Chapter 6
Theories of Biodiversity Value

It's time to survey theories of the source of biodiversity's value. My survey is not exhaustive. But it covers the theories most frequently offered by the scientific and environmentalist communities and the ones that are most robust, in my judgment. Also, I would say that these constitute a sufficiently diverse sample to give a good general sense of how suitable a peg biodiversity might be for hanging environmental or natural value.[1]

As prelude to this survey, I bound the discussion by recalling where biodiversity fits with respect to some other candidates for environmental "goods": Biodiversity does not have to do with individual organisms except insofar as individuals contribute to genomic diversity. But the usual arguments for the good of individual (nonhuman) organisms that hinge on an individual's rationality, consciousness, sentience, desires, needs, or the individual's "good of its own" offer no obvious support for the good of the *diversity* of rational, conscious, sentient, needy, or telic organisms. Any moral consideration afforded to individual organisms by dint of one or another of the aforementioned capabilities does not obviously extend to the *diversity* of individuals that possess these capabilities. One might suppose that a diversity of creatures[2] is required to make possible a diversity of *kinds* of rationality, consciousness, sentience, etc. For example, human sentience, crotaline sentience, formacid sentience,

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[1] Among other theories of biodiversity value that I omit are ones that build on religious beliefs. Three reasons, not out-of-hand dismissiveness, guided this choice. First, insofar as various western religions find grounds for a just-so model of biodiversity, I do, in fact, deal with a salient element of their position. On the other hand, I think that other, mostly eastern religions do not view biodiversity in anything like the way that western-trained scientists and environmentalists discuss it and which is the main topic of this book. Finally, I feel that a fair treatment of any religious approach would require a substantial opening out of this already substantial book, which puts such a treatment beyond its scope.

[2] With the possible exception of the possession of a *telos*, these considerations are predominantly geared towards promoting the moral status of a small proper subset of organisms – a select group of multicellular *animals* – while demoting the status of the vast majority of (all other) organisms.

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and so on are possible only with some diverse complement of creatures (people, pit vipers, and ants) that possess these various forms of sentience. But then the diversity of modes of sentience must be shown to be a good. It is hard to imagine a convincing argument for this proposition; and none has been forthcoming.

As I suggested in Sect. 3.1 (The core concept), species diversity is as central to a conception of biodiversity as it is to modern biology – whatever the flaws of the species concept. The good of a species is notoriously difficult to rationalize, since with few exceptions, there is no obvious sense in which a species leads a purposive existence in the sense that is commonly taken as requisite for grounding the value of a species' individuals.[3] But that difficulty is also irrelevant to the question of how biodiversity gets its value because the good of any particular species as the species that it is, like the good of individual organisms, lies outside the domain of concern for biodiversity insofar as it consists of the diversity of species. Of course, the loss of any particular species *does* constitute a loss – an incremental one – in species diversity. It might also constitute (more than the loss of a single individual of that species) a loss in allelic diversity, in feature diversity, or in functional diversity. But the value of that species for species diversity or biodiversity generally is restricted to that species' contribution to just that – diversity.

As an orienting device and as an introduction to problematic syndromes that affect the project to locate value in biodiversity, it is useful to reflect briefly on the upper and lower bounds for biodiversity. At the lower bound, zero biodiversity means no people – not a recommended option. Just considering bare human survival (and leaving aside other needs and desires), it seems safe to say that some sufficient, nonzero amount of biodiversity is infinitely valuable for what seems to be its essential instrumental role in ensuring the continuation of at least one particular species – *Homo sapiens*.[4] Yet even that "safe" assumption comes with caveats. It is difficult to know what that sufficient amount might be – a topic that Sect. 6.4 (Biodiversity as (human) life sustainer) explores. In fact, the amount might be impossible to determine, except by fatal experiment – especially if the boundary between adequate and fatal is thin and almost impossible to perceive on approach. This kind of precautionary consideration comes up for discussion in Sect. 6.3 (Biodiversity as service provider).

Determining a lower bound is problematic for others reasons, saliently including the fact that species diversity in itself says nothing about which species are included. It seems entirely possible that some larger number of species will, with higher likelihood, include some combination that places some terrible burden on humanity. It could even be the death, or at least the infirmity, of us all – a possibility that is

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[3] Populations of colonial animals such as ants and other social insects of the family Formicidae – already mentioned in Sect. 2.3.1 (Abstraction) – might constitute an isolated and (because not the entire species) qualified exception.

[4] It should be clear that even if this *end* – the persistence and flourishing of one peculiar primate – is supposed to be served by biodiversity, biodiversity does not serve to *justify* it. No matter. I assume along with most others that human existence can be justified on other grounds, and not just on the basis of the diversity of the human genome.

taken up Sect. 6.5.2 (Biodiversity as safeguard against infection).[5] Considerations such as these suggest that the trickier problem might be setting an upper bound – a maximum recommended therapeutic dose of biodiversity. But at some point, difficulties with lower and upper bounds and everything in between should raise suspicions that biodiversity is simply not the sort of thing that admits of credible norms along these or any other lines.

This last difficulty stems from the fact that a specification of biodiversity is also a curtain of ignorance, which conceals the exact identities of the biodiverse kinds. The difficulty is a reflection of a considerable temptation to offer reasons for why biodiversity might be valuable – including its role in mankind's survival – which toe or pass over the line between the diversity of kinds and the particular kinds in the biotic world that happen to benefit people. That temptation is in evidence throughout this chapter.

This chapter mainly concerns itself with theories according to which biodiversity is either a constituent good (as with Sect. 6.8, Biodiversity as font of knowledge) or (as with human survival) an instrumental one. A good of the former type competes with other, similar complementary goods, whose realization is sometimes mutually exclusive. A good of the latter type has a provisional quality because, as with any good that is good only as a means to an end, its value is contingent on the absence of other means or their inferiority.[6]

Finally (for this chapter's prefatory remarks), so far as I can tell, there is no *a priori* reason for why every category of diversity that figures into biodiversity should be valuable; and this supposition could well turn out to be false. The diversity of species might, in fact, be of little consequence while the diversity of orders is really important according to some norm. Or Daniel Faith might be right and what really only counts is phylogenetic diversity. In short, it is possible that the diversity of kinds in some categories is valuable while diversity in others is not. Also, as I remarked in Sect. 3.3.3 (Multiple dimensions), the situation is complicated insofar as different categories of biodiversity are likely not to be independent, but interrelated in various complex ways; and so this is likely to be true of their values, too.

Perhaps there is a presumption that the diversity of kinds in any category that is interesting to scientists – something that correlates with other, interesting biological properties and phenomena – will be valuable, if for no other reason than that studying such diversity can increase scientific knowledge. This supposition seems to lie behind much of the "scientific" discussion of biodiversity's value. I grant it provisionally and only for the purpose of engaging with many of the theories that appear in this chapter.

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[5] This point owes to some comments made by Jeffrey Lockwood.

[6] Perhaps one can even imagine humans becoming autotrophic – by acquiring the capability of manufacturing, from inorganic materials, all the organic compounds that are critical for humans to consume for their health. This is but a few steps beyond the nascent capability – in the lab at least – of growing disembodied meat (Britten 2009).

6.1 Unspecified "Moral Reasons"

In their paper on "Biodiversity Studies", Paul Ehrlich and E.O. Wilson (1991, 760) express their belief that

> Because *Homo sapiens* is the dominant species on Earth, we and many others think that people have an absolute moral responsibility to protect what are our only known living companions in the universe.

