
ECOLOGISTS, ENVIRONMENTALISTS, EXPERTS, AND THE INVASION OF THE 'SECOND GREATEST THREAT'

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Abstract

The commonplace, quantitative assertion that 'invasions' of exotic (introduced) organisms constitute the 'second greatest threat' of species extinction debuted in Edward O. Wilson's 1992 book, *The Diversity of Life*. Based only on three interrelated publications summarising concerns about the conservation status of North American freshwater fishes, Wilson laconically extended the claim to planetary significance. This inspired the most-cited article ever published in the American journal *BioScience*, subsequently underpinning thousands of peer-reviewed publications, government reports, academic and popular books, commentaries, and news stories. While carefully recounting the origin, promotion, and deployment of the 'second greatest threat', I argue that its uncritical acceptance exemplifies confirmation bias in scientific advocacy: an overextended claim reflexively embraced by conservation practitioners and lay environmentalists because it apparently corroborated one particular, widely shared dismay about modern society's regrettable effects on nature.

Keywords: invasion biology, Edward O. Wilson, 'invasive species'

In recent centuries, and to an accelerating degree during our generation, habitat destruction is foremost among the lethal forces, followed by the invasion of exotic animals.¹

Edward O. Wilson, 1992

[O]n reflection I think that assertion [that alien species constitute the second greatest global threat to biodiversity] has been debunked so often (yet is endlessly repeated) that it no longer deserves the status of a myth, and is best described merely as a straightforward lie.²

Ken Thompson, 2014

1 Edward O. Wilson, *The Diversity of Life* (Cambridge, MA: Harvard University Press, 1992).

2 Ken Thompson, *Where Do Camels Belong?: The Story and Science of Invasive Species* (London: Profile, 2014), 47–48.

In 1992, the discourse of conservation biology acquired a new axiom, thanks largely to the influence of Edward O. Wilson: ‘Habitat loss is the single greatest threat to biodiversity, followed by the spread of alien species’.³ Researchers concerned about the spread of alien species adopted Wilson’s statement and routinely began to insert some version of it in the introductory remarks of their publications. The idea of the ‘second greatest threat’ has persisted in peer-reviewed literature ever since, despite significant criticisms of its empirical merits. Outside academic circles the statement has become an ingrained orthodoxy, repeated and amplified in government agency plans and policy papers, reports by non-governmental organisations, research solicitations, press releases, and direct public information.

A historical perspective offers a useful window to understand the origins and persistence of this idea. This article argues that the trope of the ‘second greatest threat’ became established in conservation biology and invasion biology because it was a classic confirmation bias that appealed to the belief and activism of its practitioners and adherents. Without denying the effects of biotic redistributions via human agency and subsequent ecological adjustments, it warns against heuristic, categorical representations of ‘alien’ or ‘invasive’ species as demons that have breached the gates of paradise, defilers that can never properly belong inside them.⁴ The conviction that there are ‘alien’ species (loosely modelled on the nationality of people) denatured by experiencing human transportation is morbidly fascinating but ‘theoretically weak’.⁵ And asserting that these alien species invade, while idiomatically convenient, is objectively obsolete, like saying the sun rises. It seems like a sentimental throwback to the deterministic rules of prehistoric species occurrence propounded by the ecologist Frederic Clements.⁶ The threat of an overabundant, insistent nature is just as troubling as that of a sickly, waning nature. Combined, they have been used to conjure the crisis of nature forced into civil war, and facilitated the rise of a new, expert chorus of regret and recrimination.

3 David S. Wilcove, David Rothstein, Jason Dubow, Ali Phillips, and Elizabeth Losos, ‘Quantifying threats to imperiled species in the United States’, *BioScience* 48 (1998): 607–15.

4 Invasion biologists and their allies routinely invoke paradise, as in Daniel Simberloff, Donald C. Schmitz, and Tom C. Brown, eds., *Strangers in paradise: impact and management of nonindigenous species in Florida* (Washington DC: Island Press, 1997). For a discussion of the permanence of alienness and other attributes acquired in the process of becoming non-native, see Matthew K. Chew and Andrew L. Hamilton, ‘The rise and fall of biotic nativeness, a historical perspective’, in *Fifty Years of Invasion Ecology: The Legacy of Charles Elton*, ed. David M. Richardson (Chichester: Wiley Blackwell, 2011), 35–47.

5 Chew and Hamilton, ‘The Rise and fall of biotic nativeness’.

6 Frederic E. Clements (1874–1945) was a pioneering American plant ecologist who proposed a superorganismic theory of vegetation succession that has been discredited in its rigid developmental details but remains one of the field’s most influential conceptions. See, for example, Sharon Kingsland, *The Evolution of American Ecology* (Baltimore: Johns Hopkins University Press, 2005).

Conservation biology favours threat narratives because its tenets explicitly include both scientific *and* environmentalist commitments that are mutually constitutive of the discipline. Its practitioners believe that they work in a 'crisis discipline', which means that they 'must act [often] before knowing all the facts'.⁷ The assumption that conservation biology solves crises, preferably before they happen, has meant that the field provides a meaningful career choice for many people who want to improve the world or to save nature. But studying the environment with the primary goal of 'saving' it entails applying values that are difficult or impossible to support empirically, and is an approach that generates susceptibility to confirmation bias. Moreover, it requires the construction of an ideal state of nature from which we can aim to 'restore' or 'conserve' against change. There is little reason to assume that scientists today are any better than those of yesteryear at correctly gauging how nature *should be*, because such statements assume value judgments that have changed over time and space.

The assumption that introduced species are the *second* greatest threat (as opposed to first or 10th) relies on the assumption that we can measure biodiversity and then extrapolate the risks to individual species and all species as a whole. It is, quite simply, a metaphor for a variety of phenomena—not only apples and oranges, but every single species on Earth!—that simply cannot be measured without huge errors. The notion that we can quantify and rank threats to biodiversity exemplifies the interest in using science to achieve the goal of preserving nature. Like earlier attempts to find Frederic Clements' climax community or John Phillips' biotic community, the attempt to define biodiversity has proven illusive. Scholars have attempted to summarise, constrain, or dictate what biodiversity means, but to little apparent effect.⁸ It seems to be an ineffable liquid that takes the shape of any vessel it purportedly occupies while lending it an attractive tint. That is not inconsistent with an observation by the founder of the term, Walter Rosen, who quipped that biodiversity was obtained by taking 'the logical out of biological' to transform an object of scientific investigation into an object of advocacy.⁹

7 Michael E. Soulé, 'What is conservation biology?' *BioScience* 35 (1985): 727–34.

8 See, for example, David Takacs, *The Idea of Biodiversity: Philosophies of Paradise* (Baltimore: Johns Hopkins University Press, 1996); Timothy J. Farnham, *Saving Nature's Legacy: Origins of the Idea of Biological Diversity* (New Haven, CT: Yale University Press, 2007); Daniel P. Faith, 'Biodiversity', in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, Fall 2008 ed., plato.stanford.edu/archives/fall2008/entries/biodiversity, accessed 13 June 2014; James Maclaurin and Kim Sterelny, *What is biodiversity?* (Chicago: University of Chicago Press, 2008); José Luiz de Andrade Franco, 'The concept of biodiversity and the history of conservation biology: From wilderness preservation to biodiversity conservation', *História* [São Paulo] (2013): 21–48.

9 Walter Rosen, quoted in Takacs, *The Idea of Biodiversity*, 37. Takacs interpreted this comment as 'ironic', but that should not be taken to suggest it was flippant or untrue.

Social scientists recognise that the field of ecology (the forerunner and main core of conservation biology and invasion biology) has been metaphor-intensive since its inception.¹⁰ It is tempting to make allowances for threats to biodiversity as a sort of interim metaphorical muddle destined someday to be sorted out in a more principled fashion.¹¹ In his 2011 book, *Metaphors for Environmental Sustainability*, Brendon Larson examined ‘how two prominent scientists have recently coined [problematically] resonant metaphors that have drawn media attention’. He proceeded by assuming his subjects ‘use these metaphors with the best intention, to make change in the world’.¹²

This paper focuses specifically on the origin and spread of the ‘second greatest threat’ metaphor, first in Wilson’s writings, and later in conservation biology and invasion biology scholarship. There is little evidence to suggest that the ‘second greatest threat’ was self-consciously metaphorical. That option is effectively unavailable to conservation biologists because the practice is blind to its own subjective judgments about what they conceive to be an ideal state of nature, which underpins the discipline’s core values. This explains much of the so-called controversy in the field of invasion biology about whether there should be distinctions between ‘native’ and ‘alien’ species. Millions of dollars of funding, patronage, and careers are on the line if this narrative changes. Having used the rhetoric of threats to justify funding and policy, there is no turning back for adherents.

Admittedly, there is no evidence to indicate—nor claim made in this paper—that the authors who constructed, promoted, or cited the ‘second greatest threat’ did so maliciously, or with intent to deceive. Wilson and his followers believe that there is a destructive agency inherent in introduced species that are able to invade and restructure ecosystems and economies. There has been good reason to worry about the impacts of introduced species. The problem is not so much in seeing specific instances of introduced species as being problematic, but rather in the idea that there is a category of ‘alien’ species that is somehow one of the greatest threats to the world’s ecological and economic stability.

10 Matthew K. Chew and Manfred D. Laubichler, ‘Natural enemies—Metaphor or misconception?’, *Science* 301 (2003): 52–53.

11 Chew and Laubichler, ‘Natural Enemies’; also see Joel B. Hagen, *An Entangled Bank: The Origins of Ecosystem Ecology* (New Brunswick, NJ: Rutgers University Press, 1992), 12–14.

12 Brendon M. H. Larson, *Metaphors for environmental sustainability* (New Haven, CT: Yale University Press, 2011), 27.

Edward O. Wilson: An environmentalist's progress

The deployment of soldiers during World War II acquainted many young men from temperate 'Allied' countries with the ecology of tropical Pacific islands, such as Hawaii and Guam, among others. William L. Brown Jr. was one such American soldier who survived the Pacific Theatre only to gravitate back as a researcher. Serving as a technician in the US Army Air Force's 36th Malaria Survey Unit apparently whetted his appetite for studying insects. He completed a Bachelor of Science in Zoology and Entomology followed in 1950 by a PhD from Harvard.¹³ Brown was instrumental in luring Edward O. Wilson to graduate studies at Harvard, and in redirecting Wilson's taxonomic research interests from the ants of Alabama to the more widely distributed 'trapjaw' Dacetine ants.¹⁴ Escaping his socially insular Gulf Coast roots was a requisite step on the path toward Wilson's avowed goal at age 17 of becoming 'an important scientist', and turning his attention to the fate of the world.¹⁵

In the 1960s and 1970s, Wilson accumulated academic credentials and honours, achieving his goal of becoming an important scientist through his involvement in developing and promoting the ideas of Island Biogeography and Sociobiology. But he eschewed environmental activism until 1980, 'unforgivably late', as he described it.¹⁶ Wilson attributed his environmental epiphany to Norman Myers' estimates of tropical rainforest destruction rates in *The Sinking Ark* (1979), a polemic after the fashion of Charles Elton's *The Ecology of Invasions* (1958) and Rachel Carson's *Silent Spring* (1962). None of these were scholarly books written for technically adept audiences. Rather, they were deftly written polemical tracts by authors who warned about the impending environmental catastrophe that they saw unfolding as a result of human action. How scientific their verdicts were, and even how scientifically these writers understood what they feared, was never as important as how well they made their fears resonate with those of their readers.

