

Species Extinctions, Ecological Models, and Scientific Uncertainty: A Troubling Triad¹

ABSTRACT

Ecologists and conservation biologists have argued that we are in the midst of an extinction crisis. One important theoretical argument for this sixth mass extinction depends essentially on species-area models from theoretical community ecology. However, this type of argument is often considered problematic since these models are highly idealized and the data concerning rates of tropical deforestation and the extant number of species are very uncertain. I argue that in order to properly assess this type of argument we must consider several philosophical issues. We must understand what epistemic function these models are serving, what the role of risk and precaution should be in evaluating them, and what normative weight they should be given.

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1 Introduction

Many ecologists and conservation biologists argue we are on cusp of the sixth great mass extinction.² On the basis of several lines of evidence, they claim that current rates of species extinction are very high and are far greater than the “normal” background rates as found in the fossil record. One type of argument given by biologists essentially depends on species-area models used in theoretical community ecology. It is this form of argument that I evaluate in this essay.

The species-area argument goes roughly like this: There are between 5 and 30 million extant species on the Earth. Tropical rain forests are being destroyed

¹ I would like to thank Mark Ereshefsky, Edward Connor, Greg Cooper, J. M. Fritzman, Nicholas Gotelli, Stuart Pimm, and Nick Smith for helpful comments on the manuscript.

² See Ehrlich and Ehrlich 1981, Myers 1979, Wilson 1988, and Wilson 1992.

at a rate of approximately 2% per year. On the basis of the species-area model, the number of species being lost per year greatly exceeds that of the background rate of the fossil record. In the fossil record, approximately one species would be lost per year—our model predicts that between 10, 000 and 27, 000 species could be lost per year. Hence, the expected number of human-caused species extinctions is much greater than that before our appearance.

In this essay, I first present the species-area argument as given by E. O. Wilson in his book *The Diversity of Life* (1992) and as given by Robert May, John Lawton, and Nigel Stork in their essay “Assessing Extinction Rates” (1995). Second, I highlight a few of the uncertainties that are associated with species extinction arguments based on species-area curves. The uncertainties concern the model’s idealizations, data concerning tropical rainforest destruction, and the extant number of species. That is, every part of the argument. Thirdly, I explore how we should think philosophically about this argument given the uncertainties involved. I do contend that the argument is an important part of environmentalist’s rationale for preserving biodiversity. However, to appreciate what the argument can and cannot do, we must understand what functions these models are serving, what the role of risk and precaution should be in evaluating them, and what normative weight they should bear.

2 Species-Area Curves

Many biologists believe we are in an extinction crisis. Extinction, of course, is not an anomaly in the history of life. Paleontologist David Raup (1991) estimates that 99.9% of all the species that have existed have gone extinct. What

is anomalous are the projected rates of extinction. Most theoretical projections of extinctions are based on species-area models, estimated rates of habitat loss due to deforestation, and estimates of the number of extant species (13).^{3, 4} As E. O. Wilson writes,

In order to set a lower limit above which the species extinction rate can be reasonably placed, I will employ what we know about the relation between the area of habitats and the numbers of species living within them. Models of this kind are used routinely in science when direct measurements cannot be made. They yield first approximations that can be improved stepwise as better models are devised and more data added (1992, 275).

The species-area relation has quite the legacy in ecology. Ecologists have long recognized that as area increases, so does the number of species in that area. The biogeographer Phillip Darlington surmised that with every tenfold increase in area, the number of species doubles. This is known as “Darlington's rule.”⁵ As Michael Rosenzweig writes, “You will find more species if you sample a larger area. That rule has more evidence to support it than any other about species diversity” (1995, 8). Ecologist Nicholas Gotelli notes, following the work of Thomas Schoener (1976), that some have thought that the species-area relationship is one of the few laws in ecology (1995, 172). Likewise, philosopher Greg Mikkelsen (2003) has recently defended the claim that there are laws in

³ By “theoretical”, I do not mean other arguments for an extinction crisis are not “theory-laden” in some important sense. Rather, I mean that these other arguments do not depend *explicitly* on theory in sense that we are discussing. Claims can be theory-laden in many different ways because theoretical claims can be importantly different.

⁴ There are three general approaches to projecting extinction rates. First, there is the approach which utilizes species-area models. Second, there is an approach which examines how well-studied move through the categories vulnerable, endangered, probably extinct, and certified extinction on the International Union for the Conservation of Nature and Natural Resources (IUCN) “red lists”. Third, there is an approach which uses IUCN data to estimate the probability of extinction as a function of time.

