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Separated at Birth? Addressing the Twin Crises of Biodiversity and Climate Change

Daniel A. Farber[1]

Climate change is a growing threat to biodiversity, particularly in biodiversity-rich places such as tropical forests and coral reefs. At the same time, tropical deforestation is a major source of carbon emissions. Climate change mitigation measures may have positive impacts on deforestation, usually by design, or negative impacts, such as the destruction of tropical forests as an indirect result of American corn ethanol production. More generally, biodiversity and climate change both raise issues about the legality and effectiveness of bottom-up actions in the absence of global agreement.

The typical approach to reducing undesirable activities such as deforestation or overfishing is to regulate the actors who produce them (the "suppliers" of these destructive activities). But another approach is to reduce the demand that drives these activities. These methods can be considered demand side because they attempt to reduce the demand for deforestation or overfishing, rather than regulating the farmers, developers, and fishers who produce these activities. Climate change and biodiversity threats both have links to the global food system. Conversion of land to agricultural use is a major threat to wild lands that store large amounts of carbon and harbor immense biodiversity. Increased crop yields, dietary changes, and population control can reduce these pressures, benefitting both biodiversity and the climate. The ocean's fish are also heavily over-utilized, and sustainable aquaculture can reduce pressures on wild fish stocks.

1. Sho Sato Professor of Law, University of California, Berkeley. Eric Biber provided very helpful comments on a previous draft.

INTRODUCTION

Though the threat of climate change is well known, the world faces more than one global environmental crisis: biodiversity is declining at a catastrophic rate.[2] According to a recent scientific review, "[i]n the past 500 years, humans have triggered a wave of extinction, threat, and local population declines that may be comparable in both rate and magnitude with the five previous mass extinctions of Earth's history."[3] At least a seventh of all species globally are estimated to be at risk, with estimates showing disturbing average declines of

2. A central premise of this Article is that biodiversity is valuable and deserving of protection. There is an extensive body of scholarship supporting that premise. *See* RICHARD B. PRIMACK, ESSENTIALS OF CONSERVATION BIOLOGY 71–130 (5th ed. 2010).

3. Rodolfo Dirzo et al., *Defaunation in the Anthropocene*, 345 SCIENCE 401, 401 (2014). Another report notes that "biodiversity loss, however it is measured, is showing little signs sign of abatement." Ben Collen & Emily Nicholson, *Taking the Measure of Change Predictive Models of Biodiversity Change Are Required to Inform Conservation Policy Decisions*, 346 SCIENCE 166, 166 (2014). On previous mass extinction events, see John Charles Kunich, *Losing Nemo The Mass Extinction Now Threatening the World's Ocean Hotspots*, 30 COLUM. J. ENVTL. L. 1, 1–5 (2005).

over 25 percent in many species populations since 1970.[4] Many ecologists believe that there is no relevant analogy to the current situation in human experience and that the world is heading into unexplored ecological territory.[5]

Biodiversity[6] and climate change[7] seem like very different problems that would connect only rarely and by chance. Yet climate change impacts biodiversity, while forest policy affects both biodiversity and climate mitigation.[8] These connections highlight the need to understand the economic and scientific links between the areas, while also providing openings for new policy initiatives that take the interconnections into account. For instance, preserving rainforests both protects biodiversity and mitigates climate change. But rainforest preservation is arguably threatened by some climate mitigation policies involving biofuels.[9] Thus, climate mitigation must be designed with an eye to their impacts on forest and biodiversity. Other policy initiatives, such as increasing crop yields, can reduce pressure on forests, thereby serving both climate mitigation and biodiversity goals.

The typical approach to reducing undesirable activities such as deforestation or overfishing is to regulate the actors who produce them (the "suppliers"). But another approach is to reduce the demand that drives these activities. These methods can be considered demand side because they attempt to reduce the demand for deforestation or overfishing, rather than regulating the farmers, developers, and fishers who produce these activities. Fundamentally, biodiversity and climate change illustrate the increased interconnectedness of global systems.[10] The different facets of the global commons—the atmosphere, oceans, ecosystems, and polar regions—are all linked with each other and the global economy. However, governance mechanisms are fractured into multiple jurisdictions at all scales. Indeed, as we will see, there is a third global system

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4. Dirzo et al., *supra* note 3, at 401.

5. J.B. Ruhl, *Climate Change and the Endangered Species Act Building Bridges to the No-Analog Future*, 88 B.U. L. REV. 1, 11 (2008).

6. Biodiversity can be defined to include species diversity, genetic diversity, and ecosystem diversity, concepts which are overlapping, but distinct. For a discussion of the definitional issues, see PRIMACK, *supra* note 2, at 23–50. For a discussion of the corresponding problem of defining metrics for biodiversity, see Collen & Nicholson, *supra* note 3.

7. Like J.B. Ruhl, I "unapologetically adopt" the scientific consensus on climate change. Ruhl, *supra* note 5, at 2 n.2. At this point, the evidence is too massive and well known to be worth reprising here.

8. Part I of this Article discusses these connections.

9. *See infra* Part II.

10. Scientists now recognize that:

> Although our planet is a single system comprising complex interactions between humans and nature, research and management typically isolate system components (such as air, biodiversity, energy, food, land, water, and people). As a result, the compounding environmental impacts of human activities have too often been missed because they go beyond the organizational level, space, and time of focus. . . . Progressing toward global sustainability requires a systems approach to integrate various socioeconomic and environmental components that interact across organizational levels, space, and time.

Jianguo Liu et al., *Systems Integration for Global Sustainability*, 347 SCIENCE 964, 964 (2015).

apart from the biological and energy systems that has an important bearing on biodiversity—the global economic system.

One of the great challenges of our time is learning how to creatively deploy governance systems in an increasingly tightly linked world. This Article provides a somewhat different approach to this problem by framing harmful behavior such as deforestation as being akin to a product supplied by individuals and firms. Consequently, reducing the extent of the harmful behavior comes down to incentives—we can either raise producers' costs by regulating their behavior or we can lower the payoff; in effect reducing the demand for this behavior.

Both approaches have advantages and disadvantages. The traditional regulatory approach must contend with the difficulty of bringing all of the relevant players into agreement; as a result, a combination of unilateral action and coalition building may be required. For instance, in order to establish coalitions to address climate change, developed countries may use a variety of financial mechanisms to induce countries with tropical forests to restrict deforestation. The supply-side approach is less direct and probably cannot be completely effective on its own. For instance, agricultural research may reduce the incentive to engage in deforestation by increasing agricultural yields, but this may not be enough if deforestation is essentially costless for would-be farmers and ranchers. In sum, a combined strategy is needed.

Part I of this Article presents the key scientific findings about threats to biodiversity and their relationship with climate change. Climate change represents an additional source of stress on ecosystems and species that are already under threat, and conversely, destruction of tropical forests not only reduces biodiversity but is also a substantial source of carbon emissions.[11] Part II examines the legal frameworks governing biodiversity and climate change, including the key connections between those frameworks. Part III hones in on some unifying themes: the need for coalition-building—including unilateral action and methods of preventing leakage—as well as the potential for unorthodox policy initiatives to simultaneously reduce both pressures on ecosystems and carbon emissions. Thus, biodiversity and climate may be twin crises, but rather than being separated at birth they remain conjoined.

I. BIODIVERSITY AND CLIMATE CHANGE AS INTERLINKED SYSTEMS

To understand the link between biodiversity and climate change, we need to begin by understanding the current and future trajectories of the climate.

11. For extensive discussion of the contribution of deforestation to climate change, see Rosa C. Goodman & Martin Herold, *Why Maintaining Tropical Forests Is Essential and Urgent for a Stable Climate* (Ctr. for Global Dev., Working Paper No. 385, 2014), http://www.cgdev.org/publication/why-maintaining-tropical-forests-essential-and-urgent-stable-climate-working-paper-385.

According to the most recent report[12] of the Intergovernmental Panel on Climate Change (IPCC),[13] "[e]ach of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850," and "[i]n the Northern Hemisphere, 1983–2012 was *likely* the warmest 30-year period of the last 1400 years."[14] In other words, global warming is already well under way.

Furthermore, "[o]ver the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent."[15] Not surprisingly, "[t]he rate of sea level rise since the mid-nineteenth century has been larger than the mean rate during the previous two millennia."[16] Thus, we are already in the midst of sea level rise, and we can expect much more to come.

The thermometer will rise along with the oceans. Depending on future emissions and climate sensitivity, the world will probably end up 2˚C–7˚C warmer (roughly 4˚F–12˚F).[17] This global average obscures worrying regional variations. Temperature change in the Arctic will be about twice as large in scenarios with high climate sensitivity and high emissions.[18] Average global warming of 2˚C, which now seems inevitable, would leave the earth warmer than it has been in millions of years.[19] In general, wet areas will get wetter and dry areas will get drier, making extreme events such as fires, floods, and heat waves more widespread.[20] Adaptation to these impending changes poses serious challenges.[21]

The effects of a 2°C rise are bad enough. Impacts are much worse at the higher end of the scale. The World Bank considers a 4°C (7˚F) increase—the

12. In-line citations in the report will be deleted in quotations throughout this Article without notation to that effect.

13. "The IPCC is an intergovernmental body . . . open to all member countries of the United Nations" that currently has 195 members. *Organization*, INTERGOV'TAL PANEL ON CLIMATE CHANGE, http://ipcc.ch/organization/organization.shtml (last visited Sept. 23, 2015). The IPCC's mission is to improve scientific understanding of climate change. *Id*.

14. Intergov'tal Panel on Climate Change, *Summary for Policymakers*, *in* CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS 3, 5 (Thomas F. Stocker et al., eds., 2013), http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf.

15. *Id.* at 9.

16. *Id.* at 11. For a discussion of climate models, their validation, and modeling uncertainties, see Daniel A. Farber, *Modeling Climate Change and Its Impacts Law, Policy, and Science*, 86 TEX. L. REV. 1655 (2008).

17. *Id.* at 129.

18. *Id.* at 132–33.

19. *Id.* at 225.

20. *Id.* at 174; HEIDI CULLEN, THE WEATHER OF THE FUTURE: HEAT WAVES, EXTREME STORMS, AND OTHER SCENES FROM A CLIMATE-CHANGED PLANET 51 (2010).

21. *See* TIM BONYHADY, ANDREW MACINTOSH & JAN MCDONALD, ADAPTATION TO CLIMATE CHANGE: LAW AND POLICY 1–3 (2010); U.S. GOV'T ACCOUNTABILITY OFFICE, CLIMATE CHANGE ADAPTATION: STRATEGIC FEDERAL PLANNING COULD HELP GOVERNMENT OFFICIALS MAKE MORE INFORMED DECISIONS 2–5 (2006), http://www.gao.gov/assets/300/296526.pdf.

likely outcome if emissions continue to rise unabated—a potentially devastating scenario, with a list of dire consequences including "irreversible loss of biodiversity, including coral reef systems."[22] Unfortunately, "[m]any species will be unable to disperse rapidly enough to track the changing climate and remain within their 'climate envelope' of temperature and precipitation."[23]

Of course, even moderate levels of climate change will pose threats to biodiversity. Still, the contrast between a global increase of 2°C versus 4°C underscores the importance to biodiversity of reducing the amount of climate change. Thus, any effort to mitigate the extent of climate change is also a key step toward preserving biodiversity.

Subpart A explains in more detail what is currently known about biodiversity and how climate change might impact ecosystems. In particular, climate change not only poses a direct risk, but is also a "threat multiplier" for other problems such as invasive species. Subpart B then examines how changes in ecosystems can contribute to climate change and vice versa: destruction of tropical habitats, a key threat to biodiversity, causes carbon emissions that contribute to climate change, which in turn threatens biodiversity even further.

A. The Effects of Climate Change on Biodiversity

There are many highly varied ecosystems in the world, from deep ocean vents to the Siberian tundra. For our purposes, we can divide ecosystems into two large (and admittedly heterogeneous) groups:[24] terrestrial ecosystems like forests and grasslands, and marine ecosystems like estuaries and coral reefs.[25] We begin with terrestrial ecosystems. More is known about them, for two simple reasons: they are smaller than the oceans and scientists find them much easier to observe.[26] Even so, there are important gaps in our knowledge.

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22. WORLD BANK, TURN DOWN THE HEAT: WHY A 4 C WARMER WORLD MUST BE AVOIDED ix (2012), http://documents.worldbank.org/curated/en/2012/11/17097815/turn-down-heat-4%C2%B0c-warmer-world-must-avoided.

23. PRIMACK, *supra* note 2, at 208.

24. These two may be connected in many ways—for example, birds may feed at sea or in wetlands. Similarly, changes in land cover can affect levels of pollutants and sediment reaching the sea. But climate change will have distinctive effects on terrestrial as opposed to marine ecosystems, so it is helpful to discuss them separately here. For a summary of these impacts on both types of ecosystems, see PRIMACK, *supra* note 2, at 208–12. One impact unique to marine ecosystems is ocean acidification, discussed in ELIZABETH KOLBERT, THE SIXTH EXTINCTION: AN UNNATURAL HISTORY 112–14, 120 (2014).

25. Although not discussed in this Article for space reasons, freshwater bodies will also be significantly impacted by climate change. *See, e.g.*, EPA, CLIMATE CHANGE IN THE UNITED STATES: BENEFITS OF GLOBAL ACTION 70 (2015), http://www2.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf.

26. It is daunting how little we know about parts of the ocean. As one scientist has said, "We played golf on the moon before we went to the mid-Atlantic ridge, which is the single largest geological feature of our own planet; we have better maps of Mars than of some parts of our own ocean floor." Robert D. Ballard, *Ocean Exploration Past, Present, and Future*, *in* 68 BULL. AM. ACAD. ARTS & SCI. 41, 41 (2015).

1. Terrestrial Ecosystems

Terrestrial ecosystems are better understood than marine ecosystems, but our knowledge is nonetheless limited. Our examination of them begins with a look at what is known about current biodiversity, which is less than one might expect. We then examine how climate change is already affecting organisms as well as projections about its future impacts on biodiversity. Finally, we examine how climate change may cause additional harm through synergistic interactions with other biodiversity threats such as invasive species and diseases.

i. The Baseline: Current Biodiversity

There is a great deal that we do not know about the world's ecosystems. Even today, we do not accurately know the total number of species on the planet. For example, there are probably between two and seven million species of tropical insects, but the exact figure is unknown.[27] To be sure, we have better estimates for warm-blooded creatures: there are about 5500 species of mammals and 10,000 species of birds.[28] Still, uncertainty remains a prominent theme of biodiversity law.

Not knowing the total numbers of all species, we also lack an accurate count of how many are threatened with extinction or have already become extinct.[29] Nevertheless, in the most-studied categories of plants and animals the rate of extinction has accelerated far above prehuman levels, including the loss of about one-fifth of bird species.[30] There is also strong evidence of decline for vertebrates and the best-studied invertebrates such as butterflies and moths.[31] Climate change is predicted to rank alongside habitat loss as a source of biodiversity loss, with perhaps one-fifth of surviving Western Hemisphere land birds threatened with extinction by the end of the century.[32]

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27. KOLBERT, *supra* note 24, at 185. The issues involved in making a global count of species are discussed in PRIMACK, *supra* note 2, at 58–66.

28. KOLBERT, *supra* note 24, at 183. The reason is straightforward. Not only are these animals larger and easier to observe, they are of interest to more people—just compare the number of bird watchers and beetle collectors. The Audubon Society has approximately 400,000 members. Irene Nolan, *National Audubon Society By the Numbers*, ISLAND FREE PRESS (Sept. 20, 2013, 11:30AM), http://islandfreepress.org/PivotBlog/?e=260. By contrast the largest entomological group, the Entomological Society of America, has 8500 members. *Chapter 12 Entomology*, UNIV. ILL. URBANA-CHAMPAIGN, http://www.library.illinois.edu/bix/biologicalliterature/entomol.html (last visited Sept. 24, 2015).

29. For discussion of the difficulties of linking specific extinctions to climate change, see Sarah K. McMenamin & Lee Hannah, *First Extinctions on Land*, *in* SAVING A MILLION SPECIES: EXTINCTION RISK FROM CLIMATE CHANGE 89, 96–97 (Lee Hannah ed., 2011).

30. EDWARD O. WILSON, THE DIVERSITY OF LIFE 255 (1992). The title of Kolbert's book, THE SIXTH EXTINCTION, is a reference to this trend: the other five are major extinction events in the earth's history. KOLBERT, *supra* note 24, at 3.