Wilson's first intentional foray into environmentalist commentary was a short piece commissioned by the *Harvard Magazine*. There he wrote, 'the one process ongoing in the 1980s that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats'.¹⁷ This comment summarises the professional fears of a taxonomist: that things will go—and go

13 Ted R. Schultz, Richard B. Root, and Thomas Eisner, 'William L. Brown, Jr.: June 1, 1922–March 30, 1997', in *Memorial Statements, Cornell University Faculty 1996–97* (Ithaca, NY: Office of the Dean of the Faculty, Cornell University, 1997), 12–16, ecommons.library.cornell.edu/bitstream/1813/18230/2/Brown_Stuart_M_Jr_1996.pdf, accessed 28 November 2014.

14 Edward O. Wilson, *Naturalist* (Washington DC, Island Press, 1984), 132.

15 Wilson, *Naturalist*, 99.

16 Wilson, *Naturalist*, 355.

17 Edward O. Wilson, 'Resolutions for the 80s', *Harvard Magazine* 83 (1980): 21.

away—unclassified. In 1985, Wilson echoed a strategy Elton had attempted in inter-war Britain, using his academic pulpit to call for a comprehensive, publicly funded inventory of biota in the name of protecting what was deemed to be in the public interest. Wilson's vision of a full-employment plan for taxonomists was more expansive than Elton's. The Englishman wanted an accounting of British animal populations.¹⁸ The American's proposal encompassed all life on the planet.¹⁹ Neither man's argument was enthusiastically received at the time. It would be over two decades before Elton girded his loins for another overt foray as a public intellectual. But Wilson was on the cusp of a major role in formulating, and more importantly, promoting the concept of *biodiversity*.

When writing for general audiences, Wilson rarely shied from sweeping statements, including his own assertions that *his* ideas and claims are widely accepted by the scientific community. In *Scientific American*, he claimed without substantiation, '[v]irtually all ecologists, and I include myself among them, would argue that every species extinction diminishes humanity'.²⁰ He likewise asserted that 'systematists are in wide agreement that, whatever the absolute numbers, more than half of the species on earth live in moist tropical forests', and 'every tropical biologist has stories of the prodigious variety in this one habitat type'.²¹ Wilson's claims of representing consensus have been coupled with vagueness. After discussing his idea that 'human nature is rooted in heredity', he once continued: '[i]n the 1970s a great many ordinary people believed these hereditarian propositions to be more or less true'.²² Both the source of the information and the meaning of the statement are obscure; nevertheless, it sounds significant, and carries the confident authority of the 'important scientist'.

Wilson provided a clue for interpreting such vague yet global pronouncements in the final chapter of his 1994 autobiography, *Naturalist*. Discussing biophilia, his hypothesis that humans innately bond with other species, he wrote: '[b]y the ordinary standards of natural science, the evidence for biophilia remains thin, and most of the underlying theory of its genetic origin is highly speculative. Still, the logic leading to the idea is sound, and the subject is too important to neglect'.²³ Thus, Wilson excused (at least) his own lack of scientific rigour by suggesting that an idea—one of *his* ideas—is so important that it should be believed now and examined later. He could do this because he is, indeed, an important scientist. Island Press trumpeted his status on the dust jacket of *Naturalist*: 'Edward O. Wilson—University Professor at Harvard, winner of

18 Matthew K. Chew, 'Ending with Elton: Preludes to Invasion Biology' (PhD diss., Arizona State University, 2006), 126.

19 Edward O. Wilson 'The Biological Diversity Crisis', *BioScience* 35 (1985): 700–706.

20 Edward O. Wilson, 'Threats to Biodiversity', *Scientific American* 261 (1989): 108–16 (114).

21 Wilson, 'Threats to Biodiversity', 108, 110.

22 Wilson, *Naturalist*, 335.

23 Wilson, *Naturalist*, 362.

two Pulitzer prizes, eloquent champion of biodiversity—is arguably one of the most important thinkers of the twentieth century. His career represents both a blueprint and a challenge to those who seek to explore the frontiers of scientific understanding'. Popular acceptance of Wilson's importance, whether via putative-wide agreement or an exclusive writing prize is clearly significant to Wilson and the industry of Wilson promotion. Environmentalists with or without academic ecological credentials are his core constituency.

Wilson the scientist participated in a 1964 symposium on the evolutionary aspects of species introductions. However, biological invasions other than human incursions do not feature prominently in his environmentalist writings prior to 1992, even though the idea is more than implied by the tenets of theoretical Island Biogeography.²⁴ Invasions are absent from 'Resolutions for the 80s [sic]' (1980), *Biophilia* (1984), and 'The Biological Diversity Crisis' (1985), although each of these addresses habitat loss and resulting extinctions.²⁵ Invasions are absent from his foreword and introductory chapter in *Biodiversity* (1988), where the topic is subsequently mentioned or covered by other authors. Invasions went unmentioned in his published 1988 dialogue with Edward Lueders and writer Barry Lopez.²⁶ In 1989's 'Threats to Biodiversity', Wilson finally invoked the example of the intentional introduction of a new large predator, the Nile perch (*Lates niloticus*) to Lake Victoria. He mentions that '[t]he list of such biogeographic disasters is extensive', without elaborating.²⁷

By 1990, Wilson acquired the habit of deploying the four horsemen of the (biblical) apocalypse to symbolise environmental catastrophe. His first foray was in a venue appropriate to eschatological speculation: *Chronicles*, a 'weapon in fighting the culture war' published by the Rockford Institute, which works 'to preserve the institutions of the Christian West: the family, the Church, and the rule of law; private property, free enterprise, and moral discipline; high standards of learning, art, and literature'.²⁸ For his part, in *Chronicles* Wilson christened his horsemen 'global warming', 'ozone depletion', 'toxic waste accumulation', and 'mass extinction by habitat destruction'.²⁹

24 Robert H. MacArthur and Edward O. Wilson, *The Theory of Island Biogeography* (Princeton, NJ: Princeton University Press, 1967).

25 Wilson, 'Resolutions'; Edward O. Wilson, *Biophilia: The Human Bond With Other Species* (Cambridge, MA: Harvard University Press, 1984); Edward O. Wilson, 'The biological diversity crisis: A challenge to science', *Issues in Science and Technology* 2 (1988): 20–29.

26 Edward O. Wilson, 'The Current State of Biological Diversity', in *BioDiversity* (Washington DC: National Academy Press, 1988), 3–18; Edward Lueders, *Writing Natural History: Dialogues with Authors* (Salt Lake City, UT: University of Utah Press, 1989), 7–35.

27 Wilson, 'Threats to biodiversity'.

28 Thomas Fleming, 'From the President'; and Anonymous, 'Defending Christendom', from 'About The Rockford Institute', 2013–14, www.chroniclesmagazine.org/about/the-rockford-institute, both accessed 28 November 2014.

29 Edward O. Wilson, 'The New Environmentalism', *Chronicles* 14 (1990): 16–18.

The advent of the ‘second greatest threat’

By the time Wilson entered the Rockford Institute’s culture war as an apocalyptic arms dealer, his 1992 book, *The Diversity of Life*, must have been in contemplation, if not preparation. Perhaps influenced by then-recent publications like *Ecology of Biological Invasions of North America and Hawaii* (mentioned in his endnotes), Wilson renamed his horsemen for a chapter called ‘Biodiversity Threatened’ and established the shape of things to come:³⁰

[i]n recent centuries, and to an accelerating degree during our generation, habitat destruction is foremost among the lethal forces, followed by the invasion of exotic animals. Each agent strengthens the others in a tightening net of destruction. In the United States, Canada, and Mexico, 1,033 species of fishes are known to have lived entirely in fresh water within recent historical times. Of these, 27, or 3 percent, have become extinct within the past hundred years, and another 265, or 26 percent, are liable to extinction. They fall into one or another of the categories utilized by the International Union for the Conservation of Nature and Natural Resources (IUCN) which publishes the *Red Data Books*: Extinct, Endangered, Vulnerable, and Rare. The changes that forced them into decline are:

Destruction of physical habitat	73% of species
Displacement by introduced species	68% of species
Alteration of habitat by chemical pollutants	38% of species
Hybridization with other species and subspecies	38% of species
Overharvesting	15% of species ³¹

Wilson’s categories and percentages invite scrutiny. They are hardly straightforward. The extents of these ‘lethal forces’, these ‘agents’, are not self-evident. Invoking ‘agency’ raises unanswerable questions. Wilson offers no further explanation; we are left to fend for ourselves. From a scientific perspective, his explanation appears cursory, even careless. It seems to exemplify the tongue-in-cheek concept of ‘proof by blatant assertion’, providing scant justification for any quantitative claim that ‘invasion by exotic animals’ follows habitat destruction as a ‘lethal force’.³²

‘Overharvesting’ is perhaps Wilson’s most coherent category, though it is less straightforward than Jared Diamond’s (1989) ‘overkill’.³³ It fails to discriminate between, for instance, the institutionalised wastage caused by non-target ‘by-

30 See Harold A. Mooney and James A. Drake, eds., *Ecology of Biological Invasions of North America and Hawaii* (New York: Springer, 1986).

31 Edward O. Wilson, *The Diversity of Life* (New York: Knopf, 2002), 253–54.

32 Joel E. Cohen, ‘On the Nature of Mathematical Proofs’, in *A Random Walk in Science*, ed. Robert L. Weber and Eric Mendoza (New York: Crane Rusak, 1973), 34–36.

33 Jared Diamond, ‘Overview of Recent Extinctions’ in *Conservation for the Twenty-first Century*, ed. David Western and Mary Pearl (New York, Oxford University Press, 1989), 37–41.

catch', industrial-scale exploitation, and locally intensive subsistence-level consumption. When collapsed, the category provides little explanatory value, but explaining is not the point. Eliciting remorse by assigning blame is the point.

'Destruction of physical habitat' suggests many possibilities, not all of which are anthropogenic. Wilson excluded the effects of chemical pollutants, except perhaps those (like acid mine drainage) that might be said to physically destroy rather than alter habitats. The line between habitat alteration and destruction is difficult to draw when the operative context is extinction; a habitat altered to the extent that a population fails seems tantamount to a habitat destroyed. 'Alteration of habitat by chemical pollutants' seems understandable, at least as long as the array of potential sources, identities, and effects of such pollutants is left unspecified. Are we to assume that Wilson meant something like 'chemicals not typically generated except by industrial process, or rarely found in detectable quantities'? Does habitat alteration differ from physical destruction as a matter of degree? If so, can both result in extinction, or does extinction signal actual destruction of habitat?