⁵ However, it should be noted that Darlington was not the first to suggest this rule. Rather, H. G. Watson in 1835 remarked that in England as the area of a county increases by 10, the number of plant species increases by 2 (Connor and McCoy 2001, 397).

ecology using the species-area relation as an example.

One species-area model that fits many data sets is the power function

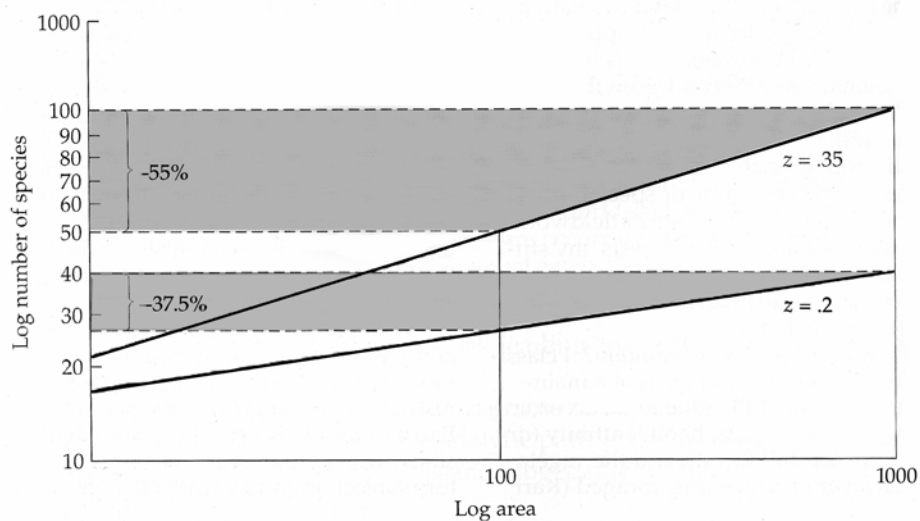
$$S = cA^z \quad (1)$$

where c is a fitted constant and z is a parameter that has values in the range 0.15 and 0.35.⁶ The value z takes depends on several factors. Most significantly, species that have small geographical distributions have higher z -values and species with larger geographical distributions have lower z -values.

We can transform equation (1) logarithmically into the following equation.⁷

$$\log(S) = \log(c) + z\log(A) \quad (2)$$

The transformation gives us a family of straight lines where $\log(c)$ is the y -intercept and z is the slope of the line. If $z = 0.3$, then we can derive Darlington's rule (Figure 2).



⁶ There are alternative models which fit some data sets better than the above power function. Another species-area model is $S = a + b \log(A)$ (Diamond and Mayr 1976).

⁷ $\log(S) = \log(cA^z) = \log(c) + \log(A^z) = \log(c) + z\log(A)$.

Figure 2. Species-area relationships based on the equation $S = cA^z$, with $c = 10$ and $z = 0.2$ or 0.35 . Note that a 90% decrease in area, from 1000 to 100 ha, would result in a predicted loss of 37.5% to 55% of the species, depending on the particular value of z . Greater z values (steeper species-area relationships) imply greater species losses per unit area (Figure taken from Meffe, Carrol, et.al. 1997).

E. O. Wilson's species-area argument occurs in his book *The Diversity of Life*.⁸ We can approximate the relation between the reduction of species and reduction of area by the following equation.

$$\Delta S = c\Delta A \quad (3)$$

where ΔS is the proportional reduction in species richness and ΔA is the proportional reduction in area. Suppose we are interested in the number of species at two distinct times, or S_{old} and S_{new} . Now, the species-area equations for the number of species at these different times are

$$\begin{aligned} S_{\text{old}} &= cA_{\text{old}}^z \\ S_{\text{new}} &= cA_{\text{new}}^z \end{aligned}$$

If we log-transform these equations we have

$$\begin{aligned} \log(S_{\text{old}}) &= \log(c) + z\log(A_{\text{old}}) \\ \log(S_{\text{new}}) &= \log(c) + z\log(A_{\text{new}}) \end{aligned}$$

After subtraction we find

$$\log(S_{\text{old}}) - \log(S_{\text{new}}) = [\log(c) + z\log(A_{\text{old}})] - [\log(c) + z\log(A_{\text{new}})]$$

Next we notice that

$$\log(S_{\text{old}}) - \log(S_{\text{new}}) = \log(S_{\text{old}} / S_{\text{new}})$$

⁸ See Wilson (1988) for a similar argument. There he uses the model $X(\text{island area})^{0.25}$. This is equivalent to $S = cA^z$ if $c = X$, $z = 0.25$. The main difference between the 1988 and 1992 arguments are the parameter estimates. In 1988, he claims $0.5(5 \times 10^6)(0.007) = 17,500$ species lost/year. He supposes that one-half of the 5 million rain forest species will perish immediately at the rate-percentage of 7% of the forests being destroyed.

