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Abstract

Climate change is already having adverse effects on animal life, and those effects are likely to prove devastating in the future. Nonetheless, the relevant harms to animals have yet to become a serious part of the analysis of climate change policy. Even if animals and species are valued solely by reference to human preferences, inclusion of their welfare dramatically increases the argument for aggressive responses to climate change. We estimate that, even under conservative assumptions about valuation, losses to nonhuman life might run into the hundreds of billions of dollars annually. Whatever the precise figure, the general conclusion is clear: An appreciation of the likely loss of animal life leads to a massive increase in the assessment of the overall damage and cost of climate change.

I. Introduction

Polar bears depend heavily on arctic sea ice for their survival. When sea ice breaks up and drifts as a result of polar warming, the bears must move northward to find stable platforms. Hunting becomes more difficult, because the bears are rarely successful in finding food on open water. Pregnant females, who must leave the ice to find their preferred terrestrial den areas, are forced to swim great distances, and fast for long periods, as the ice drifts farther from land. Even if pregnancy is successful, the bear cubs—raised in suboptimal habitats with malnourished mothers—are most unlikely to flourish.[1]

Harlequin frogs are a vibrantly colorful and active genus of frog in Central and South America. They have suffered widespread extinction in the 20th century—67% of 110 species—despite attempts at habitat protection. The culprit is apparently a pathogenic

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[1] Andrew E. Derocher, Nicholas J. Lunn, and Ian Stirling, Polar Bears in a Warming Climate, 44 Integr. Comp. Bio. 163 (2004). Polar bears were listed as threatened by extinction for the first time in the World Convervation Union's "red list" in 2006. See IUCN Red List (visited Sept. 9, 2006) <http://www.iucn.org/themes/ssc/redlist2006/redlist2006.htm>.

outbreak triggered by climate change. The chytrid fungus grows on the frogs' moist skin and eats away at their epidermis and teeth, before ultimately killing them. Tellingly, approximately 80% of the lost harlequin species have disappeared after an unusually warm preceding year.[2]

The British ring ouzel, a shy species of thrush with a high chirping call, has been in decline for most of the 20th century. Up to 58% of the population has disappeared from 1988–99, and as few as 6000 mating pairs are left. High temperatures and precipitation in the preceding year have been linked to subsequent declines in the ring ouzel population. Biologists speculate that temperature and rainfall extremes have led to a decrease in food availability.[3]

These are but three examples of the potential impact of anthropogenic climate change on animal life and welfare. While the current effects of climate change on human beings are disputed,[4] there is little question that the impact on animal life is already substantial.[5] Projections into the future are much bleaker. One particularly dramatic study, published in Nature in 2004, suggests that 15–37% of all species—potentially *millions*—could be committed to extinction by 2050 as a result of anthropogenic climate change.[6]

Yet conventional economic analysis of climate change has virtually ignored these effects on nonhuman life.[7] A highly influential study, by economists William Nordhaus and Joseph Boyer, treats the welfare cost of species loss as too small or uncertain to be quantified.[8] Bjorn Lomborg's well-known analysis of the problem simply fails to discuss

[2] J. Alan Pounds et al., Widespread amphibian extinctions from epidemic disease driven by global warming, 439 Nature 161 (2006).
[3] Colin M. Beale et al, Climate change may account for the decline in British ring ouzels, 75 Journal of Animal Ecology 826 (2006).
[4] Some studies suggest that up to 150,000 human lives are already lost annually due to climate change. See Jonathan A. Patz et al, Impact of regional climate change on human health, 438 Nature 310 (2005).
[5] See, for example, Chris D. Thomas, et al, Extinction risk from climate change, 427 Nature 145 (2004); Camille Parmesan and Gary Yohe, A globally coherent fingerprint of climate change impacts across natural systems, 421 Nature 27 (2003); and Terry L. Root, et al, Fingerprints of global warming on wild animals and plants, 421 Nature 57 (2003).
[6] Thomas, supra note _.
[7] Climate change will harm all forms of nonhuman life in natural systems. We focus on animals, however, because harm to animals will comprise the lion's share of the social welfare costs stemming from destruction to natural systems.
[8] William Nordhaus and Joseph Boyer, Warming the World (2001), ch 4.

animals at all.[9] Richard Tol, in contrast, recognizes the impact of climate change on natural ecosystems but arbitrarily stipulates a fixed $50 per person willingness to pay to "protect natural habitats" regardless of the anticipated impact.[10]

The result of these omissions and stipulations is almost certainly to underestimate, by a large margin, the monetary cost of climate change. Consider the fact that in 2004 alone, federal, state, and local governments in the United States spent over $1.4 billion to protect around 1,340 entities (a mere thousandth of the threatened loss from climate change) under the Endangered Species Act (ESA), and expenditures have increased dramatically in recent years as more species have been added to the endangered list.[11] Moreover, an expenditure measure may well underestimate the true value of endangered species protection, since most of the costs of the ESA are compliance and opportunity costs, stemming from the inability of landowners or government to engage in otherwise valuable projects. One study estimates that the true annual cost of the ESA (and thus its implied minimum value) is six times greater than nominal government expenditures[12]—implying an annual figure of $8.4 billion for 2004.

A skeptic might try to justify the neglect of animal life in climate change policy analysis in two ways. First, the value of nonhuman life—and the ESA—is heavily debated, and any particular figures will be easy to question. Second, scientific and conceptual uncertainty about climate and natural systems has clouded any attempt at quantification. In 1996, the Intergovernmental Panel on Climate Change (IPCC) wrote, "Perhaps the category in which losses from climate change could be among the largest, yet where past research has been the most limited, is that of ecosystem impacts. Uncertainties arise both because of the unknown character of ecosystem impacts, and because of the difficulty of assessing these impacts from a socioeconomic point of view and translating them into welfare costs."[13]

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[9] Bjorn Lomborg, The Skeptical Environmentalist (2001), ch. 24.

[10] Richard Tol, Estimates of the Damage Costs of Climate Change, 21 Environmental and Resource Economics 47 (2002). Tol himself notes the importance of better analysis in the area. See Tol, 55.

[11] U.S. Fish and Wildlife Service, Federal and State Endangered and Threatened Species Expenditures: Fiscal Year 2004, ii-iii (2005).

[12] Randy T. Simmons and Kimberly Frost, Accounting for Species, Property and Environment Research Center (2004), available at <http://www.perc.org/pdf/esa_costs.pdf>.

[13] IPCC, Climate Change 1995 – Economic and Social Dimensions of Climate Change (1996), 200.

In this Article, we contend that neither of these reasons can justify the failure to take account of the effects of climate change on animals. First, animal life matters, both for its own sake and because human beings care about it. As noted above, the U.S. spends billions of dollars to protect a relatively small number of species under the ESA. Contingent valuation studies consistently show high willingness-to-pay for the protection of animals. Other recent studies have suggested highly significant instrumental value for biodiversity in areas such as agriculture and medical research. Second, the scientific uncertainty over the impact of climate change on natural systems is rapidly diminishing. Many of the most important discoveries have been made only in the past few years, so previous analysts may have been right to assume that scientific knowledge was insufficient to permit precise judgments about damages or causality. But the most extreme claims of causal ambiguity are no longer tenable. And while it is an understatement to say that the magnitude of the effect of climate change on animals is still debated, its direction and general significance are not. Climate change will impose enormous costs on nonhuman life. And ignoring these costs, in evaluation of climate change policy, is no longer excusable.

This Article comes in four parts. Part I surveys the recent scientific literature that identifies the potential impact of climate change on animals and other nonhuman life. Part II explores why and how animal welfare might be counted in the evaluation of climate change regulation. Part III offers a partial and highly tentative estimate of the monetized loss from the impact of climate change on nonhuman life. Even under conservative assumptions, focused solely on extinctions and excluding other kinds of animal suffering and death, we estimate that this loss will run into the *hundreds of billions* annually. Despite the tentativeness of the particular number, the unambivalent conclusion is that prevailing estimates of the costs of climate change must be dramatically increased. In Part IV, we conclude.

II. Some Effects of Climate Change

The fact of anthropogenic climate change is no longer in serious dispute.[14] Carbon dioxide levels in the atmosphere have risen to a level probably unseen in millions of years.[15] Global temperatures have increased by 0.6°C in the 20th century, and are projected to increase an additional 1.4–5.8°C for the period from 1990 to 2100.[16] Sea levels rose by 0.1–0.2 m in the twentieth century, and are expected to rise an additional 0.09–0.88 m in the next hundred years.[17] Extreme weather events may begin to occur with increasing frequency.[18] Perhaps most ominously, some scientists have hypothesized that disruptions to the ocean's thermohaline circulation due to warming of polar waters might perversely trigger an abrupt and massive cooling event.[19]

These climatic shifts are expected to have a series of negative effects on human society. Agriculture will suffer from changes in temperature and extreme weather events. Human health will decline, as cases of heat stress increase, and diseases such as malaria spread to previously inaccessible regions. Cities such as Venice might be damaged or destroyed by changes in sea level.[20]

There is significant debate, however, about the proper accounting for these potential harms, especially for the United States. Nordhaus and Boyer, for example, report that the net cost of gradual climate change on the United States, under moderate scenarios, might be "close to zero" because of adaptive responses.[21] Mendelsohn and Neumann conclude that climate change will create net *benefits* in the U.S.—largely by boosting agricultural production.[22] In contrast, Fankhauser and Tol both find that climate

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[14] See Andrew Dessler and Edward Parson, The Science and Politics of Global Climate Change (2006); John Houghton, Global Warming: The Complete Briefing (3d ed. 2004).

[15] R.T. Pierrehumbert, Climate Change: A Catastrophe in Slow Motion, 6 Chi. J. Int'l L. 573 (2006).

[16] Percival et al., supra note _, at 1058.

[17] J.T. Houghton, et al, eds, Intergovernmental Panel on Climate Change, Climate Change 2001: The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge 2001).

[18] David R. Easterling, Climate Extremes: Observations, Modeling, and Impacts, 289 Science 2068 (2000).

[19] R.B. Alley et al, Abrupt Climate Change, 299 Science 2005 (2003).

[20] See Nordhaus and Boyer, supra note _, ch. 4.

[21] Nordhaus and Boyer, supra note _ at 32.