'Displacement by introduced species' is simultaneously vague and over-precise. The ecological implication of 'displacement' is that individuals or populations have been competitively excluded from either a functional or geographical niche, an effect that is easier to imagine than demonstrate.³⁴ Furthermore, in any ecologically strict sense, displacement does not include trophic exploitation (being eaten) by a new predator, a commonly feared outcome of introducing game-fish species. Wilson did not disclose whether his 'introduced species' were purposely stocked, or if they were themselves fishes, or indeed even animals.

'Hybridization with other species and subspecies' is a surprisingly terse construction. It glosses over two necessary questions: the perennially debated, 'what constitutes a species?' and the subtler, but more interesting, 'what constitutes extinction?' If species are demarcated by an inability to interbreed, can individuals representing two 'real' species mate and produce offspring? We know that some, such as horses and donkeys, can be mated to produce viable, but infertile, mules. But in a widely discussed case, the descendants of introduced 'American' ruddy ducks (*Oxyura jamaicensis*) are interbreeding with 'European' white-headed ducks (*O. leucocephala*), and producing fertile

³⁴ See, for example, Mark A. Davis, 'Biotic globalization: does competition from introduced species threaten biodiversity?', *BioScience* 53 (2003): 481–89; Dov F. Sax, John J. Stachowicz, and Steven D. Gaines, eds., *Species invasions: insights into ecology, evolution and biogeography* (Sunderland, MA: Sinauer, 2005).

offspring.³⁵ Were these two really different species, or were they essentially two populations denied access to each other long enough to diverge perceptibly to the human eye and mapmaker, but in reproductively inconsequential ways?

The population resulting from this reunion is neither 'ruddy' nor 'white-headed', as was once conceived. But it is still a population of ducks. Left unmolested, it might be fully capable of persisting. If we insist that they were two species, did the merger produce an extinction event? The answer is *yes* according to one criterion (the white-headed duck might no longer occur as such), and *no*, because those ducks mated and passed their genes to successive generations; no line of inheritance ended. It is a matter of convention, like patrilineal naming. In some social traditions, a family giving birth to a generation of daughters cannot continue 'in name'; but through motherhood, each female's genes will 'flow into the future' along with the name-begetting father's.

Philosophers Matthew Haber and Andrew Hamilton formally distinguished between these different kinds of events, calling them Type I and Type II extinctions. Type I extinctions represent one fundamental fear of environmentalism: for whatever reason, organisms become rare, reproduction success diminishes, and lineages ultimately fail. In Type II extinctions, lineages merge or diverge as reproduction continues, and labels change; whether new taxa subsume or succeed others is up to the classifier.³⁶ By including hybridisation in his list of threats, Wilson conflated the two extinction concepts; perhaps without noticing, certainly without giving notice to his readers. As will become evident, this was not the only tacit component of Wilson's claim, nor was it the most problematic.

Wilson's numbers added up to 232 per cent, so (as he went on to confirm) his 'lethal agents' coexist or even co-operate. We might have hoped for some discussion of common or inevitable combinations, but none was forthcoming. Some primary effects would seem to render secondary agents insignificant. For example, reservoir impoundment replaces one physical habitat with another. Habitats for 'river fish' are thereby destroyed, but in the process, 'lake fish' habitats are created. Populations of river fishes will persist in a reservoir only if

35 Judith M. Rhymer and Daniel Simberloff, 'Extinction by hybridization and introgression', *Annual Review of Ecology and Systematics* 27 (1996): 83–109; Kay Milton, 'Ducks out of water: Nature conservation as boundary maintenance', in *Natural Enemies: People–Wildlife Conflicts in Anthropological Perspective*, ed. John Knight (London: Routledge, 2000), 229–46.

36 Matthew H. Haber and Andrew L. Hamilton, 'Coherence, consistency, and cohesion: Clade selection in Okasha and beyond', *Philosophy of Science* 72 (2005): 1026–40. Haber and Hamilton point out that their extinction typology is detectable in literature that would have been available to Wilson well before *The Diversity of Life* was published; notably, Mark Wilkinson, 'A Commentary on Ridley's Cladistic Solution to the Species Problem', *Biology and Philosophy* 5 (1990): 433–46.

the newly prevailing conditions still effectively meet their habitat requirements. The arrival of lake fishes in a reservoir might correlate with an extinction of river fishes without actually causing it.

Ecologically, it does not matter whether a fish species arrives in a reservoir by surviving the damming process, by swimming downstream from an unaffected reach, by dumping from a bait bucket, or by pumping from a government hatchery's tanker truck. Any persisting population demonstrates that habitat exists; non-persistence demonstrates otherwise. Even in the latter case, some mature individuals may survive without breeding much, or at all, or where survivorship of young to adulthood has ceased. Such populations must dwindle, as has been the case for several fishes in the serially impounded, much-diverted, and much-diminished lower Colorado River. Researchers familiar with these cases have stated that '[w]e have no doubt that if nonnative species vanished, the big-river fishes would persist in today's modified habitats'.³⁷ Unfortunately there is no way to cleanly separate those factors in the real world.

As noted earlier, Edward O. Wilson is not an ichthyologist. He is by training a myrmecologist, a specialist in ants. What prompted him to construct an argument of such potential significance with reference to taxa so different from his invertebrate stock-in-trade? *The Diversity of Life's* endnotes, consisting primarily of parenthetical asides rather than formal citations, mentioned three salient journal articles, but also suggested that Karsten Hartel, Wilson's colleague at the Harvard Museum of Comparative Zoology, provided the tabular 'threats' analysis. I emailed Wilson, asking whether he knew of any statement or analysis prior to his own to the effect that invasive species constituted the second-ranked cause of extinction. He responded by encouraging me to contact Hartel. Hartel subsequently confirmed that he provided Wilson with information from the three articles identified in the book, but balked at taking responsibility for Wilson's synthesis.³⁸ Whether Wilson or Hartel came up with the idea, Wilson ultimately composed and published it. Rather than pressing the matter of ultimate responsibility any further, I set about attempting to reproduce Wilson's table of threats, seemingly a matter of reviewing readily available published material.

There is substantial overlap both in the topics and authorship of the three articles Wilson listed as sources. Hoping to reduce both repetition and confusion, I refer to them below by single word 'proxies'. The first article is 'Conservation Status of the North American Fish Fauna in Fresh Water' by Jack E. Williams and

37 Wendel L. Minckley, Paul C. Marsh, James E. Deacon, Thomas E. Dowling, Philip W. Hedrick, William J. Matthews, and Gordon Mueller, 'A conservation plan for native fishes of the lower Colorado River', *BioScience* 53 (2003): 219–34.

38 Edward O. Wilson, email message to author, 6 February 2002; Karsten Hartel, emails to author, 4 June 2004 and 21 June 2004.

Robert R. Miller (herein after CONSERVATION). Wilson's (1992) totals of 1,033 species, 27 extinctions and 265 International Union for Conservation of Nature (IUCN)-listed extant species appeared there.³⁹ The last two numbers derived, in turn, from the 1990 IUCN *Red List of Threatened Animals*, which included no data regarding specific threats.⁴⁰

The second and slightly earlier article, 'Extinctions of North American Fishes During the Past Century' (herein after EXTINCTIONS), is also by Williams and Miller, this time collaborating with James D. Williams. Wilson's (1992) five impact-ranking percentages appear here, where they were derived from and pertain specifically and *only* to the 40 extinct taxa discussed in EXTINCTIONS.⁴¹

Like Wilson's threat categories (which should mirror them, but do not exactly), those in EXTINCTIONS were drawn with imprecision. For example, in a summary table EXTINCTIONS describes the Miller Lake lamprey (*Entosphenus minimus*) as having been exterminated by 'chemical alteration or pollution'. The article's text disclosed this as the intended effect of an applied ichthyocide. Their nativeness notwithstanding (and, it seems, undetermined at the time), the lampreys, which prey on other fishes in an unappealing, parasite-like manner, were considered pests and treated as such.⁴² Meanwhile, 'chemical alteration or pollution' applied to 14 other taxa discussed in EXTINCTIONS, none of which were purposely poisoned.

'Introduced species' (sans Wilson's 'displacement by') affected 27 taxa in EXTINCTIONS. In all but two of those cases, the presence of introduced species, when correlated with the absence of a native species, was interpreted as unquestionably contributing to a native's extirpation. In the remaining two cases, impacts other than hybridisation (a separate category) were not mentioned.

The species accounts in EXTINCTIONS were peppered with rhetorical qualifiers, such as 'apparently', 'believed', 'contributed', 'may', 'presumed', 'probably' and 'undoubtedly'. The article's attributions of impacts to introduced species were much too speculative to support any calculation of summary percentages. The authors of EXTINCTIONS seemed eager to identify exotics as plausible

39 Jack E. Williams and Robert R. Miller, 'Conservation Status of the North American Fish Fauna in Fresh Water', *Journal of Fish Biology* 37A (1990): 79–85.

40 *Red List of Threatened Animals* (Geneva: International Union for the Conservation of Nature, 1990). The published IUCN *Red List of Threatened Animals* began including threat data in 1994.

41 Robert R. Miller, James D. Williams, and Jack E. Williams, 'Extinctions of North American Fishes During the Past Century', *Fisheries* 14 (1989): 22–38.

42 In 1992, reports of the demise of the Miller Lake lamprey proved to be premature. See Oregon Department of Fish and Game, 'After 50 years Miller Lake lamprey returns to Miller Lake', www.dfw.state.or.us/news/2010/july/072710b.asp, accessed 23 June 2014.

culprits; like Vichy Captain Louis Renault in the 1942 film *Casablanca*, they 'round[ed] up the usual suspects'. In effect, EXTINCTIONS was literally an article of faith in the inferences drawn by its sources.⁴³

The last article Wilson linked to his 'threats' table appeared in the same issue of *Fisheries* as EXTINCTIONS. Eight authors, led by the same Jack E. Williams (this time including James D. Williams but not Miller), compiled 'Fishes of North America Endangered, Threatened or of Special Concern: 1989' (herein after FISHES). They included 'all fishes of the North American continent that the American Fisheries Society believes should be classified as endangered, threatened, or of special concern'. In summary, they relied on something resembling US Endangered Species Act status definitions, but not the official listings.

The complexity of the FISHES authors' task was enormous. The dynamic state of fish taxonomy precluded durable consensus even on the total number of species. The authors relied on 'other lists, original data, and discussions with pertinent agencies and knowledgeable individuals', although their references did not specifically identify data sources, agencies, individuals, or contact dates.⁴⁴

The IUCN also relies on knowledgeable individuals. Their lists are scientific to the uncertain extent that contributed knowledge is scientific. The upshot is that the numbers published by IUCN, and by the authors of EXTINCTIONS, FISHES, and CONSERVATION were not really data regarding fishes; if anything, they were data regarding what a group of self-identified, self-selected experts believed and chose to report about fishes. Sometimes even the best available information is not really very good. Setting a low bar for Wilson and others to come, these authors were generating a de facto opinion poll without controlling the question being asked. That does not render the accounts untrue, but it does render them unreliable, untestable, and resistant to defensible aggregation. They represent the beliefs (the *doctrine*, it seems) of members of a professional association, but they are anecdotal.