Wilson has echoed this sentiment many times over and with great eloquence.

Certainly, a "moral responsibility" is precisely what advocates of biodiversity wish to find and justify. Unfortunately, merely making the claim for such a responsibility does not constitute an argument for it. Nor does the fact that people have the capacity to destroy biodiversity by itself entail a moral obligation to refrain from doing this. It is easily within my power to smash the coffee mug containing the black, aromatic elixir that fuels my writing of this book. But I am unaware of any moral obligation to refrain from doing so – though it might be extremely imprudent, so long as my writing task is incomplete.

There is a contrary tradition of thought – stemming from the Stoics, promulgated though Augustine, and some might say, on through welfare economists – that human dominion is evidence that all of earth's goods exist for man's pleasure, to use as he sees fit. There is no reason to believe that biodiversity is somehow exempt from this rather different brand of "stewardship". The bare matter of fact that *H. sapiens* is a dominant species on the planet lends as little (or as much) support to this Stoic interpretation of its moral implications as that fact lends support to the moral duties that Ehrlich and Wilson seek to squeeze from it.

Perhaps Ehrlich, Wilson, and others who say similar things have in mind duties to nonhuman individuals. Or perhaps they are thinking of duties to each and every particular species that happens to exist at the moment. If so, they are mistaking the value of those individuals or the value of those extant species for the value of biodiversity.

It is also possible that Ehrlich and Wilson presume that valuing each and every species entails valuing biodiversity. Unfortunately, the logic behind this presumption is faulty. While saving each and every species would, as a matter of fact, save biodiversity in the sense of preserving the current biodiverse state of affairs, the parallel inference for value commits the fallacy of composition. There is no guarantee that species diversity has independent value as a collection of species, just because each one of the species is valuable.

Or again, Ehrlich and Wilson might believe that some (possibly great) amount of biodiversity is a necessary condition for any individual organism of any species to thrive. But this appears to be a doubtful proposition, which I revisit in the special form of Biodiversity as (human) life sustainer (Sect. 6.4). And in any event, there is no evidence that this is what these authors have in mind.

6.2 Biodiversity as Resource

One of the most common claims on behalf of biodiversity is for its enormous value as a resource, and one that is critically important. Ehrlich and Wilson (1991, 760) represent this position when they note

> … that humanity has already obtained enormous direct economic benefits from biodiversity in the form of foods, medicines, and industrial products, and has the potential for gaining many more…

There are really two reasons here on offer – first, biodiversity as past and current resource; and second, biodiversity as potential future resource. Glossing over this distinction does not compromise my discussion in this section, though it can become critically important in the context of sophisticated economic analysis. The economic reckoning of future goods can involve such niceties as their discounting or (as discussed in Sect. 6.9, Biodiversity options) wrapping them in the complexities of option value.

Confusion between particular species and the diversity of species is immediately evident in the representation of biodiversity as resource. Some particular species are good for people to eat. Because people need food in order to survive, those species might qualify as critically important. Other species have been found to have value for their production of chemicals of pharmacological value. But particular species have yielded the benefits of providing sustenance and the means to restore health – not biodiversity, nor specifically, species diversity.

For the sake of trying to explore what Ehrlich and Wilson might be driving at, I overlook this confusion and presume that their position involves something more like the claim that: a great diversity of organisms increases the odds that at least some few of them are or will be around that are good to eat, that some few others of them do or will provide good medicines, and that some few others do or will provide good building materials. There remains an apparent assumption that the resource-providing organisms are a random sample of all organisms. This is almost certainly untrue and I return to this matter of fact shortly. But putting this objection aside (and alongside the previously noted category confusion), this is still a singularly unconvincing defense of the value of species diversity.

The fact is that an extraordinarily tiny minority of organisms has benefited humanity as resource, now and previously. The majority of this minority – especially when it comes to food (which I discuss just below) and medicine (which I discuss in Sect. 6.5.1) – are highly likely to persist even in the face of a general decline in biodiversity. Furthermore, there is little reason to believe that this circumstance will change in the future. These facts combine with the other that any economic resource competes with other economic demands. As a consequence, from an economic point of view (which includes both resource and "service" value, the topic of Sect. 6.3, Biodiversity as service provider), there is scarcely ever justification for not letting a species go extinct – even if the effort or cost required to save it is minimal. Certainly, many if not most of the symbolic creatures – such as *Ursus maritimus* (polar bear) and *Eubalaena* spp. (right whales) – fall into this category. When, as in the case of both these creatures, there is, in fact, a significant economic cost to saving them – for polar bears, reversing climate warming,[7] for right whales, slowing down or rerouting the ships that traverse their thoroughfares – then the mere possibility of a future benefit from their incremental contribution to species diversity is an essentially nil "expected net present value" (to use the standard economic jargon) by comparison. Daniel Faith joins other conservation biologists in supposing that biodiversity as a resource has (positive) *option value*. But demonstrating that requires showing that biodiversity commands a *premium* over its expected value to consumers, which standard it already fails to meet. Where Faith leaves off with option value, James Maclaurin and Kim Sterelny pick up. I take up their treatment of this theory of biodiversity value in Sect. 6.9 (Biodiversity options).[8]

There is yet another objection to the resource rationale. Insofar as conserving biodiversity preserves the likelihood of conserving one or more valuable resources in the future, it also preserves the likelihood of conserving creatures that are destructive of resources or otherwise harmful. Disease organisms, "pests", and destructive parasites contribute to biodiversity (or at least species diversity) at least as much as (and possibly much more than), for example, the trees that provide good building materials. In fact, because parasitism might well be the predominant "lifestyle" on the planet – by some estimates, outnumbering free-living species by a factor of four (Stiling 2002, 193) – conserving biodiversity is far more likely to ensure that parasitic creatures continue to be in good supply. Parasites even come with a diversity bonus – namely, the species on which they are parasitic (their hosts). Polyphagous parasites deliver multiple bonuses.[9]

In addition, and contrary to the random sample assumption, food for people – the most essential of resources for humans – is actually supplied by organisms in a set that is vanishingly small in the total (species) diversity picture, and that predominantly are carefully maintained and managed by humans on farms. Reliable recent estimates (Khoshbakht and Hammer 2008) are that there are around 7,000 cultivated

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[7] In May 2009, the Obama administration in the United States reaffirmed the preceding (George W. Bush) administration's position that the Endangered Species Act, as applied to polar bear, is not a basis for curbing the greenhouse gas emissions that are the root cause of that species' demise. See Revkin (2009). The rationale, supplied by Interior Secretary Ken Salazar, was largely economic (in terms of the impacts on cement manufacturing and regulatory difficulties) – though it is not at all clear that the ESA admits this sort of test as legitimate.

[8] Faith (2007) seems to regard mere mention of "option value" as sufficient to counter current uncertainty regarding what value biodiversity might have, either as resource or service. Unfortunately, he ignores the wider economic picture: Uncertainty in biodiversity supply, uncertainty in biodiversity demand, and expected consumer surplus heavily influenced by the relative certainty of savings realized by avoiding the cost of conservation can easily push (garden-variety) option value into negative territory.

