Investigating the Correlates of Biodiversity Loss: A Cross-National Quantitative Analysis of Threatened Bird Species

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Abstract

Sociological literature has increasingly become concerned with environmental issues. One less developed area of inquiry in this vein has been the study of anthropogenic impacts on biodiversity. We approach this topic through the study of threatened bird species by drawing on the small number of existing studies and by contributing our own original cross-sectional analysis of country-level data. Utilizing OLS regression techniques, results reveal several interaction effects that provide support for the basic theoretical propositions of world-systems theory. We find partial support for Treadmill of Production theory and the various ecological perspectives in the Malthusian tradition. Our results fail to support ecological modernization theory. Future research goals are also addressed.

Keywords: *biodiversity, bird species, environment, world-systems theory, quantitative methods, threatened species*

Introduction

The breakdown and loss of biodiversity has been increasingly recognized as a serious environmental and consequent societal problem (Roberts et al. 2003). Simply put, the more diverse and plentiful species there are, the more beneficial are the resources humans use in everyday life (Donahoe 2003). These are the resources that supply our food, medicines and other material items crucial to survival (Donahoe 2003). One view is that economic growth fuels such threats to biodiversity due to land conversion and resource exploitation that is a byproduct of a growing population whose per capita level of consumption is growing (Naidoo and Adamowicz 2001). Attention to the relationship between social forces and their impacts on the natural environment is particularly relevant as environmental impacts continue to broaden in scope and to worsen across an increasingly broad arena of the globe (Vitousek et al. 1997).

There is now broader awareness that harmful human practices cause species loss (Donahoe 2003; Hoffman 2004; Jorgenson and Rice 2005; Roberts 2001; Rosa 2001; York and Rosa 2003). Natural habitats throughout the world are losing species for reasons including, but not limited to, deforestation, pollution, loss of natural habitat areas, and human overpopulation and encroachment. These dynamics themselves ultimately reflect, or are a product of complex social forces (Burns et al. 1994, 1997, 2003; Grimes and Kentor 2003; Hoffman 2004; Jorgenson 2003, 2006a,b; Jorgenson and Rice 2005; Kick et al. 1995, 1996, 1998; Roberts 2001; Roberts and Grimes 1997, 2002; Roberts et al. 2003; Rosa 2001; York et al. 2003a, b).

Especially integral to the functioning of global ecosystems is a diverse bird population. There are about 10,000 known bird species in the world, over 1,000 threatened with extinction, which serve to pollinate flowers, disperse seeds, and act as a natural form of pest control. Birds are responsible for the vast majority of pollination and seed dispersal (Audubon Washington 2007), and there are many adverse consequences of truncated natural pollination processes including disruptions to plant and tree populations, thus impacting the key resource for humans, the production of oxygen (Pfannmuller and Green 1999). Without a thriving bird population, humans become even more dependent on the often times hazardous chemicals that serve the same functions that birds satisfy naturally. Birds are a natural predator to insects, and the loss of certain bird species could be economically devastating for forest areas, as the insect population would balloon (Audubon Washington 2007; Pfannmuller and Green 1999). Among other apparent consequences, deforestation would again impact human sustainability. Further, it is clear that birds are among the most crucial links in the food chain, serving other birds, mammals, and reptiles, as well as humans, both directly and indirectly (Pfannmuller and Green 1999).

It is noteworthy as well that the fate of the bird population serves as a proxy for a range of other environmental consequences (Pfannmuller and Green 1999). For instance, if the bird population in an area begins to decline, one plausible source is contaminated water or land. Similar to the proverbial "canary in the coalmine," the effects of bird species loss signal a wider threat to human survival (Sustainable Scale Project 2007). As ecosystem conditions worsen and bird species are lost, the economic and aesthetic penalties for humans are incalculable (Audubon Washington 2007). Sadly, in the economic realm this encompasses greater use of pest control, and reliance on artificial means of pollination and seed dispersal with their corresponding economic and environmental consequences (Pfannmuller and Green 1999).

As research in environmental degradation has grown, the particular test of biodiversity loss is generally lacking in the literature. Most research on national sources of environmental degradation conducted by social scientists focuses on greenhouse gas emissions such as carbon dioxide (see e.g., Burns et al. 1997; Grimes and Kentor 2003; Roberts et al. 2003), methane (see e.g., Jorgenson 2006a), and more generally on global climate change (see e.g., Roberts 2001; Rosa 2001; York et al. 2003b). Other social science research relies on broad environmental composite measures such as the ecological footprint (e.g., Jorgenson 2003; Jorgenson and Rice 2005), which can be utilized in producing sustainability estimates cross-nationally (Wackernagel and Rees 1996; Wackernagel et al. 2006). Yet, with few exceptions (e.g., Hoffman 2004), the literature is essentially silent on crucial issues related to anthropogenic sources of biodiversity loss.