FISHES included 364 taxa (including species and subspecies) purportedly affected by five categories of threats. The threats identified did not correspond well either with categories listed in EXTINCTIONS, or with Wilson's (1992) formula (Table 1). CONSERVATION and EXTINCTIONS accounted for all of Wilson's numbers and something like his categories. The dissimilarities between Wilson's categories and their supposed sources shows that his account elided an idiosyncratic and irreproducible set of judgments. This was no simple transcription error.

43 Miller et al., 'Extinctions', 22–38.

44 Jack E. Williams, James E. Johnson, Dean A. Hendrickson, Salvador Contreras-Balderas, James D. Williams, Miguel Navarro-Mendoza, Don E. McAllister, and James E. Deacon, 'Fishes of North America Endangered, Threatened, or of Special Concern', *Fisheries* 14 (1989): 2–19.

Wilson grafted already questionable summary percentages from one article onto data from another. Then he inserted them into novel categories. By drawing conclusions contingent on summary numbers extracted from such disparate and dubious sources, he glossed over numerous taxonomic and procedural objections. His conceptions could not ameliorate the weaknesses of the data he relied upon. His sources were not ‘doing science’, and neither was he.⁴⁵

Table 1: A comparison of threat categories.

EXTINCTIONS	Wilson, 1992	FISHES
Physical habitat alteration	Destruction of physical habitat	Present or threatened destruction, modification, or curtailment of its habitat or range
Chemical alteration or pollution	Alteration of habitat by chemical pollutants	
Introduced species	Displacement by introduced species	Other natural or man-made factors affecting its continued existence (hybridisation, introduction of exotic or transplanted species, predation, competition)
Hybridisation	Hybridisation with other species and subspecies	
Overharvesting	Overharvesting	Overuse for commercial, recreational, scientific, or educational purposes
(No corresponding category)	(No corresponding category)	Restricted range
(No corresponding category)	(No corresponding category)	Disease

Source: Robert R. Miller, James D. Williams, and Jack E. Williams, ‘Extinctions of North American Fishes During the Past Century’, *Fisheries* 14 (1989): 22–38; Edward O. Wilson, *The Diversity of Life* (New York: Knopf, 2002), 253–54; Jack E. Williams, James E. Johnson, Dean A. Hendrickson, Salvador Contreras-Balderas, James D. Williams, Miguel Navarro-Mendoza, Don E. McAllister, and James E. Deacon, ‘Fishes of North America Endangered, Threatened, or of Special Concern’, *Fisheries* 14 (1989): 2–19.

Quantifying threats: The second generation

Under the auspices of the IUCN Species Survival Commission, a self-identified ‘Invasive Species Specialist Group’ (ISSG), ‘a worldwide network of experts on the conservation impacts of invasive species’, formed in 1994, two years after Wilson published his analysis. ISSG granted membership only by invitation, and made its conservation orientation explicit.⁴⁶

45 Williams et al., ‘Conservation Status’; Miller et al., ‘Extinctions’; Williams et al., ‘Fishes of North America’; Williams, email to author, 4 June 2004, did not respond further after I suggested that his results did not support Wilson, and questioned his category formulations.

46 Mick N. Clout, ‘Introducing ISSG’s Newsletter’, *Aliens* 1 (1995): 1.

At roughly the same time, Wilson protégé Daniel Simberloff, then at Florida State University, wrote an entry titled 'Introduced Species' for the *Encyclopedia of Environmental Biology* (1995). He subsequently cited 'Introduced Species' in a 1997 book chapter he also authored, as the source for the observation that '[n]onindigenous species are second only to habitat destruction in harming native communities'.⁴⁷ However, the encyclopedia entry includes no such claim.⁴⁸ Simberloff's best guess regarding the citation anomaly is that the pieces were written concurrently and the claim in question might have appeared in a preliminary draft but not the final version.⁴⁹ Questions about where it came from and where it went thus persist, but since it spawned only two (necessarily copy-cat) citations, one in a 1998 advocacy document written for public consumption by a Defenders of Wildlife staff member, another in a 2009 (peer-reviewed) article by three Portuguese authors for the journal *Ecography*, the lineage appears fairly moribund.⁵⁰

In 1997, spurred by the 1996 Norway/UN Conference on Alien Species, the Scientific Committee on Problems of the Environment (SCOPE), IUCN, and CAB International (formerly Britain's Commonwealth Agricultural Bureaux) initiated the Global Invasive Species Programme (GISP) 'to conserve biodiversity and sustain human livelihoods by minimizing the spread and impact of invasive alien species', a likewise applications-oriented effort.⁵¹ A 1999 book 'based on a selection of papers presented' at the Norway conference was introduced by its editors, who immediately resurrected Jared Diamond's (1989) 'evil quartet' for the occasion.⁵² Their second paragraph flatly declared, without attribution that '[m]ost biologists consider [alien invasive species] the second most important threat factor after habitat destruction'.⁵³ This statement seems to have been overlooked by most subsequent authors, but unlike Simberloff's lost 1985 assertion, it actually appeared in print and has been cited a few times. The authors of a notable amplification wrote, 'The Norway / United Nations

47 Daniel Simberloff, 'Biogeographic approaches and the new conservation biology', in *The Ecological Basis of Conservation*, ed. Steward T. A. Pickett, Richard S. Ostfeld, Mosche Shachak, and Gene E. Likens (New York: Springer, 1997), 274–84.

48 Daniel Simberloff, 'Introduced species', In *Encyclopedia of Environmental Biology*, vol. 2, ed. William A. Nierenberg (New York: Academic Press, 1995), 323–36.

49 Daniel Simberloff, email to the author, 26 July 2014.

50 See Sara Vickerman, *National Stewardship Initiatives: Conservation Strategies for Landowners* (Washington, DC: Defenders of Wildlife, 1998), 55; Luis Reino, Jordi Moya-Laraño, and António C. Heitor, 'Using survival regression to study patterns of expansion of invasive species: will the common waxbill expand with global warming?', *Ecography* 32 (2009): 237–46.

51 Diversitas, 'Global Invasive Species Programme' (2011), www.diversitas-international.org/activities/past-projects/global-invasive-species-programme-gisp. See also Sarah Simons, 'Closure of the Global Invasive Species Programme' (BCGI Resources Centre, April 13, 2011), www.bgci.org/resources/news/0794, accessed 28 November 2014.

52 Jared Diamond, 'Overview of Recent Extinctions'.

53 Odd T. Sandlund, Peter J. Schei, and Aslaug Viken, 'Introduction: the many aspects of the invasive alien species problem', in *Invasive Species and Biodiversity Management* (Dordrecht: Kluwer, 1999), 1–11.

Conference on Alien Species considers alien invasive species as the second most important threat, after habitat destruction, to indigenous biodiversity'.⁵⁴ Still, only a relative handful of authors have relied on the Norway statement, which seems to lack any apparent methodological basis.

Nevertheless, by 1999 a nascent discipline of invasion biology was well in evidence, having generated several anthologies of proceedings and being served by two specialised peer-reviewed journals, neither of which was ever formally controlled by ISSG or GISP. Practitioners were also publishing in broader conservation biology and ecology journals, in regional natural history and taxon-based journals, and occasionally in the two major 'high impact' generalist journals, *Science* and *Nature*. On 3 February 1999, US Presidential Executive Order 13112 established a National Invasive Species Council (NISC) and defined terms including 'invasive species' for purposes of federal management actions.

Given its pedigree of applications-oriented, international, and interdisciplinary organisations, it was practically inevitable that 'invasive species'—related articles would appear in inter-organisational journals. One such is *BioScience*, produced by the American Institute of Biological Sciences (AIBS). AIBS membership is open to individuals, organisations, and institutions, so the content of *BioScience* is eclectic by comparison with most journals. Like *Nature* and *Science*, *BioScience* includes features by science writers, correspondence arising, professional news, editorials, and book reviews, alongside research articles. Occasional issues are themed; for example, in 1998 (volume 48) the peer-reviewed articles in numbers four and nine focused on particular topics. Number eight (August) was more typical. Its four peer-reviewed articles were titled, in order of appearance, 'The Reproductive Biology of Fire Ant Societies', 'Quantifying Threats to Imperiled Species in the United States', 'Animal Clones and Diversity', and 'Water for Food Production: Will There Be Enough in 2025?'. The second of these prominently cited Wilson's *The Diversity of Life* and reified his threat ranking while expanding it beyond freshwater fishes. It included a statement that (by the standards of the time) 'went viral' in the discourse of invasion biology and rapidly became one of its central dogmas.

The lead author of 'Quantifying Threats to Imperiled Species in the United States' was David Wilcove, an American born shortly after Charles Elton's *Ecology of Invasions* began incubating in the library stacks. Wilcove cites a childhood (and continuing) interest in birds and pre-teenage exposure to the 'height of the environmental movement of the early 1970s' as his impetus to study biology, culminating in a 1985 Princeton PhD. Reacting to the anti-environmentalism of

54 Roger Mann and Julia M. Harding, 'Salinity tolerance of larval *Rapana venosa*: implications for dispersal and establishment of an invading predatory gastropod on the North American Atlantic coast', *The Biological Bulletin* 204 (2003): 96–103.

the early Reagan years, he began his professional career studying rare species in Virginia for The Nature Conservancy (TNC), a non-profit, United States-based organisation. He soon moved to the Wilderness Society and went from there in 1988 to a position as Senior Ecologist with the Environmental Defense Fund (EDF). At the EDF his early work focused on describing the practical and legal challenges of protecting endangered species in the United States. Stating 'I like writing' in a 1996 interview for the *EDF Letter*, he demonstrated it with an impressive output of technical and popular articles, reviews, a recurring column for the Cornell Laboratory of Ornithology's *Living Bird* magazine, several book chapters, and in 1999, a book of his own: *The Condor's Shadow: The Loss and Recovery of Wildlife in America*, with a foreword by Edward O. Wilson.⁵⁵

Wilcove was one among a throng of late baby boomers sincerely motivated by the increasing environmental consciousness of the 1960s and 1970s who populated the enrolment lists of university biology departments and aspired to staff positions at environmental organisations. The movement had money, but rarely money to burn, and competition for even the lowest paying jobs was always intense. Those like Wilcove who had luck, enthusiasm, and the proper academic credentials got a foot in the door. Fewer found a long-term home behind it. It is difficult to stand out among so many well-qualified peers. Meanwhile, environmental organisations have foibles and faults that can dismay true-believing tyros. Wilcove managed to thrive as well as anyone under such conditions. He established and maintained connections in the power centres of the groups he worked for, and contact with the power centres of federal agencies that invited his participation in significant activities. He simultaneously established himself as a journeyman populariser through magazine articles, and a capable member of interdisciplinary teams. Unlike Wilson, Wilcove's personal testimony as an environmentalist included no mid-life epiphany and 'road to Damascus' conversion to activism, but he had barely attained mid-life by the time he entered this story.

