitehead, and John Faaborg. 1995. "Regional Forest Fragmentation and the Nesting Success of Migratory Birds." *Science* 267:1987–90.
- Rosa, Eugene E., Gary E. Machlis, and Kenneth M. Keating. 1988. "Energy and Society." *Annual Review of Sociology* 14:149–72.
- Rudel, Thomas K. 1998. "Is There a Forest Transition? Deforestation, Reforestation, and Development." *Rural Sociology* 63:533–52.
- Rudel, Thomas K. and Jill Roper. 1997. "The Paths to Rain Forest Destruction: Cross-national Patterns of Tropical Deforestation." *World Development* 25:53–65.
- Schnaiberg, Allan. 1980. *The Environment: From Surplus to Scarcity*. New York: Oxford University Press.
- . 1997. "Sustainable Development and the Treadmill of Production." Pp. 72–88 in *The Politics of Sustainable Development*, edited by S. Baker, M. Kousis, D. Richardson, and S. Young. London: Routledge.
- Schnaiberg, Allan and Kenneth Gould. 1994. *Environment and Society: The Enduring Conflict*. New York: St. Martin's Press.
- Shove, Elizabeth. 1997. "Revealing the Invisible: Sociology, Energy and the Environment." Pp. 261–73 in *The International Handbook of Environmental Sociology*, edited by M. Redclift and G. Woodgate. Cheltenham: Edward Elgar.
- Smith, David. 1994. "Uneven Development and the Environment: Toward a World-System Perspective." *Humboldt Journal of Social Relations* 20:151–75.
- Smith, Fraser D. M., Robert M. May, Robin Pellew, Timothy H. Johnson, and Kerry S. Walter. 1993. "Estimating Extinction Rates." *Nature* 364:494–96.
- Spaargaren, Gert and Bas van Vliet. 2000. "Lifestyles, Consumption and the Environment: The Ecological Modernisation of Domestic Consumption." Pp. 50–76 in *Ecological Modernisation Around the World: Perspectives and Critical Debates*, edited by A. P. J. Mol and D. A. Sonnenfeld. London: Frank Cass.
- Spangenberg, Joachim H. 2001. "The Environmental Kuznets Curve: A Methodological Artifact?" *Population and Environment* 23:175–91.
- Steadman, David W. 1997. "Human-Caused Extinction of Birds." Pp. 139–61 in *Biodiversity II: Understanding and Protecting Our Biological Resources*, edited by M. L. Reaka-Kudla, D. E. Wilson, and E. O. Wilson. Washington, DC: John Henry Press.
- Stern, David I., Michael S. Common, and Edward B. Barbier. 1996. "Economic Growth and Environmental Degradation: The Environmental Kuznets Curve and Sustainable Development." *World Development* 24:1151–60.
- Stork, Nigel E. 1997. "Measuring Global Biodiversity and Its Decline." Pp. 41–68 in *Biodiversity II: Understanding and Protecting Our Biological Resources*, edited by M. L. Reaka-Kudla, D. E. Wilson, and E. O. Wilson. Washington, DC: John Henry Press.
- . 1999. "The Magnitude of Global Biodiversity Decline." Pp. 3–32 in *The Living Planet in Crisis: Biodiversity Science and Policy*, edited by J. Cracraft and F. T. Grifo. New York: Columbia University Press.
- Takacs, David. 1996. *The Idea of Biodiversity: Philosophies of Paradise*. Baltimore, MD: Johns Hopkins University Press.

- Tester, Keith. 1991. *Animals and Society: The Humanity of Animal Rights*. London: Routledge.
- United Nations Environmental Programme (UNEP). 2001. *Global Diversity Outlook*. Montreal: Secretariat of the Convention on Biological Diversity.
- Van Rossem, Ronan. 1996. "The World System Paradigm as General Theory of Development: A Cross-National Test." *American Sociological Review* 61:508–27.
- Wilcove, David S., David Rothstein, Jason Dubow, Ali Phillips, and Elizabeth Losos. 1998. "Quantifying Threats to Imperiled Species in the United States." *BioScience* 48:607–15.
- Wilson, Don E. and DeeAnn M. Reeder. 1993. *Mammals of the World: A Taxonomic and Geographic Reference*. Washington, DC: Smithsonian Institution Press.
- Wilson, Edward O. 1999. *The Diversity of Life, New Edition*. New York: Norton.
- World Bank. 1994. *World Debt Tables: External Finance for Developing Countries*. New York: World Bank.
- . 1995. *World Data 1995*. New York: World Bank.
- World Resources Institute (WRI). 1996. *Guide to Global Environment*. Washington, DC: WRI.