Fortunately, the data available for bird species loss is more complete than the data for other groups (e.g., mammals, fish). This is largely due to The World Conservation Union's Red List of Threatened Species provided in accordance to the International Union for Conservation of Nature and Natural Resources (IUCN) criteria.[4] As Jenkins (2003, 1176) articulates, "Indications are that some other groups—mammals and freshwater fishes, for example—have a higher proportion of species at risk of extinction, although data for these are less complete."

Biodiversity loss has been addressed in the physical sciences literature (see e.g., Czech et al. 1998; Czech et al. 2000; Forester and Machlis 1996; Jenkins 2003; Kerr and Currie 1995; Redford and Richter 1999); absent are sociological perspectives that specify direct and indirect mechanisms of biodiversity loss. Noted physical scientist Machlis (1992, 164) states:

> *...the causes of habitat destruction are ultimately linked to demographic patterns, national histories, land tenure rules, distribution of wealth, and the sociopolitical role of agricultural monocultures such as coffee, sugar, and now cocaine. The worldwide trends toward industrialization, increased* per capita *energy consumption, and economic interdependence are also critical factors; understanding these socioeconomic trends is prerequisite for predicting the rate, extent, and consequences of biodiversity decline.*

These feelings are echoed in support by a number of scientists, urging that an interdisciplinary approach is required to assess the impact of human actions on biodiversity loss (see e.g., Machlis et al. 1994; National Research Council 1999).

We grant that a number of avenues to appraisal of such issues exist, but we have selected one line of special inquiry for this study. The main purpose of the current research, consistent with Hoffman (2004), is to uncover the relationship of sociological dynamics related to political economy as they impact biodiversity loss in general, and bird species in particular. We posit a causal connection between the economic structure of nations (i.e., gross domestic product per capita, nation's position of power in the global system) as well as related domestic factors (i.e., urban population growth, citizen and state environmentalism) with bird species loss. The next section reviews the literature that sustains our theoretical expectations.

Literature Review

There has been a long standing interest in population and sustainability that significantly pre-dates our contemporary environmental focus on issues such as global warming. Certainly, Malthus (1960[1798]), over 200 hundred years ago, warned about the geometric increase in human population and arithmetic rise in productivity. These themes have been echoed in more recent treatments of natural biodiversity, endangered species, and global population concerns (see e.g., Ehrlich 1968; Ehrlich and Ehrlich 1990, 1991). In addition, a variety of new paradigms have emerged to examine the processes and dynamic interplay of social phenomena (e.g., social organization) on the environment. We highlight these emerging theoretical orientations as they relate to our specific concerns with biodiversity.

Political Economy of the Environment

For our purposes, political economic theories of the environment are treated as including ecological Marxism (Foster 1997, 1999; Jorgenson 2003; O'Connor 1991), treadmill of production theory (Buttel 2004; Schnaiberg 1980; Schnaiberg and Gould 1994), and world-systems theory (e.g., Jorgenson and Kick 2006; Roberts and Grimes 2002). Generally, political-economic perspectives on the environment argue that the structure of capitalist markets and their need for continued expansion are driving forces in creating environmental externalities (e.g., byproducts of cutting production costs such as toxic dumping). We acknowledge that there are key differences between the theories. Among these differences is that, while most variants of ecological Marxism and treadmill of production theory adopt a national political-economic approach, world-systems theory maintains a global focus. For our purposes we are most interested in global dynamics, and we thus focus our attention on the latter.

According to Jorgenson and Kick (2003, 195), "the last two decades have witnessed a burgeoning area of inquiry in the social sciences that blends environmental sociology with the world-systems perspective." Research in this vein explores problems of greenhouse gas emissions (see e.g., Burns et al. 1997; Grimes and Kentor 2003; Jorgenson 2006a; Roberts and Grimes 1997; Roberts et al. 2003), deforestation (see e.g., Burns et al. 1994, 2003; Kick et al. 1996), and the ecological footprints of nations (see e.g., Jorgenson 2003; Jorgenson and Rice 2005; York et al. 2003a) as global social problems created to a significant degree by the accumulative logic of the modern world system.