and

$$\begin{aligned} [\log(c) + z\log(A_{\text{old}})] - [\log(c) + z\log(A_{\text{new}})] &= \\ z\log(A_{\text{old}}) - z\log(A_{\text{new}}) &= \\ z[\log(A_{\text{old}}) - \log(A_{\text{new}})] &= \\ z\log(A_{\text{old}} / A_{\text{new}}) & \end{aligned}$$

Therefore,

$$\log(S_{\text{old}}/S_{\text{new}}) = z\log(A_{\text{old}}/A_{\text{new}})$$

If we let $\log(S_{\text{old}}/S_{\text{new}}) = \Delta S$ and $\log(A_{\text{old}}/A_{\text{new}}) = \Delta A$, then we have equation (3)—

$$\Delta S = z\Delta A.$$

In order to determine the reduction in species, we must provide estimates for ΔA and z . By the year 1989, tropical rainforests had been reduced to approximately 8 million km². According to biologist Norman Myers, tropical rainforests were being reduced at a rate of 1.8% of their standing cover per year (Myer 1989). Since z is generally between 0.15 and 0.35, Wilson conservatively supposes $z = 0.15$ and $\Delta A = 1.8\%$ per year. Therefore, ΔS —the projected loss of species per year—equals 0.27%.

There are at least 2 million species in tropical rainforests though some estimates are as high as 15 million. Wilson supposes there are 10 million species in tropical rain forests and so our species-area model with the parameter values mentioned predicts a loss of 27,000 species per year. This is equivalent to 74 species lost per day and 3 species lost per hour. We should notice that Wilson's argument only concerns loss of species in tropical rainforests. He does not apply the model to species losses in other areas. However, this gives us a relatively conservative estimate of species loss that is still remarkably high.

Ecologists Robert May, John Lawton, and Nigel Stork in their “Assessing Extinction Rates” make an argument for a sixth mass extinction that is very similar to Wilson’s. However, their argument applies the species-area model to global losses of species. They use the same model as Wilson and they suppose z equals 0.25. Rates of deforestation have been claimed to be in the range of 0.8 – 2% per year. If $\Delta A = 0.8\%$, then our minimal projection of $\Delta S = 0.2\%$. If $\Delta A = 2\%$, then our maximal prediction of $\Delta S = 0.5\%$. So, between 0.2% and 0.5% of species will go extinct per year. May, Lawton, and Stork suppose that there are 5 million species globally. Thus, our model and estimates project a minimal loss of 10,000 species per year and projects a maximal loss of 25,000 species per year. This is equivalent to an average species’ lifespan between 200 and 500 years.⁹ Finally, this is also equivalent to losing approximately 1 to 3 species per hour.

If either of these arguments are correct, then there are many more species currently going extinct than before humans appeared. Paleontologists have argued that the average species has a lifespan of 5 to 10 million years as opposed to the 200 to 500 years our species-area model projects.¹⁰ Moreover, if these arguments are even approximately correct, then they should give us pause. How should we act in light of these projections? What policies should we adopt to avoid these expected extinctions? Before the normative issues can be addressed, we must consider how these arguments should be evaluated. There are serious uncertainties involving both the species-area model and the data on which the model is based. It is to these idealizations and uncertainties to which I now turn.

⁹ The average species lifespan is predicted to be between $5 \times 10^6 / 25,000 - 5 \times 10^6 / 10,000$.

¹⁰ One can worry about estimations of the background rate of extinction as determined by paleontologists as well. However, I am ignoring that issue for the purposes of the paper.

3 Idealizations and Uncertainties

There are a variety of worries that the species-area argument raises. In essence, they concern the following:

- (a) Idealizations of species-area models,
- (b) Uncertainties concerning rates of tropical deforestation, and
- (c) Uncertainties concerning the extant number of species.

Due to limitations of space, I will just consider some of the idealizations of species-area models though others are important as well.

As with every model, the species-area model is based on several assumptions that are known to be false.¹¹ First, the species-area model is based on the assumption that deforestation will eliminate all of the species originally in an area under consideration. This fact is hidden by the definition of “deforestation”.¹² Tropical deforestation occurs if this type of habitat is either permanently cleared or is converted to shifting cultivation cycles (Meffe et al. 1995 **page number**). However, if the area is not permanently cleared, then the plants and animals are not necessarily doomed since they may persist in fallow land (Reid 1992, 5). So, the model may overestimate the loss of species in a given habitat. It should also be said that the model ignores many other important factors such as diseases, exotic species, and over-hunting which leads the model to underestimate the rate of extinction in a given area as well.