[9] Of course, people like some parasites – such as the wasps that pollinate commercially valuable *Ficus* trees.

crop species of plants. That is only about 2% of the estimated 320,000 kinds of plants on earth (according to Spicer 2006, 27).[10] Yet that percentage is enormous in comparison to that represented by the number of livestock species. There are an estimated 7,600 breeds (in the 2006 Global Databank for Farm Animal Genetic Resources of the FAO – the Food and Agricultural Organization of the United Nations) of perhaps 40 species.[11] The contribution of these creatures to species diversity borders on infinitesimal in the context of over 9 million other animal species.[12]

A similar consideration applies to biodiversity as medicinal resource, which Sect. 6.5.1 (Biodiversity as pharmacopoeia) takes up in detail.

One final consideration might be the most devastating for the argument for biodiversity as food resource: There is perhaps no better understood and no greater conflict involving biodiversity than the one between it and the production of food. Food production involving crops or tended livestock takes land away from the many other creatures that might otherwise live on it. Chopping or burning down a forest to put the soil under the plow is the most common source of "habitat conversion". That is the euphemistic term for the phenomenon that scientists routinely cite as, by far, the single most decisive force in the global reduction of biodiversity.[13] And agriculture dominates the three leading causes of habitat destruction or "conversion" – which also (Dirzo and Raven 2003, 159) include "extraction activities (mining, fishing, logging, and harvesting), and the development of infrastructure (such as human settlements, industry, roads, dams, and power lines)."[14]

Empirical support for the conflict between biodiversity and food for humans is reinforced at a macro level by the "species-area effect", or as Robert MacArthur and E.O. Wilson (1963) put it in their seminal paper, "the fauna-area curve". MacArthur

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[10] Dirzo and Raven (2003, 142, 159) note that estimates of the number of flowering plants (the angiosperms which dominate the plant world) range from 250,000 to more than 500,000 species.

[11] This figure is due to Drucker et al. (2005, 11), who give a lower estimate than the FAO's for the number of breeds, though agree with the FAO's figure for the number of livestock species.

[12] Agroecologists have lately stressed the prudence of maintaining some greater rather than lesser variety of strains of agriculturally important plants and breeds of agriculturally important animals. But they are talking varieties of plants and animals in the hundreds or at most a few thousands. These are created and maintained as domesticated organisms, and unlikely to be much affected even by a great extinction event. Insofar as wild species are thought to be needed for future crop plant varieties, seeds (along with other *ex situ* methods of conservation) serve quite well. Kew Garden's Millenial Seed Bank alone projects having one-fourth of all wild plant species represented in their seed bank by 2020 (http://www.kew.org/ucm/groups/public/documents/document/ppcont_016021.pdf).

[13] See, for example, Sala et al. (2000, 1771), who summarize their findings on "drivers" of biodiversity loss in their Tables 6.1 and 6.2.

[14] The numbers cited by Dirzo and Raven come from the year 2000 Red List of Threatened Species due to the World Conservation Union, Gland Switzerland (IUCN). See also the discussion of "land transformation" in Vitousek et al. (1997, 494–495).

and Wilson originally proposed this principle, which posits a positive relationship between species richness and land area (proportional to a fractional exponent of the area), in the context of island biogeography. But the correlation has been found to hold in a wide range of different ecosystems, making it one of the more generally applicable and most highly verified principles in ecology. These days, great effort is devoted to finding ways to "de-intensify" the use of land given over for the production of food. There is much talk about ecologically less destructive agricultural practices and systems.[15] But "less destructive" means "still very destructive, indeed". They might somewhat ameliorate the effect on biodiversity. But they cannot undercut the general and overwhelmingly dominant principle. Food for people decreases biodiversity. Or conversely, biodiversity is the enemy of human food resources.

One might counter that sometimes, predators and parasites are introduced into agricultural systems to suppress pests; and this has a biodiversity-enhancing effect. Also, there is evidence that sometimes, cultivation of a greater diversity of crops enhances food production overall. But even if these propositions were always and not just sometimes true, no one could honestly suggest that more hectares should be appropriated for cultivation in order to increase biodiversity.[16]

Taken together, these considerations should relieve worries that the loss of biodiversity will inevitably mean the loss of valuable resources. On the evidence, great diversity – of species, at least – is not of any great benefit, considered as either actual or potential resource. Quite to the contrary, attempts to maintain biodiversity are fundamentally at odds with efforts to produce food – the most valuable of all resources.

6.3 Biodiversity as Service Provider

In their discussion of "Biodiversity Studies", Ehrlich and Wilson (1991, 760–761) prominently feature what has lately become the most popularly cited value attached to biodiversity. That is

> … the array of essential services provided by natural ecosystems, of which diverse species are the key working parts. Ecosystem services include maintenance of the gaseous composition of the atmosphere, preventing changes in the mix of gases from being too rapid for the biota to adjust... The generation and maintenance of soils is another crucial service... Soil ecosystems... are... providers of two more services: disposal of wastes and cycling of nutrients... Another... is the control of... species that can attack crops or domestic animals...

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[15] Less destructive agricultural practices attempt to retain local pollinators and enemies of crop pests. But this barely registers in the balance of biodiversity after the existing flora of a large swath of land is ripped out (which also rips out dependent fauna) and replaced by a set of food crops that is considerably less diverse (even when those crops are highly diverse by agroecological standards). Moreover, the opportunities for accommodating local organisms are limited by the fact that almost all agricultural crops everywhere are exotics whose interaction (beneficial or otherwise) with local organisms is uncertain. And many crops do not require insect pollinators.

[16] This clarification owes to a challenge made by Jeffrey Lockwood.

My discussion of ecosystem services observes the consensus usage of ecologist David Hooper and his colleagues (2005, 7) in their survey on the "Effects of Biodiversity on Ecosystem Functioning":

> *Ecosystem services* are those properties of ecosystems that either directly or indirectly benefit human endeavors, such as maintaining hydrologic cycles, regulating climate, cleansing air and water, maintaining atmospheric composition, pollination, soil genesis, and storing and cycling of nutrients. …*Ecosystem properties* include both sizes of compartments (e.g. pools of materials such as carbon or organic matter) and rates of processes (e.g. fluxes of materials and energy among compartments). [italics in the original]

This setup merits two observations. First, the very definition of ecosystem services prejudices a discussion, which focuses on them to the exclusion of ecosystem *dis*services. There is no non-arbitrary reason not to balance the discussion of the good that ecosystems do (their services) with the bad (their disservices).

The second observation is that the thesis about the value of *biodiversity*-provided ecosystem services proceeds in two steps. The first step is the biasing one, which simply identifies and selectively focuses attention on particular ecosystem services, whose positive value for humanity is guaranteed by the definition of "ecosystem services". But even aside from the obvious bias of failing to bring ecosystem disservices into the discussion on an equal footing with ecosystem services, the attribution of positive value to identified ecosystem services does not automatically clinch the proposition that these services should be maintained in their current form. Making the case for that requires that an ecosystem service value be not just positive, but greater than the value of what might replace the ecosystem if it were "developed" for some other purpose despite the sacrifice of the service. But this broader evaluative context does not even need to grant that the service is sacrificed. Nothing precludes considering how that service might otherwise be provided in another location or by some other method; or still provided by the original ecosystem despite drastic changes to it.

The second step in the value proposition for biodiversity-provided services is of greater concern for the central theme of this book. It requires that a connection from ecosystem services to biodiversity be established. That is, it requires support for the thesis that a service performed by an ecosystem – one whose value is arguably great enough to merit continuation – generally and critically depends on that ecosystem's biodiversity, as it currently exists. Doubts about this thesis can arise from doubts about either of the two steps that lead to the second observation. The thesis can fail either by failing to make a non-biased case for the existence of an ecosystem property whose benefit is not outweighed by concomitant disservices; or it can fail by failing to make the case that a service critically depends on some significant biodiversity. I discuss both sources of failure, but focus the second, which tries to link biodiversity to the (ecosystem) service sector of the human economy.