31. Dirzo et al., *supra* note 3, at 401.

32. *Id.* at 403.

These losses will be especially grave in tropical forests owing to their amazing biodiversity.[33] In a single twelve-hour period, an entomologist in Jaru (a biological reserve in Brazil) identified 429 species of butterflies, almost as many as live in eastern North America (about 440 species).[34] Manú National Park in Peru contains "one out of every nine bird species on the planet" and over a thousand species of trees.[35] By contrast, all of Canada's arboreal forests—over a billion acres—contain only twenty species of trees.[36] This is part of a general phenomenon: the closer you are to the equator, the greater the diversity.[37]

ii. Biodiversity Impacts of Climate Change

Tropical species tend to have narrow ranges of temperature tolerance,[38] a reflection of how intense competitive pressures have created species that fit within particular ecological niches.[39] As a result, many tropical plants in mountainous areas such as the Peruvian Amazon are already shifting to higher altitudes.[40] The narrower temperature ranges for tropical organisms may make them more vulnerable to climate change when they are unable to move far enough or quickly enough to maintain their preferred temperature ranges.[41] Speed matters more than magnitude: temperature increases by themselves are not a threat to tropical forests; it is the rapidity of projected rises that may cause ecological havoc.[42] Therefore, even if the ultimate level of climate change is the same, it would be beneficial to biodiversity if we could simply slow its pace.

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33. There are also smaller hotspots elsewhere. California contains a quarter of all the plant species in Canada and the United States, and about half of those species are found nowhere else. WILSON, *supra* note 30, at 261.

34. *Id.* at 198.

35. KOLBERT, *supra* note 24, at 149.

36. *Id.* at 151.

37. KOLBERT, *supra* note 24, at 152; *see* PRIMACK, *supra* note 2, at 56–58 (discussing the reasons for abundant biodiversity in the tropics).

38. KOLBERT, *supra* note 24, at 158.

39. *Id.* at 183.

40. *Id.* at 159.

41. The IPCC's assessment of this argument is that:

> Tropical species, which experienced low inter and intra-annual climate variability, have evolved within narrow thermal limits, and are already near their upper thermal limits. On this basis, tropical species and ecosystems are predicted to be more sensitive to climate change than species and ecosystems that have evolutionary histories of climatic variability (e.g., Arctic and boreal ecosystems). However, there are physiological, evolutionary, and ecological arguments that tropical species and ecosystem sensitivities to climate change are complex and may not be particularly high compared to other systems.

Settele et al., Intergov'tal Panel on Climate Change, *Terrestrial and Inland Water Systems*, *in* CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY 301 (Christopher B. Field et al., eds., 2014), http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap4_FINAL.pdf.

42. Yadvinder Malhi, *Extinction Risk from Climate Change in Tropical Forests*, *in* SAVING A MILLION SPECIES: EXTINCTION RISK FROM CLIMATE CHANGE, *supra* note 29, at 239, 240, 243.

Climate change's indirect effects on distribution also threaten species. Take the compression of habitat at higher altitudes. Warmer weather pushes animals or plants to migrate higher, where there is usually less space.[43] Animals such as the pika, a small rabbit-like animal, face extinction because the species is "running out of places to live."[44] Increased variability in precipitation may also be a problem and has been linked with the decline of the checkerspot butterfly, where weather changes were combined with a fragmented habitat to prevent the butterfly from relocating.[45] A final point is that climate change can also disrupt existing protections for endangered species, such as protected areas, because the terrain that is currently being protected to preserve endangered species may no longer be appropriate.[46]

Predicting how climate change will impact a single species is hard enough, but ecosystems are even harder. They are unpredictable even in the absence of climate change.[47] Instead of the traditional "balance of nature" dynamic which emphasizes stability, ecologists now tend to view ecosystems as characterized by complicated, chaotic interactions in which any equilibrium is purely temporary.[48] Thus the current approach stresses the highly random behavior of ecosystems, in the sense that exact prediction seems to be impossible and trends can shift unexpectedly.[49] Even when we have successfully diagnosed a biodiversity problem, uncertainties attend any attempted remedy. Take the problem of overfishing, where "[o]ur inability to ascertain safe harvest levels for even intensely studied fish stocks undermines our confidence in the evidently illusory notion of *sustainable* fishing."[50] Or rather, while there well

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43. *Id.* at 157.

44. Ruhl, *supra* note 5, at 2. Ruhl explains that the "pika's problem is that as global climate change causes surface temperatures to rise, the altitude above which pikas can find suitable conditions for survival also is rising." *Id.* at 4. Obviously, once the species reaches the top of the mountain, there is no place higher to move. Less obviously, the species has become fragmented into small populations on isolated mountain peaks, making it more vulnerable to extinction, or as Ruhl says, "they are stuck on mountaintop islands and the water is rising, so to speak." *Id.*

45. *Id.* at 156.

46. *See* Jessica J. Hellmann et al., *Strategies for Reducing Extinction Risk Under a Changing Climate*, *in* SAVING A MILLION SPECIES: EXTINCTION RISK FROM CLIMATE CHANGE, *supra* note 29, at 363, 376–77.

47. WILSON, *supra* note 30, at 182.

48. For a summary of some of the relevant literature, see Fred Bosselman, *What Lawmakers Can Learn from Large-Scale Ecology*, 17 J. LAND USE & ENVTL. L. 207, 225 (2002). Some of the implications for environmental regulation are surveyed in J.B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System How to Clean Up the Environment by Making a Mess of Environmental Law*, 34 HOUS. L. REV. 933 (1997). Recent research on large-scale networks also reveals the emergence of unexpected properties that may make control difficult. *See* Ian Foster, *Unexpected Consequences of Connections*, 297 SCIENCE 1124, 1124–25 (2002). For an accessible introduction to the subject, including a discussion of the implications for ecology, see MARK BUCHANAN, NEXUS: SMALL WORLDS AND THE GROUNDBREAKING SCIENCE OF NETWORKS 138–55 (2002).

49. *See* Bradley C. Karkkainen, *Adaptive Ecosystem Management and Regulatory Penalty Defaults Toward a Bounded Pragmatism*, 87 MINN. L. REV. 943, 947 (2003).

50. Jim Chen, *Globalization and Its Losers*, 9 MINN. J. GLOB. TRADE 157, 189 (2000) (citations omitted).

may be sustainable levels, we may not be able to reliably ascertain what they are.

Uncertainty surrounding ecosystems complicates efforts to tease out the pervasive effects of climate on a species,[51] because these effects may be due to a reshuffling of the ecosystem that does not directly involve that particular species' response to climate.[52] As one scientist recently wrote, while predicting direct impacts on even a well-studied species is "a challenging task . . . [p]redicting future impacts on the multitudinous interactions among species is more difficult by orders of magnitude."[53] Given the complex interactions involved, even after the fact, it can be difficult to determine how much of a documented ecological change was due to climate change and how much due to other factors.[54] Because of these and many other uncertainties, it may be difficult to forecast how specific species will fare as ecological networks shift.[55]

Given all the difficulties of making predictions for even a single species, we are obviously in no position to undertake such individualized predictions for every species on the planet, or even for a substantial subsample. Instead, estimates of the impacts of climate change on biodiversity rely on models of

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51. There are several sources of uncertainty in our understanding of ecosystems. These include the poorly understood connections between species within an ecosystem, the extent of habitat needed to support a long-term viable population (especially for large carnivores), the effects of invasive species, and the potential negative effects of conservation efforts. Ruhl, supra note 48, at 956. Because there are large numbers of interconnections between species, calculating all of the effects of adding or removing species can verge on the impossible. For example, adding predators would seem likely to diminish prey populations, but this is not necessarily so. *See generally* Ricard Sole & Brian Goodwin, SIGNS OF LIFE: HOW COMPLEXITY PERVADES BIOLOGY (2000). It follows that for these reasons, if climate change knocks out one species or furthers the invasion of another, then the overall repercussions on the ecosystem (including follow-on extinctions) may be unforeseeable. Further complicating matters, not all species are created equal. Computer simulations show that while removing some species may have little effect on the overall food web, removing others can cause drastic changes affecting many species. Buchanan, *supra* note 48, at 152–55.

52. Ruhl, *supra* note 5, at 22.

53. Lesley Hughes, *Climate Change Impacts on Species Interactions Assessing the Threat of Cascading Extinctions*, *in* SAVING A MILLION SPECIES: EXTINCTION RISK FROM CLIMATE CHANGE, *supra* note 29, at 337, 352.

54. Ruhl, *supra* note 5, at 21.

55. As the IPCC has observed regarding the difficulty of predicting the impact of climate change on specific ecosystems and species:

> A significant source of this uncertainty stems from the inherent complexity of ecosystems, especially where they are coupled to equally complex social systems. The high number of interactions can lead to cascading effects. Some of this uncertainty can be reduced by better systems understanding, but some will remain irreducible because of the failure of predictive models when faced with certain types of complexity (such as those which lead to mathematical bifurcations, a problem that is well known in climate science). Probabilistic statements about the range of outcomes are possible in this context, but ecosystem science is as yet mostly unable to conduct such analyses routinely and rigorously.

Settele et al., *supra* note 41, at 328 (citations omitted). On the general uncertainties involved in ecological modeling, see Daniel E. Schindler & Ray Hilborn, *Prediction, Precaution, and Policy Under Climate Change*, 347 SCIENCE 953, 953–54 (2015).

biodiversity derived from other sources.[56] These estimates take advantage of the well-documented relationship between biodiversity and available habitat area, based on estimates of how much climate change will reduce the amount of available habitat.[57] Current estimates of extinction are that about 10 percent of all terrestrial species will be "committed to extinction" by 2050.[58] These estimates may be on the low side if tropical forests turn out to suffer more habitat destruction from other sources than is currently forecasted.[59] It would seem to be a mistake to put too much emphasis on these precise figures given all the uncertainty,[60] but they do confirm the gravity of the problem. Changes of this magnitude would not leave the world devoid of biodiversity since the extinction of 10 percent of all species leaves 90 percent surviving; but much would be lost. Our only way of preserving anything close to existing biodiversity is to save the habitats that sustain it.[61]

iii. Synergies with Other Biodiversity Threats

Climate change is far from the only threat to biodiversity. In fact, climate change does not merely add a new threat; it can also intensify the impact of other threats such as excess human exploitation, habitat destruction, invasive species, and introduced diseases.[62] For instance, by 1989, about half of the prehistoric rainforest areas had been destroyed or fragmented.[63] Habitat loss and fragmentation make it harder for animals and plants to migrate in response to climate changes. As science journalist Elizabeth Kolbert pithily explains: "A species that needs to migrate to keep up with rising temperatures, but is trapped

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56. For discussion of the use of these models and their use, see PRIMACK, *supra* note 2, at 145–50, 186–87.

57. KOLBERT, *supra* note 24, at 165–67; WILSON, *supra* note 30, at 222–26; *see* Luke Gibson et al., *Near-Complete Extinction of Native Small Mammal Fauna 25 Years After Forest Fragmentation*, 341 SCIENCE 1508, 1508 (2013) (evidence suggests "small fragments are potentially even more vulnerable to biodiversity loss than previously thought.").

58. KOLBERT, *supra* note 24, at 167–168.

59. *See* PRIMACK, *supra* note 2, at 148–49.

60. For discussion of the limitations of these models and more recent modeling improvements, see Alison Cameron, *Refining Risk Estimates Using Models*, *in* SAVING A MILLION SPECIES: EXTINCTION RISK FROM CLIMATE CHANGE, *supra* note 29, at 41, 41–71; John Harte & Justin Kitzes, *The Use and Misuse of Species-Area Relationships in Predicting Climate-Driven Extinction*, *in* SAVING A MILLION SPECIES: EXTINCTION RISK FROM CLIMATE CHANGE, *supra* note 29, at 73, 73–119. As Cameron notes, one unknown is the severity of climate change given uncertainty about the degree to which emissions will be controlled. Cameron, *supra*, at 62–63.

61. Conservation biologists view habitat destruction as the primary threat to biodiversity. *See* PRIMACK, *supra* note 2, at 177.

62. WILSON, *supra* note 30, at 253–54. Wilson calls these the "mindless horsemen of the environmental apocalypse." *Id.* Adaptation to climate change, in the case of biodiversity, requires making corresponding reductions in other stressors in order to counterbalance increased climate stress. *See* M. Scheffer et al., *Creating a Safe Operating Space for Iconic Ecosystems Manage Local Stressors to Promote Resilience to Global Change*, 347 SCIENCE 1317, 1317 (2015).

63. WILSON, *supra* note 30, at 275.

in a forest fragment—even a very large fragment—is a species that isn't likely to make it."[64]

Climate change also facilitates the introduction of invasive species, which pose an additional threat to native ecosystems. In general, less specialized species are more adaptable,[65] while specialized species are more likely to proliferate in stable environments such as tropical rainforests where the comparative advantage for generalists is lower.[66] These effects have important implications for the success of invasive species: when previously stable habitats are subject to change, the advantage shifts to generalist species[67] and to species that relocate easily.[68] Not surprisingly, such species are also good at invading other habitats,[69] which could cause further ecological destabilization.[70]

Finally, human responses to climate change could intensify the pressure on ecosystems. As humans retreat from increasingly perilous seacoasts or try to hold back the sea with barriers, they may destroy wetlands.[71] Impacts of climate change on agricultural productivity could lead to the conversion of wildlands or preserves into agricultural land, destroying valuable habitat.[72] Finally, if climate change impinges on food supplies in developing countries, the effect could increase the use of wildlife as a food source—an activity already occurring at an unsustainable level.[73]

In short, we are throwing a major perturbation into large, highly complex biological systems. Some species may thrive, but many are likely to go extinct

64. KOLBERT, *supra* note 24, at 189.

65. WILSON, *supra* note 30, at 92.

66. *See id.* at 206.

67. Specialized species are three-quarters of those found in areas with complete forest cover, but when forest cover diminishes to 10 percent, their percentage falls to about a quarter of all species. *See* Cristina Banks-Leite et al., *Using Ecological Thresholds to Evaluate the Costs and Benefits of Set-Asides in a Biodiversity Hotspot*, 345 SCIENCE 1041, 1042 (2014). At 30 percent, forest specialists and generalist species are equally prevalent. *Id.* at 1042. The absence of forest specialists has detrimental effects: "Previous studies have shown that forest specialists present narrow niche breadths and high efficiency in resource exploitation, so the loss of forest specialists potentially affects trophic cascades and ecological functions, such as seed dispersal and pest control." *Id.* The authors conclude that 28.5 percent native habitat is needed to "preserve the integrity of vertebrate communities within each landscape." *Id.*

68. According to Primack, "Many species of limited distribution and/or poor dispersal ability, such as snakes, amphibians, and forest birds, will undoubtedly go extinct, with widely distributed, easily dispersed species being favored in the new communities." PRIMACK, *supra* note 2, at 208.

69. For a discussion of the factors determining a species' ability to become invasive, see *id*. at 234–36.

70. On the existing threat from invasive species, see *id*. at 226–37.

71. *See, e.g.*, Ruhl, *supra* note 5, at 25.

72. *Id.*

73. As one scientist put this recently, what "is not sustainable is the millions of metric tons of meat harvested in central Africa and the Amazon each year." Erik Stokstad, *The Empty Forest A Beleaguered National Park in Borneo Hints at What Can Happen when Animals Disappear*, 345 SCIENCE 397, 397 (2014).

because they cannot adapt quickly enough.[74] The result will not be simply to eliminate many individual species, but to wreak havoc on the world's richest and most complex terrestrial ecosystems. And, unfortunately, humans are also causing similar ecological disruption in the oceans.

2. Marine Ecosystems

As we did with terrestrial ecosystems, we begin with a discussion of the current state of marine biodiversity, which is badly threatened by overfishing and other pressures. We then consider the incremental effects of climate change and its close relative, ocean acidification. The prognosis seems gloomy, especially for biodiversity hotspots such as coral reefs.

i. The Biodiversity Status Quo

By some measures, marine biodiversity is twice that of terrestrial biodiversity.[75] Yet our understanding of marine ecosystems is much more limited than our understanding of terrestrial ecosystems.[76] The ocean is very large and very deep; our knowledge literally skims the surface. For instance, determining the population size of deep-water fish has been compared with "flying over the Serengeti at night in a helicopter, dropping a net, and estimating the total zebra population from those caught in the net."[77] Thus, our ignorance of the pre-climate change status quo hinders efforts in predicting the effects of climate change.