Second, the model ignores the effects of habitat fragmentation and this is very unrealistic. Deforestation often can leave a relatively closed forest

¹¹ In Odenbaugh (2003), I argue that models are idealized representations of empirical systems and an idealization is a false assumption that is useful for some purpose to scientists.

¹² A tropical rainforest is a habitat with a tight canopy consisting of broad-leaved evergreen trees which receives at least 100 cm of rainfall per year.

susceptible to edge effects and “islandizing” effects.¹³ This occurs by converting relatively continuous habitat into patches of smaller area. In fact, as the geographical distribution of a species becomes smaller, the rate of extinction approaches the rate of area lost.¹⁴ In this respect, the species-area model underestimates the rates of species extinction. However, forest fragmentation can also increase the number of habitats which ecologists have recognized can increase the number of species in a given area. So, the model might also overestimate the rate of species extinction.

Finally, the model assumes that the loss of habitat is random with respect to area. If areas that are lost are especially high in species richness, then the model will underestimate the loss of species. If areas are lost that are especially low in species richness, then the model will overestimate the loss of species. Thus, it should be apparent that the species-area model is highly idealized.

Similarly, there is much uncertainty around the rate of tropical rainforest destruction. In the early 1980s, the United Nations’ Food and Agriculture Organization estimated that the annual tropical deforestation was 11.4 million hectares per year.¹⁵ Of this amount, 7.4 million hectares of closed forest were lost per year. In 1990, the World Resources Institute estimated that tropical forests were being lost at a rate of 20.4 million hectares every year which is an increase of 79% from the FAO’s estimates. Norman Myers in 1989 argued that the losses of closed rainforest equaled 14.2 million hectares per year in the 1980s which is a

¹³ A *closed* forest is a forest in which the trees cover a high enough proportion of the area such that a continuous grass layer cannot grow. It is *open* otherwise (Meffe 1995 **page number**).

¹⁴ If $z = 1$, then $\Delta S = \Delta A$.

¹⁵ A hectare is 10,000 square meters.

90% larger estimate than the FAOs. In 1990, the FAO updated their estimates claiming that closed and open tropical rainforests were being lost at a rate of 16.8 million hectares per year. More recently though, deforestation rates for closed tropical rainforests are 10.5 million hectares per year. So, it should be clear that we do not have stable estimates for how much closed tropical rainforest is being lost.

It is also probable that the rates will not become stable in the future. First, in some areas, population growth and increased access to forests may increase the rates of deforestation. However, rates of forest loss will more than likely decrease as forest habitats are cleared. At best, we can estimate that we are currently losing between 5 million and 15 million hectares of closed tropical rainforest per year.

Finally, biologists do not know how many species currently exist within an order of magnitude. Until fairly recently, the total number of species was thought to be between 3 and 5 million. The very crude argument for this is the following: For species of mammals and birds, there are roughly twice as many species in the tropics as there are in temperate regions. Biologists have recorded and named approximately 1.5 million species and most of these are insects. If we suppose that the ratio of insects in tropical and temperate regions is 2:1, then the number of extant species is roughly between 3 and 5 million.

Biologist Terry Erwin (**reference**) has argued though that the number of extant species is more likely to be around 30 million. Erwin has studied insect fauna in the canopies of tropical trees with an insecticidal fog which drop the insects to the forest floor. He had found that most tropical insects live in forest

canopies where sunlight is greatest and where green leaves, fruit and flowers are plenty.

He collected his data from a specific species of tree *Luehea seemannii* in Panama over several seasons and determined that there were 1,100 distinct species of beetles that live in this tree. Erwin then estimated that 20% of the herbivorous beetles were specific to the tree. Approximately 160 beetle species live in *L. seemannii* and nowhere else. He then noted that beetles represent approximately 40% of all arthropod species which leads to an estimate of around 400 canopy arthropod species per tree species. Likewise, he noted that the forest canopy was rough twice as diverse as the forest floor where generally diverse species live. Hence, the estimate of arthropod species which live on a distinct species of tropical tree is approximately 600. Finally, if there are 50,000 species of tropical trees, then there are approximately 30 million species of tropical arthropod species. Now, before we are too critical of Erwin's work we should note as does Robert May that "Erwin does not so much as answer a question as define an agenda of research" (1988, 1448). **(Rosenzweig quote)**

It is clear that we simply do not know the number of extant species. There could be as many as 5 to 30 million extant species given our best estimates and our very poor knowledge of taxa other than mammals, birds, and some insects. Clearly, there is an enormous amount of work that needs to be done by taxonomists and systematists.