Recent years have seen increasing promotion of the thesis that there *is* a link between biodiversity (mainly, but not exclusively considered as species diversity) and ecosystem services. For some time, this view has been the gold standard for at least two of the three world's largest transnational so-called "conservation" mega-organizations – The Nature Conservancy and the World Wildlife Fund. In 2009, the third of the three "conservation" mega-organizations – Conservation

International – joined the ecosystem services fold. Many large corporations express their enthusiasm for this approach by sponsoring these dominant organizations.[17]

It is both easy and revealing to understand why corporations welcome the proposition that what really counts in ecosystems is their services, and that biodiversity counts precisely insofar as it contributes to these services. This guiding principle provides an apparently environmental justification for the most commercially profitable environment- and ecosystem-altering activities. The imprimatur and public presence of TNC, WWF, and CI serve to deflect questions of the principle's environmental credibility.[18] Unfortunately, as I will show, the implications for the environment in general and biodiversity in particular are, by most any standard, entirely unattractive, if not devastating, to nature and its value.[19]

The ecosystem-services view of natural value is built atop two exculpating principles that grant permission to activities that impinge on the environment. According to the first and most basic principle, if the activity does not compromise some one or more identified services, then the activity is environmentally permissible. According to the second principle, if the first principle does not apply because an ecosystem service is compromised or removed, then the activity is still permitted – provided that there is an alternative way to provide that service. The alternative service provider is allowed to be another ecosystem constructed specifically for that purpose. But the logic of ecosystem services does not require that a surrogate be a re-creation in any way other than in a capability to render the service.[20] In both principle and practice, the engineering details are left open.

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[17] I sometimes use scare quotes for the word "conservation" (and sometimes utilize the term "neo-conservation") in reference to these organizations as well as to allied practices that are increasingly mainstream in conservation biology. The scare in these quotes has to do with the fact that conservation, as these parties understand it, has much to do with managing and developing the planet for the production of stuff, services, and a few creature that excite the public, biologists, hunters, or fishers. It has little to do with what one might have thought to be the core meaning of "conservation" as "preserving the natural world".

[18] See Note 25 for more on the relationship between TNC and the international mining giant Rio Tinto.

[19] Those who bet nature on its provision of ecosystem services nevertheless try to weasel out of the terrible implications of a consistent application of their own principles by suggesting the ecosystem-service argument is merely a trump card, which can be pulled out when the need arises. I point out in this section that this is an arbitrary and therefore illegitimate move. Section 8.2.3 ("Living from" nature, uniqueness, and modal robustness) provides a more complete perspective, from which one can see that this card is pulled from a house of cards.

[20] The position set out by the three major "conservation" organizations (and others) is actually more radical than my description in the main text suggests. The added radicalization derives from the principles of "mitigation banking" and "habitat banking", which justify any action that compromises an environmental service on the mere *promise* that the identified, affected service will be restored *somehow or other* and this will be done *someplace or other*. There is a fairly uniformly bad track record in actually making "withdrawals" on banked mitigation efforts and banked habitats. But whether or not promises tend to be kept in actual practice, there remains the serious normative question of whether or legitimate norms concerning the value of nature justify the destruction of a natural habitat in exchange for the promise to reinstate a service or two.

So far as species diversity is concerned, the first exculpating principle essentially says that an organism's value depends on its ability to pay its own way as an indispensable contributor to a valuable ecosystem service that is not otherwise more efficiently provided. It is important to notice that this is an extraordinarily high standard for a species to meet in order to justify itself. It requires that some valued service would not be robustly maintained in the species' absence. For perspective: few species listed as "endangered" through the Endangered Species Act would meet it.

Viewing this standard from a broader economic viewpoint makes it higher yet. That is because an unbiased assessment of how biodiversity affects services cannot justifiably restrict its attention to *ecosystem* services. There is no good reason not to broaden the purview to economically valuable services generally. When that is done, the assessment must countenance the fact that biodiversity often is an *obstacle* to valuable (non-ecosystem) services. Which brings back into view ecosystem disservices of at least one variety – namely, those that obstruct other services.

But this is still not the whole story. Biodiversity is often the enemy of ecosystem services, too. Water purification would go a lot better were it not for the microbes and flora that make people sick. Of course, such an observation does not clinch the case for biodiversity being a disservice, for a greater amount of biodiversity might, in fact, not include those nasty organisms. But this is hardly a vindication of ecosystem service principles of valuation. For it is often fairly clear that, even when biodiversity is not an obstacle to an ecosystem service, it fails to pitch in; and that, according to those evaluative principles, makes its removal permissible.[21]

Still, most ecosystem *dis*services have to do with how ecosystem properties negatively impinge on other kinds of valuable services. Vociferous opposition to listing many if not most candidates for "endangered" under the Endangered Species Act arises precisely on the grounds of obstructing economically valuable services. This was behind Alaska Governor Sarah Palin's announcement (Bryson 2009) that the state of Alaska would sue to have the endangered Cook Inlet population of belugas delisted.[22] Cook Inlet is an area where exploding gas and oil development has spurred planning to expand the port of Anchorage and possibly build a new bridge, the Knik Arm version of the "Bridge to Nowhere" across the Inlet. The beluga swims – at a typically unhurried 3–9 kph – squarely in the way of the services that promise substantial increases in economic welfare. Whatever small economic benefit the little white whale contributes derives mainly from the amusement it affords people in marine "parks". So far as Palin and most Alaskans are concerned, the whales should stay there and clear of the development of vastly greater economic goods in the Cook Inlet. There it is unequivocally an economic liability.[23]

After Palin quit her job as governor later in 2009, Anchorage mayor Dan Sullivan joined with several other local mayors to take up the cause of litigating the delisting

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[21] I am indebted to Jeffrey Lockwood for a remark that forced me to clarify this point.

[22] The suit was eventually filed, as reported by Joling (2010).

[23] This commentary is derived from an online version, available at http://environmentalvalues.blogspot.com/2009/01/beluga-isnt-that-caviar.html.

of the Cook Inlet belugas. Like Palin, they made their case squarely on the grounds that the large mammals impede (non-ecosystem) services such as the transportation of oil by ship and efficient vehicular transportation of people across Cook Inlet. The belugas' disservice consists in the fact (Hunter 2009) that they "could have big negative effects on government projects and activities in and near the Inlet, as well as fisheries and oil and gas development." These anti-beluga partisans do not challenge the service framework for assessing values. Quite to the contrary, they embrace the framework as the preeminent arbiter of value and deploy their arguments within it.

There is no principled way to arbitrarily disallow consideration of the negative impacts of biodiversity on *non*-ecosystem services that might outweigh biodiversity's positive effects on ecosystem services. But even if one condones this unprincipled exclusion, the evidence is at best shaky for the proposition that biodiversity has much if any beneficial effect. The science simply does not strongly support this sanguine assessment. Even if a species is not performing *dis*services (in the restricted sense of "ecosystem disservices"), if it is rare and isolated, it is unlikely to be performing any real positive service.[24] Many ecosystem services, such as the oft-cited provision of potable water to New York City (discussed in Sect. 2.2.1, The bare assertion fallacy), make minimal demands on biodiversity. While this conclusion seems difficult to avoid, this unavoidable conclusion is routinely avoided: A high degree of biodiversity is often not critical for delivering ecosystem services; and furthermore, many species in many ecosystems are the bane of human existence. Therefore, even when the service-contribution standard of evaluation is arbitrarily confined to ecosystem services, what this standard shields is *service-providing* diversity, while blithely leaving biodiversity-at-large to suffer or, more likely, be decimated. When non-ecosystem services and disservices are brought back into the equation (as in the preceding paragraph), the status of biodiversity-at-large is even more dramatically reduced. I further explore the evidence for how biodiversity relates to ecosystem services shortly.