Ignorance has not, however, prevented massive human interference with marine ecosystems. Overexploitation is currently the most pressing threat.[78] The extent of overfishing is not obvious from the overall level of fish caught. Wild fish capture has been level for the past twenty-five years despite increasingly sophisticated fishing methods, which means that the fish are

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74. Ruhl, *supra* note 5, at 26; Settele et al., *supra* note 41, at 295 ("Under the fastest rates and largest amounts of projected climate change, many species will be unable to move fast enough to track suitable environments, which will greatly reduce their chances of survival.")

75. Kunich, *supra* note 3, at 13, 15.

76. As Robin Kundis Craig puts it: "One continuing challenge for ocean governance has been how little we know about the oceans and their ecosystems. Until recently, for example, it was a mystery where bluefin tuna go when they leave coastal areas. The oceans remain, like deep space, one of the last great frontiers of human exploration." ROBIN KUNDIS CRAIG, COMPARATIVE OCEAN GOVERNANCE: PLACE-BASED PROTECTION IN AN ERA OF CLIMATE CHANGE 26 (2012). A new system of permanent underwater observatories may help fill some of the gaps. *See Wiring the World Below*, THE ECONOMIST (Apr. 4, 2015), http://www.economist.com/news/science-and-technology/21647588-network-permanent-observatories-will-soon-monitor-oceans-wiring-world.

77. Jared R. Wigginton, *Governing a Global Commons Sharks in the High Seas*, 25 VILL. ENVTL. L.J. 431, 441 (2014).

78. Craig aptly observes that the "sad fact is that the history for the world's fishing practices has been one of progressive overexploitation." CRAIG, *supra* note 76, at 36. There are other pressures on marine ecosystems besides climate change and overexploitation, including pollution, invasive species, the growth of dead zones, and the destruction of coastal wetlands and estuaries by expanding human populations. *Id*. at 27–30.

becoming increasingly rare.[79] Moreover, the total catch remains level in part because, as key fishing stocks are decimated, the attention of fishers turns to other, previously less desired species, a process known as "fishing down the food web."[80] The reality is that about 30 percent of fish stocks are overfished.[81] Populations of large ocean species such as tuna have fallen by 90 percent. [82]

The advance of fishing technology helps explain these declines, and commercial fish stocks are not the only victims. Of the current technologies, bottom trawling is the "most catastrophic for both species and habitats" because "thousands of animal, plant, and algae species are taken incidentally," often amounting to the vast majority of the catch.[83] This would be akin to hunting by using nerve gas to kill everything in the forest and then picking through the bodies for a few trophy animals. Drift nets, up to forty miles long, can also wreak ecological havoc.[84] Today it takes only about fifteen years of highly efficient fishing to reduce a fish species by 80 percent.[85]

Even less technologically advanced fishing poses a threat. In many parts of the world, small coastal fishers (of whom there are a hundred million worldwide) "exploit marine resources persistently and intensely," causing "fisheries collapse and serial depletion—overfishing one species then another—until fishers extract virtually any marine life that might provide food or generate cash."[86] Even where fishery protections exist, enforcement has been a huge challenge given widespread illegal fisheries.[87] Scientists have given repeated warnings about potential collapses in fishing stocks, too often to little avail.[88] In sum, climate change is impacting ecosystems that are already under heavy assault.

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79. Robin Kundis Craig, *Retooling Marine Food Supply Resilience in a Climate Change Era Some Needed Reforms*, 38 SEATTLE U. L. REV. 1189, 1191 (2015).

80. Kunich, *supra* note 3, at 20. For some examples of the speed with which stocks can be exhausted given modern fishing methods, see CRAIG, *supra* note 76, at 158–59.

81. Craig, *supra* note 79, at 1194.

82. Kunich, *supra* note 3, at 23.

83. Amanda Vincent & Jean Harris, *Boundless No More Ending Illegal, Unregulated, and Unreported Fishing Would Bring Hope for Ocean Wildlife*, 346 SCIENCE 410, 420 (2014).

84. Kunich, *supra* note 3, at 24–25.

85. Kunich, *supra* note 3, at 23.

86. Vincent & Harris, *supra* note 83, at 420. This type of fishing has expanded in the past two decades. Craig, *supra* note 79, at 1195.

87. For discussion of this problem and potential solutions, see Vincent & Harris, *supra* note 83, at 420; *How to Catch the Overfishermen*, THE ECONOMIST (Jan. 24, 2015), http://www.economist.com/news/leaders/21640350-big-data-allow-fish-be-protected-never-governments-should-take-advantage; Wigginton, *supra* note 77, at 442.

88. Craig, *supra* note 79, at 1207. On the challenges to fisheries management posed by climate change, see Marianne Lavelle, *Moveable Feast As Fish Stocks Move in Response to Warming, Regulators Struggle to Keep Pace*, 350 SCIENCE 760 (2015). Overfishing also interacts with introduction of invasive species, as when overfishing has eliminated the predators that would otherwise control its spread. *See* Eric V. Hull, *Climate Change and Aquatic Invasive Species Building Coastal Resilience Through Integrated Ecosystem Management*, 25 GEO. INT'L ENVTL. L. REV. 51, 74 (2012).

ii. Marine Climate Change Impacts

Warming causes complex physical changes in the oceans.[89] As on land, there are indications that marine species are moving toward the poles to escape warming temperatures,[90] including about half of the commercial fishing stocks in the North Atlantic.[91] Ocean currents are also shifting,[92] with noticeable impacts on fish, perhaps including the new low-oxygen "dead zones" off the Pacific Northwest.[93] These climate change impacts will amplify the ecological problems already created by poor fisheries management.[94]

Climate change is also causing ocean acidification.[95] The ocean has absorbed about a third of carbon dioxide (CO_2) emissions, which has changed its pH significantly.[96] Currently, the ocean is about a third more acidic than it was at the preindustrial baseline, and unrestrained emissions will raise that to one-and-a-half times by the end of the century.[97] Some species will adapt without difficulty to more acidic conditions, but others will not.[98] Indeed, ocean acidification seems to have played a major role in some past mass

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89. *See* CRAIG, *supra* note 76, at 55. These changes are due in part to the layering of ocean habitats:

> The ocean has layers of warmer and colder water, saltier or less saline water, and hence less or more dense water. Warming of the ocean and the addition of more freshwater at the surface through ice melt and higher precipitation increases the formation of more stable layers stratified by density, which leads to less mixing of the deeper, denser, and colder nutrient-rich layers with the less dense nutrient-limited layers near the surface. With less mixing, respiration by organisms in the mid-water layers of stratified oceans will produce oxygen-poor waters, so-called oxygen minimum zones (OMZs).

Hans O. Pörtner et al., Intergov'tal Panel on Climate Change, *Ocean Systems*, *in* CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 41, at 426, http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap6_FINAL.pdf. While the precise changes to the ocean may be difficult to grasp, the result of inaction is more easily understood: "[I]mmediate and substantial reduction of CO_2 emissions is required to prevent massive and mostly irreversible impacts on ocean systems and their services." J.P. Gattuso et al., *Contrasting Futures for Ocean and Society from Different Anthropogenic CO_2 Emissions Scenarios*, 349 SCIENCE 45, 45 (2015).

90. PETER BACKLUND ET AL., *Biodiversity*, *in* THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURE, LAND RESOURCES, WATER RESOURCES, AND BIODIVERSITY IN THE UNITED STATES 164 (2008), http://www.usda.gov/oce/climate_change/SAP4_3/CCSPFinalReport.pdf.

91. Craig, *supra* note 79, at 1210. Yet climate change may reduce the ranges of other marine species. Curtis Deutch et al., *Climate Change Tightens a Metabolic Constraint on Marine Habitats*, 348 SCIENCE 1132, 1132–35 (2015).

92. *See* CRAIG, *supra* note 76, at 54–57 (discussing these changes and the importance of currents for marine life).

93. Craig, *supra* note 79, at 1219–20.

94. *See* CRAIG, *supra* note 76, at 34. As in tropical forests, many ocean species require narrow ranges of conditions such as light and temperature. Kunich, *supra* note 3, at 18. Thus, shifts in water temperature and currents can have serious effects, particularly when the current habitat is isolated from other potentially suitable ones.

95. For a more detailed discussion of acidification, see CRAIG, *supra* note 76, at 59–60.

96. *Id.* at 59; Christopher L. Sabine et al., *The Oceanic Sink for Anthropogenic CO_2*, 305 SCIENCE 367, 367, 371 (2004).

97. CRAIG, *supra* note 76, at 59.

98. *Id.* at 59–60.

extinctions.[99] The impact is likely to be greatest on organisms, such as corals, that engage in calcification.[100] The impact of acidification on corals is of particular concern because coral reefs are biodiversity hot spots that can provide homes to hundreds of species.[101]

Acidification is only one threat facing reefs. Reefs are also at direct risk from climate change, since warmer water may cause bleaching, in which the coral-building polyps expel symbiotic algae, weakening the coral's vitality.[102] There were only three recorded bleaching incidents from 1900 to 1980, whereas there were sixty in the following thirteen years.[103] Some projections are dire, with estimates of a third of reefs under risk of collapse within the next twenty to forty years, potentially dramatic ecosystem changes in surviving reefs, and the possible extinction of tens of thousands of reef-dependent species.[104]

As on land, ecological stressors may be synergistic. Several lines of evidence converge to suggest that "the combination of changes in ocean surface temperatures, increasing ocean acidity, and a host of other stresses could bring coral reef ecosystems to critical ecological tipping points within decades rather than centuries, and that some regions of the ocean are already near that point from a biogeochemical perspective."[105] Human activities are also key stressors that will combine with climate change to impact marine ecosystems. As the IPCC puts it, "[s]trong interactions with other human impacts like eutrophication, fishing, and other forms of harvesting accelerate and amplify climate-induced changes."[106]

Climate change is not the only threat to critical ecosystems, but it amplifies existing threats. As we have seen, climate change seems likely to dramatically affect the very ecosystems—tropical forests and coral reefs—that are the greatest repositories of biodiversity. Without intense effort on our part, the world will be a good deal poorer in this vital area by the end of the

99. *Id.* at 60. Indeed, it has now been implicated in the earth's largest extinction event. M.O. Clarkson et al., *Ocean Acidification and the Permo-Triassic Mass Extinction*, 348 SCIENCE 229, 229 (2015).

100. *Id.* at 61–62. However, phytoplankton are also affected by warming and acidification, resulting in some changes in populations that are already evident. See Meike Vogt, *Adrift in An Ocean of Change Rising Temperatures and Ocean Acidification Drive Changes in Phytoplankton Communities*, 350 SCIENCE 1466 (2015).

101. KOLBERT, *supra* note 24, at 139–41. About 40 percent of the known marine species live in coral reefs. Craig, *supra* note 79, at 1210–11.

102. KOLBERT, *supra* note 24, at 142.

103. BACKLUND ET AL., *supra* note 90, at 160.

104. Peter W. Glynn, *Global Warming and Widespread Coral Mortality Evidence of First Coral Reef Extinctions*, *in* SAVING A MILLION SPECIES: EXTINCTION RISK FROM CLIMATE CHANGE, *supra* note 29, at 103, 114. There is considerable complexity in the responses of reefs to warming and acidification, but the result is likely to be "increasingly bleak." Mark D. Spalding and Barbara E. Brown, *Warm-Water Coral reefs and Climate Change*, 350 SCIENCE 769, 769 (2015).

105. BACKLUND ET AL., *supra* note 90, at 162 (citations omitted).

106. Pörtner et al., *supra* note 89, at 465.

century—which is to say, within the lifetimes of some people who are now young children.

B. The Effect of Ecosystem Destruction on Climate Change

As we have seen, climate change can increase ecosystem destruction. But it is also true that ecosystem destruction can intensify climate change. In particular, deforestation is an important source of greenhouse gases (GHGs).[107] The IPCC reports that land use "is responsible for just under a quarter . . . of anthropogenic GHG emissions mainly from deforestation and agricultural emissions from livestock, soil and nutrient management."[108] However, it is more difficult to estimate emissions from deforestation than from energy use, where it is possible to track fuel consumption.[109] There are several drivers of deforestation including clearance by large landowners and commercial interests for agricultural purposes, subsistence farming by displaced and impoverished populations, and commercial logging.[110] But most estimates indicate a decline in forest and other nonagricultural emissions even in the last few years, mostly because of a slowdown in deforestation.[111]

Although tropical forests are of special concern, other types of wild lands also store significant amounts of carbon.[112] Draining peat lands leads to "a rapid increase in decomposition rates, leading to increased emissions of CO_2, and N_2O [nitrous oxide], and vulnerability to further GHG emissions through fire."[113] Mangrove swamps also store substantial amounts of CO_2—yet "[m]angrove ecosystems have declined in area by 20% . . . since 1980."[114] In short, converting never-cultivated lands to human use is tied with carbon emissions as the stored carbon is released.

107. According to EPA, 17 percent of global emissions are due to deforestation and other forms of land-use change. *Global Greenhouse Gas Emissions Data*, EPA, http://www.epa.gov/climatechange/ghgemissions/global.html (last updated Sept. 11, 2015).

139 Pete Smith et al., Intergov'tal Panel on Climate Change, *Agriculture, Forestry and Other Land Use (AFOLU) in* CLIMATE CHANGE 2014: MITIGATION OF CLIMATE CHANGE 811, 816 (O. Edenhofer et al., eds., 2014), http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter11.pdf. On the interaction between invasive species and climate change, see Hull, *supra* note 88, at 75–78.

109. Smith et al., *supra* note 108, at 819.

110. PRIMACK, *supra* note 2, at 180–82.

111. Smith et al., *supra* note 108, at 825. On Brazil's largely successful effort to limit (though not eliminate) deforestation, see Britaldo Soares-Filho et al., *Cracking Brazil's Forest Code*, 344 SCIENCE 363 (2014).

112. For instance, dry forests store considerable amounts of carbon. *See* Georgina Conti et al., *Large Changes In Carbon Storage Under Different Land-Use Regimes In Subtropical Seasonally Dry Forests Of Southern South America*, 197 AGRIC , ECOSYSTEMS & ENV'T 68, 73 (2014).

113. Smith et al., *supra* note 108, at 828.

114. *Id.* More positively, "the rate of loss has been slowing in recent years, reflecting an increased awareness of the value of these ecosystems." *Id.*

II. REGULATORY PARALLELS AND LINKAGES

The connections between deforestation and overfishing, biodiversity, and climate change, have by no means escaped previous notice. We will explore them in subpart A as they arise in the context of climate change mitigation. Subpart B then considers current legal regimes protecting biodiversity and how they might be used as a partial response to the impact of climate change on biodiversity. In other words, subpart A considers climate mitigation as a biodiversity protection strategy, and subpart B considers biodiversity protection laws as a climate adaptation strategy.

A. Mitigation and Ecosystems

We have already seen how the destruction of tropical forests, in particular, is a major source of carbon emissions.[115] The mitigation/biodiversity nexus therefore centers on tropical forests, with positive effects where mitigation preserves forests and negative effects where it increases deforestation. This subpart discusses how measures to mitigate climate change relate to biodiversity positively or negatively.[116] We will begin with the U.S. experience and then turn to international law.

1. U.S. Law and the Mitigation/Biodiversity Nexus

Although limiting carbon emissions is a crucial part of efforts to protect biodiversity, carbon mitigation efforts can have other effects on biodiversity. This subpart discusses the potentially harmful indirect effects of increased biofuel use on habitats such as tropical forests. As we will see, biofuel production can interact with global economic markets to increase deforestation, a phenomenon known as indirect land use change (ILUC).

Biofuels vividly illustrate the operation of interlinked systems—energy, climate, biodiversity, food, and land use.[117] Until a 2008 article sparked the debate over ILUC, it was not an obvious effect of biofuels, nor was it clear that its scale would be significant.[118] The basic theory is simple. The use of croplands for biofuels raises food prices by reducing supply and thereby increases the incentive to convert forests and grasslands to crop production, leading to the release of stored carbon and decreasing future carbon sequestration.[119] The extent of the effect depends on market conditions and on how exactly farmers react to the higher prices. Logically, since the mechanism

115. *See supra* Part I.B.

116. Mitigation efforts sometimes have the unintended potential to increase deforestation, but they can also be used to create mechanisms to encourage forest preservation. At least in principle, there are win-win solutions where mitigation and forest preservation are mutually supportive.

117. *See* Liu et al., *supra* note 10, at 967–68.