World-systems theory itself is a politically and largely economically-based orientation used to understand the workings of the modern world-system. Drawing on earlier dependency formulations (Amin 1974, 1976; Frank 1978, 1980) and most thoroughly developed by Immanuel Wallerstein (1974; 1979; 1984; 1999), world-system theorists tend to argue that the current capitalist world economy or world-system, which emerged most clearly in the middle 15th century, continues to evolve despite enduring components in its structure. The world-system is characterized by a global division of labor, as well as unequal exchange (Emmanuel 1972) that has generated and maintained a relative structural inequality across core, semiperipheral and peripheral zones of the world-economy. Highly dependent upon geophysical location, trade resources and technology (Lenski and Nolan 1984), the structured inequality of nations and the patterns of exchange are visible in that some nations have risen to the top of the hierarchy of nations (i.e., the core) while some remain trapped in the lowest strata of under-developed, poor nations (i.e., the periphery). A third classification of countries emphasized by world-system theorists are those in the middle of the global hierarchy, the "semiperiphery," which are less prosperous than core nations but not as destitute as peripheral zones. While the processes of the world hierarchy and its maintenance are nuanced in the extreme, more world-system theorists emphasize the crucial role played by global economic dynamics (Wallerstein 1974, among many others) as well as cultural dynamics (Meyer et al. 1997), and political-military processes (Kick 1987). For a more elaborate discussion of this general view we refer the reader to a number of works elaborating this perspective (Bollen 1983; Chase-Dunn 1998; Chase-Dunn and Hall 1997a, b; Frank 1978, 1980; Kick et al. 1995, 1998; Modelski and Thompson 1996; Snyder and Kick 1979; So 1990; Terlouw 1993).

Most important for our present purposes is that in order to maintain their advantaged position in the system, core nations must continually expand their direct or indirect control over global resources, in the process creating a range of environmental externalities (such as pollution and loss of land and natural habitats). This is illustrated by a number of analyses encompassing a variety of independent variables that link the global system to numerous environmental externalities including, but not limited to, deforestation (Bunker 1984, 1985; Burns et al. 1994, 2003; Kick et al. 1996); problematic patterns in the accumulation and transfer of hazardous waste (Frey 1995, 1998); and the ecological footprint of nations (Jorgenson 2003; York et al. 2003a). The global system is foundational in our theoretical and empirical approach to environmental degradation as operationalized by biodiversity loss, in this case for bird species.

Ecological Modernization Theory

While our principle focus is on these political-economic theories of the environment, alternative approaches require examination as well. Another theory viewing capitalism as having the potential to beneficially affect the state of the environment is that of Ecological Modernization Theory (EMT). "EMT argues that the modernization process is dynamic and capable of restructuring itself along ecologically rational lines, allowing for environmental protection without renouncing economic growth" (York et al. 2003b, 35). Ecological Modernization Theory highlights the roles of state environmentalism and economic development in light of contemporary environmental problems (see e.g., Christoff 1996; Cohen 1999; Mol 1995, 2001; Mol and Spaargaren 2000; Spaargaren et al. 2000). Theories of state environmentalism posit that as industrialization progresses, so does a country's ability and willingness to minimize its negative consequences. Fisher and Freudenburg (2004) test this proposition with carbon dioxide emissions, juxtaposing environmental policies with actual emissions. In terms of state environmentalism, Fisher and Freudenburg (2004, 157) claim that, "recent literature on the environmental state sees environmental protection as becoming a basic responsibility of postindustrial states," but note most environmental sociologists and other scholars, "tend to see environmental damage as proportionate to economic prosperity." Their findings do not indicate that strong environmental policy is a predictor of positive environmental outcomes. This is in opposition to environmental state theory that posits advanced capitalist nation-states will truly make environmental protectionism their responsibility. Studies in environmental policy tend to support the claim that per capita increase in income levels will positively affect the demand for environmental quality and the amount of resources available for environmental investment (Naidoo and Adamowicz 2001).