It should be apparent that there are tremendous uncertainties surrounding the three crucial elements needed for generating the species-area argument for mass extinction. Namely, the model itself is idealized in important

ways. We are unsure of how much of our tropical rainforests are being lost per year. Similarly, we do not know how many species currently exist within an order of magnitude. Some might conclude that the argument is hopeless—there simply is too much that we do not know. I would disagree. However, in order to evaluate the argument we must consider philosophically what criteria ought to be used.

4 Evaluating the Arguments

In evaluating these arguments, there are three *philosophical issues* that I think we must consider. The three issues concern:

- (a) What function does the species-area model and arguments based on it serve in debates over extinction,
- (b) What role do risk and precaution play in evaluating the arguments, and
- (c) What are scientific arguments capable of accomplishing in contexts of environmental policy

Let me consider each of these issues in turn.

Models in sciences are often predictively inaccurate. This should not be surprising given that the systems that interest scientists are often extremely complex and the representations used by them are highly idealized as we have seen. Predictive inaccuracy as I will use the term can arise in one of three different ways. First, a model may be predictively inaccurate because it makes *no* predictions. The model may be so imprecisely formulated that nothing of any consequence follows from it.¹⁶ Second, a model may be predictively inaccurate because it only makes *untestable* predictions. The predictions may concern states

¹⁶ This should not be confused with the Duhem-Quine consideration that hypotheses only make predictions in conjunction with auxiliary hypotheses. The imprecise models mentioned above do not make predictions over and above what the auxiliary hypotheses and initial conditions make on their own.

of affairs so remote from us in space and time that they cannot be corroborated. There may be such uncertainty in our parameter estimates that very few of these possibilities can be ruled out. Third, a model may be predictively inaccurate because it makes *false* testable predictions. More exactly, a model given parameter and structural uncertainty makes predictions that do not have a sufficiently good fit to the phenomena. Thus, a model may be predictively inaccurate because it makes no predictions, only untestable predictions, or its testable predictions are false.

Species-area models do make predictions when conjoined with parameter estimates concerning the *z*-values, rates of tropical deforestation, and extant number of species that are independently testable. That is, one can deduce various claims about the rate of species extinctions from the models. However, some have alleged that these models do not give us *accurate* predictions—they are not *testable* or some of their testable predictions are *false* (Mann and Plummer 1993, Lomborg 2001). For example, critics Charles Mann and Mark Plummer in their book *Noah's Choices* note that among several different functional forms for the species-area relationship, no single model fits all of the data sets best (see Connor and McCoy 1979).