So far, I have dwelt on the first and more fundamental exculpating principle of ecosystem service evaluation, whose essence might be expressed as "no service for organisms that give no service". When the first principle does not apply, the second one often does. It legitimizes the development of a landscape or habitat and its concomitant eviction of resident organisms when a surrogate provider of that habitat's services can be engineered elsewhere, "elsehow", or both. In itself, this principle of substitution does not *logically* entail anything one way or the other about the net affect on biodiversity. But the surrogate – even when it is some other habitat – might be, and as a matter of fact often is, less biodiverse than the original habitat. Even if the surrogate is a thing constructed from soil and some number of living

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[24] For example, Díaz et al. (2006, 1300–1301) say that "… rarer species are likely to have small effects at any point in time." These authors confront the fact that rare species don't count for much in the way of services by falling back on an unexplicated concept of "biotic integrity". It is entirely unclear what "biotic integrity" might mean. (On this, see Sect. 4.1.5, Biodiversity as process.) But whatever it is, these authors suggest that it should be the goal of conservation rather than "simply maximizing the number of species present".

bio-parts – for example, when a natural wetland in one place is sacrificed in the name of condominium development and an artifactual wetland created someplace else – and even if the "same" services, such as those of filtering water are reinstated by the human-made edition, there seems to be little evidence that the living complement of resident creatures is also routinely re-created *en masse*.

Furthermore, some *service* surrogates are quite obviously not also *biodiversity* surrogates. One might naturally assume that the surrogate is a cleverly constructed re-creation of the original, complete with the original's complement of denizens, just sited some place that is economically more "efficient". But as I noted in my original mention of the second exculpating principle, nothing in the ecosystem services paradigm requires this. It is the service that counts. And so the surrogate could just as well be constructed from steel, concrete, pumps, and bulldozed mounds of gravel. It need not bear any particular resemblance – in physical appearance or in its biotic or abiotic component parts – to its predecessor service provider, provided that it "does the job", or it is thought to do so.

This problem – that biodiversity can and does suffer in the name of more economically efficient maintenance of service levels – is little acknowledged, let alone addressed in the ecosystem services literature. But two recent addenda to the ecosystem service framework can be reimagined as responses. The first response is to sever the previously supposed direct link between biodiversity and of ecosystem services and to treat these two matters separately. This leads to the recently popularized notion that "biodiversity banking", "biodiversity offsets", or "biodiversity development"[25] can ensure "no net loss" of biodiversity; and this is considered quite separately from the question of maintaining services. Nevertheless, "no net loss" tends to be rationalized via the fictional ability of people to create a duplicate habitat from whole cloth. It makes Creators out of ecosystem engineers, who populate their Creation with the appropriate complement of bio-parts. Though the Creators of this Creation relieve the bio-parts of service-rendering expectations, they breathe into them another expectation. These bio-parts are supposed to coalesce with the abiotic bits into something recognizable as "the same" as the developed-out-of-existence home of their sacrificed brethren.[26]

The second and more recent response takes off in the opposite direction, to presume a tight *bi*directional link between ecosystem services and biodiversity.

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[25] The term "biodiversity development" and its unblinking usage as one type among others of economic development might sound like fiction to someone not inoculated with the serum of Natural Capitalism. Sadly, it is not my invention, but rather a quite real touchstone of current-day conservation. See The Nature Conservancy Leadership Council (2008) (which features a presentation by Rio Tinto's manager of biodiversity offsets) and Richards (2005). Section 8.1.8.1 (Biogeoengineering as right action) further explores this concept.

[26] It is hard to exaggerate the enthusiasm with which this fiction is embraced and used for self-praise and self-aggrandizement by the most ravenous developers, such as the international mining company Rio Tinto. This is made possible by such organizations as The Nature Conservancy, which, while receiving donations from Rio Tinto, eagerly supplies and endorses the "conservation" rationale for that company's extraction practices. Because this topic crosses the boundary that circumscribes "biodiversity as service provider", I will not pursue it here.

This is supposed to make it essentially unnecessary to distinguish the two for purposes of conservation. Not only is biodiversity said to have value as a means of ensuring ecosystem services, but also it is said that "conserving" ecosystem services is among the surest means of conserving biodiversity. In fact, it is said that focusing on ecosystem services better ensures that biodiversity is conserved than trying to conserve biodiversity directly – that is, with biodiversity specifically in mind as the goal.[27] In effect, this response simply denies, without accompanying reasons for denying, that biodiversity fails to track ecosystem service levels. Unfortunately, as I have already observed, there is clear and abundant evidence that ecosystem services can and do continue in substantially transformed landscapes with substantially reduced biodiversity.

Of these two responses, the second is emblematic of the consensus supposition that biodiversity derives its value from ecosystem services because the biodiversity of ecosystems and their services are joined at the hip. This supposition suffers from much the same *logical* lacunae as the similar proposal, examined in the preceding section, for Biodiversity as resource. But before examining these lapses in logic, let's take a look at the *empirical* basis of the claim and various lapses in accounting for the facts. In their paper on the "Effects of Biodiversity on Ecosystem Functioning", David Hooper and his colleagues (2005, 4) express a scientific disciplinary consensus in saying that they

> … *are certain* [that]… More species are needed to insure a stable supply of ecosystem goods and services as spatial and temporal variability increases, which typically occurs as longer time periods and larger areas are considered. [italics added]

The proposition is presented as if it were a general law of ecology. But while some evidence instantiates the generalization, much other evidence does not. In other words, the generalization is false: It crumbles under the weight of the full complement of scientific evidence and in the absence of any credible way to qualify it to account for exceptions.

It is undoubtedly true that some (though, as I shall shortly observe, not all) properties regarded as services depend on certain species – sometimes acting single-handedly, sometimes in certain combinations ("assemblages"). But Hooper et al.'s claim that "more species are needed" is undermined by an abundance of counterexamples. One counterexample is perhaps *the* classic textbook example of the salt mash – a relatively species-impoverished type of ecosystem that is often highlighted as a service provider. These habitats, dominated by naturally occurring (not human-designed) monocultures of *Spartina* and *Juncus* and a few other salient

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[27] This is the entire point of the paper by Goldman et al. (2008), for example. Originating from the epicenter of "The Natural Capital Project", which is closely linked to TNC, it contends that greater biodiversity ensues from "protecting" ecosystem services. In this context, "protecting" must be interpreted in the very odd way that can be understood only in terms of the economic calculus, which permits new service providers to be created (or the mere promise of creating them) in exchange for a license to destroy existing ones.

species (mollusks and others) provide (for example) water-filtering services.[28] It does not appear that more species must be recruited to get this job done. A second counterexample or class of counterexamples is provided by exotic species, which, more often than not, are "experiments" in increased biodiversity at local and regional scales. The hard evidence shows that much of the time, the arrival of new species in an ecosystem does not cause "natives" to disappear; and so the new arrivals must be supposed to increase biodiversity or at least species diversity.