[22] Robert Mendelsohn and James E. Neumann, The Impact of Climate Change on the United States Economy (1999). See also Olivier Deschênes and Michael Greenstone, The Economic Impacts of Climate Change: Evidence from Agricultural Profits and Random Fluctuations in Weather (forthcoming 2006).

change will cause more than $70 billion in annual costs to the U.S.[23] Some estimates are much higher.[24] The most recent IPCC panel took a quite different approach: By shifting its focus from evaluation of costs to their mitigation, the panel implicitly assumed that the impact of climate change justified attempts to mitigate its effects *regardless* of the costs.[25]

Notably missing from the debate about the costs of climate change, however, has been a recognition of its potential impact on nonhuman life. As noted above, this is in part due to scientific uncertainty. The IPCC emphasized the "unknown character" of potential ecosystem impacts.[26] A string of recent studies, however, has served to reduce this uncertainty.

Consider one finding: A global pattern of "poleward" shifts in habitat range has emerged across ecosystems.[27] As temperatures have increased globally, species have been forced to move to cooler regions; climate change thus acts as a source of human-induced habitat loss. A recent study found that climate change had caused an average 6.1 km per decade poleward shift in range in the 20th century. The required per-decade shift would be magnified under the predictions of even greater temperature change for the 21st century. Of course, if new regions and ecosystems were always perfect and perfectly-accessible substitutes for a species' old habitat, then there would be no negative impact from such range shifting. (Even if so, many individual animals would suffer and die.) But shifting is generally imperfect: climate change can move faster than species; natural or human-made barriers can prevent shifting; and geographically-contiguous habitat is sometimes simply ecologically unsuitable.[28]

Climate change has also caused a chronological shift in "spring events," such as migrant arrival and nesting dates. Such events are occurring earlier in the season—a 2.3

[23] Samuel Fankhauser, Valuing Climate Change (1995) and Richard S. Tol, The damage costs of climate change: Towards more comprehensive calculations, 5 Environmental and Resource Economics 353 (1995).
[24] Claudia Kemfert, Global Climate Protection: Immediate Action Will Avert High Costs, 1 DIW Weekly Report 135-141 (2005); Frank Ackerman and Ian Finlayson, The Economics of Inaction on Climate Change: A Sensitivity Analysis (forthcoming 2007).
[25] See Lomborg, supra note _ at 301.
[26] See IPCC, supra note _.
[27] Camille Parmesan and Gary Yohe, A globally coherent fingerprint of climate change impacts across natural systems, 421 Nature 27 (2003).
[28] See Chris D. Thomas, et al, Extinction risk from climate change, 427 Nature 145 (2004).

day per decade shift has been demonstrated in a study of 172 species.[29] As with range shifts, this change need not have a direct negative effect. Going to work an hour earlier is not intrinsically harmful. But many species have behavioral patterns, such as migration, that are not linked to seasonal temperature change. And if chronological shifting is either absent or imperfectly linked to temperature, animals will suffer as they attempt to feed, breed, and raise their young in excessively warm or rainy seasonal conditions.[30]

Species that cannot adjust to climate change, either geographically or chronologically, face a number of severe difficulties. Heat is a direct stressor of animal physiology.[31] Rising temperatures affect the availability of vegetation and food necessary for survival.[32] Various biological mechanisms affected by temperature—such as nesting and mating—go haywire under abnormal temperature conditions.[33] Diseases triggered by threshold climate events become more common and deadly.[34] And species must expend more time and energy on thermoregulation, when their climatic environment is suboptimal.[35]

Extreme weather events, and abrupt climate change, also hit animals hard. Even aside from the direct damage of storms, periods of abnormal precipitation or drought can have adverse behavioral and physiological consequences on species ranging from elephants to turtles.[36] The most recent example of abrupt climate change stemming from disruption of the ocean's thermohaline circulation system—the Younger Dryas event 10,000–11,000 years ago—led to catastrophic ecosystem disruption and extinction.[37]

One study modeled the expected impact of gradual climate change on 1,103 species (including mammals, birds, reptiles, and insects) and predicted that a remarkable

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[29] See Parmesan and Yohe, supra note _.

[30] See, for example, Christiaan Both and Marcel E. Visser, Adjustment to climate change is constrained by arrival date in a long-distance migratory bird, 411 Nature 296 (2001).

[31] William R. Dawson, Physiological responses of animals to higher temperatures, in Global Warming and Biological Diversity 158 (Robert L. Peters & Thomas E. Lovejoy eds., 1992).

[32] Kevin M. Johnston and Oswald J. Schmitz, Wildlife and climate change: assessing the sensitivity of selected species to simulated doubling of atmospheric CO2, 3 Global Change Biology 531 (1997).

[33] Marcel E. Visser, et al, Warmer springs leads to mistimed reproduction in great tits, 265 Proc. R. Soc. Lond. 1867 (1998).

[34] Pounds, et al, supra note _.

[35] Arthur E. Dunham and Karen L. Overall, Population responses to environmental change, 34 American Zoologist 382 (1993).

[36] David R. Easterling, Climate Extremes: Observations, Modeling, and Impacts, 289 Science 2068 (2000).

[37] See R.B. Alley et al, Abrupt Climate Change, 299 Science 2005 (2003) and Dorothy Peteet, Sensitivity and rapidity of vegetational response to abrupt climate change, 97 Proc. Nat. Acad. Sci. 1359 (2000).

15–37% would be committed to extinction by 2050.[38] In contrast, over that same period, global habitat loss—the other major source of ecosystem destruction—leads to projected extinction ranges from 1–29%, with a figure in the lower end of that range being most plausible. That is, climate change might very well be more destructive to nonhuman life than *all other sources of habitat loss combined*.[39] The lead researcher of the relevant study has stated that "well over a million species could be threatened with extinction as a result of climate change."[40] In comparison, the 1,340 entities protected by the ESA are but a drop in the biodiversity bucket.

While such projections are becoming increasingly common, a great deal of scientific uncertainty remains, and the concrete estimates detailed above have been subject to many criticisms.[41] The models used for climate change impact projections, like all models, are simplifications of the real world.[42] The fact of causation is not seriously disputed, but the precise causal mechanisms for observed and anticipated species loss have been difficult to identify.[43] In addition, the specific regions and species surveyed might not be representative of the global pattern of risk. Finally, as in previous periods of catastrophic ecosystem disruption, new species will eventually move in to replace the old,[44] and some animals are even predicted to benefit from climate change.[45] It is indisputable, however, that many animals will not be so lucky. Like human beings,

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[38] Thomas, supra note _. The 15% projection is associated with low climate change scenarios for 2050, i.e. an 0.8-1.7°C increase in global temperature. The 37% projection is associated with high climate change scenarios, i.e. >2.0°C.

[39] Ibid at 146.

[40] Press release from University of Leeds, available at http://www.leeds.ac.uk/media/current/extinction.htm.

[41] See Richard J. Laddle, et al, Dangers of crying wolf over risk of extinctions, 428 Nature 799 (2004).

[42] An alternative and recently released extinction study takes a different approach from the Thomas study, by focusing on expected loss of vegetation as a proxy for extinction. The reported extinction range is 1-43%. Jay R. Malcolm, et al, Global Warming and Extinctions of Endemic Species from Biodiversity Hotspots, 20 Conservation Biology 538 (2006). We focus on the Thomas figures because the Malcolm study is likely to under-report extinctions, since it analyzes biodiversity effects only when a vegetation class changes.

[43] See J. Alan Pounds and Robert Puschendorf, Clouded futures, 427 Nature 207 (2004).

[44] The rate of new speciation, however, is exceedingly low -- a mere 3 species/year -- relative to the anticipated annual losses due to climate change. See J. John Sepkoski, Rates of speciation in the fossil record, 353 Phil. Trans. R. Soy. B 315 (1998).

[45] For examples of species that might benefit from climate change, see Johnston and Schmitz, supra note _. Even if some species benefit from climatic warming, current extinction rates -- even aside from climate change – far exceed baseline rates of new speciation. Substitution and replacement of animals or species thus will not proceed at a pace that implicates the social costs of climate change within a foreseeable timeframe. See Stuart L. Pimm et al, The Future of Biodiversity, 269 Science 347 (1995) and E.O. Wilson, Biophilia (1986).

animals will be affected by climate change. But more than with human beings, the harms to animals are already apparent, scientifically clear, and of first-order significance.

The question that remains is how to take account of this harm in policymaking. Some might be inclined to treat that harm as irrelevant. But that inclination would be extremely hard to defend in principle. On any plausible view, harm to animals matters, at least to some degree. This judgment is firmly reflected in American law. At the national level, the Endangered Species Act is complemented by the Animal Welfare Act, which is designed to protect a wide range of animals against suffering and premature death. Every state attempts to accomplish the same goal through anticruelty laws. We now turn to competing understandings of how, exactly, human societies should account for the interests of animals.

III. Accounting for Animals

In sketching the effects of climate change, we have emphasized the loss of species as such. With this emphasis, we follow the scientific literature. But there are two separate interests here. The first is species loss; the second is the suffering and death of individual animals. Both are important, though not for the same reasons, and the second deserves independent attention. If 1,000 polar bears or tigers are condemned to extended periods of distress followed by premature death, their suffering and death would matter even if many polar bears and tigers remain.

To be sure, the loss of a species is generally counted as an independent harm—in part because of the ecological and medicinal functions that species provide, in part because human beings want the opportunity to be able to see and enjoy biological diversity.[46] As we shall see, human beings are willing to pay significant amounts to protect endangered species. But our broader interest here is in harms done to individual animals. Compare, for example, the loss of the last five harlequin frogs with the loss of 1,000 polar bears. In our view, the latter loss is far worse, because it involves so much more in the way of suffering and death. More generally, we believe that much of social policy has been unduly focused on extinction to the neglect of the effects of individual

[46] See, e.g., Gardner M. Brown and James F. Shogren, Economics of the Endangered Species Act, 12 J. Econ. Per. 3 (1998).

animals. From the moral point of view, threats to both endangered and nonendangered species should matter to climate change policy.

A. Intrinsic and Instrumental Value

The most straightforward reason to account for animals is that their interests are intrinsically important. A version of this view was held by Jeremy Bentham, who compared disregard for animal welfare to slavery. In 1789, the year of ratification of America's Bill of Rights, Bentham argued[47]:

> "The day may come when the rest of the animal creation may acquire those rights which never could have been withholden from them but by the hand of tyranny. The French have already discovered that the blackness of the skin is no reason why a human being should be abandoned without redress to the caprice of a tormentor. . . . A full-grown horse or dog is beyond comparison a more rational, as well as a more conversable animal, than an infant of a day, or a week, or even month, old. But suppose the case were otherwise, what would it avail? the question is not, Can they reason? Nor, Can they talk? But, Can they suffer?"