In 1994, TNC set to work on a tour-de-force report to be titled *Precious Heritage: The Status of Biodiversity in the United States*.⁵⁶ Wilcove and a team of co-authors whose credentials included tenures in a variety of environmental groups and

55 Anonymous, 'Pew Fellows: David S. Wilcove, Ph.D.', Pew Fellows Program in Marine Conservation (1999), accessed 18 October 2002, www.pewmarine.org/PewFellows/pf_WilcoveDavid.html; Anonymous, 'Professor David Wilcove, Ecologist, Joins PEI's Faculty' [Princeton Environmental Institute, Princeton, NJ], *PEI News* (Fall 2001): 3, web.princeton.edu/sites/pei/PDFfiles/PEIFallNL2001.pdf, accessed 18 October 2002; David S. Wilcove, 'Curriculum Vitae', Princeton University (2001), www.eeb.princeton.edu/FACULTY/Wilcove/cv.pdf, accessed 18 October 2002; David S. Wilcove, 'Publications by David S. Wilcove', Princeton University (2001), www.eeb.princeton.edu/FACULTY/Wilcove/Publications.pdf, accessed 18 October 2002; David S. Wilcove, *The Condor's Shadow: The Loss and Recovery of Wildlife in America* (New York: W. H. Freeman, 1999).

56 Deborah B. Jensen and Thomas F. Breden, Preface to *Precious Heritage: The Status of Biodiversity in the United States*, ed. Bruce A. Stein, Lynn S. Kutner, and Jonathan S. Adams (Oxford: Oxford University Press, 2000), xiv.

academic institutions were tasked with producing a chapter on invasive species. The volume's lead editor was Bruce Stein, a TNC stalwart who had just co-edited their booklet, *America's Least Wanted: Alien Species Invasions of U.S. Ecosystems*.⁵⁷ At about the same time, David Wilcove found himself collaborating with Edward O. Wilson and others, including Jane Lubchenco, (then) future Administrator of the US National Oceanographic and Atmospheric Administration, on a perspective article for *Science*, titled 'Building a Scientifically Sound Policy for Protecting Endangered Species'.⁵⁸

Daniel Simberloff 'generously provided advice on the new TNC book through ... participation in project workshops and through ... analyses of heritage data'.⁵⁹ Simberloff had recently co-authored 'Biological Invasions: A Growing Threat' for the National Academy Press' *Issues in Science and Technology* and was translating *Killer Algae*, a French biologist's narrative of apparent disregard—by the Jacques Cousteau-led Oceanographic Museum in Monaco—for a biological invasion of the Mediterranean Sea.⁶⁰ He would shortly pen the foreword for the University of Chicago Press's 2000 reissue of Elton's *Ecology of Invasions by Animals and Plants*.⁶¹ Simberloff was also co-editing *Strangers in Paradise: Impact and Management of Nonindigenous Species in Florida*, with a foreword by Wilson, for Island Press. In that foreword, Wilson inflated his 1992 claim about US freshwater fishes by declaring that '[o]n a global basis [conservation biologists] recognize that the two great destroyers of biodiversity are, first, habitat destruction, and, second, invasion by exotic species'.⁶²

TNC's *Precious Heritage* would not see print until 2000. Wilcove's team finished their chapter ahead of the curve. In the venerable academic tradition of filling two CV lines with one publication, they submitted the piece to *BioScience*, advisedly, if confusingly, acknowledging it as 'part of an ongoing collaboration ... as part of the forthcoming book' and thanking Wilcove's recent collaborator Jane Lubchenco, among others, for 'their helpful reviews of earlier versions'. It was more than auspiciously timed. Simberloff was also a member of *BioScience's*

57 Bruce A. Stein and Stephanie R. Flack, *America's Least Wanted: Alien Species Invasions of U.S. Ecosystems* (Arlington, VA: The Nature Conservancy, 1996).

58 Thomas Eisner, Jane Lubchenco, Edward O. Wilson, David S. Wilcove, and Michael J. Bean, 'Building a scientifically sound policy for protecting endangered species', *Science* 269 (1995): 1231–32.

59 Stein, Kutner and Adams, acknowledgements in *Precious Heritage*, xix.

60 Andre Meinesz, *Killer Algae*, trans. Daniel Simberloff (Chicago: University of Chicago Press, 1999); Don C. Schmitz and Daniel Simberloff, 'Biological Invasions: A Growing Threat', *Issues in Science and Technology* 13 (1997): 33–40.

61 Daniel Simberloff, foreword to *The Ecology of Invasions by Animals and Plants*, by Charles S. Elton (Chicago: University of Chicago Press, 2000), vii–xiv; Wilcove, *The Condor's Shadow*, xiii–xv.

62 Edward O. Wilson, foreword to *Strangers in Paradise: Impact and Management of Nonindigenous Species in Florida*, ed. Daniel Simberloff, Don C. Schmitz, and T. C. Brown (Washington, D.C.: Island Press, 1997), ix–x.

Editorial Board.⁶³ He does not specifically remember handling the submission, however, and the current *BioScience* managing editor reported such information 'may have been lost to the ages'.⁶⁴

'Quantifying Threats to Imperiled Species in the United States' appeared in *BioScience* well before its publication in *Precious Heritage*, where it stands as chapter eight under the heading 'Leading Threats to Biodiversity'. Although the two versions are similar in many respects, they are not identical. The book chapter includes an introductory vignette about the extinction of a Hawaiian bird, the 'o'o (*Moho braccatus*), attributed to a combination of causes including habitat loss and avian malaria, a disease accidentally introduced to the islands in the 1820s. It also includes a section headed with the title, 'Horsemen of the Environmental Apocalypse', which appeared in *BioScience* sans emphasis. A further nod to Wilson and the equally citable Paul Ehrlich followed in both versions: '[i]n general, scientists agree that habitat destruction is currently the primary lethal agent (Ehrlich 1998, Wilson 1992) followed by the spread of alien species (Wilson 1992)' [citations in originals].⁶⁵

'Wilson, 1992' is *The Diversity of Life*, and what appeared there was explained above. Neither quotes nor careful paraphrases, the ideas attributed in this case to Wilson merely resemble his statements. Wilcove's 'the spread of alien species' is far more general than either Wilson's 'invasion of exotic animals' or his 'displacement by introduced species'. Furthermore, although 'scientists generally agree' looks credibly like a Wilsonism, it cannot be found in the 1992 edition of *The Diversity of Life* (although it suggests another possibility, discussed below). It is not clear until much later in these twin works that the statements attributed to Ehrlich and Wilson were the hypotheses of their study, or perhaps more appropriately the thesis of their essay. Returning to comparisons, *BioScience* readers were told more about methodology and statistics, and that no anthropogenic threats were identified for 52 of the species examined. Both versions contain a lengthy disclaimer, also customised to the needs of each publication and its audience. Their differences are notable and are emphasised below in bold-face:

BioScience version:

We emphasize at the outset [some eight hundred words into the article] that there are some important limitations to the data we used. The attribution of a specific threat to a species is usually based on the judgment of an expert source,

63 Anonymous, masthead in *BioScience* 44 (1994), number nine and following.

64 Emails to the author from Daniel Simberloff, 26 July 2014, and James Verdier, 13 August 2014.

65 David S. Wilcove, David Rothstein, Jason Dubow, Ali Phillips, and Elizabeth Losos, 'Quantifying Threats to Imperiled Species in the United States', *BioScience* 48 (1998): 607–15; David S. Wilcove, David Rothstein, Jason Dubow, Ali Phillips, and Elizabeth Losos, 'Leading Threats to Biodiversity: What's Imperiling U.S. Species', in *Precious Heritage*, ed. Stein, Kutner, and Adams, 239–54.

such as a USFWS [Fish and Wildlife Service] employee who prepares a listing notice or a state **Fish and Game** employee who monitors **endangered** species in a given region. Their evaluation of the threats facing that species may not be based on experimental evidence or **even** quantitative data. Indeed, such data often do not exist. With respect to species listed under the [US Endangered Species Act], Easter-Pilcher (1996) has shown that many listing notices lack important biological information, including data on past and possible future impacts of habitat destruction, pesticides, and alien species. Depending on the species in question, the absence of information may reflect a lack of data, an oversight, or a determination **by USFWS** that a particular threat is not harming the species. **The extent to which such limitations on the data influence our results is unknown.**⁶⁶

Precious Heritage version:

There are some important limitations to the data we used. The attribution of a specific threat to a species is usually based on the judgment of an expert source, such as a USFWS employee who prepares a listing notice or a state **natural heritage program** employee who monitors **imperiled** species in a given region. Their evaluation of threats facing that species may not be based on experimental evidence or quantitative data. Indeed, such data often do not exist. With respect to species listed under the [US Endangered Species Act], Easter-Pilcher (1996) has shown that many listing notices lack important biological information, including data on past and possible future impacts of habitat destruction, pesticides, and alien species. Depending on the species in question, the absence of information may reflect a lack of data, an oversight, or a determination that a particular threat is not harming the species.⁶⁷

Like their precursors a generation (by reference) removed, Wilcove et al. confirmed the inevitable consensus. It seems clear that any ‘quantifying’ conclusions based on such dubious data are no less dubious. As the saying goes, ‘the plural of anecdote is not data’.⁶⁸ They could gloss over this problem in the TNC book; after all, their message was primarily environmental advocacy, not scientific analysis. But *BioScience* is published by, and for, professional biologists. It includes commentaries and editorials, but ‘Quantifying Threats’ was published as a research paper, with other research papers in the issue. Intervention by a *BioScience* editor may account for the slightly more explicit wording of the disclaimer in ‘Quantifying Threats’. If so, it remains puzzling that *BioScience* included an assertive statement in the central column of the article’s first page, emphasised with paragraph borders and a larger, bolder font (Figure 1).

66 Wilcove et al., ‘Quantifying Threats’, 608–609.

67 Wilcove et al., ‘Leading Threats to Biodiversity’, 241.

68 Economist Roger Brinner of the Parthenon Group claims credit for coining the ‘plural of anecdote’ phrase ‘decades ago’ but cannot himself ‘remember exactly when’. Email to author, 20 September 2004.

Quantifying Threats to Imperiled Species in the United States

Assessing the relative importance of habitat destruction, alien species, pollution, overexploitation, and disease

David S. Wilcove, David Rothstein, Jason Dubow, Ali Phillips, and Elizabeth Losos

Biologists are nearly unanimous in their belief that humanity is in the process of extirpating a significant portion of the earth's species. The ways in which we are doing so reflect the magnitude and scale of human enterprise. Everything from highway construction to cattle ranching to leaky bait buckets has been implicated in the demise or endangerment of particular species. According to Wilson (1992), most of these activities fall into four major categories, which he terms "the mindless horsemen of the environmental apocalypse": overexploitation, habitat destruction, the introduction of non-native (alien) species, and the spread of diseases carried by alien species. To these categories may be added a fifth, pollution, although it can also be considered a form of habitat destruction.

Habitat loss is the single greatest threat to biodiversity, followed by the spread of alien species

passed by them—is responsible for endangering species. In general, scientists agree that habitat destruction is currently the primary lethal agent (Ehrlich 1988, Wilson 1992), followed by the spread of alien species (Wilson 1992). However, apart from several notable exceptions—including studies of North American fishes by Williams et al. (1989), endangered plants and animals in the

fine-scale analysis of the types of habitat destruction affecting US plants and animals protected under the federal Endangered Species Act (ESA). We also speculate on how these threats have changed over time and are likely to change in the future. We conclude with a brief discussion of the implications of our findings for the long-term protection of imperiled species in the United States.