There is debate among environmental economists regarding the existence of a Kuznet's curve between per capita income levels and environmental degradation. In assessing the relationship between economic growth and environmental outcomes, several researchers (Beckerman 1992) propose the existence of an Environmental Kuznet's curve (EKC). York et al. (2003b, 34) state, "The EKC is an inverted U-shaped curve....the EKC predicts a relationship between economic development and environmental impacts, where economic growth initially increases impacts but reaches a turning point, after which further development brings a decline in impacts." This orientation views society as being capable of rationally controlling environmental adversities in advanced capitalist states. Studies have shown that in some cases, environmental degradation is the worst in the semiperipheral zones. Some research has led to the inference of an environmental "Kuznets" effect in which there is a non-linear relationship between development variables (e.g., economic growth, urbanization) and environmental degradation (e.g., Bergesen and Bartley 2000; Burns et al. 1994, 1997; Erhhardt-Martinez 1998, 1999; Ehrhardt-Martinez et al. 2002; Kick et al. 1996; Roberts and Grimes 1997). However, "most cross-national studies of ...environmental degradation fail to support ecological modernization theory" (Jorgensen 2006a, 1781; see also Burns et al. 1997; Jorgensen and Rice 2005; Roberts et al. 2003) and, "previous studies supporting the EKC suffered from methodological and interpretation problems" (Naidoo and Adamowicz 2001, 1022).

Human Ecological Perspectives

A final perspective highlights that environmental problems are not purely born out of industrialization or the parallel growth in consumption and production, but instead are the result of human ecological factors. An example of this is the IPAT model (Ehrlich and Holdren 1971), which postulates that environmental impacts (I) are a multiplicative combination of: population numbers (P), affluence or consumption levels (A), and technological development (T). Using an abbreviated and stochastic version of this model, Dietz and Rosa (1994) test the impact of population and affluence on carbon dioxide emissions. Their analysis shows affluence to be a strong starting point for understanding the dynamics of carbon dioxide emissions. In later research, York, Rosa and Dietz (2003a, b) assess the impact of population, affluence and technology on environmental degradation. It is demonstrated that each factor is important and has varying impacts on the environment: "our findings suggest that population is a consistent force behind GHG [greenhouse gas] emissions, that affluence also drives emissions, that urbanization and industrialization increase emissions" (York et al. 2003b, 31). Hence, they show the relevance of looking at human ecological factors in addition to political economic factors in the prediction of environmental outcomes.

Data and Methods

We investigate the relationship between the world-system position of nations, national attributes and consequent environmental profiles. Our current research aim is to examine the causal linkages of biodiversity loss by focusing on threatened bird species. It is our expectation that economic structure and ecological variables will have an effect. Specifically, we hypothesize that affluence, world-system position, economic structure and particular geophysical locations will have systematic, adverse effects on levels of biodiversity. Unlike the proponents of EMT or of state environmentalism, we contend that current trends of exporting environmental problems to nations outside of the core, the most affluent and developed nations, will lead to greater environmental impacts on those countries who receive the exported externalities. Informed by a range of quantitative cross-national efforts (e.g., Burns et al. 1994, 1997, 2003; Kick et al. 1995, 1996; Roberts and Grimes 1997; Rudel 1989), we hypothesize different biodiversity consequences for the core, semiperiphery and periphery. Work that examines the dynamics surrounding biodiversity loss within the modern world economy or world-system is generally lacking in social science literature; the current research serves to fill a gap by uncovering the pertinent processes and general trends.

Dependent Variable

In assessing biodiversity loss, Hoffman (2004) examines the aggregate of the number of threatened bird and mammal species at the country level. Our approach differs from Hoffman in two ways. First, we disaggregate birds and mammals, and focus solely on birds as this data is more reliable (Forester and Machlis 1996). We also differ from Hoffman in that we examine threatened as a percent of known bird species rather than examining the raw number of threatened species (WRI 2003).[5] By making the number of known species part of the dependent variable—in other words, the percent is calculated as the number of threatened divided by the number of known species—we are able to more accurately assess the influence of the remaining variables in the model (Kerr and Currie 1995). To correct for skewness and kurtosis, we transform the dependent variable into its natural log. To aide interpretation of the results, we emphasize that our dependent variable represents biodiversity loss. Thus, a positive relationship indicates the *loss* of bird species.

Independent Variables

World-Systems Theory

In order to measure world-systems position, we use the measure developed by Kick (1987). We transform this into a categorical variable consisting of core, semiperipheral, and peripheral countries. In turn, we examine these as separate dummy variables, and we test interaction effects with these variables with other independent variables explained below.

Ecological Modernization Theory

We measure environmental modernization using a combination of economic modernization variables—per capita GDP (WRI 2003) and urbanization (WRI 2003). In addition we examine a measure of state environmentalism that indicates the level of participation of a given country in international environmental treaties, following the same rationale as York et al. (2003a). However, the indicator we use is different as it is based on data from the Environmental Treaties Institute (World Conservation Union and Center for International Earth Science Information Network 2002).