On Bentham's view, utility is what matters, and because animals are capable of suffering, they deserve to count in the social calculus. Utilitarianism is of course highly controversial. Perhaps we should accept a form of welfarism,[48] not tied to the contested metric of utility, or instead emphasize capabilities[49] or even rights.[50] We do not mean here to endorse any particular theory of why animal life matters. Whatever the proper account, it is widely agreed that the animals should count in the social calculus. On this point, there is an incompletely theorized agreement—an agreement in support of judgments and practices, amidst disagreement or uncertainty about what accounts for them.[51] Millions of Americans treat their dogs and cats as beloved family members whose interests count independently of the interests of human beings. Many more agree that animal suffering should be reduced, even if there is no clear gain from such action to

[47] Jeremy Bentham, Introduction to the Principles of Morals and Legislation 310-11 n1 (1988).
[48] See Amartya Sen, Development As Freedom (2001).
[49] See Martha Nussbaum, Frontiers of Justice (2005).
[50] See Tom Regan, The Case for Animal Rights (1985) and Gary Francione, Your Child or the Dog? (2000).
[51] See Cass R. Sunstein, Legal Reasoning and Political Conflict (1996).

humans. Call this position the *intrinsic value* approach, because it seeks to protect animal welfare for its own sake, not because animals are a tool for the ends of human beings.

Of course, many human practices treat animals as worth little or nothing, or as solely of instrumental value. Consider, for example, the use of animals for food, and in particular the harm imposed on animals by factory farms—where chickens have their beaks seared off, cows and pigs are castrated without anesthetic, and veal calves are chained down in tiny crates for the duration of their short and miserable lives.[52] In many contexts, animal life is valued only to the extent that human beings benefit from it. To be sure, social practices cannot dispose of the normative question. Bentham himself believed that the infliction of suffering is a prima facie wrong, not to be justified by its pervasiveness; and we agree with him. But many people continue to act as if some, most, or all animal life has largely or solely instrumental value, in a way that would raise questions about the extent of human responsibility for their deaths and suffering—especially, perhaps, with respect to animals in distant lands. Even this view, however, acknowledges that animals can have value, sometimes significant value, and under the instrumental value approach, that value must be included in assessment of social policy.

B. Monetary Valuation

Whether or not animals are to be valued intrinsically or instrumentally, difficult issues remain. In the context of human life and health, American agencies assign monetary values on the basis of private "willingness to pay" (WTP).[53] For example, the Environmental Protection Agency (EPA) values a human life at about $6.1 million, a figure that comes from real-world markets.[54] Human life has intrinsic as well as instrumental value, and risks to human life can be monetized. In the workplace and for consumer goods, additional safety has a price; market evidence is investigated to identify that price. The $6.1 million figure, known as the value of a statistical life (VSL), is a product of studies of actual workplace risks, attempting to determine how much workers and others are paid to assume mortality hazards. Suppose that people must be paid $600,

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[52] See Peter Singer, Animal Liberation (2001).
[53] See W. Kip Viscusi, Fatal Tradeoffs (New York: Oxford University Press, 1993).
[54] See Frank Ackerman and Lisa Heinzerling, Priceless: On Knowing the Price of Everything and the Value of Nothing (New York: The New Press, 2003).

on average, to eliminate risks of 1/10,000. If so, the VSL would be said to be $6 million. Where market evidence is unavailable, agencies often produce monetary valuations on the basis of contingent valuation surveys, which ask people how much they are willing to pay to eliminate or reduce certain risks. Drawing on market evidence and contingent valuation studies, the EPA has recently valued a case of chronic bronchitis at $260,000, an emergency hospital visit for asthma at $9,000, hospital admission for pneumonia at $13,400, a lost work-day at $83, and a specified decrease in visibility at $14.[55]

Can similar tools be used to determine the value of a statistical life for animals? No labor markets are available to provide compensating differential studies of mortality risk. A contingent valuation study would be infeasible. Polar bears do not have money, and they cannot tell us how much they care about arctic sea ice. We might be tempted to apply existing market and contingent valuation studies to animals, valuing them at some fraction of human beings. But if so, an appropriate scaling factor would have to be determined, and any such factor might well seem arbitrary. What weight should a frog's life or health have relative to that of a wolf, eagle, or human being?

An alternative approach is to value animals by reference to human preferences, turned into monetary equivalents. Economists typically make the relevant assessments by inquiring into use and non-use value—a division that corresponds closely to the distinction between instrumental and intrinsic value. Use value includes, for example, the ecosystem services provided by natural life (e.g., pollination by butterflies and bees); the value of biodiversity for agriculture and medical research; and the recreational value of observing natural wildlife. Non-use value reflects the pure "existence" value of animals or species (such as the value people place on simply knowing that some polar bears will survive) and the "option" value of knowing that animals, including some members of an endangered species, are available for future use. Neither use nor non-use value need be particularly controversial,[56] even from the perspective of committed opponents of animal

[55] See Cass R. Sunstein, The Cost-Benefit State 145 (American Bar Association: Washington, DC 2002).
[56] The idea of existence value raises several puzzles. For example, it makes the value of an animal or species depend on the human population size. If biological resources are conceived of as public goods that can be nonrivalrously consumed by many humans, however, this puzzle disappears. For discussion of other concerns with the concept of existence value, see David Dana, Existence Value and Federal Preservation Regulation, 28 Harv Envl Law Rev 343 (2003).

rights. If people care about animals and are willing to pay to protect them, then animals should matter for policy regardless of their moral status.

The economic approach to valuation of animals raises many questions. Is the value of animals, or species, adequately captured by human willingness to pay for their protection? Imagine a society in which existence value were effectively zero; we might well reject the moral judgments of the people in that society, and refuse to believe that those judgments should be the basis for policy and law. Those inclined to accept this objection might nonetheless agree that when it is positive, existence value will be included in the overall calculus. If people's willingness to pay does not reflect the proper valuation of animals, it is not easy to identify the proper response. Perhaps the figures should result from processes of democratic deliberation, not from market evidence. But whatever its source, any monetary valuation of animals will inevitably be made by human beings. At the very least, we believe that use, existence, and option value, to the extent that they can be elicited, are a legitimate part of the climate change debate, and that they should be incorporated rather than neglected.

Even if this conclusion is accepted, there are severe implementation difficulties in determining the relevant monetary values. As we shall see, serious efforts have been made to generate monetary figures for the use value of species. But when the use value of animals is a public good or commons, reliable market mechanisms are unavailable for translation into monetary benefits. For non-use value, the ordinary instrument consists of contingent valuation studies, and we shall make use of such studies here. But such studies raise many problems and, if not designed carefully, will produce implausible answers. In the climate change context, the possibility of small errors is especially important: when one is talking about millions of species, even miniscule changes in the species- or individual- level analysis will lead to dramatic changes in the estimated social value or cost.

Valuation difficulties of this sort, however, are not a reason for ignoring the relevant costs entirely, particularly when the stakes are large. And just as scientific uncertainty has been reduced over time, so too has the conceptual uncertainty about the accuracy of various methods of nonmarket valuation. If there is a gap in analysis of climate change and animals, it is a gap of the literature—and not the availability of relevant facts or conceptual tools. Our initial submission is that losses of animal life should play a significant role in the debate. Let us attempt, then, to make some progress on the question of monetization.

IV. The (Animal) Costs of Climate Change

We provide here a tentative estimate of some of the social welfare costs of climate change on nonhuman life, focusing on human valuations. Because of empirical and conceptual difficulties, we do not insist on any particular figures.[57] Instead, we offer ranges designed to give a sense of the monetized value of merely one component of social loss: the loss of endangered species. The foregoing discussion should be enough to show that this loss cannot possibly capture the full value of harms to animals as a result of climate change. If suffering and death matter as such, animals that belong to nonendangered species matter as well, and the resulting losses will not be included in our analysis. But monetization of the loss of species presents the more tractable questions, because we have some information about the number of species at risk and human valuation of species loss. Our exclusion of animal death and suffering means that our ultimate figures will be far too low.

We have two minimal goals, one substantive and the other methodological. The first is to show that the numbers are high, and that they need to be considered in assessing the losses from climate change. The second is to give a sense of some of the difficulties—normative, conceptual, and empirical—involved in assigning monetary values to those losses.

A. Extinctions

Our analysis focuses, in particular, on the 15–37% projected extinction rate noted above.[58] Given the importance of this estimate, some discussion of its nature and plausibility is merited. Quantitative projections of the global impact of climate change are

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[57] Indeed, one of us is generally skeptical of cost-benefit analysis as a decision mechanism in environmental regulation; the other is a defender of considering the outcome of that analysis, without making it decisive. See, e.g., Cass R. Sunstein, Risk and Reason (2002).
[58] Thomas et al., supra note _.

necessarily difficult.[59] This is true even of the impact on economic systems, where data is abundant. But it is even harder for natural systems. Human beings lack a clear measure of the number of species.[60] Determining how each will be affected by climate change is thus a Herculean task. The approach used in extinction studies in biology focuses on generic species-area relationships (SAR) rather than specific causal mechanisms; the key assumption is that there is a systematic relationship between habitable area and survival. While this method has received some criticism,[61] it is firmly established in the biological field.

The method can be applied to climate change because global warming has the effect of reducing the habitable area of most species. Using recently-released climate change data, Thomas and his coauthors determine "climate envelopes"—climatic conditions under which particular species can survive—and predict how changes to these envelopes reduce effective habitat size. While the climatic stress for any particular animal in any particular year is small, the yearly and global accumulation of habitat loss leads to massive long-run consequences. If human beings impose a small stress on the habitat of every animal on the planet, but do so every year over a period of many decades, many of them will eventually die off.

There are, however, potential problems with our use of the extinction projections from Thomas and his coauthors, and these should be noted at the outset. First, there is the question of representativeness.[62] The 1,103 species examined by Thomas and his coauthors—while an immense, joint scientific endeavor—nonetheless represent a miniscule portion of the total number of species. The 20% of the terrestrial Earth sampled by this study, moreover, might not accurately reflect the other 80%. But in the absence of good reasons to think that generalization is flawed, reliance on such methods is plausible.

[59] See Pounds and Puschendorf, supra note _.

[60] See J.E.M. Baillie et al, 2004 IUCN Red List of Threatened Species: A Global Species Assessment (2004).

[61] See Lomborg, supra note _, at 251-257 and Owen T. Lewis, Climate change, species-area curves and the extinction crisis, 361 Phil. Trans. R. Soy. B 163 (2006).

[62] See Laddle, supra note _.