An overview of the threats

To obtain an overview of the threats to biodiversity in the United States, we tabulated the number of species threatened by five categories of threats: habitat destruction, the spread of alien species, overharvest, pollution (including siltation), and disease (caused by either alien or native pathogens). We restricted this

Figure 1: Detail from the first page of Wilcove et al. (1998).

Source: David S. Wilcove, David Rothstein, Jason Dubow, Ali Phillips, and Elizabeth Losos, 'Quantifying threats to imperiled species in the United States', *BioScience* 48 (1998): 607–15.

This teaser to journal browsers is, as usual, a direct quote from the body of the paper. But the quote includes only part of the statement actually made by Wilcove et al. Here again it is useful to compare the two versions:

BioScience version:

The major findings of this study confirm what most conservation biologists have long suspected: Habitat loss is the single greatest threat to biodiversity, followed by the spread of alien species. However, the discovery that nearly half of the imperiled species in the United States are threatened by **alien species—combined** with the growing numbers of alien species—suggests that this particular threat may be far more serious than many people have heretofore believed.⁶⁹

69 Wilcove et al., 'Quantifying Threats', 614.

Precious Heritage version:

The major findings of this **chapter** confirm what most conservation biologists have long suspected: Habitat loss is the single greatest threat to biodiversity, followed by the spread of alien species. However, the discovery that nearly half of the imperiled species in the United States are threatened by **invasive aliens—coupled** with the growing numbers of alien species—suggests that this particular threat may be far more serious than many people have heretofore **recognized**.⁷⁰

Wilcove et al. thus clearly signalled their satisfaction at confirming a supposedly broad bias, but gave it a puzzling twist. Their claim ‘most conservation biologists have long suspected’ something that ‘may be far more serious than many people have heretofore believed/recognized’ approaches the paradoxical, but it might only be an awkward bit of boundary work disparaging the sceptical.

Perhaps the most important conclusion to be drawn from this comparison is that Wilcove et al. either considered the terms ‘alien species’ and ‘invasive aliens’ synonymous or they were comfortable drawing different conclusions for different audiences. The lexicon of biological invasion has long been criticised from within and without for its imprecision and militaristic, metaphorical constitution.⁷¹ In an attempt to control the damage, some authors have parsed the terms *alien* (= non-native = introduced = non-indigenous) and *invasive* such that the latter should be considered a small subset of the former.⁷² In this regard, perhaps ‘Quantifying Threats’ tacitly exemplifies invasion biology’s early rush to claim a precious heritage: identification of their new post-Cold War alarmism with that of a Cold War Cassandra, the ‘father of animal ecology’, Oxford zoologist Charles S. Elton.

Elton was a proto-environmentalist and occasional populariser of population ecology who influenced better-known contemporaries, including Aldo Leopold and Rachel Carson. Even though Elton used and promoted the term ‘invasions’, his views on the matter of introduced species were considerably more complex and nuanced than those of the distant followers who claimed his legacy.⁷³ In his foreword to the otherwise facsimile 2001 reissue of Elton’s *The Ecology*

70 Wilcove et al., ‘Leading Threats’, 252.

71 See, for example, Banu Subramaniam, ‘The aliens have landed! Reflections on the rhetoric of biological invasions’, *Meridians: feminism, race, transnationalism* 2 (2001): 26–40; Robert I. Colautti and Hugh J. MacIsaac, ‘A neutral terminology to define “invasive” species’, *Diversity and Distributions* 10 (2004): 135–41; Brendon M. H. Larson, ‘The war of the roses: demilitarizing invasion biology’, *Frontiers in Ecology and the Environment* 3 (2005): 495–500; Jozef Keulartz and Cor van der Weele, ‘Framing and reframing in invasion biology’, *Configurations* 16 (2008): 93–115.

72 See, for example, Petr Pyšek, David M. Richardson, Marcel Rejmánek, Grady L. Webster, Mark Williamson, and Jan Kirschner, ‘Alien plants in checklists and floras: towards better communication between taxonomists and ecologists’, *Taxon* 53 (2004): 131–43.

73 Chew, *Ending with Elton*, 270–86.

of *Invasions by Animals and Plants*, Simberloff attempted to distance modern invasion biology from those nuances. As much as anything, Simberloff's purpose then and in later writings was not to praise Elton, but to bury him: to de-emphasise Elton's significance to the nascent discipline, and succeed him as its de facto leading light.⁷⁴

Given the strong disclaimer's internal repudiation of the paper's basis, neither version of 'Quantifying Threats' recommends itself as a reliable foundation stone for a scientific subdiscipline. But uniquely among competing proposals such as Wilson's 'mindless horsemen', and Diamond's 'evil quartet', the 'second greatest threat' became firmly entrenched in both the popular and technical literature of 'biological invasions'.

Responding to an early abstract of the present paper, Wilcove wrote:

The primary reason we did the study was to see if, in fact, alien species emerged as a significant threat to biodiversity. Based on the data we obtained from The Nature Conservancy, the Network of Natural Heritage Programs and Conservation Data Centers, and the Fish and Wildlife Service, alien species emerged as the second most frequent threat to imperiled species (after habitat destruction). I do not know how E. O. Wilson's written statement about alien species may have influenced other scientists, but it did affect our analysis. Had the data shown otherwise, we would not have hesitated to disagree with him.⁷⁵

Nevertheless, it seems unlikely that Wilcove's team ever contemplated the prospect of falsifying Wilson's assertion, and both the history of the paper's development and its methodology show that publicly disagreeing with Wilson was an unlikely outcome. Recall that TNC's *Precious Heritage*, like Wilcove's *The Condor's Shadow*, opened with a Wilson foreword.⁷⁶

A 1999 reissue of *The Diversity of Life* included a new foreword of its own, in which Wilson again inflated his own 1992 claims by stating that '[e]xperts generally agree that on a worldwide basis the causes of extinction, which are virtually all due to human activity, can be ranked from the top down as follows: habitat destruction or degradation, the spread of exotic (nonnative) species, pollution, overharvesting and disease'.⁷⁷ He also rushed to endorse *Quantifying Threats* (making him one of the earliest to do so) and repeated its findings: 'The data that measure the factors endangering U.S. species, as compiled by David S. Wilcove and his co-workers in 1998 ... are habitat loss, 88 percent, exotics, 46 percent; pollution, 20 percent; overharvesting, 14 percent; and disease, 2 percent'.

74 Chew, *Ending with Elton*, 274; Simberloff (personal communication, 2008) concurred with my assessment.

75 David S. Wilcove, email to author, 20 September 2002.

76 As of June 2014, Edward O. Wilson has written forewords to at least forty books, mostly with explicitly environmentalist themes.

77 Edward O. Wilson, *The Diversity of Life* (New York: W. W. Norton, 1999), xvii.

Wilson neither repeated nor mentioned the procedural caveats of Wilcove et al. And neither Wilson nor his editors apparently fretted over the recursive logic of allowing a book to reify one of its own claims by citing a paper that reified *its* claims by citing an earlier printing of the book. Finally, and even more strangely, we have at last encountered Wilson making the statement, ‘experts generally agree ...’ which Wilcove et al. seemingly attributed to him before he made it. There are three likely explanations: (1) coincidence; (2) Wilcove et al. saw Wilson’s 1999 foreword before it was published; and (3) Wilson used the inflated statement of Wilcove et al. as a basis for inflating his own.

In 2002, I asked Wilson whether he felt Wilcove et al. had appropriately cited his work, given the differences between his statements in *The Diversity of Life* (1992) and the conceptually expanded paraphrase in the *BioScience* paper. His response: ‘Yes, I believe it fair to say that specialists are in agreement that habitat destruction is the primary extinction agent, followed by invasive species.’⁷⁸ It had been 10 years since the original publication of *The Diversity of Life*, three since its new foreword, and more than three since the *BioScience* article, and here was a third formulation. We have seen that ‘invasive species’ does not wholly correspond with ‘exotic’ or ‘alien’ species. Wilcove’s ‘scientists’ are not necessarily Wilson’s 2002 ‘specialists’ or his 1999 ‘experts’. Either the whole idea was very vague, its terminology very fluid, or both. And there was no certain way to tell whether Wilson felt it was more important to uphold the alleged consensus founded on his 1992 book than to reflect on it critically in the presence of a sceptical nobody.

The year 2002 also saw the advent of Wilson’s book, *The Future of Life*, this time with the straightforward trade publisher Alfred A. Knopf (by then a division of Random House). Unconstrained by any university association, Wilson could say whatever his specialist expertise moved him to. He did not mention Wilcove in the text or endnotes, but devoted part of a chapter to introduced species. Here, again, he attempted to represent something as a scientific consensus regarding

the forces that hammer nature everywhere in the world ... These factors are summarized by conservation biologists under the acronym HIPPO:

Habitat destruction. Hawaii’s forests, for example, have been three-fourths cleared, with the unavoidable decline and extinction of many species.

Invasive species. Ants, pigs, and other aliens displace the native Hawaiian species.

Pollution. Fresh water, marine coastal water, and the soil of the islands are contaminated, weakening and erasing more species.

78 Edward O. Wilson, email to author, 10 February 2002.

Population. More people means more of all the other HIPPO effects.

Overharvesting. Some species, especially birds, were hunted to rarity and extinction during the early Polynesian occupation.⁷⁹

A strained acronym for a poorly wrought taxonomy; but if conservation biologists had already summarised it thus, Wilson was merely the messenger. Alas, the acronym HIPPO appears to have originated (at least in print) in this context. Those who later used it and identified a source, invariably cited *The Future of Life*. Wilson apparently invented a term while vaguely attributing it as a common usage, invented a consensus, or both.

In 2004, Jessica Gurevitch and Dianna Padilla of Stony Brook University cited 'Quantifying Threats' as the major impetus for a paper with a question for a title: 'Are invasive species a major cause of extinction?' Unlike 'Quantifying Threats', the publishing journal chose to identify their effort as an opinion piece, but not for lack of data analysis. The New York pair noted the strong influence exerted on the results of Wilcove et al. by the inclusion of Hawaiian endemics and questioned the degree to which alien species had been blamed for their predicaments. They subdivided alien species contributions into functional types (for example, herbivory by livestock, competition from plants, alien pathogens, and parasites) and de-aggregated effects on plants and animals. Based further on information from the IUCN Red List, Gurevitch and Padilla concluded that 'the assumed importance of the invaders in causing widespread extinctions is to date unproven, and is based upon limited observation and inference. Evidence supporting a general and primary role for invasive aliens in extinctions remains limited'. They went on to caution that '[w]e must be as specific and as clear as possible about the nature of threats to species at risk ... The generalization that alien species are playing a widespread role in extinctions is, to date, too unspecific to be either accurate or useful'. And, unlike Wilcove et al., they admitted more work was needed to understand the relative impacts of alien species in different systems.⁸⁰

Their cautionary assertions attracted a vigorous rejoinder in the form of a letter from two Spanish ichthyologists, published in early 2005. Miguel Clavero and Emili García-Berthou took issue with Gurevitch and Padilla's methods, accepting anecdotal inferences they claimed the Stony Brook pair had overlooked. Tellingly, though, the Spaniards concluded that '[a]lthough extinction is often the end result of invasions, there are other ecological and evolutionary impacts of biotic

⁷⁹ Edward O. Wilson, *The Future of Life* (New York: Alfred A. Knopf, 2002), 50.