118. Timothy Searchinger et al., *Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change*, 319 SCIENCE 1238, 1238 (2008).

119. *Id.*

involves the conversion of forests into farmland, the effect on tropical forests is muted to the extent that farmers respond in ways that do not require use of forest lands. These include more intensive farming methods on existing lands such as higher fertilizer use and employing plant varieties with higher yields, as well as expanding production into forested lands.[120]

Legal efforts to ban deforestation, such as a legal prohibition on logging in tropical forests, are one possible response. But such efforts may be difficult to implement and could have harsh impacts on the poor.[121] Yet, the alternative of diverting cropland to biofuel production without expanding agricultural lands elsewhere can raise food prices, reducing food supplies and resulting in less adequate diets for the poor in developing countries.[122] Moreover, reducing deforestation in one place might simply result in more deforestation elsewhere in order to meet the demand for more agricultural land.[123] Thus, controls on deforestation are not a panacea for ILUC.

The logic of ILUC seems undeniable: diverting land from food production to ethanol reduces food availability and increases prices,[124] which in turn encourages production increases elsewhere in the world. It is also plausible to assume that at least some of those production increases would come in the form of increasing agricultural acreage by converting forests and grasslands, rather than exclusively by increasing yields on existing croplands.[125] The key question is the size of these effects.[126] Various research teams have now

120. Note that the ILUC effect is mediated by world food and fiber prices and therefore requires no geographic link between the land used for biofuels and the land converted to crops. For instance, the biofuels crops could be grown in Iowa, while the forest could be lost in Brazil, accompanied by large CO_2 discharges, through a "chain of dominoes" including the displacement of U.S. soybeans by corn, displacement of cattle by soybeans in Brazil, and displacement of forest by cattle raising. Given that 20 percent of the U.S. corn crop went to ethanol production by 2006, these effects could well be significant. BRENT D. YACOBUCCI & TOM CAPEHART, CONG. RESEARCH SERV., RL34265, SELECTED ISSUES RELATED TO AN EXPANSION OF THE RENEWABLE FUEL STANDARD 11 (2008), http://www.nationalaglawcenter.org/wp-content/uploads/assets/crs/RL34265.pdf.According to the Congressional Research Service, the "ethanol-driven surge in corn demand has been associated with a sharp rise in corn prices." *Id.* at 6. For an overview of lifecycle analysis and ILUC, see BRENT D. YACOBUCCI & KELSI BRACMORT, CONG. RESEARCH SERV., R40460, CALCULATION OF LIFECYCLE GREENHOUSE GAS EMISSIONS FOR THE RENEWABLE FUEL STANDARD (2010), http://nationalaglawcenter.org/wp-content/uploads/assets/crs/R40460.pdf.

121. YACOBUCCI & BRACMORT, *supra* note 120, at 13–17.

122. *Id*.

123. *See* ERIN C. MYERS, POLICIES TO REDUCE EMISSIONS FROM DEFORESTATION AND DEGRADATION (REDD) IN TROPICAL FORESTS: AN EXAMINATION OF THE ISSUES FACING THE INCORPORATION OF REDD INTO MARKET-BASED CLIMATE POLICIES 65–69 (2007).

124. *See* T. Searchinger et al., *Do Biofuel Policies Seek to Cut Emissions by Cutting Food?*, 347 SCIENCE 1420, 1420–21 (2015).

125. An additional complication is that increased yields might mean greater cultivation (requiring additional fuel for farm equipment) or fertilization (which can release GHGs). So increased yield of food crops can also add to the carbon debt caused by conversion of cropland to biofuels production.

126. There are also potential positive side effects of biofuels, although they are likely to be smaller: "Albeit at lower magnitude, beneficial ILUC effects can also be observed, for example, when some semi-perennial crops, perennial grasses or woody plants replace annual crops grown with high

addressed the magnitude of carbon releases from ILUC.[127] The early estimates may have been high, but it is difficult to be sure of this given the large range of uncertainties in the studies and their differing conclusions—one recent estimate was two-fifths the size of the initial projection found in the pioneering paper on the subject.[128]

Consequently, as with so many things relating to climate change and biodiversity, specific numbers must be taken with a grain of salt. Or in more scientific language: "Given the uncertainties in key parameters and in the resulting estimates of ILUC emission intensity it is possible to produce point estimates that are quite low or quite high, suggesting that no single point estimate should be taken as representative of actual ILUC emissions intensities."[129] Given the extent of uncertainty, the exact magnitude is unclear, but it is clear that biofuels can create potentially significant ILUC-related emissions, and that these emissions are more likely in some situations (use of food crops for biofuels) than others (use of nonfood perennials on already degraded lands to produce biofuels).[130] In the United States context, a very rough calculation contained in the Appendix suggests that the U.S. ethanol program may already have resulted in the loss of around two million acres of tropical forest and the accompanying biodiversity. Again, this "back of the envelope" calculation should be taken with a grain of salt—but it does suggest something about the magnitudes involved.

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fertilizer levels, or where such plants are produced on lands with carbon-poor soils." Smith et al., *supra* note 108, at 880.

127. Richard J. Plevin et al., *Carbon Accounting and Economic Model Uncertainty of Emissions from Biofuels-Induced Land Use Change*, ENVTL. SCI. & TECH. 2656, 2656 (2015).

128. Thomas W. Hertel et al., *Effects of US Maize Ethanol on Global Land Use and Greenhouse Gas Emissions Estimating Market-Mediated Responses*, 60 BIOSCI. 223, 223 (2010) ("We find the increase in cultivated land associated with US-based maize ethanol to be just two-fifths of the amount estimated by [Searchinger et al., *supra* note 118, at 1238–40]."). More recent results from some members of the same team resulted in a larger range of uncertainty. Richard J. Plevin, *Greenhouse Gas Emissions from Biofuels' Indirect Land Use Change Are Uncertain but May Be Much Greater than Previously Estimated*, 44 ENVTL. SCI. & TECH. 8015, 8015–20 (2010).

129. Plevin et al., *supra* note 127, at 2662. The IPCC stresses the difficulties and uncertainties involved in these modeling efforts:

> Causes of the great uncertainty include: incomplete knowledge on global economic dynamics (trade patterns, land-use productivity, diets, use of by-products, fuel prices, and elasticities); selection of specific policies modelled; and the treatment of emissions over time. In addition, LUC modeling philosophies and model structures and features (e.g., dynamic vs. static model) differ among studies. Variations in estimated GHG emissions from biofuel-induced LUC are also driven by differences in scenarios assessed, varying assumptions, inconsistent definitions across models (e.g., LUC, land type), specific selection of reference scenarios against which (marginal) LUC is quantified, and disparities in data availability and quality. The general lack of thorough sensitivity and uncertainty analysis hampers the evaluation of plausible ranges of estimates of GHG emissions from LUC.

Smith et al., *supra* note 108, at 881.

130. Federal law takes these biofuel impacts into account in determining the degree of carbon emissions associated with particular fuels. *See* Daniel A. Farber, *Indirect Land Use Change, Uncertainty, and Biofuels Policy*, 2011 U. ILL. L. REV. 381, 391 (2011).

If biofuels threaten possible harm to biodiversity, other climate mitigation strategies involve efforts to preserve wild lands in general and tropical forests in particular. In those settings, climate policy promotes biodiversity preservation—or at least, that is the intended outcome.

Some background on climate mitigation is necessary to understand the current debate over efforts to link climate mitigation and forest preservation. In the United States, California is leading the effort to incorporate forest preservation into climate mitigation strategy. This is not the only respect in which California is a national leader on climate policy. In California, efforts focusing specifically on climate change can be traced back to 1988, when a law required the first inventory of in-state GHG emissions.[131] Since then, California has pursued a wide range of policies to reduce GHG emissions. In 2006 Governor Schwarzenegger signed the capstone of the state's climate policy into law—the California Global Warming Solutions Act of 2006 (A.B. 32).[132] A.B. 32 sets a binding GHG emissions target, requiring California to reduce emissions to 1990 levels by 2020 and to make deeper reductions by 2050.[133] The state is now operating a cap-and-trade system for GHGs under the umbrella of A.B. 32.[134] This emissions trading system is the lever that California is attempting to use to protect forests.

Specifically, California is exploring the possibility of providing carbon credits (offsets) to local emitters in exchange for forest preservation in other countries.[135] Offsets can be used to satisfy part of an in-state source's obligation to reduce carbon emissions. California already has detailed guidelines for when forest preservation in the United States can be used for offset purposes.[136] The state is now attempting to expand this program to include forests in parts of Latin America such as the Brazilian state of Acre and the Mexican state of Chiapas. According to supporters of this effort, it represents a "historic opportunity" to lower GHG emissions from tropical deforestation.[137]

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131. *See California Energy Commission's Climate Change Activities*, CAL. ENERGY COMM'N, http://www.energy.ca.gov/climatechange/ (last visited Oct. 22, 2015).

132. 2006 Cal. Stat. 89 (codified at CAL. HEALTH & SAFETY CODE §§ 38500–38599 (West 2011).

133. Erwin Chemerinsky et al., *California, Climate Change, and the Constitution*, 37 ENVTL. L. REP. 10,053, 10,053 n.6 (2007).

134. The system is described in detail at *Cap-and-Trade Program*, AIR RES. BD. (Sept. 18, 2015), http://www.arb.ca.gov/cc/ab32/ab32.htm.

135. Note that the failed effort in 2009–2010 to pass federal climate change legislation featured a similar offset program. *See* Maron Greenleaf, *Using Carbon Rights to Curb Deforestation and Empower Forest Communities*, 18 N.Y.U. ENVTL L.J. 507, 507–11, 523–35 (2011).

136. *Compliance Offset Protocol U.S. Forest Offset Projects*, AIR RES. BD. (Mar. 27, 2015), http://www.arb.ca.gov/cc/capandtrade/protocols/usforest/usforestprojects_2014.htm.

137. REDD OFFSET WORKING GRP., CALIFORNIA, ACRE AND CHIAPAS: PARTNERING TO REDUCE EMISSIONS FROM TROPICAL DEFORESTATION: RECOMMENDATIONS TO CONSERVE TROPICAL RAINFORESTS, PROTECT LOCAL COMMUNITIES AND REDUCE STATE-WIDE GREENHOUSE GAS EMISSIONS 2 (2013). For a more in-depth discussion of this California project, see Jesse Lueders et al., *The California REDD+ Experience The Ongoing Political History of California's Initiative to Include*

Besides these enthusiastic supporters, however, the California effort also has outspoken critics. They argue that "expecting carbon markets to do the job of protecting forests can, and does, lead to very problematic outcomes," including the destruction of subsistence farming, eviction of underprivileged groups from their lands, and increased social conflict.[138] As discussed below, the use of carbon trading systems to provide incentives for forest preservation has been a lively subject of international interest and dispute. The debate about California's effort mirrors this larger international discussion.

2. International Law and the Mitigation/Biodiversity Nexus

Efforts such as California's to link forest preservation with climate change mitigation draw on experience with debt-for-nature swaps. At the federal level, a 1998 statute[139] authorizes such swaps by the U.S. government with democratic nations containing intact blocks of forests.[140] Essentially, in return for assurances that forests will be protected, the United States can use debt swaps, buy-backs, or other forms of debt adjustment, accompanied by payments from local governments in their own currency (sometimes with the help of nongovernmental organizations) into a tropical forest fund.[141] The argument for this program has been specifically linked to its carbon mitigation benefits.[142] On the other hand, critics have worried about the effect of these

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Jurisdictional REDD+ Offsets Within Its Cap-and-Trade Program (Ctr. for Glob. Dev., Working Paper No. 386, 2014), http://ssrn.com/abstract=2622763.

138. Jeff Conant, *California REDD A False Solution*, FRIENDS OF EARTH (May 20, 2013), http://www.foe.org/news/archives/2013-05-california-redd-a-false-solution.

139. The Tropical Forests Conservation Act of 1998, 22 U.S.C. § 2151 (2012).

140. Private swaps have also been important:

> Most early transactions involved debt owed to commercial banks and were administered by nongovernmental conservation organizations and referred to as three-party swaps. Since 1987, three-party transactions have generated more than an estimated $140 million in local currency for conservation projects, as a result of the purchase of approximately $170 million in debt (face value) for approximately $49 million.

PERVAZE A. SHEIKH, CONG. RESEARCH SERV., RL31286, DEBT-FOR-NATURE INITIATIVES AND THE TROPICAL FOREST CONSERVATION ACT: STATUS AND IMPLEMENTATION, at Summary (2010), https://www.cbd.int/financial/debtnature/g-inventory2010.pdf.

141. Kunich, *supra* note 3, at 116–18. These governmental swaps have generated over $240 million in host country spending on forest preservation. SHEIKH, *supra* note 140, at 7.

142. The Congressional Research Service notes that "[t]ransactions under the [Tropical Forests Conservation Act] are expected to continue since it is included in strategies to address global climate change. Tropical forests make up the largest proportion of carbon stored in terrestrial land masses and are thought to be a carbon sink." SHEIKH, *supra* note 140, at 13. Moreover,

> [T]ropical countries with high levels of total debt owed to the United States also have some of the largest areas of tropical forest cover. For example, Brazil and Peru have debts to the United States totaling over $1 billion each, and have two of the largest areas of tropical forest cover in the world. Other countries, such as the Democratic Republic of Congo and Sudan, also fit this pattern; however, these countries may be ineligible for debt-for-nature transactions under the [Tropical Forests Conservation Act] due to political and economic eligibility requirements.

Id. at 10.

debt-for-nature swaps on indigenous populations; reflecting this, more recent swaps give additional attention to development goals beyond environmental protection.[143]

Climate negotiators have been moving toward something like a global swap, although the currency in this case is carbon rather than debt. The negotiations take place under the rubric of Reducing Emissions from Deforestation and Forest Degradation (REDD+).[144] Specifically,

> In a REDD+ project an entity—a national or regional government, a community, a private developer, an individual landowner-reforests a degraded ecosystem or preserves a forest that would otherwise be cut down or degraded. The entity may then sell the carbon, now sequestered in the trees, for a contracted period of time. REDD+ may happen on a project-by-project basis-one developer, one landowner. Or REDD+ may happen on a broader scale, i.e. a nation or state/province pledges to use REDD+ funding to reduce deforestation or foment reforestation resulting in sequestered GHGs above a "business as usual" (BAU) baseline.[145]

REDD+, in other words, is a mechanism for the wealthy global North to invest "in the vast, imperiled forests of the South."[146] Negotiators have pursued this goal through a series of international climate conferences. The Copenhagen Accord called for "the immediate establishment of a mechanism including REDD-plus, to enable the mobilization of financial resources from developed countries."[147] The Cancun Agreements to the Framework Convention on Climate Change went further, requesting a "robust and transparent" monitoring system as well as safeguards for sustainable development, poverty reduction, and indigenous peoples.[148]

It remains to be seen what role REDD+ will play in the next rounds of climate negotiations. But the idea seems to have a great deal of momentum;

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143. *See* Jared Knicley, Note, *Debt, Nature, and Indigenous Rights Twenty-Five Years of Debt-For-Nature Evolution*, 36 HARV. ENVTL. L. REV. 79, 88 (2012) (changing focus of swaps); *id.* at 94–109 (impacts on indigenous peoples). A related issue in arranging swaps with some countries is that their federal systems make it difficult to know whether the national government or a province or state should be involved. *See generally* Blake Hudson, *Federal Constitutions, Global Governance, and the Role of Forests in Regulating Climate Change*, 87 IND. L.J. 1455 (2012).

144. *See* David Takacs, *Forest Carbon (REDD+), Repairing International Trust, and Reciprocal Contractual Sovereignty*, 37 VT. L. REV. 653, 653–656 (2013). For an explanation of how REDD operates in practice, *see* Greenleaf, *supra* note 135, at 517–23.

145. *Id.* at 658–59.

146. *Id.* at 658.

147. Conference of the Parties, United Nations Framework Convention on Climate Change, Copenhagen, Den., Dec. 7–19, 2009, Report of the Conference of the Parties, Fifteenth Session, *Copenhagen Accord*, U.N. Doc. FCCC/CP/2009/11/Add.1 para. 6 (Mar. 30, 2010).