If we are to make *some* assumption about the expected losses, better to use the best available figure—representativeness concerns notwithstanding—than no figure at all.[63]

Second, and even more fundamentally, the 15–37% extinction rate gives us no information about the number or distribution of species, or the total number of animals at risk. This information is vital to a sound analysis, because the absolute number (and neurological characteristics) of creatures matters a great deal, whether intrinsic or instrumental value is emphasized. Human beings are undoubtedly willing to spend more to save some species than to save others. In addition, they are more willing to save large numbers of animals than small numbers. Our own treatment pays no attention to species-specific characteristics (which might bias our findings upwards or downwards), or to the absolute numbers of organisms (rather than species)—a serious omission on both fronts.

More specific information, however, is difficult to come by. Approximately 1.55 million species have been described and counted to date, but many more remain undiscovered.[64] Projections of the total number of species range from 5–50 million,[65] with a recent study suggesting that an even lower figure—less than 5 million—is possible.[66] In terms of taxonomic distribution, vertebrates comprise a comparatively tiny 57,739 of the 1.55 million known species. The vast majority of species are arthropods—which are a small portion of the Thomas sample (79 of 1,103 species, 69 of which are butterfly species). Finally, the absolute number of animals is virtually impossible to estimate; it is difficult to estimate population sizes of species that are not known to exist! To say the least, uncertainty of this sort is important.

A third problem with the 15–37% figure is that it provides no guidance as to the *timing* of extinctions. If we are speaking about human valuations, losing polar bears tomorrow would presumably be worse than losing them a hundred years from now.[67] But

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[63] A recent study published in Nature suggests that global patterns of species richness are highly correlated across taxons, suggesting representativeness concerns may not be very significant. See John F. Lamoreux, et al., Global tests of biodiversity concordance and the importance of endemism, 440 Nature 212 (2006).
[64] Baillie, et al, supra note _, 7.
[65] See Robert M. May, How many species are there on Earth?, 247 Science 1441 (1988).
[66] Vojtech Novotny, et al, Low host specificity of herbivorous insects in a tropical forest, 416 Nature 841 (2002).
[67] There is a significant debate, however, as to whether discounting is appropriate when it comes to human health and life. Presumably, critics would be equally concerned about animal life. See Lisa Heinzerling, Discounting Life, 108 Yale LJ 1911 (1999); Symposium, University of Chicago Law Review, forthcoming 2007.

the SAR models do not estimate the date of extinction but instead its inevitability. A predicted extinction thus might occur tomorrow, in 2050, or 2100.

Fortunately, the estimation methods we use below partially account for this chronological uncertainty. (The exception is the "use" value estimate, which we discuss below.) For example, the CV results we rely on ask individuals how much they value the prevention of a negative change in a threatened species' population, rather than immediate extinction. Similarly, the ESA expenditures we use for our "revealed preference" analysis are incurred to prevent population losses and risks of extinction in the future. If we conceive of the Thomas extinction rates as probabilistic risks that are imposed *today*, and find monetary measures that reflect risk rather than immediate extinction, then the discounting problem fades in importance. If, for example, people are now willing to pay $20 to reduce a 1/10,000 risk that will come to fruition in twenty years, then the resulting figure can be used without discounting.

Fourth, and as we have emphasized, extinction rates ignore the death and suffering of creatures that do not go extinct. This will serve to bias our estimates downward, and significantly so. Warming of polar waters will have severe consequences for polar bears, even if it does not lead to extinction. An effort to calculate human use and non-use value would take account of the relevant losses, to the extent that people cared about polar bear suffering independent of extinction risk. Global estimates of the suffering caused by climate change, however, are even harder to come by than death estimates.[68] Such estimates would require close observation of every species—certainly not possible when most species have not even been identified.

Fifth and finally, the SAR models do not fully account for the expected costs of extreme weather events[69] or abrupt climate change. Again, this will only serve to bias our results downward.

The upshot of this discussion is that, while there are significant problems in using the Thomas extinction measure, it is a useful foundation for our analysis. If we can obtain

[68] Correspondence with Prof. Chris D. Thomas, University of York (June 2, 2006).
[69] Extreme weather related to differences in mean temperature, e.g., heat waves, are accounted for. The Thomas model does not, however, account for possible increases in storm activity, year-to-year temperature variance, and other changes in climate extremes. See Thomas, supra note _.

a monetary value from that measure, it will at least identify a component of the social loss from climate change.

B. Three Assumptions

Before proceeding to our estimates, we describe three additional assumptions. First, we rely on a low-end assumption regarding the total number of species—5 million—throughout. (This is half the minimum number cited by Lomborg, for example.[70]) This figure provides a conservative baseline for evaluating the impact of climate change. The implication is that anywhere from .75–1.85 million species will be lost under climate change scenarios for 2050.

Second, for calculations that are sensitive to taxonomic distribution, we assume that all vertebrate species have been identified. Under this assumption, the 57,739 figure cited above exhausts the universe of vertebrate species. The alternative assumption is that vertebrates comprise the same portion of unknown as known species. This would increase the estimate of vertebrate species from 57,739 to around 186,000. The real number of vertebrate species is somewhere between these two figures but probably much closer to the former, as vertebrate species are more likely to be currently identified.[71] In order to avoid speculation in an area in which biologists have little information, we conservatively assume that the 57,739 figure is correct. Relying on the 15–37% extinction rate, we thus estimate that anywhere from 8,700–21,400 vertebrates eventually will be lost under climate change scenarios for 2050.[72]

Finally, we assume a linear individual and social value function for species loss in all estimates. If we are valuing animals for their own sake, i.e. intrinsically, then presumably each animal should count for approximately the same amount as the last.[73] On the other hand, the correct value or cost function for instrumental value might be

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[70] See Lomborg, supra note _.
[71] See Baillie, supra note _, at 8.
[72] We assume that the extinction rate for fish will be similar to the extinction rates for other vertebrates. Due to data limitations, Thomas et all examined only terrestrial vertebrate species; the impact of climate change on fish and other aquatic life, however, is not thought to be fundamentally divergent. See, for example, Catherine M. O'Reilly, et al, Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa, 424 Nature 733 (2003) and Allison L. Perry, et al, Climate Change and Distribution Shifts in Marine Fishes, 308 Science 1912 (2005).
[73] There might be different population sizes across species, of course, but as noted previously, data on population sizes is hard to come by.

concave or convex in species loss rather than linear. Concavity would imply diminishing marginal utility for species protection. For example, if we conceive of species protection as a consumption good, we might decide, after spending money to protect polar bears and ring ouzels, that protecting harlequin frogs "just isn't worth as much." Some experimental findings suggest that species protection is a "warm glow" good—that individuals will pay a fixed amount, and only that fixed amount, to "be part of a good cause" regardless of the expected consequences.[74] Convexity, in contrast, would imply increasing marginal costs for species loss. If we conceive of species loss as a social harm, losing one species might not harm us much—and might not elicit a high marginal willingness to pay—but losing the millionth species would leave us in a biological wasteland. It is unclear which effect should dominate, but we follow a default assumption of linearity. Ideally, contingent value surveys should be able to capture the curvature of the value or cost function, if any, but no studies to date that we are aware of have engaged in this line of research.

C. Estimates

We now proceed to our estimation analysis. We report values in two ways: by 2005 US dollars and by percentage of GDP. The two measures have independent significance. The former assumes that real willingness to pay will remain static in perpetuity. The latter implies that species protection will remain a fixed proportion of GDP; that is, as income grows, willingness to pay will grow exactly proportionately. Our own hunch is that species protection, like health and environmental protection more generally, will comprise an increasing portion of GDP, both because species protection is likely to be a "luxury good" (i.e., we will spend proportionately more on it as our wealth increases), and because species protection becomes more valuable as more species go extinct. If that is true, then both of our reporting methods will underestimate true social costs.

[74] See Tol, supra note _ at 54-55.

1. Use Value Estimates

Ecosystems provide immense value for human use. The air we breathe, the soil we farm, the plants we harvest, and the water we drink, all depend on ecosystem services. A significant portion of this value is generated by biological sources.

Two recent studies have estimated the value of natural systems for human use. First, a 1997 study published in Nature estimated the total (and largely nonmarket) annual value of ecosystem services to be around $33 trillion—around twice the value of global GDP at the time.[75] Not all of this is generated by biological sources, but the aggregate value is broken down by categories, such as food production, gas and climate regulation, water supply, and raw materials.

Previous studies of climate change have accounted for at least some of this value. For example, virtually every study of climate change has examined its impact on food production. The categories relating to natural biological processes, however, have been ignored in climate change analysis. And at least four of these categories—pollination, biological control, habitat/refugia, and genetic resources—are comprised entirely of natural biological sources.

Table 1: Value of Biological Ecosystem Services to the World

Categories	**Dollars** ($US 2005, billions)
Pollination	154
Biological Control	550
Habitat/Refugia	164
Genetic Resources	104
World Total	**973**
U.S. Total	**280**

Source: Robert Costanza et al, The value of the world's ecosystem services and natural capital, 387 Nature 253 (1997).

Summing these four, we obtain an annual value of biological services of $973 billion in 2005 dollars, for the world. Using the Thomas extinction estimate of 15–37%, the projected loss from climate change is thus $146–360 billion in annual value. Excluding habitat/refugia—which is arguably a "non-use" value—the summed value is $809 billion in 2005 dollars, and the projected loss range is $121–299 billion. If we

[75] Robert Costanza et al, The value of the world's ecosystem services and natural capital, 387 Nature 253 (1997).

assume that the United States receives a proportion of this use value equal to its proportion of 2005 global GDP, the projected loss for the U.S. alone ranges from $42–103 billion ($35–86 billion if habitat/refugia is excluded) annually, or anywhere from 0.4–1.1% of annual US GDP (0.4–0.9% if habitat/refugia is excluded).[76]

This figure underestimates the true use value of nonhuman life because many categories of eco-system services—e.g., erosion control, soil formation, and nutrient cycling—are of mixed biological and nonbiological origin.

The second study we use, published in Bioscience in 1997, avoids this under-inclusion problem by breaking down the value of *all* ecosystem services (including services of mixed biological/nonbiological origin, such as soil formation) to which biological sources contribute.[77] The reported annual value of biodiversity for the U.S. is $389 billion in 2005 dollars, and $3,572 billion for the world.