⁸⁰ Jessica Gurevitch and Dianna K. Padilla, 'Are invasive species a major cause of extinctions?', *Trends in Ecology & Evolution* 19 (2004): 470–74.

homogenization that are less understood [citing two references] thus prevention and the precautionary principle are of particular relevance to invasive species'.⁸¹ They did little more than to demarcate the boundary of acceptable thinking.

Later in 2005, Wilcove joined a colleague from Beijing to again quantify threats, this time to 437 species of Chinese vertebrates, and to compare them with the 1998 conclusions of Wilcove et al. regarding 'imperiled' American species. Publishing again in *BioScience*, they relied primarily on the *China Red Data Book of Endangered Animals*. Again, they essentially cautioned readers against relying on the results. They excluded 'potential or hypothetical threats' and 'did not try to distinguish between ongoing and historical threats because such information is often lacking, and the distinction itself is problematic in the case of habitat destruction'. They went on to detail 'five important assumptions ... attached to these data:'

First, although the Red Data Book and other sources used in this study represent an impressive compilation of information on threats to species, we do not know the extent to which they may be biased for or against particular threats. In other words, some of the many contributors to the Red Data Book may have focussed on particular threats to the exclusion of others. The same is true for the data underlying Wilcove and colleagues' (1998) analysis of threats to US vertebrates. Thus, our comparisons are based on the assumption that all threats had equal probabilities of being detected and recorded for each species and country. Second, in most cases there is little actual experimental evidence connecting a particular threat to a particular species. The determination that a given human activity is now or has been a threat to a species is typically the result of someone's professional judgment, rather than the result of a formal experiment. We assume that documented threats are accurate, and that any biases in the data are consistent across all vertebrate classes and between the two countries. Third, because the faunas of both countries are essentially allopatric, we assume that the threats to biodiversity in each nation are independent, notwithstanding obvious linkages through international commerce. Fourth, although individual species in each country may be listed under multiple threats (a reflection of the reality that many species are threatened by more than one factor), we considered the data independent because any species theoretically could fall into any of the individual categories or combination of categories. (It is possible, however, that imperiled species with broader ranges encounter more threats and therefore contribute disproportionately to our data.) Fifth, we assumed no interaction between threats, although in reality there probably are (e. g., between habitat destruction and the spread of alien species).⁸²

81 Miguel Clavero and Emili García-Berthou, 'Invasive species are a leading cause of animal extinctions', *Trends in Ecology & Evolution* 20 (2005): 110.

82 Li Yiming and David S. Wilcove, 'Threats to vertebrate species in China and the United States', *BioScience* 55 (2005): 147–53.

Having thus (again) disclaimed any expectation of producing accurate or precise results, they proceeded with their analysis. This time 'alien species' ranked a distant fourth of five putative threats, affecting only three per cent of the taxa reviewed. They called the contrast between the American and Chinese situations 'striking' in relationship to two types of threats, one of which ('alien species') was 'harder to explain'. After paying lip-service to the possibility that there might be actual differences (but ignoring the possibility that the American results might have been skewed), they offered their preferred explanation: 'it may simply be an artifact of neglect: Chinese ecologists have not focussed on alien species as a threat to biodiversity until relatively recently'. They followed that observation with supporting citations and comments that apparently had not been eligible for evaluating their data, pre-analysis. And evidently the disparity appeared too significant to explain away, leading them to conclude there were significant differences between the situations in the two countries.⁸³ To his credit, Wilcove (unlike Wilson) did not attempt to universalise his geographically constrained conclusions, but the awkward shifting of blame for differing results on a perceived naïveté among Chinese scientists raised a spectre of Western academic condescension that even his Chinese colleague's placement as lead author could not diminish.

A little less than two years later another quantification of threats was undertaken, this time in Canada, by five Canadians whose results (published yet again in *BioScience*) diverged substantially from those of *Quantifying Threats*. Like Gurevitch and Padilla (but independently, it seems), they noted the extent to which the results of Wilcove et al. were influenced by the heavy representation of Hawaiian endemics. The Canadian team found 'introduced species' to be 'the least common broadscale threat' in Canada. They also criticised Wilcove et al. for failing to consider threats from 'native species interactions' and 'natural disasters', each of which they found to be more significant than 'introduced species'.⁸⁴

'Me, too!': Generations three and following

In the interest of saving time, graduate science students with heavy reading loads are commonly encouraged to skip the introductions (and even the conclusions) of peer-reviewed papers. As one online pundit explained: 'it's all regurgitation and conjecture'.⁸⁵ However, introductions have other functions. The ways authors

83 Yiming and Wilcove, 'Threats to vertebrate species'.

84 Oscar Venter, Nathalie N. Brodeur, Leah Nemiroff, Brenna Belland, Ivan J. Dolinsek, and James W. A. Grant, 'Threats to endangered species in Canada', *Bioscience* 56 (2006): 903–10.

85 Isaiah Hankel, '130 Things Surviving Graduate School Taught Me About Business Success' (2014), www.isaiiahankel.com/graduate-school, accessed 5 June 2014.

introduce papers helps situate them in disciplinary contexts. It establishes their bona fides. In case the name of the field leaves room for doubt, the introductions of invasion biology papers are places for authors to bemoan the existence of their objects of study, which are to be resisted, not deemed objectively interesting. The Wilson/Wilcove declaration, 'invasive exotic species are the second greatest threat to biodiversity', justifies studying any particular case because it implies the result will be used to resist an invasion. By citing it, authors laconically declare themselves fellows of the alien deprecation league. Like the alien/native dichotomy itself, the 'second greatest threat' rapidly attained the status of a truism, a fact everyone (who was anyone) simply understood to be the case.

As such, the nearly 1,200 citations recorded by the Web of Science (June 2014) for 'Quantifying Threats' represent an indeterminate percentage of the number of times some form of the statement has appeared in peer-reviewed literature since 1998. It appears with considerably less frequency in the two specialist journals (*Biological Invasions* and *Diversity and Distributions*, where it might be considered somewhat redundant to make such declarations) than in general ecology- and conservation-related titles.

In his 2009 Oxford University Press book *Invasion Biology*, Macalester College ecologist Mark Davis devoted about two pages to critiquing 'Quantifying Threats' and its credulous reception. Citing Gurevitch and Padilla's concerns and the Canadian results of Venter et al., Davis framed the effort of Wilcove et al. as a case of too much, too soon, and too good to be true, beginning: 'In any discipline, it is important that preliminary ideas or tentative conclusions made on the basis of one or a few studies do not acquire a life of their own, eventually assuming a level of validity and generality that is unjustified on the basis of the actual data'.⁸⁶ How often this has actually happened in other disciplines is a moot point Davis did not pursue. His analysis, too, reproduced the full 'disclaimer' from 'Quantifying Threats' and drew a strong conclusion: '[i]t is difficult to believe that all those who have cited this article actually have read it'.

Lax citation practices are a well-known rattling skeleton in academe's closet. Categorising and quantifying their occurrence to determine whether ecologists, conservation biologists, or invasion biologists are any more predisposed to citing unread sources based on their reputed content than practitioners in any other discipline would be a monumental undertaking. But the flexibility with which the claim of Wilcove et al. has been deployed is impressive. There are so many extant permutations that it is impractical, even electronically, to inventory them. Many paraphrasers fail to acknowledge that the finding was limited to the United States. Few ever note that it was strongly skewed by the inclusion

86 Davis, *Invasion Biology*, 181–83.

of Hawaiian cases, and virtually none that it was grounded in anecdotal data. They have often generalised it vaguely or globally (as might be suggested by the article's teaser), but even then the full title and its implications usually appeared among their references. Some attached a geographical or taxonomic scope relevant to their own work.

I reviewed the first 25 relevant results of a 17 June 2014 Google Scholar search for peer-reviewed papers published in 2014 that cited 'Quantifying Threats' regarding the effects of introduced species to determine how current authors were using and contextualising the 'second greatest threat' statement. Firstly, its ubiquity in the literature was confirmed by the fact that these 25 appeared in 23 different journals and one MSc thesis, and were produced by authors from at least 14 countries. Twenty-three listed it in their introductions among litanies of putatively established facts. Only two accurately confined the scope of 'Quantifying Threats' to the United States. Six explicitly expanded it to a 'global' or 'worldwide' finding. Twelve paraphrased it in such vague terms as to represent it as a universal truism. Five suggested it specifically applied to their own areas of interest: 'agricultural landscapes', 'plants', 'local biodiversity', 'coastal ecosystems', and 'indigenous species'. The last, in full: 'Exotic species are considered the second most insidious cause of biodiversity loss and population decline of indigenous species.'⁸⁷

Experts, ecologists, environmentalists

During a 2004 television interview, University of California linguist George Lakoff was commenting on the rhetoric of the ongoing US Presidential campaign. He observed that one party was actively dismissing the science of environmental issues and appealing instead to common sense. In the process, Lakoff conflated three identities: '[w]ho are the *experts*? They're *ecologists*, *environmentalists*' [emphasis added].⁸⁸ Lakoff's assertion seemed common-sensical in its own way, perhaps because the distinction between being an environmentalist and being an ecologist is vague, even to those who claim such identities.

87 Kamal J. K. Gandhi, Annemarie Smith, Diane M. Hartzler, and Daniel A. Herms, 'Indirect Effects of Emerald Ash Borer-Induced Ash Mortality and Canopy Gap Formation on Epigeic Beetles', *Environmental Entomology* 43 (2014): 546–55.

88 David Brancaccio and George Lakoff, 'Talking About Talk', *NOW With Bill Moyers* (New York, Thirteen/WNET for PBS, first broadcast 23 July 2004). An active environmentalist himself, George Lakoff consults for the Sierra Club and 'dozens of environmental organizations'; cf. Katy Butler, 'Winning Words', *Sierra* (July–August 2004) www.sierraclub.org/sierra/200407/words.asp.