But what about the ecosystem functions? Sometimes they do not change upon the arrival of a new visitor. But sometimes they do. In the neat tripartite classification scheme due to Peter Vitousek (summarized in Vitousek and Walker 1989, 262), "invaders can cause changes in overall resource availability, in the trophic structure of an area, or in disturbance frequency or intensity".[29] Vitousek and Walker (1989) chronicle the dramatic changes that *Myrica faya*, an actinorhizal nitrogen fixing tree, brought to Hawai'i's young volcanic soils by vastly increasing the previously meager supply of the nutrient nitrogen to coresident organisms. In this dramatic case and others not so dramatic, the increase in biodiversity is accompanied by a change in ecosystem properties. But that proposition is entirely different from the one that says that "more species are needed" to provide desired services.

One might object that I have misinterpreted the "more species are needed" dictum – that it was not meant to apply to the effects of adding species, but to the effects of removing them. But this supposition is not congruent with what Hooper et al. say. Another "certainty", according to them (Hooper et al. 2005, 4) is that:

> Some ecosystem properties are initially insensitive to species loss because (a) ecosystems may have multiple species that carry out similar functional roles, (b) some species may contribute relatively little to ecosystem properties, or (c) properties may be primarily controlled by abiotic environmental conditions.

This passage indicates that species are often dispensable, so far as their role in providing services is concerned. This hardly supports the case for biodiversity or the need for more species as the key to providing services. One might further object that the key word in this "certain" proposition is "initially". Emphasizing the importance of the word, one might interpret Hooper et al. to be saying that a further diminishment of biodiversity *might* seriously compromise an initially unaffected service. This line of thought leads to the complex and perplexing realm of precautionary argument.

I return to the important topic of framing principles of precautionary prudence at the end of this section. But the last-quoted statement by Hooper and colleagues provides an opportunity to first show that the application of any precautionary principle in the domain of ecosystem services is extraordinarily restricted or even marginalized. To that end, I characterize two classes of ecosystem services for which precaution with respect to biodiversity is quite difficult to justify because they are

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[28] See, for example, Stiling (2002, 292), Kareiva and Marvier (2003, 347), and some related remarks in Sect. 3.3.3 (Multiple dimensions).

[29] See also Note 34 for more on the work described by Vitousek and Walker (1989).

largely indifferent to biodiversity. Yet the services in the union of these two classes constitute the vast majority.

The services in the first class are characterized by radical indifference to which species, the number of species, and the diversity of species that provide them. Any species in a large pool of candidates will do, without compromising the quality and level of the service. Moreover, that pool of candidates is so large so as to be practically inexhaustible. Many could vanish and species diversity could plummet – again, without detriment to the service. Services in this class are also indifferent to which particular *ecosystems* render them. Thus, for example, pretty much any vegetation in pretty much any kind of ecosystem suffices when it comes to sequestering carbon, filtering water, cycling water, mitigating floods, and controlling erosion. A place can be wiped fairly clean of vegetative and other diversity – say as the result of strip mining or a volcanic eruption. But if it still can support vegetation, then any single species of recolonizing plant – even one that never before grew in that place (that is, an exotic) – is likely to do well in rendering any one or more of these services. Unless all vegetation in all places capable of growing it vanish, services in this class are highly likely to persist.

The scientific literature contains occasional glimmers of awareness about this class of services and its significance. David Ehrenfeld (1988, 214–215), for one, generates a large shaft of light:

> The sad fact that few conservationists care to face is that many species, perhaps most, do not seem to have any conventional value at all, even hidden conventional value. True, we cannot be sure which particular species fall into this category, but it is hard to deny that there must be a great many of them. And unfortunately the species whose members are the fewest in number, the rarest, the most narrowly distributed – in short, the ones most likely to become extinct – are obviously the ones least likely to be missed by the biosphere. Many of these species were never common or ecologically influential; by no stretch of the imagination can we make them out to be vital cogs in the ecological machine.

Another glint of awareness comes from Norman Myers (1996b, 2764), who correctly diagnoses one of the maladies that underlies Ehrenfeld's disheartening assessment: "While biodiversity often plays a key role, the services can also derive from biomass and other attributes of biotas." In other words, biodiversity counts for little in providing a service if what really counts is a diversity-independent attribute such as biomass. Unfortunately, there has been no full reckoning, let alone a clear one, of what this implies for the thesis that "ecosystem services depend on biodiversity".

In the second class of biodiversity-indifferent services are ones that are unusually robust because they depend on unusually robust interrelationships or "functional groups". While these functional groups might change in composition from time to time or from place to place, they tend to require species that reproduce easily, are abundant, and are unusually adaptable. They are the species whose ubiquity spans even dramatic ecosystem changes in the face of which many more vulnerable species succumb. David Wardle (1999) and his colleagues provide one example – of nutrient recycling service by soil detritivores. They find that, in a grassland setting, rates of decomposition, measured as microbial respiration, depend on the presence or absence of plants, but not on their diversity. The implication is that the persistence of the recycling service depends on the grassland continuing to have grasses *simpliciter*, no matter how great or lacking in their diversity.

Also focusing on detritus recycling, E.O. Wilson (1987 and reprised elsewhere) claims that if all the insects vanished, all humanity would likewise vanish. But this is hardly an argument for the *diversity* of species.[30] Arthropods most likely represent the vast majority of (non-microbe) species on the planet. If you toss in all the other invertebrate animals that perform the detritus-processing function that Wilson has in mind in making his claim, and beef up this collection with the fungal and bacterial organisms that also do a substantial share of it, then but a miniscule number of organisms remain. A more sober interpretation of Wilson's remarks is that they argue for preserving some very small portion of an overwhelming abundance of detritivores – a selection that would likely include sufficiently many well-adapted arthropods and other organisms that recycle adequate amounts of detritus.

What sort of hard evidence supports the claim that maintaining biodiversity is essential to maintaining essential services? One of the most cited experiments designed to answer the question of "how many is enough" is that of David Tilman and his colleagues (2001). Tilman's work examines the consolidated productivity of various combinations of grasses. In it, the combinations are chosen at random from a pool. The pool, in turn, is apparently chosen for its diversity (within the realm of grasses), but according to no other identified or identifiable rationale. Tilman and his colleagues find that, under these conditions, the values for this one property (productivity measured as biomass) increase with increasing biodiversity. These increases are mostly realized with the assemblage of the first few species, but continue with diminishing returns up to the experiment's grand total of 16 species of grasses.

What does this say about the role of biodiversity in ecosystem services? Grass productivity might be considered a service if the grasses in question somehow fed the economy – for example, by feeding cattle. On the other hand, grass productivity would be considered a disservice were these grasses considered weeds or "aliens" (that is, exotics viewed negatively), which insinuated themselves, unwanted, into other agricultural efforts or into manicured lawns. I return below to this difficulty – the several respects in which classifying "properties" as services or disservices is highly problematic. In the current context, it is more important to reflect on what resemblance, if any, Tilman's "ecosystems" – the very simple creations of his experimental design – have to the "self-assembled" ecosystems that are the concern of most environmentalists. Tilman's work undoubtedly lends plausibility to the supposition that 16 species of grass in neatly planned experimental plots might, *in toto*, create more biomass than one or two species. But to claim that this says anything at all about natural ecosystems and how their diversity relates to the services they provide to humanity would be an inductive leap that no scientist could in good conscience defend.