Table 2: Value of Biodiversity to the U.S. and the World

Categories	**U.S., Dollars** ($US 2005, billions)	**World, Dollars** ($US 2005, billions)
Waste Disposal	75.6	927.2
Soil Formation	6.1	30.5
Nitrogen Fixation	9.8	109.8
Bioremediation of Chemicals	27.5	147.6
Crop Breeding (Genetics)	24.4	140.3
Livestock Breeding (Genetics)	24.4	48.8
Biotechnology	3.1	7.3
Biocontrol of Pests (Crops)	14.6	122
Biocontrol of Pests (Forests)	6.1	73.2
Host Plant Resistance (Crops)	9.8	97.6
Host Plant Resistance (Forests)	1	13.4
Perennial Grains (Potential)	20.7	207.4
Pollination	48.8	244
Fishing	35.4	73.2
Hunting	14.6	30.5
Seafood	3.1	100
Other Wild Foods	0.6	219.6

[76] All economic statistics are drawn from the Bureau of Economic Analysis National Income and Product Account Tables, available at <http://www.bea.gov/bea/dn/nipaweb/index.asp>. The exception is US share of global GDP, which is taken from the CIA World Factbook, available at <https://www.cia.gov/cia/publications/factbook/index.html>. U.S. GDP percentages are calculated with reference to the year of the study.
[77] Daniel Pimentel et al, Economic and Environmental Benefits of Biodiversity, 47 BioScience 747 (1997).

Table 2: Value of Biodiversity to the U.S. and the World (continued)

Categories	**U.S., Dollars** ($US 2005, billions)	**World, Dollars** ($US 2005, billions)
Wood Products	9.8	102.5
Ecotourism	22	610
Pharmaceuticals from Plants	24.4	102.5
Forests sequestering of Carbon Dioxide	7.3	164.7
Total	**389.2**	**3572.1**

Source: Daniel Pimentel et al, Economic and Environmental Benefits of Biodiversity, 47 BioScience 747 (1997).

Here, no exclusion is necessary for our estimate, since *all* of these values are from biological sources. The projected loss from climate change is $58–144 billion, or 0.6–1.4% of GDP, in annual value for the U.S.—surprisingly close to the estimate suggested by the Costanza et al study—and $539–1,322 billion for the world. Our estimates are summarized in Table 3.

Table 3: Loss in Annual Biodiversity Use Value for the U.S.

		World Value ($US 2005, billions)	**U.S. Value** ($US 2005, billions)	**U.S. Percent** GDP
Costanza	Low Climate Change	121	35	0.4
	High Climate Change	299	86	0.9
	Low Climate Change (including Refugia)	146	42	0.4
	High Climate Change (including Refugia)	360	103	1.1
Pimentel	**Low Climate Change**	**539**	**58**	**0.6**
	High Climate Change	**1322**	**144**	**1.4**

Note: best estimate **in bold**. "Low" and "high" refer to low and high end climate change scenarios for 2050. See note _.

2. Use Value Objections

Three implicit assumptions of our analysis might be challenged. First, we assume that, in ex ante expectation, threatened species will not systematically differ in use value from nonthreatened species. It might be argued, in contrast, that valuable species tend to be more durable, or more adapted to human society, and thus less susceptible to damage from climate change. It seems rather unlikely that dogs or cats will be among the species extinguished by global warming.

While a full empirical defense of this assumption would require an inquiry beyond the scope of this paper, we believe our assumption is at least plausible. First, we have no reason to suspect that value has any inherent correlation with durability or survivability. Second, value need not imply adaptation to human society; indeed, many currently endangered species, such as some varieties of salmon and sturgeon, have been over-used to threatened status precisely because of their value.

Second, and as noted above, we assume a linear value function. That is, the first generic species lost is no more or less valuable, from an ex ante perspective, than the last. Thus, a 10% loss in species implies a 10% loss in biological use value. Some commentary, in contrast, has suggested that the biodiversity use value is concave because of redundancies in biological resources.[78] The value of biodiversity, under this view, is not heavily affected by a particular species loss, so long as there are biologically and genetically similar organisms that are not lost, i.e. the "genetic distance" between lost and surviving species is small. For example, we might not care much about the first 109 species of harlequin frog, if we know that the 110th will survive.

We have three responses to this objection. First, if threats to biologically similar organisms are correlated, as is surely the case, redundancy need not make the value function concave over its entire domain, but rather simply discrete (e.g., a stepwise function, that increases or decreases only at certain threshold points). So long as we expect one class of organisms is no more or less valuable than the next class, the linear approximation will be valid. Second, more recent commentary has challenged the "genetic distance" approach to valuing biodiversity because redundancy serves an insurance-like function against catastrophic loss. For example, if some pathogen attacks harlequin frogs, we will be better off with 110 species than 1, since the 110 species will be more likely to have some adaptive characteristic that will allow it to survive the threat.[79] More generally, the fact that two species are very similar need not make them redundant in value, if the small differences serve some vital function. Finally, to the extent that species are ecologically interdependent, protection of one species will be

[78] See Gardner M. Brown and James F. Shogren, Economics of the Endangered Species Act, 12 J. Econ. Per. 3 (1998); Martin Weitzman, On Diversity, 107 Quarterly Journal of Economics 363 (1992); and Stephen Polasky and Andrew R. Solow, On the Value of a Collection of Species, 29 Journal of Environmental Economics and Management 298 (1993).
[79] See William A. Brock and Anastasios Xepapadeas, Valuing Biodiversity from an Economic Perspective: A Unified Economic, Ecological, and Genetic Approach, 93 Am. Econ. Rev. 1597 (2003).

required to protect many others.[80] However, if our assumption here is wrong, our figure must be diminished accordingly.

A third implicit assumption in our analysis is that there is no adaptive response possible when a particular species is threatened. It might be argued, in contrast, that once a valuable species is threatened, human society will act in an ad hoc fashion to prevent its loss. The difficulty with this argument is that damage from climate change, unlike other human-caused environmental damage, is hard to mitigate on a case by case basis. The harlequin frogs discussed in the introduction provide an example a species where mitigation strategies have proven futile.[81] Protecting habitat from human intrusion does little good if climate change has already undermined the viability of a creature's habitat. And creating a biosphere or zoo for the world, with controlled environments, would seem prohibitively costly.

There are three other major sources of error in our estimates. First, we have failed to account for chronological uncertainty about species extinction. This is inevitable since, as noted above, the SAR models provide no guidance as to the timing of extinctions. If a species goes extinct in 2100, the loss in use value will be significantly less than if it goes extinct in 2007. Suppose, as seems plausible, that most of the extinctions will occur later rather than earlier. If so, the use of a standard discount rate—say, 3%—will significantly decrease the monetary figures above. On the other hand, the use of the standard discount rate is contested, and it is by no means clear that it ought to be used.[82]

Second, our absolute value estimates ignore the possibility that improved technology will either reduce or amplify the value of biodiversity. Both reduction and amplification are possible. If synthetic substitutes are found, perhaps biodiversity will be less important than it now is. On the other hand, the progress of genetic research may mean that we will find more and more valuable uses for biological resources.[83] The GDP measures simply assume that use value will grow in the same proportion as the other components of GDP—so that a 1% loss today implies a 1% loss in 2050.

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[80] See Pimentel, supra note _.
[81] See Pounds, et al, supra note _.
[82] See Ackerman and Finlayson, supra note.
[83] See, for example, Paulo Prada, Poisonous Tree Frog Could Bring Wealth to Tribe in Brazilian Amazon, N.Y. Times, May 30, 2006, at C1.

Third and finally, we assume that extinction is the only harm to global biodiversity. In reality, if 90% of a species' population is reduced, this will undermine use value nearly as much as extinction.

The first of these three errors suggests overestimation; the second suggests possible over-estimation and possible underestimation; the third suggests underestimation. For this reason, we lack confidence in our particular figures. The only unambiguous conclusion is that the costs of climate change will be seriously underestimated if account is not taken of the use value of biological resources.

3. Non-use Value

We offer two strategies for estimation of non-use value. First, we use contingent valuation studies of threatened species to estimate the monetized welfare costs of species loss from climate change. As we shall see, this estimation strategy runs into exceedingly serious problems, and one of our goals is to explain those problems. Second, we use expenditures on the ESA as a "revealed preference" measure of species value. Under both strategies we offer a range of estimates based on differing assumptions about the appropriate valuation method.

a. Contingent Valuation: Foundations

Contingent valuation studies directly elicit willingness to pay through surveys that develop a hypothetical market for public goods.[84] Survey participants are given detailed information about the resource in question, as well as the nature of the proposed protection. They are also informed of the consequences of protective inaction—suffering, population loss, extinction, and so forth. In some instances, WTP is determined through open-ended inquiry; in others, respondents are given a discrete set of payment choices, or even a single referendum-style yes/no choice for a specified dollar amount.

The virtue of the contingent valuation method is that it provides a direct measure of human valuation and avoids the potential circularity of using revealed preferences, as based on existing regulatory practices. When the question is "What amount should be

[84] For an overview of CV methodology, see Robert C. Mitchell and Richard T. Carson, Using Surveys to Value Public Goods: The Contingent Valuation Method (1988).

spent to protect animals?" it might seem most sensible to elicit people's judgments, and not to rely on current regulatory expenditures. The current expenditures might very well be too low, because of collective action problems in political action, or too high, because of interest group pressures. On the other hand, contingent valuation methods might be problematic because of "protest" valuations, framing problems, or other cognitive defects.[85]

Even with these concerns, a well-designed contingent valuation study may turn out to be the best or only available method for measuring non-use values.[86] In the area of species loss, two major contingent valuation surveys have examined individual willingness to pay. The first, by Pearce, provides values for ten major threatened species, using seven source studies.[87]

Table 4: Contingent Value of Species Protection (Pearce)

Species	**Annual Value per Person** ($US 2005)
Bald Eagle	18.48
Emerald Shiner	6.71
Grizzly Bear	27.57
Bighorn Sheep	12.81
Whooping Crane	1.79
Blue Whale	13.86
Bottlenose Dolphin	10.43
Sea Otter	12.07
Northern Elephant Seal	12.07
Humpback Whale	65.56
Total	**181.33**
Per Species	**18.13**
Total (No Humpback)	**115.77**
Per Species (No Humpback)	**12.86**

A more recent study, by Loomis and White, surveyed twenty contingent valuation studies and provides values for seventeen threatened species.[88] Where multiple estimates

[85] For potential problems with the CV method, see Daniel Kahneman and Jack L. Knetsch, Valuing Public Goods: The Purchase of Moral Satisfaction, 22 J. Env. Econ. & Man. 57 (1992); Peter A. Diamond and Jerry A. Hausman, Contingent Valuation: Is Some Number better than No Number?, 8 J. Econ. Per. 45 (1994); Daniel McFadden, Contingent Valuation and Social Choice, 76 Amer. J. Agr. Econ. 689 (1994); and Jerry A. Hausman ed., Contingent Valuation: A Critical Assessment (1993).
[86] David W. Pearce, Economics Values and the Natural World (1993).
[87] Pearce, supra note _.
[88] John B. Loomis and Douglas S. White, Economic analysis of rare and endangered species, 18 Ecological Economics 197 (1996).

for a species are provided by Loomis, we use the average value. We also convert Loomis/White's reports of one-time, lump-sum valuation into annual values (using a .10 discount rate), for the purpose of making apples to apples comparisons in our analysis.