Human Ecological Perspectives

The STIRPAT model was first developed by Dietz and Rosa (1994), and we will not repeat the discussion of how this model was developed, but instead refer the reader to this publication. The main variables for inclusion here—following York, Rosa, and Dietz (2003a, b)—are population (WRI 2003) and per capita GDP (WRI 2003), as an indicator of affluence.

Physical Geography

In addition to the variables mentioned above, we find it necessary to include additional controls in terms of physical geography (Espenshade 1993). First, we believe that the latitude of a given country will have an influence on the level of biodiversity, and thus the percent of threatened bird species (York et al. 2003a). In addition, the size of a country's land mass (WRI 2003) should have a positive effect on the basis that a larger land mass can potentially contain more known species (Forester and Machlis 1996; Kerr and Currie 1995). Both of these variables—latitude and land area—are thought to have a proximate relationship with biodiversity, and therefore are considered to be important control variables.

Sample and Analysis Techniques

Our sample consists of all countries (n=139) with available data on our dependent variable. This follows in the tradition of political economic research to test all countries for which the data are available and not limit the analyses to a subset of nations (e.g., developing nations). We feel the inclusion of nations from each strata of the world-system aids interpretation as social processes are likely to emerge from research that considers the world as a whole (Tilly 1984). Where data are missing for our independent variables for these countries, we use mean substitution procedures, as it is the most conservative estimation technique reducing possible errors in interpretation. Following a long tradition in the area of environmental sociology, we use OLS regression techniques to estimate the effects of each independent variable in the prediction of our dependent variable.

One possible concern about this approach is that our dependent variable—the log of the percent threatened bird species—has upper and lower bounds. While this could potentially lead to biased estimates, we find that our dependent variable has an acceptable normal distribution, as indicated by a visual inspection of the univariate scatterplot (not shown, but available upon request), and by the skewness and kurtosis to standard error ratios, .32 and 2.27, respectively (ideal ratios are close to 2 or less). Given the normal distribution of the dependent variable, we conclude that the assumptions of OLS regression have been sufficiently met. We concede that, given that the dependent variable has upper and lower bounds, other methods such as tobit regression might be appropriate. However, interpretation with tobit is not as straightforward as it is with OLS regression. Tobit regression estimates a latent variable and therefore does not estimate values of the observed variables themselves. In addition, the coefficients for tobit regression are not as intuitively meaningful, whereas unstandardized coefficients in OLS regression may in principle be used to estimate precise impacts on the dependent variable that are due to unit increases in the independent variables.

Analysis

Univariate and Bivariate Analyses

Table 1 provides the descriptive statistics for the dependent and independent variables in our analysis. In addition to considering the metric versions of these variables, we examine and substitute where appropriate the natural log transformations in order to correct for problems of extreme skewness and kurtosis. Some of our variables have non-normal distributions, and therefore do not meet the basic assumptions for OLS regression. Log-transformation of non-normally distributed variables is a common method for making such vari-

Table 1. Descriptive Statistics

						Skewness			Kurtosis		
	N	Min	Max	Mean	St. Dev.	Statistic	St. Error	Ratio	Statistic	St. Error	Ratio
Percent Threatened Birds	139	0.005	3.501	1.589	0.839	0.065	0.206	0.317	-0.927	0.408	-2.270
Land Area (In)	139	4.220	14.352	10.153	1.663	-0.114	0.206	-0.553	0.434	0.408	1.062
Arctic latitude	139	0.000	1.000	0.029	0.168						
Temperate latitude	139	0.000	1.000	0.410	0.494						
Population Size (In)	139	5.394	14.023	9.310	1.448	0.375	0.206	1.826	0.718	0.408	1.759
Per Capita GDP (In)	130	3.898	10.684	7.230	1.560	0.492	0.212	2.316	-0.599	0.422	-1.420
Percent Urban (In)	138	1.668	4.605	3.712	0.623	-1.058	0.206	-5.130	0.898	0.410	2.192
Treaty Ratification	137	20.000	283.000	86.146	48.467	1.878	0.207	9.071	3.921	0.411	9.535
Core	139	0.000	1.000	0.144	0.352						
Semipheriphery	139	0.000	1.000	0.410	0.494						

ables suitable for OLS regression, and it is the method used here.

Bivariate relationships between the independent and dependent variables identified above are reported in the zero-order correlation matrix in Table 2. This shows that the dependent variable has a weak or moderate relationship with each of the independent variables. Further examination of the zero-order correlations among the independent variables reveals potential issues of multicollinearity between per capita GDP, percent urban, treaty ratification, and world-system position. Thus, in the multivariate analyses we both monitor and address this potential problem.