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[30] I am sympathetically supposing that Wilson takes himself to be presenting *some* argument for defending, as he does in his paper, the value of the diversity of invertebrates.

To be scrupulously clear about this, the phrase "ecosystem service" is not to be found in the paper by Tilman et al. However, the phrase is promoted to titular status in the paper by Hooper et al., who are among the myriads who cite Tilman's research in the context of trying to connect biodiversity to ecosystem services. They are representative of a literature that invokes Tilman's and other, similar work to urge that changes in biodiversity might well compromise, as Ehrlich and Wilson (1991, 760) say, "essential services provided by natural ecosystems, of which diverse species are the key working parts". When explicitly referring to Tilman's work, Hooper et al. use the word "properties", which in the case of Tilman's work refers to productivity as measured by biomass. They never once justify their leap from "biodiversity affects properties" to "reduced biodiversity compromises critical services". Yet like many others who cite Tilman's work, they regard it and similar work to be a springboard for launching them across this logical void. In this case, the void spans the chasm between "16 arbitrarily selected grasses produce more biomass than one" to "essential services require diverse species".

In the end, Hooper and his colleagues give some signs of understanding that there is no credible basis for this leap in logic. They do not make any clear statement to this effect. However, they review several logically possible candidates for characterizing how biodiversity might relate to the properties or functioning of ecosystems. The possibilities range from no influence, to a direct variation, to an asymptotic correlation, and end with "idiosyncratic patterns". For all but the last candidate, there is contravening evidence, not just a lack of it. That leaves "idiosyncratic patterns", which is a scientific gloss for: irrelevance – because the truly relevant factors might be species composition, trophic structure, nutrient availability, or some other factor that has little to do with biodiversity. In other words, the leap looks plausible only when "biodiversity" is misunderstood in terms of category mistakes or unless its meaning is distended beyond recognition to encompass any and all function-determining factors.[31]

In their final analysis of the "Effects of Biodiversity on Ecosystem Functioning", Hooper and colleagues (2005, 8–15) say that they cannot find any convincing evidence or reason to prefer any one of the above candidate characterizations to another. But this inconclusive summation does not adequately reflect the real gist of the stubborn science that they recount. The correct scientific inference, I believe, is that the last class of possible "relationships" – "idiosyncratic patterns" – wins the lottery, for that is the "relationship" that denies that any real relation exists. It says, in agreement with my reading of Hooper et al., that there is no known consistently characterizable connection between biodiversity and ecosystem functioning, despite persistent attempts to find one. *A fortiori*, there is no consistently characterizable relationship between biodiversity and ecosystem *services*. The inference that this warrants is that the biodiversity of an ecosystem is simply the wrong lens through which to view its functioning. This is not to deny that some properties, processes, and functions – including ones that are regarded to be services – depend on specific

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[31] In the latter case, the claim – that functions of organisms influence the functions or processes observed where they live – becomes tautologous. See Díaz et al. (2006, 1300).

interactions of specific resident organisms with each other and with their specific abiotic environment. It *is* to deny that this has something to do with the *diversity* of those "working parts".

In the absence of credible scientific evidence, the case that services depend on biodiversity rests on major lacunae in logic, concept, and representations of fact. Some of these will be familiar from previous discussion of Biodiversity as resource (Sect. 6.2) and from Sect. 3.3.2.3 (regarding Functions). One pervasive form of reasoning goes from a "job" done by some one species or group of species to the conclusion that it is diversity that is responsible for this beneficial industry. The plausibility of this inferred relationship tacitly but heavily leans on the functional-trait-as-appendage view of organisms, which folds the observed functions and properties of ecosystems into their denizens. This picture of ecosystems depicts certain species as having service-providing attributes that enable them to pitch in and do their job, while others not well endowed with such attributes sit it out on the functional sidelines – slackers or free riders, as it were.

Unfortunately, this picture is oversimplified to the point of being misleading. There simply is no fixed "job" that a species inherently performs independent of the biotic and abiotic environments in which it finds itself. Examples of the disutility of this conception abound. One, related in Sect. 3.3.2.3, involves trophic interactions between invertebrates and trout, which this conception would describe as the trout-fattening function of stoneflies. Another (previously mentioned in this section) elegantly illustrates how easily this picture can mislead. A nitrogen-fixing plant might not provide any significant nitrogen-enriching or fertilization function in a place where some other source of reactive nitrogen (deposition, for example) already provides an ample supply (Vitousek and Walker 1989). When agricultural crops benefit from bee pollination, then bees can provide a pollination function. But replace the crop with one that is not bee-pollinated, and like an invisible appendage, that function is summarily amputated from those busy and unsuspecting insects.[32]

At least as pervasive is a class of problems characterized by an unwarranted leap from the beneficial activities of a specific organism to the alleged service-providing benefits of species diversity. Often the burden of providing the service – for example the "pollination service" proffered by *Apis mellifera* (European or western honey bee) in North America – falls largely upon the "shoulders" (or species-appropriate body part) of a single species.[33] But it is hard to connect this circumstance or the economic value that derives from it with the claimed role of the *diversity* of

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[32] This example is from a much-heralded study of how native bees in Costa Rican forests adjoining a coffee plantation were observed to increase coffee yields. Subsequently, coffee prices plummeted and the fields were replanted with pineapple, which does not benefit from bee pollinators. The bees were thus put out of work. Their service value, as well as the service value of the peripheral forest that housed them, thereby plummeted to zero. See Ricketts et al. (2004) for the first part of this story. There has been considerably less fanfare surrounding the story's conclusion. See also Note 38 in Chap. 8 and Sect. 8.2.3 ("Living from" nature, uniqueness, and modal robustness) for the broader significance of this story.

[33] It is worth noting that this case is representative of ones in which hard work earns a reprieve from derogation as an "alien": *A. mellifera* is exotic in North America.

species or the diversity of anything else. Consider that an enormous portion of the world's productivity – including the production of perhaps one-fifth of the world's atmospheric oxygen – can be credited to species of the single genus *Prochlorococcus* – chlorophyll b-containing marine cyanobacteria. So this genus might be regarded as providing breathable air-producing services. But diversity is clearly not the key to this. Indeed, there appears to be little convincing evidence that most functions vital to or highly valued by people could not be performed by a tiny fraction of the world's various kinds of organisms.

All told, there seems to be a gross superfluidity of species – a true *embarras des richesses* – associated with the majority of ecosystem services. In terms of the two classes of biodiversity-indifferent service that I distinguished earlier in connection with the "more species are needed" refrain: Either the work (for a class one service, such as carbon sequestration) is handily performed by more or less any organism blindly drawn from an enormous pool; or (for a class two service such as nutrient recycling), the work is handled by a small, species-indifferent, but robust and functionally coherent set of species. Some scientists who press the case for biodiversity's value as the basis for ecosystem services seem to realize this. They therefore shift their focus from species diversity to functional diversity. While removing (or adding) any number of species might leave a function largely intact, removing the function itself (thereby decreasing functional diversity) obviously would not. The diversity of functions would intuitively seem to be far more closely related to the provision of services ("properties" with functional benefits) than to species or species diversity.

I would say that the relationship – between the diversity of functions and the provision of services – is so close that it borders on, or even crosses over into, tautology. Sandra Díaz, David Tilman, and others (2006, 1300) present this near tautology as if it were a scientifically discovered empirical fact about the world:

> The evidence available indicates that it is the functional composition – that is, the identity, abundance, and range of species traits – that appears to cause the effects of biodiversity on many ecosystem services.