Table 5: Contingent value of species protection (Loomis and White)

Species	**Annual Value per Household** ($US 2005)	**Annual Value per Person** ($US 2005)
Arctic Grayling/Cutthroat Trout	2.03	0.79
Atlantic Salmon	10.80	4.20
Bald Eagle	32.40	12.61
Bighorn Sheep	28.35	11.03
Gray Wolf	9.05	3.52
Grey Whale	35.10	13.66
Grizzly Bears	62.10	24.16
Humpback Whale	23.36	9.09
Monk Seal	16.20	6.30
Northern Spotted Owl	94.50	36.77
Pacific Salmon/Steelhead	85.05	33.09
Red-Cockaded Woodpecker	17.55	6.83
Sea Otter	39.15	15.23
Sea Turtle	17.55	6.83
Squawfish	10.80	4.20
Striped Shiner	8.10	3.15
Whooping Crane	47.25	18.39
Total	**539.33**	**209.85**
Per Species	**31.73**	**12.34**

One striking fact about these two surveys is that they imply per species valuations that are relatively similar. Dividing the per household measure from Loomis/White by the average size of a household (2.57)[89] leads to a per species estimate of approximately $12.34 per person annually—compared to the $18 per person measure from Pearce. Moreover, if the humpback whale outlier is removed from the Pearce survey, as Pearce himself suggests ought to be done, his survey's average drops to $12.86 per person—virtually identical to the $12.34 Loomis/White result. While there is some overlap in the CV source studies surveyed by Pearce and Loomis/White,[90] the fact that per species estimates are similar in magnitude, and not extremely sensitive to the particular species

[89] Average size of household is taken from the 2005 Current Population Survey, US Census Bureau, available at http://www.bls.gov/data/home.htm.
[90] Three of the seven surveys used by Pierce are also used by Loomis/White.

surveyed, is a comforting feature of the data. CV methods seem to be arriving at consistent average values.

On the other hand, there are also some troubling irregularities. For example, the whooping crane is valued at $1.79 in Pearce, but an order of magnitude more ($18.39 per person) in Loomis/White. Similarly, the estimated values in both studies exceed the amounts actually expended by respondents on conservation.[91] This fact, however, is as consistent with a collective action problem hypothesis as it is with an erroneous methodology. Finally, there is a strong possibility of reporting bias: researchers are probably more likely to conduct surveys for high-value than for low-value species. Indeed, two of the twenty-one species surveyed (steelhead, and the red-cockaded woodpecker) are among the ten most costly species in 2004 ESA expenditures.

One final note should be made about this data. The studies surveyed by Pearce and Loomis/White offer a variety of different population change scenarios in their queries. For example, many of the surveys were framed in terms of a *gain* to an endangered population, rather than avoidance of extinction.[92] In contrast, our analysis assumes that all elicited valuations are tied to extinction. Since valuations for extinction would presumably be higher than valuations for population loss or gain without extinction, our estimates of the cost of climate change will be biased downward.[93]

b. Contingent Value: Estimates

We now proceed to our estimation analysis. We merge the Pearce and Loomis/White data, using mean values where species are examined in both studies, to arrive at an annual per person willingness to pay of $11.84 annually for a generic species.[94] The obvious way to use this data is to multiply total social willingness to pay to protect a species by expected species loss—.75–1.85 million species. Using 2000 Census population figures, this leads to an astronomical range estimate of $2,499–6,164 trillion in annual costs for the U.S.! Of course this number should not be trusted. The most

[91] See Pearce, supra note _, at 75.
[92] Moreover, the enhanced valuation of losses relative to gains is one of the central findings of behavioral economics. See Daniel Kahneman and Amos Tversky, Prospect Theory: An Analysis of Decision under Risk, 47 Econometrica 263 (1979).
[93] Only 17 of the 43 total queries were framed in terms of extinction loss. See Loomis and White, supra note _, at 200, 201.
[94] We exclude the humpback whale outlier, as suggested by Pearce.

obvious reason is that the vast majority of the .75-1.85 million species anticipated to be lost due to climate change are arthropods (e.g., insects). In contrast, the contingent valuation studies generally focus on vertebrates such as mammals and birds. Presumably, most people will value vertebrate species more highly than, say, butterflies and beetles.

An alternative estimation method would thus exclude all nonvertebrate species, on the assumption that human beings are not willing to pay anything for them. With that exclusion, the threatened loss is 8,700–21,400 species. The range estimate drops considerably but is still extremely high—$29–71 trillion in annual costs, or anywhere from 3–7 times annual GDP. This number also raises serious difficulties; would U.S. citizens be willing to pay multiples of their current income to protect *any* number of species?

It seems, probable, therefore, that we face a problem of reporting bias: species examined by CV surveys might not be representative of species that are not. We adjust our estimate for this possibility in the following way. First, we determine a mean ESA expenditure for the fifteen domestic endangered species in our surveys. We then debias our estimate, by using ESA expenditures as a baseline. The key assumption underlying this method is that the distribution of ESA expenditures across species roughly captures the distribution of social value. Table 6 provides the species-specific expenditure data.

Table 6: ESA expenditures on surveyed species

Species	**ESA Expenditures** ($US 2005, thousands)
Atlantic Salmon	7496
Bald Eagle	9837
Bighorn Sheep	714
Blue Whale	67
Gray Wolf	6662
Grizzly Bears	7742
Humpback Whale	666
Monk Seal	2321
Northern Spotted Owl	6980
Pacific Salmon/Steelhead	117380
Red-Cockaded Woodpecker	14125
Sea Otter	734
Sea Turtle	28868
Squawfish	5732
Whooping Cranes	1757
Total	**211081**
Average	**14072.07**
Total (Excluding Steelhead)	**93701**
Average (Excluding Steelhead)	**6693**
Average (All Species in ESA)[95]	**592**
Bias Factor (Excluding Steelhead)	**11.3**

An obvious outlier in this data is the pacific salmon/steelhead, which at $117 million exceeds the next highest species by an order of magnitude. In contrast, the CV data shows that the steelhead is valued highly—the second highest in our sample—but certainly not as highly as suggested by its ESA expenditures. We thus drop the steelhead in our analysis.

Excluding the steelhead, the bias multiple we calculate is 11.3. That is, the representative species from our sample is approximately 11.3 times more valuable than the mean endangered species. Dividing our estimates of the harm of climate change by this value leads us to a revised cost range from $2.6–6.3 trillion in annual value, or anywhere from 27–66% of GDP. Our results are summarized in Table 7.

[95] The average here differs from the average ESA cost reported below because we exclude non species-specific expenditures.

Table 7: Total Contingent Value of Species Loss ($US 2005, Trillions)

	Low Climate Change	**High Climate Change**
Estimated Costs	2499	6164
Estimated Costs (Vertebrates Only)	29	71
Estimated Costs (Vertebrates Only, Adjusted for Reporting Bias)	2.6	6.3
%GDP	27%	66%

Note: %GDP is calculated relative to 1995 baseline (the year of the Loomis study) from the U.S. Bureau of Economic Analysis National Income Tables.

Even these adjusted estimates should be taken with many grains of salt. As noted above, CV methods are plagued by various anomalies. Perhaps most important is what Kahneman and Knetsch describe as the "embedding effect"—the tendency for elicited valuations to remain relatively similar across surveys, even where theory would predict dramatic differences in WTP.[96] One manifestation of this effect is the insensitivity of valuations to the size of a prospective harm; surveys often elicit similar values from respondents, whether 1, 10, or 100 of a particular good are the subject of inquiry.[97] If a CV survey were commissioned to examine popular WTP for ten species, it might very well obtain values identical to the value we use for a single species. This, of course, would greatly undermine our linear aggregation method.

For this reason, we do not believe that our estimate accurately captures human valuations, even in a first best world where collective action problems are eliminated. To say the least, people are most unlikely to devote nearly all of GDP, and much less a multiple of GDP, to the protection of nonhuman life. Individuals would not follow their initial inclination when they see the total bill. Opponents of CV will see our results as confirming evidence for the implausibility of the method. Advocates will urge more careful and contextually-sensitive inquiries.

We offer a third possibility: instead of interpreting the CV results as actual willingness to pay, we might instead understand them as clues to individuals' intuitions about the intrinsic value of nonhuman life, i.e. the welfare of animals for its own sake. Surely human society would pay many multiples of GDP to prevent *human* extinction. And some surveys suggest that individuals value foreign *human* suffering by an order of

[96] See Kahneman and Knetsch, supra note _.

[97] See William H. Desvouges et al, Measuring Natural Resource Damages with Contingent Valuation: Tests of Validity and Reliability 91-164, in Contingent Valuation: A Critical Assessment (Jerry A. Hausman ed., 1993)

magnitude more than the U.S. actually expends.[98] The fact that the United States does not spend as much as people state they would prefer for such causes—whether human or nonhuman—does not necessarily undermine the elicited figure as a normative matter, even if it does undermine it as a descriptive matter.

In short, at this point, our conclusion is lamentably vague: Americans are willing to spend a great deal to protect endangered species—and hence nonuse value, once properly monetized, is quite large.

c.. Revealed Preference

An alternative and less troublesome strategy for estimating non-use value is to use data on current ESA expenditures to protect threatened animals. A significant advantage of this data is that it reduces the problem just mentioned—that is, the aggregate figure is alert to a budget constraint, and in that sense it is much more realistic than a figure that emerges from aggregating willingness to pay for each individual species, taken one at a time.

Federal and state government expenditures on the ESA in 2004 were approximately $1.4 billion to protect 1340 entities.[99] ("Entity" and "species" have slightly different meanings in the ESA, but the differences are not significant for the purposes of our analysis.[100]) In contrast, in 1994, nominal expenditures were only $245 million. While part of the reason for this vast jump is the use of a different, and more expansive, measure for expenditures starting in 2001,[101] there is nonetheless a clear and steady trend of increased expenditures over the past decade. The seven-year period from 1994–2000 saw an approximately 150% nominal increase; the period from 2002–04

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[98] In a poll of Americans preferences for foreign aid in the federal budget, Stephen Kull found that the mean response was 14%. In fact, the federal government devotes less than 1% of its budget to aid. See Stephen Kull, Americans on Foreign Aid and World Hunger, Program on International Policy Attitudes, available at <http://www.worldpublicopinion.org/pipa/articles/btdevelopmentaidra/>.