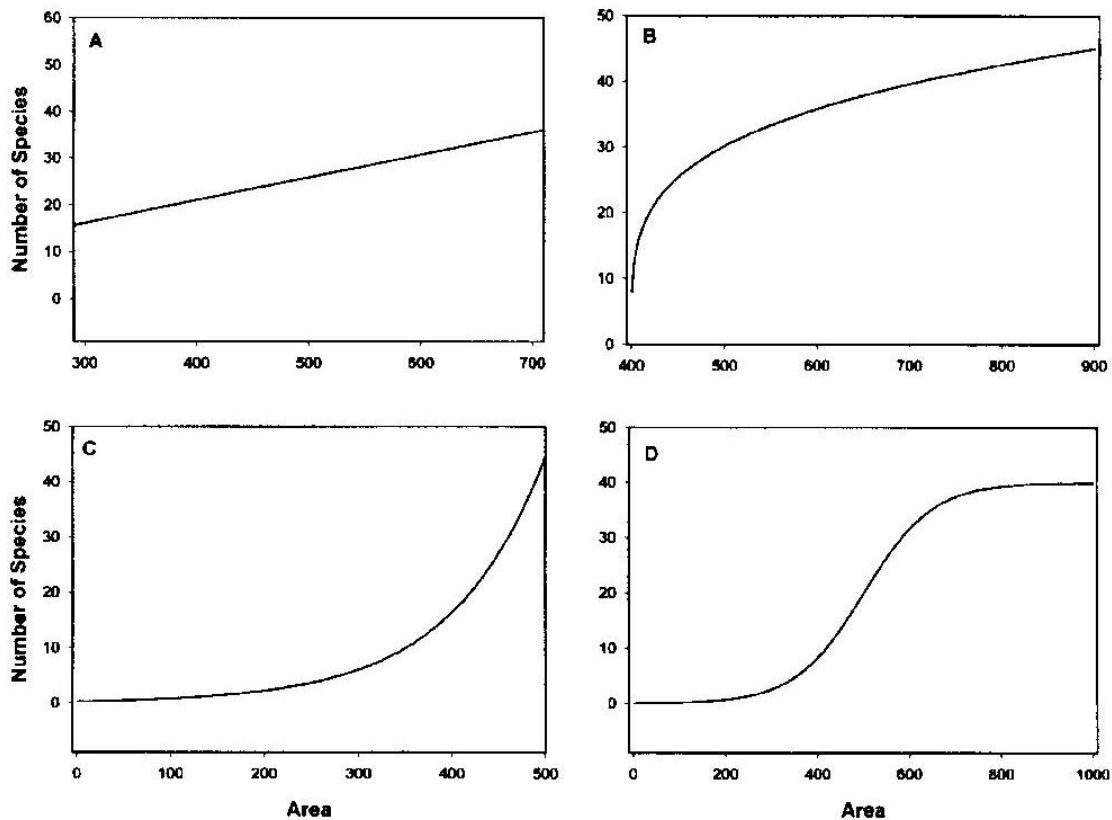


Figure 3. Shapes of species-area curves encountered in empirical studies: (A) linear species-area curve; (B) concave-downward species-area curve (linearized by the log-log transformation); (C) concave-upward species-area curve (linearized by a semilogarithmic transformation, area log-transformed); (D) sigmoid species-area curve (usually not transformed). Linear curves are encountered at intermediate spatial scales, concave downward curves at larger spatial scales, concave upward curves at small spatial scales, and sigmoid curves when a wide range of spatial scales is studied (from Connor and McCoy 2001, 402).

They write,

For the loss of the same area, the four equations would produce different predictions, and an extinction prognosticator would have no way of knowing which, if any, was right. Although these conclusions in no way contradicted the warning that shrinking habitats would produce some extinctions, they cast grave doubt on the practice of causally transforming that warning into an exact prediction (1993, 67).¹⁷

¹⁷ However, it should be noted that Simberloff when evaluating whether a mass extinction could be expected in the tropics writes, “However, the qualitative results described below are valid if species and area are related by any of the relationships proposed by Connor and McCoy (1979)” (169).

Mann, Plummer, and Lomborg have also alleged that the species-area model inaccurately predicts the number of bird extinctions from the reduction of forest in the eastern U.S (**references**). If there was a 50% reduction in area with a z -value between 0.15 and 0.3, then out of 160 bird species, there should have been between 16 and 32 species lost. However, only 5 species are claimed to have been lost. Biologists Stuart Pimm and Robert Askins (reference) have reanalyzed the data and argued that the model only applies to endemic species found in the reduced area which leaves only 28 bird species. Their adjusted predicted extinctions with a $z = 0.25$ is that 4 or 5 species should have gone extinct.

I agree that the species-area model should not be expected to give us exact predictions in every case. My reasons are probably shared with the critics. For example, our species-area model predicts how many species should go extinct with a reduction in area when the system attains its equilibrium. However, there are no agreed upon models that can tell us when such an equilibrium will be reached (however, see Diamond 1972, Terborgh 1974). We simply do not know when this “relaxation” to equilibrium will occur. Likewise, many of the extinctions that will occur in tropical rainforests will go unnoticed simply because we have classified so few of the species which reside there. Finally, the margins of error on these predictions are enormous given the uncertainties in our parameter estimates (Boecklen and Gotelli 1984). It is no surprise that our species-area model does not make accurate predictions global extinctions.

However, we must remember that claims of predictive accuracy are *contextual* claims. That is, any claim about a model's predictive accuracy is relative to three things:¹⁸

- (a) the *respects* in which the model is meant to be an accurate representation,
- (b) the *degree* to which those respects are supposed to accurately represent phenomena, and
- (c) the *system* of which the model is supposed to be an accurate representation.

So, just because the species-area models are not predictively accurate concerning global extinctions does not mean they are not accurate with respect to more localized extinctions. For example, if we knew all of the bird species in a given area and we could estimate A , z , and c , then we could determine how accurate our model is with respect to the number of species in that area. Let me give an example. Islands in the Lesser Antilles have between 11 and 42 species of land birds. In Figure 3 below, we should notice that though there is some residual spread around the curve, the curve is a good predictor of the number of species in a given island area. So, species area models *can* and *have* been corroborated by such local studies. Thus, the model does have evidence in its favor. Our skepticism should be tempered by the genuine local successes of the model.