A 1976 college biology textbook stated: ‘most ecologists are environmentalists, because of the nature of their training and interests. The reverse is not necessarily true, however; not all environmentalists are ecologists’.⁸⁹ Twenty years later, another biologist concluded, ‘many undergraduates enrol for introductory ecology classes in the expectation that ecology will offer enlightenment as well as factual knowledge—an enlightenment with moral and spiritual dimensions’, and wondered, ‘how should we cope with the divergence between the academic’s definition of ecology as a branch of disinterested science, and the general public’s understanding of ecology as a life philosophy or quasi-religion that connect[s] interpretations of how ecosystems function to moral imperatives and spiritual significance?’⁹⁰

These are indicative, not isolated comments. Since the founding of the first ecological societies a century ago, ecologists have concerned themselves with nature conservation. The Ecological Society of America’s 1926 ‘Naturalist’s Guide to the Americas’ was compiled by its ‘Committee for the Preservation of Natural Conditions’ because, it claimed, the society’s ‘membership includes a larger proportion of persons interested in the preservation of natural conditions for research in pure science and for educational work than any other of our national scientific societies’.⁹¹ Despite that declaration of objective purpose, the body of the book opened with an outline of ‘The Value of Natural Areas to Literature and Art’, followed by ‘The Value of Natural Preserves to the Landscape Architect’. Spiritual matters are addressed obliquely in a quotation from a Harvard University emeritus president: ‘Something more than economic remedies must be found for the great evils which beset modern society, and particularly for the diseases, physical and moral, which are caused by congestion of population’.⁹² It seems ecologists have been concerned about threats of one kind or another since ecology began, and at least some have taken their ecological knowledge to authorise their opinions.

Many arguments have been deployed to justify seeing the ecological sciences as sources of deeper truths. Other arguments are devoted to exposing expert eco-piety as naïve disregard of Realpolitik or fraudulent self-serving. All those can hardly be summarised here. Looking at the advent of the ‘second greatest threat’, the most charitable possible conclusion is that Edward O. Wilson and (subsequently) David Wilcove et al. sincerely believed what they wrote and submitted it for publication assuming there was no time to be lost in making

89 William C. Scheffler, *Biology: Principles and Issues* (Reading, MA: Addison-Wesley, 1976), 266.

90 Mark Westoby, ‘What Does “Ecology” Mean?’ *Trends in Ecology and Evolution* 12 (1997): 166.

91 Victor E. Shelford, ‘Chairman’s Preface’, in *Naturalist’s Guide to the Americas* (Baltimore, MD: Williams & Wilkins, 1926), v–vii.

92 Charles W. Eliot, quoted by Stanley White, ‘The Value of Natural Preserves to the Landscape Architect’, in *Naturalist’s Guide to the Americas*, ed. Shelford, 8–9.

such vital information available. They certainly could have done that in ways that more clearly and appropriately emphasised the contingency of their source materials and their methods. However, there seems to be little reason to doubt that Wilson was serving his own purposes as much as any other. Perhaps he too readily accepted his own opinion as inevitably consonant with objective reality. His justification for ignoring not only norms of scientific practice but also the simplest rules of logic are hard to fathom. He is by any measure a celebrity, which may be the key point. The world occupied by celebrity scientists has a peculiar characteristic. Having achieved (or assumed) a state of peerlessness, a celebrity scientist is no longer subject to peer review. But having abandoned peer review, he is no longer speaking as a scientist.

'Quantifying Threats' (reduced to its primary, oft-repeated, and strangely elastic central claim) became a celebrity itself, identified by *BioScience* as its most-cited article (as of 1 August 2014).⁹³ In this light, Mark Davis' assessment that few of those who cite the paper can actually have read it takes on gloomy new significance. Nevertheless, its reification by repeated reference, abetted by Wilson's endorsement, quickly (and persistently) made citing it a catechistic imperative for invasion biologists, whether supplicant tyros or established true believers. Meanwhile its authors, especially the four routinely subsumed under the shorthand 'et al.', did not share in their brainchild's celebrity.⁹⁴ In 2008, lead author Wilcove published a second book, *No way home: the decline of the world's great animal migrations*, perhaps an ironic coda to his disparagement of the new class of great migrations as the 'second greatest threat' to biodiversity.⁹⁵

In 2011, two more Canadian authors 'surveyed reviewers of the journal *Biological Invasions* to obtain a better sense of how invasion biologists evaluate several foundational issues'. One of those issues was the credibility of the 'second greatest threat'. They found that 'only 27.3 per cent of respondents [115 of 422] ranked invasive species as the first or second greatest threat to biodiversity'. The corresponding author of that paper, Brendon Larson, has been a leading observer and sometime critic of invasion biology for the past decade, publishing numerous thoughtful articles on the field's affinity with hyperbolic advocacy and reliance on militaristic constitutive metaphors. His willingness to discuss ranking threats to biodiversity suggests he still operates largely within the framing pioneered by Wilson in 1992. Despite Wilson's foundational role in

93 Anonymous, 'Most-Cited Articles', *BioScience*, bioscience.oxfordjournals.org/reports/most-cited, accessed 3 September 2014.

94 As of the time of writing, David S. Rothstein is an attorney for the US Fish and Wildlife Service; Jason Dubow is Director of Environmental Planning for the State of Maryland; Ali Phillips could not be positively identified online; Elizabeth Losos is President and CEO of the Organization for Tropical Studies.

95 (Washington, D.C.: Island Press, 2008).

setting the terms of the issues Larson and his colleague were examining, they never mentioned him. That as much as anything suggests Wilson's framing has succeeded to paradigmatic status.

Over the years I have talked to many life scientists who found 'Quantifying Threats' wanting in some respects, but who chose not to openly challenge it. I did not collect their stories and can offer only general impressions. Some suggested no one really took the paper seriously, so it did not require serious attention from serious minds engaged in serious science. That seems either naïve or disingenuous. A few felt that openly criticising 'Quantifying Threats' could jeopardise their careers or standing in conservation biology circles. Hesitancy and rationalisation may be the rule, but there are exceptions; two have already been noted (Davis; Gurevitch and Padilla). Invasion biology's relentless proselytising in the news and popular media spawned responses there as well. Two in particular are relevant here: science writer Emma Marris' personal manifesto, *Rambunctious Garden: saving nature in a post-wild world*, and British plant ecologist Ken Thompson's wide-ranging rebuttal of invasion biology's more hyperbolic (perhaps egregious) assertions, *Where do Camels Belong?: the story and science of invasive species*. Marris merely acknowledged the existence of 'Quantifying Threats' and its famous finding.⁹⁶ She went on to say, 'Biodiversity may be the most problematic goal precisely because it embraces so much: several levels of biological organization, from genes to whole landscapes. Nevertheless, it may come closest to capturing what people like about nature'.⁹⁷ Marris kept one foot inside the Wilsonian paradigm, even if only for lack of a clear alternative. Thompson took another tack, calling the 'second greatest threat' 'a straightforward lie'.⁹⁸ But he also invoked biodiversity with less hesitation than Marris. This brings us back to the problem of deciding who (if anyone) the liars were and whether their lies (if any) were straightforward.

Ecology is hardly monolithic, and it has been noted that 'ways in which ecological scientists interrelate their own beliefs about environmental advocacy, values, and scientific integrity is an extremely complex issue'.⁹⁹ Operating in a consistent, principled manner at the intersection of ecology and environmental advocacy (or its precursors) has never been simple. During the 1970s early proponents of science studies were already observing its hazards. Sociologist Dorothy Nelkin tracked American ecologists' excitement at suddenly feeling relevant as popular environmentalism coalesced, to being 'overwhelmed' by relevance, to being

96 Emma Marris, *Rambunctious Garden* (New York: Bloomsbury USA, 2011), 103.

97 Marris, *Rambunctious Garden*, 163.

98 Thompson, *Where do Camels Belong?*, 47–48.

99 Derek S. Reiners, William A. Reiners, and Jeffrey A. Lockwood, "The relationship between environmental advocacy, values, and science: a survey of ecological scientists' attitudes," *Ecological Applications* 23 (2013):1226–42.

disillusioned by actual policy outcomes and the (commercial) professionalisation and exploitation of a once primarily academic discipline, all in the space of a single decade. Nelkin noted, 'the tendency to adjust one's research to "useful" directions may follow less from intellectual conviction than from professional opportunity'. She concluded with still relevant questions: '[a]s scientists become increasingly involved in public policy problems, does this inevitably encourage greater outside direction of scientific work? And if scientists avoid such involvement, can they reduce interference [in] the working of their disciplines? The ecologists' dilemma suggests that outside relationships and controls will develop willy-nilly whenever the work of scientists is perceived to be relevant to public problems'.¹⁰⁰ A decade later, concerning the relationship of science to press coverage, she wrote, 'Often errors derive less from inaccurate reproduction of details than from the inevitable distortions that occur in translating complex technical terms into lay English'.¹⁰¹ She meant errors propagated by reporters, perhaps never anticipating the trajectory of 'biodiversity', an object of reverent qualitative advocacy that was to be insinuated into scientific discourse as if it were actually an object of quantitative analysis.

In a posthumously published essay, Nelkin did have something salient to say about Wilson, albeit in the context of Wilson's 1989 book, *Consilience*, and it was not exactly complimentary:

Harvard University entomologist Edward O. Wilson (1989), a founder and advocate of sociobiology and evolutionary psychology, has explicitly equated science and religion: 'Perhaps science is a continuation on new and better tested ground to attain the same end [as religion]. If so, then, in that sense science is religion liberated and writ large' ... Science, he claims, 'offers the boldest metaphysics of the age ... there is a general explanation of the human condition proceeding from the deep history of genetic evolution.' Without directly relying on the notion of a God, he and other evolutionary psychologists use a language replete with theological metaphors that convey concepts of immortality and essentialism. And they invest their theories with ethical implications and moral obligations.¹⁰²

Nelkin went on to conclude:

The God talk, the cosmic claims, the organizations for dialogue and reconciliation are all ways to minimize the distance between science and religion, to answer

100 Dorothy Nelkin, 'Scientists and Professional Responsibility: The Experience of American Ecologists', *Social Studies of Science* 7 (1977): 75–95.

101 Dorothy Nelkin, *Selling Science: How the press covers science and technology* (New York: W. H. Freeman, 1987), 126.

102 Dorothy Nelkin, 'God Talk: Confusion between Science and Religion', *Science, Technology & Human Values* 29: 2 (2004): 139–52; 148.

the accusations of critics, and to compete for credibility in the public domain. By drawing on powerful images of Christianity, scientists are seeking to attract converts—to convince the public and many skeptics of the power of their ideas.¹⁰³

Whether or not she intended ‘God Talk’ to appear posthumously, it was the kind of dangerous confrontational piece many others have reserved for their final words on fraught topics. Nelkin saw Wilson’s exertions as an attempt to become very important indeed by moving beyond science to prophecy, where neither methods nor peers constrained him.

His appropriation of St. John’s apocalyptic four horsemen reveals the clarity of Nelkin’s insight. The second greatest threat was not a demonstrable fact of the world awaiting scientific discovery. It was the sum of specific fears selected, calculated, cultivated and wholesaled by Edward O. Wilson in a work published by Harvard University Press, retailed by David Wilcove et al. in *BioScience*, then ‘virally’ distributed and adopted as the password of invasion biology through misreading and misleading citation. Biodiversity was conceived as a threatened quality. Opinion polls of true believers regarding those threats, compiled by their prophets, cast light on some of conservation biology’s apocalyptic concerns. They have catechistical, boundary-marking applications for practitioners of that ‘crisis discipline’ and offer a *raison d’être* verging on gnosis for invasion biologists. As points of departure for ecological science, they offer neither destination nor means of conveyance. If it is valuable (or indeed, possible) to truly quantify threats to biodiversity, clearer objectives and more principled methods are needed.

103 Nelkin, ‘God Talk’: 150.

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