In addition to the zero-order bivariate correlations, we also examined alternative regression lines to determine if the relationships between the independent and dependent variables were non-linear. Specifically, we considered R^2 values for linear, logarithmic, quadratic, S, and exponential curves. The results (available upon request) indicate that the linear line is the best-fitting within 3 or 4% of the explained variation in each case. Therefore, we treat the assumption of linearity as having been met.

Multivariate Regression Analysis

Main Effects

We begin our analysis with an examination of the full or saturated main effects model, shown in Model 1 of Table 3. This includes all of the variables in our analysis and explains nearly 40% of the variation in the percent of threatened bird species. The highest statistically significant standardized betas are population, treaty ratification, temperate latitude, per capita GDP, and the semiperiphery world-system position dummy variable. Not statistically significant are percent urban, land area, and the core dummy variable.

However, this model reveals that the inclusion of both per capita GDP and the World System Position dummy variables creates a high level of multicollinearity for this sample of countries, as indicated by high VIFs (Variance Inflation Factors). Therefore, a choice must be made as to which variable should be removed and which variable(s) should remain. From a theoretical standpoint, we are most interested in differential world-system effects that may only be tested by keeping the WSP variables. On the other hand, in order to examine the treadmill of production and modernization theses it

Table 2. Bivariate Correlation Matrix

		X1	X2	X3	X4	X5	X6	X7	X8	X1	X12
X1	Percent Threatened Birds	1.000									
X2	Land Area (In)	0.184	1.000								
X3	Arctic latitude	-0.146	0.166	1.000							
X4	Temperate latitude	-0.290	-0.119	-0.144	1.000						
X5	Population Size (In)	0.264	0.650	0.023	0.100	1.000					
X6	Per Capita GDP (In)	-0.046	-0.043	0.199	0.329	0.052	1.000				
X7	Percent Urban (In)	-0.134	0.038	0.151	0.375	0.018	0.716	1.000			
X8	Treaty Ratification	-0.235	0.118	0.204	0.326	0.344	0.687	0.468	1.000		
X9	Core	-0.102	-0.092	0.175	0.283	0.087	0.755	0.395	0.663	1.000	
X10	Semiperiphery	0.112	0.037	0.031	0.048	-0.036	0.214	0.329	0.014	-0.342	1.000

Table 3. OLS Coefficients Predicting Threatened Bird Species: 139 Nations

	Model 1			Model 2			Model 3			Model 4			Model 5		
Independent Variables	**B**	**(b)**	**(S.E.)**	**B**	**(b)**	**(S.E.)**	**B**	**(b)**	**(S.E.)**	**B**	**(b)**	**(S.E.)**	**B**	**(b)**	**(S.E.)**
Constant	-.706		(.715)	-1.339	**	(.611)	-.018		(.590)	-.103		(.419)	-.052		(.388)
Land area per capita (log)	-.030	(.059)	(.050)	-.036	(.070)	(.050)	-.028	(.055)	-.029	(.058)	(.049)				
Latitude[a]															
Arctic	-.843	(.169)**	(.376)	-.819	(.164)**	(.377)	-.846	(.169)*	(.378)	-.851	(.170)*	(.376)	-.946	(.189)**	(.365)
Temperate	-.544	(.320)***	(.137)	-.541	(.318)***	(.138)	-.558	(.328)***	(.138)	-.566	(.333)***	(.132)	-.052	(.330)***	(.130)
Population (log)	.296	(.512)***	(.060)	.299	(.515)***	(.060)	.289	(.499)***	(.060)	.292	(.503)***	(.059)	.251	(.433)***	(.044)
GDP per capita (log)	.169	(.304)†	(.101)	-.110	(.081)	(.138)									
Percentage Urgan (log)	-.132	(.097)	(.144)	-.010	(.566)***	(.002)	-.027	(.020)	(.130)						
Treaty Ratification	-.010	(.584)***	(.002)	.278	(.501)***	(.067)	-.010	(.557)***	(.002)	-.010	(.560)***	(.002)	-.009	(.539)***	(.002)
World System Position[b]															
Core	.565	(.237)	(.422)				1.095	(.460)***	(.280)	1.076	(.452)***	(.264)	1.071	(.450)***	(.259)
Semiperiphery	.358	(.211)**	(.192)				.551	(.324)***	(.155)	.536	(.316)***	(.137)	.527	(.310)***	(.135)
Residualized Interactions															
Core*Treaty								-1.770	(.201)*	(.837)					
Semiperiphery*Treaty							1.360	(.212)*	(.611)						
R^2		.377			.360			.364			.363			.388	
Highest VIF		6.850			2.970			2.830			2.530			2.517	
Condition Number		43.08			33.12			32.98			26.41			20.03	