¹⁸ See Ronald Giere (1988, 1999) for a discussion of this sort of contextualism and some of what he believes are its interesting implications. For example, he has argued for "perspectival realism" where theories are understood to provide perspectives from which the world is represented. One need not, nor cannot, evaluate a theory or model from all or no perspectives, but one must evaluate them epistemically relative to particular perspectives. Newtonian mechanics for example serves wonderfully for oceanic navigators and NASA (certain "perspectives"), but fails in other cases where, for instance, the velocity of an object approaches the speed of light (other perspectives). Giere's views count a theoretical hypothesis as realistic insofar as theoretical hypotheses are mind-independently, objectively successful or not even if they are relative to perspectives. Thus, science can never provide a totalizing, ultimately unified account of the world. See Teller (2001) as well.

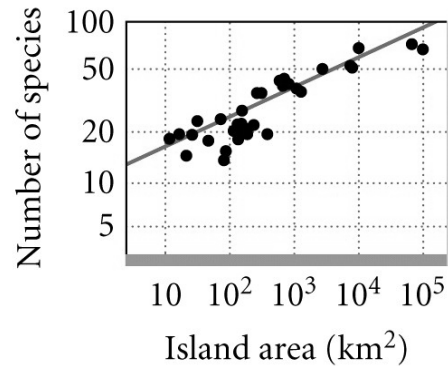


Figure 4. Species-area curve for land birds of the West Indies, including both the Greater and Lesser Antilles.

Nonetheless, critics often offer the following argument against using models like the ones we have been considering in ecology and conservation biology (Peters 1991, Shrader-Frechette and McCoy 1993). If models are going to be a successful part of the science, then they must be predictively accurate or empirically testable. However, many of these models either do not make testable empirical predictions or when they do, they are either false because of the model's idealized assumptions, or extremely vague and imprecise (see Mann and Plummer 1993, 64-5, 69-72, 75-81). Therefore, these models are not a successful part of the science. However, this argument assumes that the most important function of models is to provide empirically accurate predictions. Models can be used to do a variety of different things that do not involve predictive accuracy.

There are a variety of functions that models in population and community ecology perform but I will focus on one (Odenbaugh 2003). One of the ways in which models contribute to ecologist's understanding of the biological world is through the exploration of possibilities. Often models are tools that help biologists recognize the possible relations between natural phenomena by

tracking relationships between variables and parameters in models. These possibilities can be articulated through plausibility arguments, place constraints on what we think the causal mechanisms of the system are, or they may be the basis for theoretical hypotheses as to what ecological systems *would do* under certain circumstances. Models can help scientists successfully explore possible dynamics even when they cannot determine which of them is actual.

This I claim is exactly the role of species-area models in debates over extinction rates. We are trying to determine if a new mass extinction is *possible* given our best estimates of the number of extant species and rates of tropical deforestation. It may even be immaterial whether or not we can devise predictively accurate models, as biologist W. V. Reid writes, "...it can be argued that the exact rate of extinction is not terribly important given that current extinction rates greatly exceed background rates (1993, 55). It is in virtue of the fact that the species-area model can explore these constrained possibilities that Daniel Simberloff writes, "Nevertheless, it is a worthwhile exercise to use the species-area relationship to attempt a first guess at how many extinctions deforestation will generate in tropical forests" (1993, 78). In order to properly assess species area models we must understand how they are being used in the debate.

I would also suggest that one of the ways to deal with skeptical worries about our models is to determine whether their predictions depend *essentially* on our specific idealizations. In order to determine this, we must consider a variety of assumptions and parameter values. If the predictions of species-area models remain qualitatively the same with respect to different independent assumptions,

then the falsity of our assumptions do not matter and our predictions are *robust* with respect to these idealizations (Levins 1966, Wimsatt 1981). This is a crucial step in determining the *reliability* of the species-area models in exploring the possible species extinctions expected in the near future.

The second philosophical issue I would draw our attention to is the role of *risk* and *precaution* concerning the loss of species. Even if we cannot *establish* a loss of 27,000 species per year, we still must consider the possibility of such losses when making policy decisions. This loss must be considered both in virtue of its probability of occurrence and in virtue of the value lost with these species. More exactly and without argument, if tropical rainforest destruction will instigate a sequence of extinctions that are

- (a) statistically dependent,
- (b) can lead to serious harm to humans,
- (c) the harmful effects are irreversible, and
- (d) the benefits of the destruction are marginal,

then we are *prima facie* morally obligated to preserve those species as best we can.¹⁹ Importantly, we could have this moral obligation *even if* the extinctions do not occur. Mann and Plummer claim that “We need much more evidence to believe that the world is in the midst of an immediate extinction crisis” (1993, 72). Even if this is true, this does not entail that we should not *act* as though we