148. Conference of the Parties, United Nations Framework Convention on Climate Change, Cancun, Mex , Nov. 29–Dec. 10, 2010, Report of the Conference of the Parties, Sixteenth Session, *Cancun Agreements*, U.N. Doc. FCCC/CP/2010/7/Add.1 paras. 60(c), 71, 73 (Mar. 15, 2011). There was little further progress on REDD+ at the Lima talks in 2014, leading some to refer to "REDDlock." *See* Chris Lang, *What came out of Lima COP20 on REDD? Part 1 "REDDlock*," REDD MONITOR (Dec. 9, 2014), http://www.redd-monitor.org/2014/12/09/what-came-out-of-lima-cop20-on-redd-part-1-reddlock/

developed nations have pledged $100 billion by 2020 to support mitigation activities in developing countries, much of it likely involving REDD+.[149] Deals might be done on a project-by-project basis with local owners or might involve block transactions with nations or their subdivisions.[150] At this point, $5 billion in funding has been pledged specifically to REDD+,[151] and the World Bank has developed a program to help countries prepare to participate in REDD+ programs.[152] In short, the effort seems to be developing strong momentum.

While some praise this as an "historical opportunity" to link climate stabilization and finance for forest protections (and by extension for biodiversity preservation),[153] REDD+ has been subject to strong criticism. There are some practical concerns about the verifiability of carbon reductions.[154] Apart from the considerable problems of verification and monitoring, perhaps the biggest practical problem with REDD+ is the lack of clarity over who is actually entitled, through possession, ownership, or sovereignty,[155] to make deals for carbon credits and receive the benefits.[156] Other concerns are more philosophical. Some view it as a dodge to enable developed countries to avoid controlling their emissions, and others argue it will disadvantage local peoples who may be forced from their land or otherwise impacted.[157] But even some critics are beginning to see merit to the idea.[158]

Despite these difficulties, something like REDD+ seems inevitable for a variety of reasons. It is also important to remember that the alternative to REDD+ is not preservation of forests and their human inhabitants in their current state; it is damage to the forests from climate change and continued pressures for deforestation by developers.[159]From the point of view of the world at large, REDD+ provides an attractive way to reduce carbon emissions at relatively low cost.[160] Developed countries are likely to demand some effort by developing countries to control emissions relating to land use, as a quid pro

149. Takacs, *supra* note 144, at 655.

150. *Id.* at 659.

151. *Id.* at 664.

152. Lloyd C. Irland, *"The Big Trees Were Kings" Challenges for Global Response to Climate Change and Tropical Forest Loss*, 28 UCLA J. ENVTL. L. & POL'Y 387, 395 (2010).

153. *Id.* at 387.

154. Takacs, *supra* note 144, at 668. For a discussion of some of the measurement issues see *id.* at 671–75.

155. In the key countries with tropical forests, most of the forest is held as public property. Irland, *supra* note 152, at 396. Brazil, however, is experimenting with public-private partnerships in protected reserves. *See generally* Maria Augusta Ferreira, *The Brazilian Amazon Region Protected Areas (ARPA) Program The Challenges to a Public-Private Partnership*, 26 GEO. INT'L ENVTL. L.J. 389 (2014).

156. Takacs, *supra* note 144, at 711.

157. *Id.* at 661, 677; Greenleaf, *supra* note 135, at 523–26, 561–67.

158. Takacs, *supra* note 144, at 662.

159. As Irland points outs, demanding too much of REDD "is likely to lead to further paralysis, inaction, and continued forest loss," and to "suppose that available programs can turn aside deforestation and hold the line for a century seems a fantasy." Irland, *supra* note 152, at 431.

160. *See* Irland, *supra* note 152, at 392 (projected offset cost is lower than mitigation costs in industrial countries).

quo for decarbonizing their own energy systems. REDD+ also provides financial benefits that might flow to local residents,[161] landowners (not necessarily the same group), and national governments. But the final formulation of REDD+ is still in flux.[162] The upshot may well be a messy compromise that is just barely satisfactory to enough parties to get the deal done.[163]

There are two important lessons to be learned from the biofuels and REDD+ controversies. The biofuels debate reminds us that global food prices can be an important driver of deforestation. Simply by diverting farmlands in the United States or other producing countries to produce nonfood fuel, we are likely to increase deforestation elsewhere in the globe. The more positive lesson, however, is that we might be able to use this effect for beneficial purposes. By taking steps to increase U.S. production and lower global prices, we could actually reduce pressure for tropical deforestation. Second, as REDD+ illustrates, there are mechanisms for connecting climate mitigation efforts to forest preservation efforts. As we have seen, the problem is designing them to minimize any undesirable side effects.

Programs along the lines of REDD+ have the potential to mitigate climate change by reducing carbon emissions while at the same time protecting biodiversity. Biodiversity protection, however, is also linked with climate adaptation as well as mitigation. We consider that subject below.

B. Adaptation and Ecosystems

Climate change poses many threats, one of them being a potentially severe impact on biodiversity. To the extent that this harm is not—or cannot be—addressed by limiting emissions, we must undertake an effort to save as much diversity as we can.

This effort requires addressing other causes of biodiversity loss, such as invasive species, habitat fragmentation, and habitat conversion (e.g., forest to farmland). Some ecosystems and species may be beyond hope. Others will survive with no special effort on our part. But some will need human help of various kinds—including protection from other stressors that might exacerbate climate impacts.[164] Hence, we need to examine existing biodiversity protections to see how they might provide protection for species threatened by climate change. As above, we begin with the American situation and then turn to international law.

161. Unfortunately, the evidence suggests that decentralization does not further forest preservation. *Id.* at 405–06.

162. For case studies of efforts to define carbon rights in land in various countries that might be models for REDD+ programs, see Greenleaf, *supra* note 135, at 548–49, 556–58.

163. Many of the relevant issues to be decided are listed in Irland, *supra* note 152, at 426–28.

164. The theory behind this approach is to "use traditional conservation to reduce other threats so that target individuals can expend more time and energy in coping with climate change." *See* Hellmann et al., *supra* note 46, at 373. Others may require more intensive conservation techniques. *Id.* at 374–75.

Adaptation will require a host of measures—relocating communities and industrial activities away from some coastal areas, enhanced flood control measures, water projects to deal with increased drought, and so forth. The ESA can help ensure that those adaptation measures themselves do not threaten biodiversity.

1. Climate Change and the Endangered Species Act

In the United States, the key protection for biodiversity is the Endangered Species Act (ESA).[165] Although the statute is relatively simple compared to federal pollution law, it is neither straightforward nor transparent. Hence a short survey of the statute will provide useful background for an analysis of its treatment of climate change.

Listing an endangered or threatened species under the ESA triggers its protections.[166] Those protections are substantial. First, the species obtains protection on federal lands and during the course of federal action. Section 7(a)(2) of the ESA provides that "[e]ach Federal agency shall. . . insure that any action authorized, funded, or carried out by such agency . . . is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical] habitat of such species."[167] Second, section 9 of the ESA, arguably the most controversial aspect of the statute, establishes a broad prohibition against "taking" an endangered species, which includes hunting and trapping as well as habitat destruction.[168] Unlike section 7, which applies only to federal agencies, section 9 applies to "any person subject to the jurisdiction of the United States."[169] The Supreme Court has held that the "taking" prohibition applies not only to direct killing but also to habitat modifications that proximately cause the death of members of the species.[170]

Nevertheless, although the ESA can be a powerful tool to deal with discrete projects or individual actions that threaten a species, it was not

165. *See generally* 16 U.S.C. §§ 1531–1544 (2012). For a critique of the statutes and suggested alternatives, see REBUILDING THE ARK: NEW PERSPECTIVES ON ENDANGERED SPECIES ACT REFORM (Jonathan Adler, ed., 2011).

166. The listing determination is based on factors enumerated in § 1533(a). The decision must be made "solely on the basis of the best scientific and commercial data available." § 1533(b)(1)(A); *see* N.M. Cattle Growers Ass'n v. U.S. Fish & Wildlife Serv., 248 F.3d 1277, 1282 (10th Cir. 2001) (holding that Fish and Wildlife Service may not consider economic impacts in listing decision); *see also* Ctr. for Biological Diversity v. Badgley, 335 F.3d 1097, 1100–01 (9th Cir. 2003) (holding decision not to list was based only on best available scientific and commercial data and therefore was not arbitra4ry or capricious).

167. § 1536(a)(2). For an explanation of how this provision is applied, see Ruhl, *supra* note 5, at 42–44. The critical habitat component of this provision is frequently ignored in practice. *See* Dave Owen, *Critical Habitat and the Challenge of Regulating Small Harms*, 64 FLA. L. REV. 141, 146 (2012) (noting, however, that other provisions have been used to provide significant habitat protection).

168. 16 U.S.C. § 1538(a)(1)(B)–(C) (2012).

169. *See* Ruhl, *supra* note 5, at 14–15, 39.

170. Babbitt v. Sweet Home Chapter of Cmtys. for a Great Or., 515 U.S. 687, 708 (1995).

designed to address widely dispersed human activity such as carbon emissions by the world's energy system.[171] For instance, the ESA's requirement that an action proximately cause the death of members of the species arguably excludes carbon emissions.[172] Indeed, this is why the government issued a rule accompanying its finding that polar bears were threatened that made it clear that carbon emissions would not be considered takings.[173] Where species are not already irreversibly doomed by climate change, however, the statute could provide the impetus to protect remaining populations from other threats and to help species in overcoming barriers to migration to safer havens.[174]

It seems clear that agencies must consider climate change in listing decisions.[175] For instance, in *Greater Yellowstone Coalition v. Servheen*, the Ninth Circuit invalidated a decision to delist the Yellowstone grizzly bear because of the lack of appropriate consideration of the threat posed by climate change.[176] The emblematic victim of climate change, however, is the polar bear, whose threatened status was upheld by the D.C. Circuit in the appropriately named *In re Polar Bear* case.[177] Climate change has become a key consideration in a number of other marine species listing decisions,[178] as well as an increasingly prevalent consideration in new and revised recovery plans for listed species,[179] including two species of coral.[180]

The ESA is not the only federal statute relevant to biodiversity. The Magnuson-Stevens Fishery Conservation and Management Act allows the federal government to impose fisheries management plans for highly migratory species, including endangered species such as sharks.[181] The law has resulted

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171. Ruhl, *supra* note 5, at 6.

172. *Id.* at 41.

173. *See Polar Bear 4(d) Rule—Q's and A's*, U.S. FISH & WILDLIFE SERV., http://www.fws.gov/home/feature/2009/pdf/QandApolarbear4drule.pdf (last visited Oct. 10, 2015).

174. *See* Ruhl, *supra* note 5, at 13.

175. *Id.* at 33.

176. 665 F.3d 1015, 1024–1026, 1030 (2011).

177. *In re* Polar Bear Endangered Species Act Listing & Section 4(d) Rule Litig., 709 F.3d 1, 8–9 (D.C. Cir. 2013), *cert. denied sub nom*. Safari Club Int'l v. Jewell, 124 S. Ct. 310 (2013). The D.C. Circuit had little difficulty affirming the listing decision in this landmark case:

> The Listing Rule rests on a three-part thesis: the polar bear is dependent upon sea ice for its survival; sea ice is declining; and climatic changes have and will continue to dramatically reduce the extent and quality of Arctic sea ice to a degree sufficiently grave to jeopardize polar bear populations. No part of this thesis is disputed and we find that FWS's conclusion—that the polar bear is threatened within the meaning of the ESA—is reasonable and adequately supported by the record.

Id. at 8–9. Other arctic species also face peril because of climate change. *See* CRAIG, *supra* note 76, at 49.

178. Eric Seney et al., *Climate Change, Marine Environments, and the U.S. Endangered Species Act*, 27 CONSERVATION BIOLOGY 1138, 1142 (2013).

179. *Id.* at 1143.

180. CRAIG, *supra* note 76, at 11.

181. 16 U.S.C. §§ 1852(a)(3), 1854(g) (2012); Stijn Van Osch, *Save Our Sharks Using International Fisheries Law Within Regional Fisheries Management Organizations to Improve Shark*

in significant new restrictions on a number of fisheries, including some temporary shutdowns.[182] The Marine Mammal Protection Act (MMPA)[183] limits takings and importation of marine mammals, whether or not they are endangered, in order to ensure acceptable population levels and help maintain biodiversity.[184] The MMPA also authorizes the creation of marine sanctuaries.[185] These reserves are not like wilderness areas but are managed for multiple uses, including but not limited to biodiversity preservation.[186] However, the statute does require federal agencies and fishery management councils to consult with the National Ocean Service to ensure that their activities do not destroy marine resources.[187] In the past, presidents have also used other statutes such as the Antiquities Act to establish marine preservation areas.[188]

These statutes may need more vigorous application as marine species struggle to survive the climate crisis. Once carbon is in the atmosphere, we may not be able to prevent marine species from being impacted by climate change,[189] but we can at least give them a fighting chance by guarding them from overexploitation by humans.

2. International Law, Biodiversity, and Climate Adaptation

The legal regime of biodiversity protection at the international level is more complicated and, as we will see, in need of serious strengthening. As one observer remarks, "[t]here is a profusion of law relevant to marine

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Conservation, 33 MICH. J. INT'L L. 383, 392 (2012). The European Union (EU) has its own fisheries protections, though these have been criticized as ineffective. *Id.* at 394–95.

182. CRAIG, *supra* note 76, at 11. There also are statutes addressing specific problems such as invasive species from releases of ballast water. *Id.* at 58–71.

183. 16 U.S.C §§ 1361–1421 (2012). For discussion of the problems posed under the statute by climate change, see Keith Rizzardi, *Marine Mammal Protection Act Implementation in an Era of Climate Change*, *in* CLIMATE CHANGE IMPACTS ON OCEAN AND COASTAL LAW (Randall S. Abate ed., 2015).

184. For discussion of the operation of the statute, see Kunich, *supra* note 3, at 91–92.

185. 16 U.S.C. § 1431–1434 (2012). Such provisions are not unique to U.S. law. For discussions of reserves in other contexts, see CRAIG, *supra* note 76, at 148 (EU law), 140–41 (Australian law). California also has been active in this arena. *Id*. at 146–48.

186. § 1431.

187. §§ 1434(a)(5), 1434(d)(1)(A). The Coastal Zone Management Act requires federal agencies to ensure that their actions are consistent with approved state coastal management plans. 16 U.S.C § 1456(c) (2012).

188. 54 U.S.C.A. § 320301 (West 2014); *see* Jeff Brax, *Zoning the Oceans Using the National Marine Sanctuaries Act and the Antiquities Act to Establish Marine Protection Areas and Marine Reserves in America*, 29 ECOLOGY L.Q. 71, 123–27 (2002).

189. At present, the use of geo-engineering to reduce ocean acidification is only speculative and "would require large-scale terrestrial mining with associated consequences." Pörtner et al., *supra* note 89, at 454. The IPCC has this to say about methods for reducing global warming once CO_2 is already in the air: "The knowledge base on the implementation of SRM [solar radiation management] and CDR [carbon dioxide removal] techniques and associated risks is presently insufficient. Comparative assessments suggest that the main ocean-related geoengineering approaches are very costly and have large environmental footprints." *Id.*

biodiversity," including not only international law but "towering piles of statutes" by coastal nations covering everything from fisheries to ocean dumping.[190] Still, it is hard to quarrel with the conclusion that although "[g]overnance mechanisms have made some improvements in managing anthropogenic stressors of ocean ecosystems," it remains true that "what few successes exist are almost always limited and qualified."[191]

The United Nations Convention on the Law of the Sea (UNCLOS) contains provisions designed to limit overfishing and other forms of environmental harm.[192] For instance, within a country's exclusive economic zone (EEZ),[193] that country must ensure "through proper conservation and management measures that the maintenance of the living resources . . . is not endangered by over-exploitation."[194] Further, these measures are to consider "the effects on species associated with or dependent on harvested species with a view to maintaining or restoring [their] populations . . . ."[195] Article 119 imposes similar conservation obligations for fishing on the high seas—though apparently not very effectively, given that the high seas experience more overfishing than nations' territorial waters.[196] UNCLOS protections are not limited to fishing. For example, Article 192 provides that "States have the obligation to protect and preserve the marine environment," and Article 196 orders the implementation of "all measures necessary to prevent" the introduction of invasive species.[197]

The United Nations Straddling and Highly Migratory Fish Stocks Agreement fleshes out some of these rather abstract commitments.[198] It

190. Kunich, *supra* note 3, at 2. For a discussion of Australian statutes as an example, see *id*. at 93–96. For a good recent overview of international treaties and transboundary preservation efforts see Arie Trouwborst, *Global Large Carnivore Conservation and International Law*, 24 BIODIVERSITY AND CONSERVATION 1567 (2015).