[a]Tropical is the reference category [b]Periphery is the reference category

† p<.10 *p<.05 **p<.01 ***p<.001

is important to first examine the alternative choice of keeping per capita GDP and removing the WSP variables. From a methodological standpoint, net of the effects of the other variables in the model, per capita GDP is barely significant while WSP is significant, thus suggesting that it may be appropriate to retain the latter.

In order to gain a better understanding of the effects of per capita GDP, Model 2 removes the WSP variables. This model reveals that, in comparison to the full model, latitude, and population have fairly robust effects. By taking WSP out of the equation, per capita GDP becomes non-significant. In this model the percent urban becomes significant and grows in magnitude. Land area remains non-significant.

Next, we examine the other choice of reducing the multicollinearity between per capita GDP and WSP by removing from the equation per capita GDP in Model 3. In comparison to the full model, latitude, population, and treaty ratification each have similar effects on the percent of threatened bird species. The statistically significant effects of both WSP dummy variables increase in magnitude as the variation that was shared with per capita GDP is now attributed to them. In comparison to Model 2, the R^2 values are essentially the same, meaning that regardless of which variable is removed—GDP or WSP—the total amount of explained variation is comparable. Also, in either of the reduced models the level of multicollinearity is acceptable, as indicated by the highest VIF values for each as well as the overall condition numbers.

Model 4 removes both per capita GDP as well as the percent urban as the latter is not found to be statistically significant in Models 1 or 3, has a moderate level of collinearity with population and per capita GDP, and because its removal does not decrease the total amount of explained variation. The remaining results of Model 4 mirror Model 3 closely. In this model, none of the VIFs exceed 3, and the condition number is acceptable, thus leading us to conclude that the main effects in this model are robust and not influenced by multicollinearity.

In summarizing the analysis of main effects we note that the effect of population is positive so that higher populations increase the percent of threatened bird species for a given country. The latitude of a country is shown to have a negative effect on the percent of threatened bird species, such that as latitude increase to temperate and arctic levels, the percent of threatened bird species diminishes. The other robust finding is the effect of treaty ratification that tends to lead to a decrease in the total percent of threatened bird species for a given country. The effect of the percent urban population is not significant in any of the models that contain world-system position, but is significant net of the other variables and per capita GDP. Finally, the effects of world-system position and GDP are difficult to disentangle when included in the same model. However, when world-system position is removed, per capita GDP is not statistically significant. Last, we observe that the main effects models assume implicitly that the effects are additive and that there are therefore not interaction effects. However, world-systems theory predicts the opposite of this by stating that social processes are conditioned by where a country resides in the world hierarchy. Thus, we next examine the non-additive effects of the above variables on the percent of threatened bird species that this theory predicts.

Interaction Effects

The analysis of main effects above shows that the effects of per capita GDP and world-system position are difficult to separate in the prediction of threatened bird species. In Model 5 we are interested in non-additive effects of world-system position, so per capita GDP is not included for its tendency to confound these results. The percent urban and land area are also not included in this analysis as they are not statistically significant (an additional interaction model that is not shown that includes the percent urban and its interaction effects confirms this). Model 5 includes the main effects of the variables analyzed above, in addition to the interaction terms of the statistically significant variables with world-system position.

To review, additive (non-interaction) models assume that the nature of the relationship between two variables will be the same at different levels of other variables in the model. In non-additive (interaction) models, we do not make this assumption. Instead, we assume that the nature of the relationship between the two variables will differ at different levels of another variable. In the present study, for instance, we test the idea that signing international environmental treaties will have conditional effects on biodiversity at different levels of world-system position. Specifically, we predict that signing such treaties will have more of an effect in core countries than will be the case in peripheral or semiperipheral countries.

The results show that the main effects of latitude, population, treaty ratification, and world-system position are robust controlling for their interaction effects.[6] The world-system position interaction effect with treaty ratification is statistically significant. In the core, the effect of treaty ratification is to decrease the percent of threatened bird species, while in the semiperiphery the effect is to increase the percent of threatened bird species.