[99] The operational categories for expenditures at the Fish and Wildlife Service include fisheries, refuge, land acquisition, law enforcement, research, listing, and consultation, among others. State agencies do not have the same formal categories, but undertake similar activity. See Fish and Wildlife Service, supra note _, at 3.

[100] "Entity" is a more narrow category than "species," so a single species might be represented by multiple entities in the endangered species list. The per species values we report, therefore, will be *underestimates*. See Fish and Wildlife Service, supra note _.

[101] In particular, nonspecific expenditures were recorded beginning in 2001. See Fish and Wildlife Service, supra note _.

(under the new measure of expenditures) saw an approximate 19% increase. (The year 2001 was an outlier in the general trend, with $2.4 billion in expenditures.)

Part of the reason for this expenditure trend is an increase in the number of listed species. In 1994, there were 914 listed organisms—there was thus a 47% increase in listed endangered or threatened species over the examined period. The per-species average, however, has jumped far more than 47%—from $.27 million per species in 1994 to $1.05 million in 2004, a 290% increase. There are at least two economic explanations for this increase: first, as social wealth increases, demand for species protection will increase, especially if environmental protection is a "luxury" good; second, as more species go extinct, preservation of a marginal species might be deemed of higher importance. It is also possible, of course, that the increase is simply the result of interest group politics.[102]

Table 8: Federal and state expenditures on ESA (nominal dollars)

Year	**Expenditures** (Millions)	**Listed Entities**	**Per Species Average** (Millions)
1994	245	914	0.27
1995	298	957	0.31
1996	286	963	0.30
1997	301	1111	0.27
1998	454	1166	0.39
1999	514	1202	0.43
2000	610	1235	0.49
2001	2442	1272	1.92
2002	1192	1285	0.93
2003	1201	1335	0.90
2004	1412	1340	1.05

Source: Fish and Wildlife Service, Federal and State Endangered and Threatened Species Expenditures: Fiscal Year 2004.

The expenditure data can be used directly to estimate a social cost for species loss from climate change. (Note that we are dealing here with the costs to Americans alone, which will bias our estimates downward.) Current expenditures on endangered species

[102] Public choice dynamics, however, could cut in the other direction as well. Widespread but relatively weak preferences generally lead to collective action problems in public good provision. See Mancur Olson, The Logic of Collective Action (1971). If collective action problems in protecting endangered species are significant, then our revealed preference measure will significantly underestimate the true value of such protection.

act as a (minimum) "revealed preference" for species loss more generally.[103] Following Simmons and Frost, we assume the true cost of the ESA (including compliance/opportunity costs) is sixfold nominal government expenditures, making the 2004 per species value approximately $6.32 million.[104] This is a conservative multiple; compliance costs in environmental regulation often dominate direct government expenditures by an order of magnitude or more.[105]

We first estimate the cost of climate change with no adjustments for taxonomic distribution. The $6.32 million per species revealed preference from 2004 implies a range estimate of $4.9–12.0 trillion annually. A serious criticism of this estimate is that it fails to account for the fact that ESA expenditures are distributed unevenly. The top 100 species account for almost 90% of the government expenditures, and the top 50 account for a little more than 75%.[106] Presumably, opportunity and compliance costs would be similarly proportioned. As long as the taxonomic distribution of species threatened by climate change is the same as the distribution of currently listed endangered species, this should not be a problem. However, this is most unlikely to be the case, as arthropods make up the vast majority of existing species but a relatively small portion of the ESA's list, and an even smaller portion of the top 100. (It is worth noting, however, that two arthropods do make the ESA top 100 list.)

A more plausible estimate thus focuses on vertebrate species. We break down expenditures by taxonomy and calculate a value for per-vertebrate loss. Notably, as with

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[103] See Don Coursey, The Revealed Demand for a Public Good: Evidence from Endangered and Threatened Species, 6 Env. Law. J. (1997).

[104] See Simmons and Frost, supra note _.

[105] The exact multiple is likely to vary significantly on a case by case basis; we proceed merely on the assumption that there is a rough correlation between government expenditures and total social costs. It is worth noting, however, that the sixfold multiple is probably very conservative. The Bonneville Power Administration in CA estimated that its compliance costs with regulations governing a single species of salmon were approximately $350 million in 1994 (compared to the mere $250 million in total expenditures for all species and government entities in that same year). See Brown and Shogren, supra note _. Similarly, regulations protecting the California coastal gnatcatcher will likely lead to compliance and opportunity costs of up to $5 billion in the period from 2003-2020. Government expenditures for the gnatcatcher, in contrast, were only around $1 million in 2004 -- suggesting up to a 294:1 ratio of true costs to expenditures. See David L. Sunding, Economic Impacts of Critical Habitat Designation for the Coastal California Gnatcatcher, California Resource Management Institute (2003), available at http://www.calresources.org/CRMICHGnatcatcherAnalysis.pdf. While the species that have been examined carefully for total social costs are unlikely to be perfectly representative, they are at least suggestive of the likely average ratio.

[106] See Fish and Wildlife Service, supra note _.

the vertebrate analysis using the CV method, we ignore impacts on nonvertebrate life. This will serve to bias our estimate downward.

Table 9: ESA Revealed Preference by Taxon

Taxonomy	# Species	2004 Expenditures ($US 2004, Millions)	2004 Percentage Share	2004 Expenditures (Adjusted)	Per Species Social Cost (6x Multiple, $US 2004, Millions)
Mammals	86	122	0.15	208	14.51
Birds	98	103	0.13	176	10.75
Reptiles	40	42	0.05	72	10.74
Amphibians	19	8	0.01	14	4.31
Fish	142	475	0.60	810	34.22
Total	**384**	**750**	**0.94**	**1280**	**19.98**
Total (Excluding Fish)	**243**	**275**	**0.34**	**470**	**11.58**

Table 9 summarizes per species values by vertebrate taxon. An obvious outlier is fish, where the annual per species revealed social value is a whopping $34 million—arguably the result of mixed use and non-use value.[107] One might question why commercial fish interests would lobby for endangered species protection rather than direct subsidies. We nonetheless calculate net social values both including and excluding fish. The results, which are not hugely divergent, are reported in Table 10.

Table 10: Costs of Climate Change to the U.S.: Revealed Preference
($US 2005, billions, %GDP in Parentheses)

	Low Climate Change	High Climate Change
Costs (No Exclusion)	4882 (39.5%)	12043 (96.9%)
Costs (Excluding Arthropods)	179 (1.4%)	439 (3.5%)
Costs (Excluding Fish)	**104 (0.8%)**	**255 (2.1%)**

Note: best estimate **in bold**.

The estimated cost including fish ranges from $179–439 billion annually, or 1.4–3.5% GDP. The estimated range excluding fish, which should be viewed as the best estimate, is $104–255 billion, or 0.8–2.1% GDP. Again, since *both* of these estimates

[107] A representative to the National Marine Fisheries Service offered three explanations for the unusually high expenditures on fish. First, many fish species have significant commercial value. Second, fish species often serve as indicators ("canaries") for the health of aquatic ecosystems. Protecting fish therefore implicitly entails protecting many other aquatic species. Third, fish implicate many diverse sectors of the economy -- fisheries, hydropower, and even the timber industry. Email to Wayne Hsiung from Marta Nammack, National Marine Fisheries Service (Sept. 8, 2006).

exclude all nonvertebrate life, they should be viewed with skepticism. However, (downwardly) biased as they are, the minimum values of these ranges are nonetheless very high—$104 billion is nearly as high as the projected annual abatement costs of Kyoto.[108]

D. Summary and Caveats

Our best estimate of the total cost of climate change in terms of species loss, including both use and non-use values, is $162–399 billion, or 1.4–3.5% GDP, using the revealed preference method. The range variance is driven by uncertainty in the global temperature projections. Thus, we can move from the high end of these cost estimates to the low end, if climate change is mitigated. (An approximately 1.2° C mitigation in expected climate change will move us from the high climate change scenario to low climate change.)

Table 11: Net Costs of Climate Change for the U.S.
($US 2005, billions, %GDP in Parentheses)

	Low Climate Change	High Climate Change
Use	58 (0.6%)	144 (1.4%)
Revealed Preference	104 (0.8%)	255 (2.1%)
Contingent Value	2565 (27%)	6310 (66%)
Total (RP)	**162 (1.4%)**	**399 (3.5%)**
Total (CV)	**2623 (27.6%)**	**6454 (67.4%)**

We can now take a fresh look at the costs and benefits of the Kyoto Protocol.[109] While there is significant debate over the effectiveness of Kyoto, some estimates anticipate mitigation of approximately 0.15° C by 2100.[110] Nordhaus and Boyer have suggested that mitigation might be as low as 0.03° C, as fossil fuel emissions shift to developing countries. The costs of Kyoto are similarly disputed, but most models suggest

[108] See William Nordhaus, Global Warming Economics, 294 Science 1283 (2001) and Terry Barker, infra note _.
[109] We focus exclusively on the most-commonly cited version of the protocol that allows permit trading between "Annex I" (largely high income) countries.
[110] Parry et al estimate 0.15° C mitigation. The WEC also predicts 0.15° C mitigation. Nordhaus and Boyer, in contrast, suggest 0.13° C in an initial paper, but predict a mere 0.03° C in mitigation in their latest models. See Martin Parry et al, Buenos Aires and Kyoto targets do little to reduce climate change impacts, 8 Global Environmental Change 285 (1998); WEC, Global Warming and Global Energy After Kyoto (1998); William Nordhaus and Joseph Boyer, Requiem for Kyoto: an economic analysis of the Kyoto Protocol, The Energy Journal 93 (1999); and Nordhaus and Boyer, Warming the World, supra note _.

annual costs of anywhere from 0–4% of GDP, with a value in the lower end of that range (<1%) being most plausible.[111] Nordhaus, a skeptic about the treaty, most recently estimated annual abatement costs of $125 billion for the U.S.—$186 billion in 2005 dollars—compared to the $18 billion estimated benefit.[112] (For comparative purposes, the U.S. budget for national defense is over $400 billion annually.[113])

If species loss (not animal loss as a whole) is included, the calculus is significantly changed. Using the revealed preference measure of willingness to pay, we estimate that that if the Kyoto Protocol reduces warming by 0.15° C, it would buy around $30 billion in annual savings, relative to its worst-case $186 billion annual cost. Even under the most conservative cost-benefit assumptions, in other words, the impact of climate change on nonhuman life alone justifies almost one sixth of the costs of the Kyoto Protocol for the United States. (Under the low, 0.03° C mitigation scenario suggested by Nordhaus and Boyer, the Protocol would buy the U.S. $6 billion in annual value.) Due to its low anticipated value for the United States, the Kyoto Protocol nonetheless continues to impose costs in excess of benefits. But it is noteworthy that the benefit-cost calculus is improved significantly by the inclusion of nonhuman life.