191. CRAIG, *supra* note 76, at 41.

192. United Nations Convention on the Law of the Sea, art. 61, § 2, Dec. 10, 1982, 1833 U.N.T.S. 397. For an overview of UNCLOS, see DAVID BEDERMAN, INTERNATIONAL LAW FRAMEWORKS 125–29 (2001). There are also numerous regional agreements relating to marine environmental protection. *See* Kunich, *supra* note 3, at 36 n.139, 36–37.

193. A country's EEZ extends out two hundred nautical miles from shore. Kunich, *supra* note 3, at 40. Cumulatively, EEZs cover about 30 percent of the ocean and about 90 percent of commercial fisheries. *Id.* at 41.

194. United Nations Convention on the Law of the Sea, *supra* note 192, at art. 61, § 2.

195. *Id.* at art. 61, § 4.

196. *The Tragedy of the High Seas*, THE ECONOMIST (Feb. 22, 2014), http://www.economist.com/news/leaders/21596942-new-management-needed-planets-most-important-common-resource-tragedy-high.

197. United Nations Convention on the Law of the Sea, *supra* note 192, at arts. 192, 196.

198. United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, *opened for signature*, Dec. 4, 1995, 2167 U.N.T.S. 3 (entered into force Dec. 11, 2001). The agreement currently has eighty-one parties, and many states regard it as customary international law. *See* Cassandra Brooks et al., *Challenging the "Right to Fish" in a Fast-Changing Ocean*, 33 STAN. ENVTL. L.J. 289, 295–96 (2014). The majority of the fish catch falls into the straddling-stock category, crossing between EEZs and the high seas. *Id.* at 294.

provides for the establishment of Regional Fisheries Management Organizations (RFMOs) to govern fishing of particular stocks.[199] To date, seventeen RFMOs have been established.[200] All nations that exploit a stock are supposed to be brought under these RFMOs,[201] although enforcement powers remain with the member nations themselves.[202] These RFMOs have taken steps to protect endangered species such as sharks from incidental harm,[203] including imposition of some quotas and restrictions on fishing gear.[204] Owing to the potential for evasion of regulations by ships under flags of convenience, RFMOs have increasingly emphasized enforcement by port states.[205] RFMOs have gotten decidedly mixed reviews, with some observers expressing serious doubts about their effectiveness.[206]

Given RFMOs' limitations, the expanded use of marine preserves and other forms of ocean zoning may be especially important for mitigating the additional stresses climate change will impose on marine ecosystems.[207] Positively, there are a large number of current reserves.[208] Yet worryingly, reserves do not cover a dramatic percentage of ocean surface and their implementation has been spotty.[209] Still, despite some substantial problems in such reserves, even a vigorous critic of current marine biodiversity law says that, "All of the above issues notwithstanding, a large network of well-chosen and zealously guarded marine protected areas is perhaps the most indispensable ingredient in any effective legal response to the threats to life in our oceans."[210]

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199. Van Osch, *supra* note 181, at 407; *see* Kunich, *supra* note 3, at 57–58.

200. Wigginton, *supra* note 77, at 439.

201. Van Osch, *supra* note 181, at 407–08.

202. *Id.* at 418.

203. *Id.* at 410–12.

204. *Id.* at 414–15.

205. *Id.* at 419–20. The primary enforcers are supposed to be the flag states of vessels, but these are often "flag[] of convenience" nations that have little interest or ability to engage in regulation. Wigginton, *supra* note 77, at 442–43. About two-thirds of stocks subject to the agreements are depleted or overfished. Brooks, *supra* note 198, at 289, 297. For a discussion of the causes, see *id*. at 297–302. New technologies may facilitate enforcement. *See* Darryl Fears, ***Federal Officials Plan to Track Every Fish and Crustacean Shipped to U.S. Ports***, WASH. POST (Mar. 15, 2015), http://www.washingtonpost.com/national/health-science/sea-hunt-officials-plan-to-track-seafood-bait-to-plate-to-end-fraud/2015/03/14/0ab191d8-c7fe-11e4-aa1a-86135599fb0f_story.html.

206. Van Osch, *supra* note 181, at 421; Wigginton, *supra* note 77, at 440–41.

207. Craig, *supra* note 79, at 1222–26; CRAIG, *supra* note 76, at 35–39.

208. Perhaps the most striking example is President George W. Bush's decision to protect almost 140,000 square miles of coral ecosystems around the northern end of the Hawaiian Islands. CRAIG, *supra* note 76, at 122. Most marine protected areas are in coastal areas. *See* Brooks, *supra* note 198, at 207.

209. Kunich, *supra* note 3, at 51–52.

210. *Id.* at 108. That critic concedes that "intelligently chosen, appropriately sized, and vigorously regulated [marine protected areas] have been proven to be effective in preserving and replenishing populations of threaten[ed] marine species." *Id.* In addition, reserves may provide scientists with the opportunity to distinguish between the effects of stressors that are excluded from these areas such as overfishing and climate change, which cannot be excluded. CRAIG, *supra* note 76, at 129.

There are also some international efforts directed specifically at biodiversity. The Convention on Biological Diversity[211] requires parties to develop National Biodiversity Strategies and Action Plans.[212] These plans should "as far as possible and as appropriate" contain a lengthy list of measures, including creation of protected areas, ecosystem protection, restoration of degraded ecosystems, and controls on invasive species.[213] Much of the convention is designed to give countries an incentive to preserve biodiversity by giving them property rights in the products of wild species.[214]

Another biodiversity treaty, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES),[215] is designed to eliminate international markets for endangered species and their body parts.[216] The agreement is based on a system of import and export permits for listed species.[217] Notably, although more attention has been given to protecting animals, CITES also protects some types of tropical wood.[218] Yet, CITES is an imperfect tool. There are exceptions to the permit requirement, which appear limited on their face but have been subject to widespread abuse.[219] In addition, countries can issue reservations with regard to particular species, thus exempting them from the treaty's requirements.[220] Compliance has also been a problem.[221] And while CITES contains a trust fund to finance activities such as enforcement by developing countries, the fund has been underfinanced despite

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211. Convention on Biological Diversity, June 5, 1992, 1760 U.N.T.S. 79. For a description of the treaty, see Kunich, *supra* note 3, at 59–66.

212. *Id.* at art. 6.

213. *Id.* at art. 8.

214. For discussion of this strategy, see Andrew Jacoby & Charles Weiss, *Recognizing Property Rights in Traditional Biocultural Contribution*, 16 STAN. ENVTL. L.J. 74, 79 (1997).

215. Convention on International Trade in Endangered Species of Wild Fauna and Flora, Mar. 3, 1973, 993 U.N.T.S. 243.

216. *See id.* at arts. 1–4. For discussion of the provisions for listing species under CITES, including the requirement of a two-thirds vote of members, see Wigginton, *supra* note 77, at 444. Kunich, *supra* note 3, at 82 n.361 provides a list of species listed under the various Appendices of CITES. There have been repeated arguments that CITES should allow limited trade in the embargoed goods in order to incentivize local communities to preserve the stock. For a recent example of this argument, see Stefan Carpenter, *The Devolution of Conservation Why CITES Must Embrace Community-Based Resource Management*, 2 ARIZ. J. ENVTL. L. & POL'Y 1 (2011).

217. *See* EDITH BROWN WEISS ET AL., INTERNATIONAL ENVIRONMENTAL LAW AND POLICY 819–20 (2d ed. 2007). The Lacey Act also protects against invasive species. Hull, *supra* note 88, at 72.

218. WEISS ET AL., *supra* note 217, at 835. Going beyond CITES, the United States now imposes criminal liability for importing any plant if the plant was illegally obtained in its home country. *See* Stephanie Eberhardt, Comment, *The Act Amendments and United States' Policing of International Trade*, 35 HOUS. J. INT'L L. 398 (2013).

219. *Id.* at 820. The lack of coordination between CITES and fisheries provisions has also drawn criticism. Wigginton, *supra* note 77, at 449.

220. *Id.*

221. *See* John Heppes & Eric McFadden, *The Convention on International Trade in Endangered Species of Wild Fauna and Flora Improving the Prospects for Preserving Our Biological Heritage*, 5 B.U. INT'L L.J. 229, 231–34 (1987).

the addition of some voluntary contributions to its base funding.[222] Unfortunately, trade restrictions may often be much less effective in species preservation than other measures, provided that those other measures can be effectively enforced.[223]

The list of international agreements goes on. For instance, in addition to CITES and the Convention on Biological Diversity, there is a nonbinding set of forest principles designed to support sustainable development of forests.[224] There was a 1983 agreement on tropical timber, but this was later replaced by a 1994 successor agreement.[225] REDD+ is a further overlay. The proliferation of agreements is not encouraging. Rather, the multitude of efforts is an indication of legal fragmentation and a lack of confidence that any one of the treaties is effective enough to deal with the problem.

Biodiversity protections in the ocean are also numerous but fragmentary. In addition to the general treaties protecting biodiversity such as CITES, there are also numerous efforts focusing specifically on some aspect of marine biodiversity, covering everything from Antarctic seals to African-Eurasian migratory water birds.[226] This hodgepodge of efforts dealing with particular species exemplifies the fragmentation of ocean governance, which may be a hindrance to dealing with increasingly urgent problems.[227] An alternative would be to focus on specific areas of the ocean, either in terms of integrated coastal management or ocean zoning.[228] But more coherent forms of management may be difficult except in areas within national EEZs, where a single nation is in a position to undertake the governance effort, or perhaps in regional seas where the number of affected nations is limited.

In sum, the state of international biodiversity law can hardly be considered satisfactory, even apart from climate change. Given the added threat to biodiversity that climate change poses, it is all the more important that this legal regime be strengthened.

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222. Wigginton, *supra* note 77, at 455. Indeed, financial contributions are close to nominal amounts by the standards of major governments. *See How Is CITES Financed?*, CONVENTION ON INT'L TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA, http://www.cites.org/eng/disc/fund.php (last visited Oct. 11, 2015).

223. *See* Laura H. Kosloff & Mark Trexler, *The Convention on International Trade in Endangered Species No Carrot, but Where's the Stick?* 17 ENVTL. L. REP. 10,222, 10,226–27 (1987).

224. WEISS ET AL., *supra* note 217, at 902. The principles endorse the sovereign right to utilize forests and call for international cost-sharing of sustainability measures. *Id.* at 904.

225. *Id.* at 907–14.

226. CRAIG, *supra* note 76, at 91–92 (providing a lengthy list of such treaties).

227. *See id.* at 93. One reason that fragmentation is troubling is that it may reduce the cost of violating agreements. Specifically, a major cost of violation can be reputational harm. DANIEL BODANSKY, THE ART AND CRAFT OF INTERNATIONAL ENVIRONMENTAL HARM 91, 221 (2010). Yet fragmentation reduces transparency and limits the number of parties who might respond negatively to violation; thus lowering the reputational cost.

228. *See* CRAIG, *supra* note 76, at 95. President Obama has called for coastal and marine spatial planning in U.S. waters. *Id.* at 106–07.

III. COMMONALITIES AND SYNERGIES

We will explore two types of responses to the biodiversity crisis. One type of response, discussed in subpart A, focuses on the *supply* of overfishing and deforestation by imposing mandatory restrictions. The other type of response, discussed in subpart B, focuses on the incentives that drive overfishing and deforestation measures to reduce these pressures. These measures focus on the *demand* for overfishing and deforestation. In both contexts, the strategy is to allow countries that do want to address biodiversity to take action without waiting for agreement from laggards.

A. Coalition Formation and Unilateral Action

A key problem in both biodiversity preservation and climate change is developing coalitions of countries to address problems of global importance. Analysis of the challenges of building coalitions is much better developed in the climate context, although this analysis has direct applications to biodiversity. Yet progress in the climate arena has been frustratingly slow.[229] There have also been efforts in both areas to engage in transnational efforts outside of the traditional mechanisms of international law, such as treaties. Bottom-up and network approaches are beginning to play an important role in limiting carbon emissions.

1. Unilateral Measures

Given the difficulty of international cooperation, both climate change and protection of biological resources have led to some unilateral initiatives aimed not only at immediate results but also at helping build cooperative networks.[230] In both arenas, these unilateral efforts have raised legal challenges due to their potential interference with the rights of other jurisdictions, as we will see below.

In terms of climate change, a prime example in the United States is the litigation over California's low-carbon fuel standard (LCFS),[231] which attempts to cut the carbon intensity of transportation fuels by 10 percent by 2020.[232] The

229. For instance, a recent evaluation concludes that "[o]n current trajectories, results suggest that despite accelerating policy and management responses to the biodiversity crisis, the impacts of these efforts are unlikely to be reflected in improved trends in the state of biodiversity by 2020." Derek Tittensor et al., *A Mid-Term Analysis of Progress Toward International Biodiversity Targets*, 346 SCIENCE 241, 241 (2014).

230. For discussion of the potential benefits and drawbacks of unilateral action in the climate context, see Daniel A. Farber, *Carbon Leakage Versus Policy Diffusion The Perils and Promise of Subglobal Climate Action*, 13 CHI. J. INT'L L. 359 (2013). For an important recent contribution to this literature, see William Nordhaus, *Climate Clubs Overcoming Free-Riding in International Climate Policy*, 105 AM. ECON. REV. 1339 (2015).

231. *See* Rocky Mtn. Farmers Union v. Corey, 730 F.3d 1070, 1077–78 (9th Cir. 2013).

232. *Low Carbon Fuel Standard Program*, AIR RES. BD., http://www.arb.ca.gov/fuels/lcfs/lcfs.htm (last updated Oct. 7, 2015).

LCFS sets a baseline that is equal to the average carbon intensity for all vehicular fuels consumed in California and requires each supplier of vehicular transportation fuels in California to reduce its average carbon intensity from that baseline by set amounts each year between 2011 and 2020.[233] Because the carbon intensity is based on a lifecycle analysis, it includes emissions connected with the production of a fuel and its transportation to market, both of which are activities that arise outside of the state. More importantly, for our purposes, the lifecycle analysis also includes ILUC.[234]

In legal terms, the big issue about efforts to take ILUC into account relates to claims of impermissible extraterritoriality. Specifically, unilateral actions that attempt to account for out-of-jurisdiction emissions arguably exceed the legitimate geographic scope of a state's regulatory authority. Consequently, opponents challenged the California LCFS under the dormant Commerce Clause doctrine as an extraterritorial regulation—an argument the courts ultimately rejected.[235] This holding suggests that state efforts to prevent ILUC should also be found acceptable under U.S. law, although it remains to be seen whether other American courts will take a similarly permissive attitude.

However, U.S. law is not the only pitfall. To the extent that it affects international trade, the validity of the LCFS under World Trade Organization (WTO) law remains subject to debate.[236] At the international level, there have not yet been cases involving climate mitigation. But as we will discuss, unilateral action to protect marine species has repeatedly sparked litigation, often involving U.S. laws that require the use of fishing methods that prevent harm to other species as a condition for importing fish (even though the fish were not caught in U.S. waters).

Early decisions involved the United States' efforts to prevent incidental killing of dolphins by tuna fishermen, with tribunals striking these restrictions down as an unlawful exercise of extraterritorial jurisdiction.[237] Yet more recently, the WTO's Appellate Body rejected the extraterritoriality argument in

233. *Id.*

234. AIR RES. BD., LOW CARBON FUEL STANDARD RE-ADOPTION CONCEPT PAPER 7 (2014).

235. *Rocky Mountain Farmers Union*, 730 F.3d at 1103–04 ("Here, California properly based its regulation on the harmful properties of fuel. It does not control the production or sale of ethanol wholly outside California"). Admittedly, even if they are not considered extraterritorial or discriminatory, state regulations such as the California LCFS can still be challenged on the grounds that their local benefits are outweighed by their impacts on interstate commerce. *See* Paul T. Stewart, *Pike Balancing Vulnerabilities of State Greenhouse Gas Regulations and Possible Solutions*, 44 ENVTL. L. REP. 10874, 10874 (2014). Still, at least one expert in the dormant Commerce Clause considers it highly unlikely that the California LCFS will fail the balancing test. *See* Brannon Denning, *Environmental Federalism and State Renewable Portfolio Standards*, 64 CASE W. RES. L. REV. 1510, 1547 (2014).

236. *See* Cymie Payne, *Local Meets Global The Low Carbon Fuel Standard and the WTO*, 34 N.C. J. INT'L L. & COM. REG. 891, 908–15 (2009).