¹⁹ Here I am indebted to the work of Bryan Norton (1987, 64-72) and his discussion of “zero-infinity dilemmas”.

are in the midst of such a crisis. The species-area argument could be sufficient to convince us of the latter and not the former.²⁰

The third philosophical issue I want to make mention of concerns what can be reasonably expected from biological arguments like the one that we have been considering. As Hume apparently taught us, the naturalistic fallacy is just that—a fallacy. No moral claims follow simply from non-moral claims about matters of fact. If the conclusion of some argument is that we should preserve many if not most species thought to be imperiled by our actions, then one of the premises of this argument must be moral in nature. This I take as relatively uncontroversial. As uncontroversial as the point may be, biologists do not always pay it sufficient attention and this produces two problems.

First, if we are to speak of extinction *crisis*, then the loss of species must purportedly threaten some values at stake. But, if the conclusion of some biologist's argument is that we are in the middle of an extinction crisis, then there must be an implicit moral premise if the argument is to be any good. So, normative claims are introduced into debates over loss of biodiversity from the very beginning and it is important to put the values squarely on the table and not to assume that biology is doing all the work.²¹

²⁰ The argument above is an instance of what sometimes is termed a “precautionary principle” or maximin rule of decision-making under uncertainty. One might object that such a principle would license patently irrational actions. That is, we should prevent any sequence of events that we believe *possible*, their benefits marginal, and their consequences grave. However, I believe this objection can be blunted if we recognize that the relevant possibilities concern what is scientifically or technologically possible (not just logically possible) and that “ought implies can”. If we could not prevent some event, then we have no moral obligation to try. These two provisos would remove most, if not all, the alleged irrational actions sanctioned by such a precautionary principle. Thanks to Nick Smith and J. M. Fritzman for help on this point.

²¹ I am indebted to Sahotra Sarkar on this point.

Second, philosophers and policy-makers often place enormous weight on biological considerations. For example, many have thought that as the diversity or complexity of an ecological community increases, so must its stability (Elton 1927, MacArthur 1955, and see Odenbaugh 2001). Hence, by making sure that the communities were sufficiently rich in species, we could make sure they were stable. But, the complexity-stability hypothesis has come under much fire both theoretically and empirically (May 1973, Pimm 1983). And though it is rearing its head again in new forms (Pascala, Tilman, and Kinsig 2001), we should bear in mind that scientific theories, models, and data shift and do not always bear the normative weight we rest upon them. We may be convinced of the need to protect biodiversity. Nonetheless, we must attend to the moral philosophy that ultimately undergirds these judgments and not expect the science to do all or even most of the work. Otherwise, we can jeopardize the genuine scientific expertise of biologists (Odenbaugh 2003).

5 Conclusion

In this essay, I have considered arguments for the mass extinction of species based on species-area models from theoretical community ecology. There are many relevant idealizations in the models and uncertainties in the data used to make the theoretical projections. Nonetheless, the models are extremely important for exploring the possible rates of extinctions we can expect in the near future. Moreover, the possible rates are important to consider given the likely effects they will have on our own species well-being. However, we must be careful

in not expecting these arguments to bear more weight than they can bear especially when that weight is essentially moral.

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Appendix: z-values

Here is a representative table of z-values for different groups of organisms (from Diamond and May 1981, 229; see also MacArthur and Wilson 1967, 9).

Organism	Location	Z	Source
Beetles	West Indies	0.34	Darlington
Reptiles and amphibians	West Indies	0.30	Darlington
Birds	West Indies	0.24	Hamilton, Barth, and Rubinoff
Birds	East Indies	0.28	Hamilton, Barth, and Rubinoff
Birds	East-Central Pacific	0.30	Hamilton, Barth, Rubinoff
Ants	Melanesia	0.30	MacArthur and Wilson
Land vertebrates	Lake Michigan Islands	0.24	Preston
Birds	New Guinea Islands	0.22	Diamond
Birds	New Britain Islands	0.18	Diamond
Birds	Solomon Islands	0.09	Diamond and Mayr
Birds	New Hebrides	0.05	Diamond and Marshall
Land plants	Galapagos	0.32	Preston
Land plants	Galapagos	0.33	Hamilton, Barth, and Rubinoff
Land plants	Galapagos	0.31	Johnson and Raven
Land plants	World-wide	0.22	Preston
Land plants	British Isles	0.21	Johnson and Raven
Land plants	Yorkshire nature reserves	0.21	Usher
Land plants	California Islands	0.37	Johnson, Mason, and Raven

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