In conclusion, and in addition to the main effects discussed earlier, our analysis reveals some important non-additive relationships. Population and treaty ratification have statistically significant effects that move in opposing directions at different levels of the world-system. In the core, higher population sizes tend to increase the percent of threatened bird species while in the semiperiphery it tends to decrease it. In the core, treaty ratification tends to decrease the percent of threatened bird species, while in the semiperiphery, it tends to increase it. In sum, it is a mistake to assume that the effects of the variables in this analysis are simply additive. In each case the non-additive effects reflect differences in both magnitude and direction at different levels of the world-system.

Discussion and Conclusion

The multivariate analysis in the preceding section sheds light on the relatively unexplored territory of biodiversity loss in sociology by examining the percent of threatened bird species at the country level. We now consider the substantive meaning of our analysis in terms of theoretical import. Our results indicate that by itself world-systems theory does a better job of predicting species loss than do the competing theories that were tested. This was true in terms of the main effects of world-system position, and was underscored by the numerous interaction effects that were found. The substantive meaning of this is that state environmentalism operates differently in the core, semiperiphery, and periphery. For instance, treaty ratification in the core was more effective at reducing the percent of threatened bird species than it was in the semiperiphery and periphery. We interpret this to mean that when core countries sign international environmental treaties, they indirectly choose to outsource dirty industrial practices to the other zones of the world-system. This in turn creates what Jorgenson (2006b) refers to as an unequal ecological exchange. More precisely, the less developed countries of the world engage in trade with the core by exporting goods produced through extractive industries. These practices then lead to a host of problems for developing countries, including biodiversity loss. Unequal ecological exchange thus refers to the high environmental price that is paid to subsidize consumption patterns in the core, as facilitated through the structure of international trade relations.

Another interesting finding is the effect of modernization on species loss. Neither per capita GDP nor the percent urban were found to have robust effects on species loss, net of state environmentalism and world-system position. This runs counter to conventional wisdom in specifying the relationships between modernization and environmental outcomes. Thus our analysis challenges the central theses of both Treadmill of Production theory and Ecological Modernization Theory. In other words, it is not pure unfettered economic growth within countries that fosters biodiversity loss, but the more complex global trade relations that exist between countries.

Related to the findings reported above is the result of our human ecological perspectives test. The lone effect of population is robust across all of our models, and this provides support for the Malthusian tradition that focuses on the aforementioned problems of overpopulation and encroachment. This emphasizes the importance of human ecological considerations in future analyses of biodiversity loss. In terms of the

STIRPAT variant of ecological research, we find that the key variables are important, but that population is a more robust predictor, while per capita GDP may confound the processes and nuances associated with different strata in the world-system hierarchy.

Finally, we would comment on some differences between this study and that by Hoffman (2004). One observation is that we assess world-system effects differently by using interaction terms rather than running separate analyses for each block of countries, as this is a better way of dealing with the problem of degrees of freedom that results from having a large number of variables and a small number of countries. Another important difference is that we analyzed bird species alone, as these data are more reliable. In addition, we examined threatened bird species as a percent of known species.

From an empirical standpoint, it is clear that more research is needed to uncover the underlying processes that lead to biodiversity loss. The conventional environmental sociology perspectives and associated measures provide a good starting point, but more is needed in the total explanation. From a practical standpoint, research on the biodiversity crisis is crucially needed, as noted by Hoffman (2004). By exploring the issue more deeply, we may be able to inform the needed policies and actions to create such a solution. This research contributes to the view Hoffman takes, in that political-economic processes are crucial to the understanding of biodiversity loss. More specifically, unequal exchange in the trade relations between the core and the other zones of the world-system is resulting in the non-core countries shouldering a heavier environmental burden. The burden exists as a direct result of core import and related consumption patterns. Future research that uncovers particular dynamics underlying environmental processes as they relate to a modern world-system is called for. Ultimately, this type of research will aide in the proscription of public policy initiatives and agendas that will maintain equilibrium between the earth and its inhabitants.

Endnotes

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4. For more information, visit www.iuncredlist.org.
5. According to the IUCN Red List Standards, the measure of threatened species is counted as belonging to a region based on the breeding home. The most common migration patterns involve flying north to breed in the temperate or Arctic summer and returning to wintering ground in warmer regions to the South. The measure of threatened species captures their habitat in the North (Standards and Petitions Working Group 2006).
6. Though not shown, we note an additional test for a model controlling for the level of deforestation in each country. It could be argued that deforestation might be included in our models as a proximal cause of bird biodiversity loss. However, we examined this possibility and found deforestation exerted no effect whatsoever on the dependent variable. We choose therefore to present the results of the most parsimonious model.

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