237. For discussion of these cases, see Mark Wu and James Salzman, *The Next Generation of Trade and Environmental Conflicts The Rise of Green Industrial Policy*, 108 NW. U. L. REV. 401, 408–13 (2014).

a case involving a U.S. statute relating to sea turtles, although it did require efforts at international negotiation before resort to unilateralism.[238]

The European Union (EU) has been a leader in climate mitigation and has undertaken some assertive—and controversial—unilateral actions. One of particular note was the inclusion of aviation within the EU emissions trading system,[239] which proved contentious because of the requirement that airlines account for all carbon emissions on flights to and from the EU, including emissions outside of Europe.[240] In another bold step, the EU has taken efforts to assure that palm oil biofuels come from sustainable sources, arguably intruding on the sovereignty of the countries where those fuels are produced.[241]

It remains to be seen how domestic and international legal systems will sort out these extraterritoriality issues. In an increasingly interconnected world, however, it obviously becomes ever more difficult to draw a line between a jurisdiction's legitimate authority over its own affairs and the affairs of other countries. On the one hand, a country that attempts to control carbon used to produce goods that it imports and consumes could be said to invade the sovereignty of the producer country. On the other hand, the producer country could be said to invade the sovereignty of the importing country by contributing to carbon emissions causing harm to the importing country's internal environment. From this perspective, the importing country could be said to be exercising its own sovereignty by limiting its consumption of a good whose production is causing it harm. Ultimately, none of these sovereignty claims has any logical claim to exclusive validity. Instead, a pragmatic adjustment of these claims is required; one that recognizes the urgent need for action in a heavily interconnected world where the idea of harmonized international concord cannot readily be achieved.

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238. *See generally* Robert Howse, *The Appellate Body Rulings in the Shrimp/Turtle Case A New Legal Baseline for the Trade and Environment Debate*, 27 COLUM. J. ENVTL. L. 491 (2002). For further discussion of the WTO issues, see Margaret Young, *Trade Measures to Address Environmental Concerns in Faraway Places*, 23 REV. EUR. COMP. & INT'L ENVTL. L. 302 (2014); Alessandra Arcuri, *Back to the Future US-Tuna II and the New Environment-Trade Debate*, 3 EURO. J. RISK REG. 177 (2012).

239. For discussion of this controversial effort and of the European Court of Justice decision upholding it, see Elaine Fahey, *The EU Emissions Trading Scheme and the Court of Justice The "High Politics" of Indirectly Promoting Global Standard*s, 13 GER. L.J. 1247 (2012). For background on the EU's efforts to leverage its market power, see Joanne Scott, *Extraterritoriality and Territorial Extension in EU Law*, 62 AM. J. COMP. L. 87 (2014).

240. *See* Jed Odermatt, *Case C-366/10 Air Transport Association of America and Others v. Secretary of State for Energy and Climate Change*, 20 COLUM. J. EURO. L. 143, 144 (2013).

241. *See* Jody Endres, *Barking Up the Wrong Tree? Forest Sustainability in the Wake of Emerging Bioenergy Policies*, 37 VT. L. REV. 763, 805 (2013).

2. Coalition Building

There has been considerable discussion of the dynamics of coalition building in the case of climate change.[242] A key problem confronting coalition efforts is that the coalition's effectiveness might be undermined by carbon leakage (that is, by countervailing increases in emissions elsewhere).[243] Still, this need not be fatal. Trade measures can provide one solution by discouraging noncoalition members from taking counterproductive actions.[244] And in any case, even with leakage, coalitions can be effective—particularly if they are able to induce carbon mitigation by nonmembers through trade measures, reducing the costs of mitigation technologies, or serving as role models.[245] A similar analysis may apply in the case of tropical forests, to the extent that forest preservation in one area might increase pressures for deforestation in others, a different kind of "leakage."

One reason for the fragmentation of international biodiversity law is that treaties often involve different coalitions of nations and different levels of involvement. For instance, the United States is a signatory to some treaties such as CITES[246] and the International Convention for the Regulation of Whaling,[247] but has eschewed others such as the Convention on Biological Diversity[248] and UNCLOS[249]—yet despite the lack of ratification it still complies with much of UNCLOS as a form of customary international law.[250] The international regime might be more effective if these various agreements were woven together more coherently.[251]

242. The discussion in this paragraph is based on the more detailed analysis in Farber, *supra* note 230.

243. Farber, *supra* note 230, at 368–72.

244. A novel approach of this sort is Richard Nordhaus's recent call for the use of "climate clubs"—coalitions which would address leakage via carbon tariffs against imports from countries with weak carbon policies. *See* Nordhaus, *supra* note 230, at 1339. Indeed, Nordhaus even argues for punitive tariffs on all imports from nonmembers in order to pressure countries to join the international effort to mitigate carbon. *See id*. at 1148–51.

245. Farber, *supra* note 230, at 374–77.

246. For ratification information, see *Digest of Federal Resource Laws of Interest to the U.S. Fish and Wildlife Service*, U.S. FISH & WILDLIFE SERV.**,** http://www.fws.gov/laws/lawsdigest/treaty.html #CITES (last visited Oct. 11, 2015).

247. *See Membership and Contracting Governments*, INT'L WHALING COMM'N, https://iwc.int/members (last visited Oct. 11, 2015).

248. The United States signed the Convention but did not ratify it. *See List of Parties*, CONVENTION ON BIOLOGICAL DIVERSITY, https://www.cbd.int/information/parties.shtml (last visited Oct. 11, 2015).

249. BODANSKY, *supra* note 227, at 114.

250. MICHAEL GERRARD, GLOBAL CLIMATE CHANGE AND U.S. LAW 234 (2007).

251. On the benefits of reduced fragmentation and increased coherence in ocean protection, see CRAIG, *supra* note 76, at 93. She contends that the "treaties' species-by-species approach to ocean resource management—like fragmented ocean governance generally—poorly addresses the systemic and synergistic threats to marine ecosystems." *Id.* In addition, fragmented governance results in "regulatory chaos—that is, multiple authorities regulating different aspects of the same marine environments while pursuing individual and often conflicting priorities." *Id.* Place-based management systems have been proposed as a way of dealing with this problem. *See id.* at 95.

A few additional thoughts about international coalitions are in order. Like REDD+ or debt-for-nature swaps, trade restrictions and other similar actions provide a means for coalitions of the willing to deal with threats to biodiversity and carbon emissions taking place outside of their own jurisdictions. Although they can create a backlash to the extent that other nations see them as overbearing or as invasions of sovereignty, they can also provide a driving force toward broader international agreement when other nations accept them or decide to join the effort. In an ideal world, efforts of this kind would not be necessary. But, in our decidedly nonideal world, they may be important levers to deal with global issues.

Because much of the discussion of coalition building has focused on climate change, it has had to rely on modeling predictions as much as experience. Broadening the inquiry to include other global problems would be useful. A focus on how coalitions form and deal with outsiders could provide a new perspective on international law more generally.

B. Addressing "Nonenvironmental" Drivers of Climate Change and Global Biodiversity Loss

Like laws and treaties directly protecting biodiversity, the measures discussed above operate by restricting deforestation or overfishing through mandates or contracts. Another strategy is to make these activities less profitable by reducing the demand for them. These policies can involve seemingly nonenvironmental activities such as the food choices of consumers in faraway countries. Hence, here we consider a varied list of policy tolls that can reduce pressures on tropical forests and fishing stocks: dietary change, greater crop yields, increased sustainable aquaculture, population control, and the elimination of subsidies.

1. Dietary Changes

Our food system is a major source of environmental problems, including a substantial source of GHGs.[252] In 2002 the food industry, from fertilizer production through fast-food outlet, accounted for a startling 14.4 percent of U.S. energy use.[253] In terms of carbon emissions, shifting one day a week from

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252. HANNAH PEARCE ET AL., SUSTAINABLE CONSUMPTION ROUNDTABLE, DOUBLE DIVIDEND? PROMOTING GOOD NUTRITION AND SUSTAINABLE CONSUMPTION THROUGH HEALTHY SCHOOL MEALS 14–23 (2005), http://www.sd-commission.org.uk/data/files/publications/Double_Dividend.pdf.

253. PATRICK CANNING ET AL., U.S. DEP'T OF AGRIC., ENERGY USE IN THE U.S. FOOD SYSTEM 11–12 (2010), http://www.ers.usda.gov/media/136418/err94_1_.pdf ("This estimate puts the food-related share of the national energy budget at 15.7 percent for 2007."). However, most of the food industry's energy use occurs after food leaves the farm—barely over 1 percent of U.S. energy use is agricultural. *See* RANDY SCHNEPF, CONG. RESEARCH SERV., RL32677, ENERGY USE IN AGRICULTURE: BACKGROUND AND ISSUES 2, 4 (2004), http://nationalaglawcenter.org/wp-content/uploads/assets/crs/RL32677.pdf.

meat or dairy products to chicken, fish, or eggs is said to be equivalent to reducing driving by around 760 miles per year.[254]

It is not only the amount of food and the way it is produced, but also the balance between different food groups that contributes to the problem.[255] Every year, Americans slaughter more than ten billion animals for food, over 15 percent of the global total—meat production thus accounts for large part of national GHG emissions.[256] A review of the literature concluded that "higher consumption of animal-based foods was associated with higher estimated environmental impact."[257] This reflects its greater energy intensity: "one calorie from beef or milk requires 40 or 14 calories of fuel, respectively, whereas one calorie from grains can be obtained from 2.2 calories of fuel."[258] Consequently, the scientific advisory report on the forthcoming nutrition guidelines for Americans favors less meat for both health and environmental reasons.[259]

Because it takes a great deal of feed to produce just one pound of meat,[260] meat consumption drives up prices for grains and other feeds—and as we have seen in the discussion of ILUC, higher prices translate into greater deforestation via global agricultural markets. Reducing prices through higher yields or greater efficiency does not undo past deforestation; but it reduces pressures for further deforestation and may make reforestation more feasible by encouraging farmers to abandon some of the converted land. At the risk of creating additional jargon, one might call this the "reverse ILUC effect," since unlike ordinary ILUC it actually favors protections of forests, other wildlands, and biodiversity. Thus, dietary change is a demand-side measure to reduce deforestation.

254. JASON J. CZARNEZKI, EVERYDAY ENVIRONMENTALISM: LAW, NATURE & INDIVIDUAL BEHAVIOR 86 (2011).

255. As a report commissioned by the British government notes:

> Many studies show that meat and dairy products, when produced using modern intensive methods, have the highest environmental impacts of all food groups. These impacts reflect the resources (fertiliser, pesticides and energy) required to produce and transport animal feed in the first place, the low efficiency with which animals convert that feed to milk or meat, the high water needs of cattle, slaughterhouses and processing factories, and the waste produced by farm animals. There are also lesser impacts associated with overgrazing when this occurs, which reduces soil carbon and biodiversity.

PEARCE ET AL., *supra* note 252, at 17.

256. *See* CZARNEZKI, *supra* note 254, at 86.

257. BARBARA MILLEN ET AL., U.S. DEP'T OF AGRIC., SCIENTIFIC REPORT OF THE 2015 DIETARY GUIDELINES ADVISORY COMMITTEE 15 (2015), http://health.gov/dietaryguidelines/2015-scientific-report/pdfs/scientific-report-of-the-2015-dietary-guidelines-advisory-committee.pdf (Part D, Chapter 5).

258. *Id.*

259. *Id.* at 49.

260. Mark Bittman, *Rethinking the Meat Guzzler*, N.Y. TIMES (Jan. 27, 2008), http://www.nytimes.com/2008/01/27/weekinreview/27bittman.html?pagewanted=1 ("[A]bout two to five times more grain is required to produce the same amount of calories through livestock as through direct grain consumption . . . It is as much as 10 times more in the case of grain-fed beef in the United States.").

2. Improved Agriculture and Aquaculture

As the ILUC effect of biofuels illustrates, increased demand for cropland increases deforestation. Logically, then, reduced demand for cropland should have the opposite effect. Consequently, an alternative way of meeting food demand is to increase yields on existing acreage rather than increasing croplands. Higher yields mean lower food prices, which in turn provide less incentive to convert forests into fields or pasture. In short, increased yields can also promote the reverse ILUC effect.

Demand-side measures may also help protect fisheries. Aquaculture provides an alternative that may reduce pressures on wild fish stocks.[261] In 2012 fish farming produced ninety million tons of fish at a value of $144 billion, with China as the largest producer, and the amount continues to rise.[262] Indeed, the World Bank projects that farmed fish will serve as an increasingly important source of protein for the also-increased midcentury global population.[263] For those reasons, a substantial expansion of sustainable aquaculture (primarily of herbivorous fish) could reduce pressure on wild stocks and could also potentially reduce demand for other forms of animal protein such as beef.[264] In the United States, the food guideline advisory group found that expanding aquaculture could provide sufficient seafood to comply with dietary guidelines and concluded that, from a GHG perspective, farm-raised fish were more sustainable than beef or pork.[265] Likewise, the IPCC has observed that "[i]f cattle production contributes to tropical deforestation, land-use related GHG emissions are particularly high," findings that "underline the importance of diets for GHG emissions in the food supply chain."[266]

3. Population Control

Population growth will increase food consumption which, in turn, is likely to place pressure on wildlands. In exploring this connection, the U.N. Food and Agriculture Organization (FAO) has noted that global population is expected to grow by 2.3 billion by midcentury, with almost all of the growth occurring in developing countries and the fastest growth in sub-Saharan Africa.[267] Because

261. For discussion of efforts to expand sustainable aquaculture in China in order to reduce strains on wild stocks, see Eric Vance, *Fishing for Billions*, SCI. AM. 51 (Apr. 2015).

262. Craig, *supra* note 79, at 1196–97.

263. SIWA MSANGI ET AL., WORLD BANK, FISH TO 2030: PROSPECTS FOR FISHERIES AND AQUACULTURE xii–xv (2013), http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/01/31/000461832_20140131135525/Rendered/PDF/831770WP0P11260ES003000Fish0to02030.pdf.

264. Craig, *supra* note 79, at 1230–35.

265. MILLEN ET AL., *supra* note 257, at 16 (Part D, Chapter 5).

266. Smith et al., *supra* note 108, at 840.

267. FOOD & AGRIC. ORG. OF THE UNITED NATIONS, GLOBAL AGRICULTURE TOWARDS 2050, at 1 (2009), http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf.

of population growth and economic growth allowing people to secure more adequate food supply and to change their diets, the FAO forecasts that the world food supply will need to increase 70 percent in the first half of this century.[268] This will require a 12 percent increase in arable land in developing countries, with nearly all of the required increase being in sub-Saharan Africa and Latin America.[269] In turn, since those areas of the globe where the expansion of arable land would be greatest also feature major tropical forests, much of the newly-cultivated land will be converted forests. Population growth at the global level, then, indirectly threatens to decrease biodiversity and accelerate climate change because of its effect on food needs. And lessening it will have the opposite effect.

Population growth also directly contributes to deforestation, as expanding populations in currently forested regions need additional living space. Currently, population density in forested areas varies between countries, with India, Nigeria and Vietnam at the high end.[270] But many of the other forested countries are projected to have major population increases by midcentury for a total increase of 1.2 billion people in those countries, equivalent to adding another China to today's world.[271] Population increase in these countries is bound to put increasing pressure on forests there as human settlements expand. Conversely, population control policies can boast positive effects on biodiversity.

In sum, there are two reasons why population growth increases pressures on biodiversity. One reason is geography: some areas where high growth is predicted are also near biodiversity hotspots. The other reason is that population growth increases food needs, which can lead to conversion of wild lands into agricultural use even if the population growth takes place in other areas.[272] Recognition that human population growth increases pressures on biodiversity is important, but it should not be allowed to detract from the role of consumption by developed countries in producing environmental stress, often in the form of higher carbon emissions. Controlling population growth is obviously a complex topic, but one that deserves more attention from biodiversity advocates.

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268. *Id.* at 2.

269. *Id.* at 3.

270. Irland, *supra* note 152, at 400–10.

271. *Id.* at 401.