The picture for the rest of the world is even better. While both our contingent value and revealed preference data is drawn from U.S. sources, we can make a back-of-the-envelope calculation for the rest of the world by using U.S. proportion of global GDP as a scaling factor.[114] The predicted value of the Kyoto Protocol in protecting natural biological systems is $74 billion for the rest of the world, making the total value of the Protocol approximately $78 billion for the rest of the world.[115] The net value of the treaty for the world is still negative, at –$77 billion annually, however, given the heavy U.S. costs.

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[111] For a survey of various models, see Terry Barker and Paul Ekins, The Costs of Kyoto for the US Economy, 25 The Energy Journal 53 (2004). See also William Nordhaus, Global Warming Economics, 294 Science 1283 (2001) and Lomborg, supra note _, at 303.

[112] See Nordhaus, supra note _.

[113] See National Defense Budget for FY 2006, Office of the Undersecretary of Defense, available at <http://www.dod.mil/comptroller/defbudget/fy2006/index.html>.

[114] The key assumption in this calculation is that the rest of the world is willing to spend to protect nonhuman life in proportion to its GDP.

[115] We use Nordhaus and Boyer's 2000 data for our calculations of the benefits value of the Kyoto Protocol to the United States and the world. See Nordhaus and Boyer, supra note _, ch. 8.

Table 12: Value of Kyoto ($US 2005, Billions Annually)

U.S. Value (excluding Animals)	–185
U.S. Savings from Protection of Animals	30
U.S. Total	–155
Rest of World Value (excluding Animals)	4
Rest of World Savings from Protection of Animals	74
Rest of World Total	78
World Total (including U.S.)	–77

One large problem with our estimates of the value of Kyoto is that they presume that mitigation is permanent when, in fact, Kyoto and most other mitigation strategies will merely slow, rather than prevent, the onset of climate change.[116] Under our no-discounting assumption, this is especially problematic—if the damage will inevitably occur at some point in the near future, there is no true "savings" from mitigation. Unlike many of the other harms from climate change, moreover, additional time probably will not be useful for adaptation purposes; again, global ecosystems cannot adapt, even with human assistance, at the pace of climate change. For these reasons, our estimate of the value of Kyoto should be viewed skeptically.

It is worth reiterating that our estimates of the cost of climate change include a number of conservative assumptions. First and most notably, we have ignored any impacts of climate change short of extinction. In contrast, both the use and non-use value of nonhuman life will be dramatically affected by declines in population and suffering independent of extinction. Even species that survive will face habitat loss of up to 85%, under high-end climate change scenarios—with population declines of similar magnitude.[117] One could plausibly amplify all of our cost estimates by a substantial figure on this basis. At first glance, an 85% multiplier might be the place to start. To the extent that people place a special premium on the loss of species, however, that figure is likely to be far too high. Nonetheless, an estimate of WTP for the loss of many millions of animals would undoubtedly produce substantial figures. And if human WTP does not adequately capture that loss—as we believe—than such an estimate is itself likely to be far too low.

Second, our reported "best estimates" of non-use value have neglected nonvertebrate life entirely. This is necessary because of data limitations. CV studies tend

[116] See Nordhaus and Boyer, supra note _, at Ch. 8.
[117] Correspondence with Prof. Chris Thomas, University of York (June 22, 2006).

to examine charismatic mammals and birds rather than insects or plants. The ESA expenditures we use for revealed preference analysis cluster around a similar set of organisms. Nonvertebrates nonetheless account for approximately 5% of total ESA expenditures.[118] It might be reasonable, therefore, to increase our non-use estimates by that factor.

Third, we have made a number of assumptions that have an unquantifiable but downward impact on cost estimates. For example, we assume a low-end value for the number of species and the number of vertebrates. We ignore the impact of a possible increase in extreme weather events. And we do not even attempt to quantify the risk of catastrophic ecosystem destruction stemming from abrupt climate change. All of these factors will serve to downwardly bias our estimates.

Fourth, in our evaluation of Kyoto, we ignore the potential learning value of the protocol, in establishing a test case and framework for future international agreements on climate change. Indeed, if we conceive of Kyoto as the first step in a series of progressively-steeper greenhouse gas reductions (that will eventually apply to developing as well as developed countries), evaluating the agreement's costs and benefits on the margin might be entirely inappropriate.[119]

On the other hand, there are some reasons to think that our estimates of the cost of climate change might be biased upward. First, we assume that individuals in the U.S. value unknown and foreign wildlife as much as they value domestic wildlife. Revealed preference analysis suggests dramatic differences in the value of domestic versus foreign *human* lives.[120] Might the same be true for animals?

Since the FWS has no jurisdiction over foreign wildlife, we cannot compare expenditures for domestic and foreign species in any precise fashion. We offer two reasons, however, to think that the difference between domestic and foreign species value may not be significant. First, modern human life is so detached from wildlife that, to the vast majority of individuals, a domestic endangered species is as "foreign" as a foreign

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[118] See Fish and Wildlife Service, supra note _.

[119] Even Nordhaus, a Kyoto skeptic, concedes the learning value of the protocol. See Nordhaus, supra note _, at 1284.

[120] See Wojciech Kopszuk et al., The Limitations of Decentralized World Redistribution: An Optimal Taxation Approach, 30 European Economic Review 1051 (2005). Kopszuk estimates, by revealed preference, that foreign lives are valued at 1/2000th the value of domestic lives.

one. For example, among the top 10 most valuable species, by ESA expenditures, are the red-cockaded woodpecker, pallid sturgeon, and right whale; are such species any less foreign than polar bears or giant pandas?[121] Second, it is not even clear which way the foreign/domestic distinction should cut, if there is a difference. Foreign and exotic species (tigers, elephants, etc.) might very well be more prized, precisely because of their rarity on U.S. lands. Indeed, public and private organizations in the U.S. spend many millions of dollars annually on a handful of foreign giant pandas, possibly making the panda the most valued endangered species, on a per animal basis, in this country.[122]

A second possible source of upward bias is our failure to discount. As a result of scientific uncertainty in the SAR models, we cannot discount use value with any degree of accuracy. And in our analysis of non-use value, we assume that there are no significant timing differences between extinction caused by climate change, and other sources such as habitat loss.

Third, we treat our measures of use and non-use value as conceptually independent when, in fact, there might be significant overlap—e.g., the high ESA expenditures to protect threatened fish.[123] This is not a serious problem for the contingent valuation analysis, since the use value is trivial relative to our calculated non-use values. However, our central, revealed preference estimate would be significantly reduced—up to 50%—by any redundancy in use and non-use value.

Finally, we should note again that we assume a linear value or cost function for species loss. In reality, there are probably ranges of convexity and concavity. The recent and vast increases in per species expenditures under the ESA suggest that we are currently in a range of convexity. But at some point well short of 100% of GDP, society would presumably decide to stop paying for species protection, or at least significantly reduce its marginal willingness to pay.[124]

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[121] To be sure, this would not be true of some forms of use value. However, our use value calculations do not depend on the foreign/domestic distinction, since we are not using a species multiple.

[122] See Brenda Goodman, Eats Shoots, Leaves and Much of Zoos' Budgets, N.Y. Times, Feb. 6, 2006 and Lynne Warren, Panda Inc., National Geographic, July 2006.

[123] Of course, we exclude fish from our revealed preference analysis. However, it might be the case that commercial interests are important in other cases.

[124] Putting the disputed nature of animal rights aside, this will be true due to income effects. That is, if society were actually spending a significant portion of GDP to protect animals, total social wealth would be reduced. And at reduced wealth levels, demand for all goods and services will decrease.

V. Conclusion

Our principal goal in this Article has been to suggest that climate change threatens to kill countless animals, and that their suffering and death should matter to climate change policy. By all estimates, climate change is causing, and will cause, a massive loss of animal life and also produce a great deal of suffering. An adequate accounting of the costs of climate change must take account of these effects.

At the same time, we have attempted to explore some of the complexities in assigning monetary values to species and animals. We have distinguished between two overlapping but independent sets of losses: extinction of species and harms done to particular animals. Both of these losses should be included in the overall calculation. Because of limitations in existing data, we have focused only on the loss of species, with the belief that this loss is an important component of the problem.

On the basis of current climate change projections, a plausible and conservative range estimate of lost use values, for the world as a whole, is from $.0.5–1.3 trillion annually. A plausible and conservative estimate of lost non-use values, for the world as a whole, is from $0.6–1.5 trillion annually. For the United States, the corresponding figures are $58–144 billion in lost use value and $104–255 billion in lost non-use value. We have argued, moreover, that these estimates might be downwardly biased because we ignore harms short of extinction; ignore impacts on nonvertebrate life; and fail to account for a possible increase in extreme weather events. On the other hand, our estimates might be upwardly biased because we fail to closely examine the distributional mix of threatened species (e.g., foreign versus domestic); do not even attempt to discount; and treat our measures of use and non-use value as completely nonredundant. Finally, there is a serious and unanswered question about the curvature of the species value function. Our estimates, therefore, are necessarily tentative.

We have nonetheless used our analysis to take a fresh look at the costs and benefits of the Kyoto Protocol. If the Kyoto Protocol reduces warming by 0.15 C, we have estimated that its benefits, to Americans, increase by $30 billion annually, and for the world by $74 billion (with the major caveat that these savings might not be sustained without a permanent and long-term solution to climate change). Wider and deeper restrictions on greenhouse gases—for example, those that include developing countries, above all China, a growing contributor—would deliver correspondingly larger benefits.

Our central claim here is that, for too long, the debate over climate change policy has been conducted without paying significant attention to nonhuman life. In our view, animals have intrinsic value, and that value should be included in any judgment about appropriate regulation. But our emphasis has been on existing human valuations, not on abstract claims about the appropriate treatment of species and individual animals. To that extent we bracket some of the most controversial claims about animal welfare. If regulators attend to human valuations of nonhuman life, they will find that existing estimates of the costs of climate change are far too low.

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