272. As Primack notes, "human population density is a good predictor of the intensity of threats to biodiversity," and "rates of deforestation are greatest in countries with the highest rates of human population growth." PRIMACK, *supra* note 2, at 175. He also observes that "[t]he 1 billion impoverished people of the world who live on less than $2 per day are too hungry and desperate to worry about protecting biodiversity." *Id.*

4. Subsidies

Reducing subsidies is another important route to protecting biodiversity. Governments spend up to $20 billion per year subsidizing fishing; without this support much fishing would be unprofitable.[273] In particular, poorly designed subsidies encourage overfishing.[274] These problems have not gone unnoticed; the United Nations Environmental Programme (UNEP) has called upon the WTO to address fishery subsidies.[275]

Given that agricultural expansion is a primary cause of deforestation,[276] agricultural subsidies are also a concern. According to a recent report from the WorldWatch Institute the top food-producing countries dispense annual agricultural subsidies of nearly half a trillion dollars in the top food-producing countries,[277] with a quarter of a trillion dollars in the predominantly wealthy Organisation for Economic Co-operation and Development (OECD) member countries alone.[278] These subsidies distort world trade, which means that food is not produced in the most efficient manner. Given the need to use land efficiently in order to reduce the pressure on forests, this seems environmentally undesirable.[279] In addition, eliminating subsidies could free up government funds that might be more productively used for agricultural research on matters such as agricultural productivity and sustainability.[280]

Some subsidies, like regulations, may be designed to decrease the environmental footprint of agriculture, either in terms of harm to biodiversity or other impacts such as water pollution. The analysis in this Article suggests a possible cautionary note about such efforts, although it does not by any means suggest that they should be abandoned. For instance, suppose the government pays farmers to take land out of production or to use less intensive farming method. Despite the appealing possibility that these restrictions produce local environmental benefits, they may also have undesired effects like reducing

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273. Van Osch, *supra* note 181, at 389; Kunich, *supra* note 3, at 27.

274. *See Subsidies in Fisheries*, FOOD AND AGRIC. ORG. OF THE UNITED NATIONS, http://www.fao.org/fishery/topic/13333/en (last visited, Oct. 23, 2015).

275. *See* WORLD WILDLIFE FUND AND UNITED NATIONS ENVTL. PROGRAMME, SUSTAINABILITY CRITERIA FOR FISHERIES SUBSIDIES: OPTIONS FOR THE WTO AND BEYOND i (2007), http://www.unep.ch/etb/publications/fishierSubsidiesEnvironment/UNEPWWF_FinalRevi09102007.pdf.

276. Greenleaf, *supra* note 135, at 515.

277. These food-producing countries are the OECD countries, plus Brazil, China, Indonesia, Kazakhstan, Russia, South Africa, and Ukraine. GRANT POTTER, WORLDWATCH INSTITUTE, AGRICULTURAL SUBSIDIES REMAIN A STAPLE IN THE INDUSTRIAL WORLD 1 (2014), http://vitalsigns.worldwatch.org/sites/default/files/vital_signs_trend_agricultural_subsidies_final_pdf_0.pdf

278. *Id.*

279. Admittedly, the ramifications for developing countries of global subsidy reductions are complex. For a detailed discussion, see WORLD BANK, WORLD DEVELOPMENT REPORT 2008, at 96–117 (2008), http://siteresources.worldbank.org/INTWDR2008/Resources/2795087-1192112387976/WDR08_08_ch04.pdf. As a result, the precise effects on land use (including forest preservation) deserves much fuller exploration than can be attempted here.

280. Of course, it is also possible that the budgetary savings might be used in some other way, perhaps for tax cuts, to reduce borrowing, or to finance nonagricultural activities.

agricultural output in the United States and raising world food prices, prompting conversion of tropical forests to agricultural use elsewhere in the world.[281]

This potential cost may need to be weighed against the local environmental benefits, another similarity to biofuel production. For example, suppose that agricultural runoff of pesticides or fertilizer endangers some freshwater fish in the United States. Addressing the problem would preserve U.S. biodiversity, but doing so might decrease crop yields, which could have negative effects on biodiversity elsewhere. As in the case of ethanol production and ILUC, this could in turn result in tropical deforestation and the loss of an even greater number of species. Of course, there are a number of "ifs" in this scenario. The point is not that we should decrease protection of endangered species in this country because of this potential problem, but simply that we need to keep it in mind.

5. Advantages of Demand-Side Measures

To summarize the discussion of demand-side measures, several policy options that do not directly address climate change could, if properly implemented, reduce pressures on tropical forests and attendant carbon emissions. First, dietary changes that favor plant products rather than meat (particularly beef) could reduce emissions, thereby mitigating climate change and reducing ILUC pressures on forests. Second, if implemented sustainably, increased agricultural yields would reduce the land needed for crops, reducing pressures on forests through the reverse ILUC effect.[282] Likewise, greater use of aquaculture could preserve fisheries and marine biodiversity. Thus, research and development to improve agriculture and aquaculture productivity would help protect biodiversity hotspots. Third, noncoercive measures to reduce population growth in key countries with tropical forests would reduce pressures on those forests. Fourth, we should work to eliminate agricultural and fishing subsidies.

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281. This may not always be the case—these measures could help limit insect or other threats to crops by providing buffers, or they might reduce erosion and improve long-term production sustainability.

282. However, as the IPCC explains, there are pitfalls as well as benefits:

> While yield increases can lead to improvements in output from less land, generate better economic returns for farmers, help to reduce competition for land, and alleviate environmental pressures, agricultural intensification if poorly implemented incurs economic costs and may also create social and environmental problems such as nutrient leaching, soil degradation, pesticide pollution, impact on animal welfare, and many more. Maintaining yield growth while reducing negative environmental and social effects of agricultural intensification is, therefore, a central challenge, requiring sustainable management of natural resources as well as the increase of resource efficiency, two components of sustainable intensification.

Smith et al., *supra* note 108, at 842.

Although these methods of reducing future pressure on tropical forests or marine ecosystems are indirect, they have some strategic advantages over traditional international mechanisms. Many of the indirect methods do not require other nations to agree to restrictions on their own actions,[283] and some of them, such as agricultural research to increase yields, can be purely unilateral.[284] Demand-side restrictions also have the added advantage of allowing coalitions with other groups that are not primarily environmental. For instance, groups concerned with nutrition and health, rather than climate or biodiversity, also support dietary changes. Similarly, those whose primary interest is free markets or smaller government—some of whom may be otherwise antipathetic to environmental causes—can still support reductions in subsidies.[285] In other words, unconventional measures provide the opportunity to form equally unconventional partnerships that indirectly achieve environmental goals such as limiting deforestation

These efforts to address the demand for deforestation or overfishing should not be seen as alternatives to the more traditional efforts that focus on the supply side. Instead, the two approaches are complementary. Any progress that is made on the demand side by definition reduces the incentives for overfishing and deforestation. It is logical to expect that reduced incentives for these undesirable behaviors will make it easier to adopt and enforce regulations directed at the supply side, such as the creation of protected reserves.[286] Moreover, without supply-side regulations, some kinds of demand-side interventions might result in leakage. For instance, lowering demand for meat in some countries might produce lower prices for grains. This would decrease deforestation to produce feed for beef, but the lower feed prices would also make producing beef cheaper, which could increase demand in other countries.[287] Thus, supply-side efforts can reinforce demand-side efforts and vice versa. The two types of efforts are mutually supportive.

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283. Americans, for instance, do not need the consent of other countries to change our diets.

284. It is possible for a single country to do a great deal in the realm of agricultural research. The United States government alone spends $4 billion per year on such research. David Malakoff, *U.S. Should Grow Research Spending, White House Panel Recommends*, SCIENCE: SCIENCE INSIDER (Dec. 7, 2012, 5:45 PM), http://news.sciencemag.org/people-events/2012/12/u.s.-should-grow-agricultural-research-spending-white-house-panel-recommends.

285. For example, both the libertarian Cato Foundation and the Environmental Working Group support reductions in agricultural subsidies. Daniel Griswold et al., *Ripe for Reform Six Good Reasons to Reduce U.S. Farm Subsidies and Trade Barriers*, CATO INST. (Sept. 14, 2005), http://www cato.org/publications/trade-policy-analysis/ripe-reform-six-good-reasons-reduce-us-farm-subsidies-trade-barriers; Craig Cox, *Crop Insurance Creates "Destructive Incentives" for Farmers NRDC Study Confirms Fundamental Reform is Needed*, ENVTL. WORKING GRP. (Aug. 27, 2013), http://www.ewg.org/agmag/2013/08/crop-insurance-creates-destructive-incentives-farmers.

286. Conversely, high prices for the fruits of illegal fishing or agriculture on deforested lands will give rise to more opposition to creating reserves and more temptation to violate them. Thus, demand-side measures can further those on the supply side.

287. This is an example of leakage—some of the carbon saved by the diet reductions in one country "leaks" elsewhere via market mechanisms.

Although a more accurate estimate of the magnitude of demand-side effects would require complex modeling such as that used to investigate ILUC from biofuels, it is possible to get a sense of the magnitude of the possible effects. Given the rough estimate in the Appendix that ILUC from biofuel production has resulted in the destruction of about two million acres of tropical forests, the benefits from adopting measures to reduce pressures on tropical forests would seem significant. But the long-term benefits of demand-side measures might become much more significant as food supplies come under increased pressure and prices rise accordingly.[288]

Whether or not we choose to frame them as demand-side approaches to reducing deforestation, we have little choice except to find ways to increase yields, reduce meat consumption, improve aquaculture, and so forth. The most compelling reason is humanitarian—we must do so in order to feed an ever-larger human population.[289] But it is also true that, unless we meet the increased need for food in some other way, the pressures to overfish and to convert forests into agricultural production will become intense—perhaps more powerful than we can expect to control through regulatory measures. In short, we must dramatically improve our ability to obtain food from areas that are already in use or that are not ecologically sensitive, as a prerequisite of effective biodiversity preservation.

The upshot is that U.S. environmentalists might do well to broaden their horizons when thinking about biodiversity. Too heavy a focus on biodiversity in the United States may detract attention from the threats to biodiversity elsewhere, which may be much more important to biodiversity on the global level. This does not mean that issues in this country should be ignored; indeed, one might argue that given the sparser endowment of biodiversity in the United States, protecting what we have is even more important. But in terms of richness of species and ecological complexity, the real action is elsewhere.[290]

CONCLUSION

The world has entered the Anthropocene, a geological period dominated by humans.[291] Humans have already begun to change the climate, and unless we take serious steps to limit emissions, the changes may become severe. We

288. According to one estimate, past intensification of grain production has saved eighteen to twenty-seven million hectares of additional land that would otherwise have been needed to maintain the same level of grain supplies. *See* Ruth DeFries et al., *Metrics for Land-Scarce Agriculture*, 349 SCIENCE 238, 238 (2015).

289. *See* Deepak K. Ray et. al., *Yield Trends Are Insufficient to Double Global Crop Production by 2050*, PLOS ONE, June 2013, at 1.

290. *See supra* Part I.A.1.i.

291. Whether to make this designation official is still under consideration, but it seems clear that humans have had a massive impact on the planet already. *See* Hillary Young, *The Hitchhiker's Guide to the Anthropocene*, 347 SCIENCE 955, 955–56 (2015).

have also had a massive impact on ecosystems across the globe, accelerating the pace of extinction far beyond the baseline rate.[292]

Sea level rise and the destruction of some rare butterfly may seem unrelated, and sometimes they may be. But at a larger scale, biodiversity and climate are closely related, given the impact of climate change on biodiversity and the feedback loop from deforestation back to climate change. Because neither our activities nor our impacts on the planet are localized, it is increasingly easy for events in one location such as a biofuel mandate to impact biodiversity in a far-removed portion of the world. An early ecological slogan was that "everything is connected to everything else."[293] That slogan has, if anything, even greater relevance today.

Runaway carbon emissions pose perhaps the greatest risk of wreaking havoc with the planet, including its ecological systems. As we attempt to create an international regime to control carbon, control of deforestation is a necessary component, with a co-benefit of preserving biodiversity. REDD+ is emblematic of the functional connection between mitigation and forest preservation. Moreover, efforts to preserve biodiversity must now take climate change into account, whether in relatively mature domestic biodiversity laws or in the still-developing international biodiversity regime. One of the challenges in adapting to climate change is finding ways to preserve biodiversity, so conservation biology must take climate change as a key variable.[294]

Connections between climate change and biodiversity run even deeper. In both cases, in the absence of effective global agreement, unilateral actions and efforts to form "coalitions of the willing" continue to play a central role.[295] These piecemeal actions may be indispensable, but they may also cause tensions between jurisdictions and raise complex legal issues. Thus, we are likely to see an increasing interplay between climate and biodiversity, as efforts to build coalitions to deal with one problem provide the foundation for efforts to deal with the other, and as lessons are learned in one area provide insight into fruitful strategies for the other.

Furthermore, as shown in Part III, both biodiversity loss and deforestation are partly driven by the global food system, as pressures to increase food supply place pressure on marine resources and tropical forests. A variety of strategies to reduce this pressure have promise for indirectly limiting carbon emissions and protecting biodiversity. For instance, enhanced levels of agricultural research might raise crop yields and allow agriculture on degraded lands, reducing incentives to turn to tropical forests and other wildlands for agriculture.

292. *See supra* Part I.

293. BARRY COMMONER, THE CLOSING CIRCLE 33 (1971)

294. See, for instance, the discussion of climate change in PRIMACK, *supra* note 2, at 204–13.

295. *See supra* Part III.A.

All of these strategies will take creativity and extraordinary effort. Achieving international cooperation is never easy, and cooperation on a particularly wide scale is needed to deal with the twin crises of biodiversity and climate. Unfortunately, we have now placed the planet and ourselves in a position where nothing less will suffice. But we can only hope that human creativity and dedication show themselves to be equal to the task.

APPENDIX

It is instructive, just to get a sense of relative magnitudes, to perform a rough calculation of how devoting an extra acre of land translates into loss of tropical forest.[296] The calculation goes like this:

One acre of corn produces approximately 423 gallons of biofuel annually.[297]

One gallon of ethanol produces eighty-nine megajoules (MJs),[298] so one acre of corn translates into 37,647 MJ of energy from the ethanol annually.

One MJ of energy produces twenty-seven grams of CO_2 from ILUC.[299] Thus 37,647 MJ (annualized energy yield from one acre of corn) produce 1,016,469 grams of CO_2, or 1016.5 kilograms (kgs) annually.

We now need to convert from annualized to total figures. The reason is that an acre of forest is only destroyed once due to ILUC from a particular cornfield, whereas the ILUC estimate needs to spread that loss over the fuel produced from that field over an extended period of time. Hertel et al. assume a thirty-year production period, so we need to "de-annualize" the ILUC estimate by multiplying by thirty. This gives total emissions due to ILUC from one acre of corn as 30,495 $kgCO_2$.

One acre of tropic forest stores 109 metric tons of CO_2, or 109,000 kg CO_2.[300] That number, divided by the 30,495 $kgCO_2$ of ILUC emissions from an acre of corn, means that 3.5 acres of corn devoted to ethanol cause the destruction of about one acre of tropical forest.

Therefore, for every 3.5 acres of corn devoted to corn biofuel, this calculation suggests that we lose an acre of tropical forest. In 2011 91 million acres of corn were planted in the United States, of which 27 percent were used for corn ethanol—about 24.5 million acres. This would translate into a loss of seven million acres of tropical forest. However, a significant correction is required because roughly two-thirds of the indirect land use change takes place in Europe and the United States through conversion of pastureland and forests to cropland.[301] This leaves us with an estimate of 2.3 million acres of forest loss in Asia, Latin America, and Africa (one-third of the seven million total).

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296. One reason that calculation is rough is that it assumes for simplicity that all the land lost due to ILUC is rainforest, whereas in reality ILUC could also involve other types of terrain such as grasslands and nontropical forests.

297. *Corn Ethanol Production*, EXTENSION (Oct. 2, 2014), http://www.extension.org/pages/14044/corn-ethanol-production#.VgNbx49Vikp.

298. *Converter*, ITEC, http://www.itecref.com/resources-converter.html (last visited Oct. 23, 2015).

299. This estimate is from Hertel et al., *supra* note 128, at 225.

300. *Frequently Asked Questions - Ecosystem Services*, WORLD LAND TRUST, http://www.worldlandtrust.org/eco-services/faq#Q19 (last visited Oct. 10, 2015).

301. Both the two-thirds figure and the two million acres estimate are based on inspection of Hertel, *supra* note 128, at 224 fig.1.

Thus, this calculation suggests that the U.S. corn ethanol program has resulted in the loss of something like two million acres of tropical forest. Although some of the loss of those acres of tropical forest may be irreversible, ending the U.S. corn ethanol program would reduce the pressures leading to continuing deforestation, presumably with an approximately equal effect. Of course, this calculation is very rough, and it probably should be viewed as simply an indication of the order of magnitude.