In this context, it is evident that "species traits" means "functional traits", which in turn means "the traits that are evidenced by functions or processes observed in the species' habitat". So it seems that Díaz and colleagues end up saying that the traits of organisms that yield identifiable ecosystem functions yield ecosystem functions – and particularly, the preferred class of functions known as "ecosystem services".

Tautologies are uninteresting. But let me try to honor the literal meaning of Díaz et al. by reinterpreting what they say as an argument to conserve *functional* diversity. According to this interpretation, care must be taken not to deprive humanity of a function that provides a valuable service – such as (in addition to the production of oxygen) pollination and the recycling of nutrients. The species involved in these functions – *A. mellifera* in the case of pollination, and arthropods et al. in the case recycling detritus – are merely means to the more proximate means (of a diversity of functions) to the final end of providing people with these services.

But this line of reasoning nosedives back into the logical lacuna that confuses a kind for a diversity of kinds. Previously encountered in connection with claims about the need for a diversity of species, it reemerges here in connection with functions. It is this particular function – for example, the pollination of an extremely narrow range of cultivated plants – that is valued, not the *diversity* of functions. And the value placed on a function such as pollination does not seem to be merely, if at all, a matter of its incremental contribution to the diversity of all functions. But let's make the same sort of provisional assumption made for the *resource* value (as contrasted with service value) of species diversity. For the sake of argument, let's consider the possibility that the more functions provided and the greater their diversity, the greater the likelihood that the set of all functions will implement services prized by humans.

Unfortunately, this suggestion to salvage the case for functional diversity is also unconvincing, and for reasons similar to those that make unconvincing the like claim for the resource value of species diversity. The major problem is that functions that are *dis*valued by humans crash the party. Lots of them. On what principled (as opposed to arbitrary) grounds can one exclude, for example, the vegetation-reducing function (otherwise known as "herbivory") performed by *Diatraea grandiosella* (southwestern corn borer)? Or the human population reducing function performed by deadly microbes such as *Mycobacterium tuberculosis* and *Plasmodium falciparum*? Or along the same lines, the disease-transporting function performed by *Anopheles* and *Aedes* spp. vectors?

Despite the last example, "serving human health" features prominently in support of the thesis that biodiversity underwrites ecosystem services. There is undoubtedly much in the biological world that influences human health. But it is doubtful that any sort of diversity is unambiguously beneficial in this regard. Discussions that tout the human health services provided by biodiversity invariably fail to take into account what I hinted at above – namely, the diversity of disease organisms and their vectors. An explosion of claims for the health benefits of biodiversity warrants a separate discussion of this topic, which appears in Sect. 6.5 (Biodiversity as a cornerstone of human health).

The ecosystem service theory of biodiversity value also encounters difficulties because the sometimes very particular context required for some services to be services makes them considerably less than an unqualified good. Notably, certain disservices are necessary conditions for some services. The vector function of mosquitoes, a disservice for *H. sapiens*, is a good *resource* for species of the infraorder Anisoptera (dragonflies), *Progne subis* (Purple Martin), and various species of the suborder Microchiroptera (microbats). These creatures are thereby given a chance to provide their (good) disease vector-reducing function on behalf of *H. sapiens*. This situation should not be unfamiliar. It is of a piece with the economic reckoning of situations commonly encountered in the service economy. Economic welfare can be and has been bolstered by such services as those for cleaning up oil spills and other "environmental disasters". This uncomfortable contingency of (good) services on disservices or on other conditions that are quite undesirable is yet another central issue that is routinely ignored by those who try to connect biodiversity to services.

I now return to the several respects in which classifying "properties" as services or disservices is highly problematic, mentioned in connection with David Tilman's grassland experiments. One way to characterize the problem is as a certain porosity in the containers that ostensibly compartmentalize kinds of service, and even that separate services from disservices. A radical compartmental leakage occurs because the same kind of function can have (positive) value in one context and disvalue in another. Nutrient retention and nitrogen fixation can be services when agriculture is served by fertilization efficiency. But these are viewed as disservices when they impinge on the success of favored plants and other organisms whose adaptive advantage derives from their ability to thrive in nitrogen-impoverished soils.[34] Pollination services might be pollination disservices when what is pollinated is considered a noxious weed. Weed control services, provided by an arthropod herbivore on noxious plants, can be food production disservices when applied to farm crops. In fact, the "noxious weed" and "farm crop" can, in different places, be one and the same species. They can even be one and the same plant in the same place. Population ecologists Lesley Campbell and Allison Snow (2009, 498) provide one example:

> Volunteer populations occur when unharvested seeds from a previous crop germinate and grow in and around agricultural fields. For example, canola harvesting can drop more than a thousand seeds per acre, and volunteers often compete with subsequent crops…

Flood control services are desired when floods endanger human lives, structures, and property whose dry state is valued. But not when agriculture depends on regular flooding. The flood control that the Aswan High Dam offers is, according to many environmental precepts, a major disaster.[35]

One might object that the ecosystem that the Aswan High Dam regulates is an engineered ecosystem. This objection seems irrelevant. Nothing in the definition of "ecosystem service" disqualifies engineered ecosystems from supplying ecosystem services. However, it is possible that *Castor canadensis* (North American beaver) makes this point nearly irrelevant. Beavers historically have been systematically extirpated in North America for their dispensing a number of ecosystem disservices, including tree-destroying, field- and road-flooding, water-stealing, and water-rights-violating disservices. But lately, the same beaver activities are being viewed (for example, in Taylor 2009) as providing water storage services. In fact, enthusiasm for how efficiently these creatures supply these services has led to talk of a

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[34] For example, Vitousek et al. (1997, 742) suggest that nitrogen deposition is reducing biodiversity – by (among other effects) transforming heathlands, with their characteristically nitrogen-poor soils, into more commonly encountered grasslands. Vitousek and Walker (1989) report that the relatively recent appearance of *Myrica faya* – a nitrogen-fixer – in Hawaii altered ecosystem processes in ways that most conservationists view as bad. Therefore, their contribution of nitrogen to the environment is viewed as a disservice.

[35] For a perceptive history of the Aswan dams, see Hughes (2009, 175–181). Hughes' book accomplishes the seemingly impossible task of surveying humankind's impact on the environment – globally and over essentially the entire course of human history.

different kind of engineering that involves introducing beavers into places where there's a beaver-friendly river and a desire for water storage (Groc 2010).

So it is not the diversity of properties or functions that is valued, but rather the particular benefits of a carefully selected, desired group of them, dubbed "services". And these are not always welcome; they are positively valued only in "appropriate" contexts. With this again firmly in mind, one might still insist that these services *depend* on some other kind of diversity – and the most likely kind is the diversity of species. But having circled back to supposing that species diversity anchors ecosystem services, one again runs into the brick wall of scientific evidence that simply does not support the proposition of a dependent relationship of ecosystem services on species diversity, let alone any kind of consistent correlation between them. The fact is that many functions in the human-coveted set – that is, many services – derive from relatively non-diverse landscapes. And many of these landscapes are highly human-engineered according to a specification that requires the weeding out of previous, naturally occurring resident organisms. Moreover, the addition of a species (variously tagged "exotic", "alien", "invasive", or "means of restoration") that increases species diversity in an ecosystem is just as likely to do any of: nothing (so far as recognizable functions are concerned); remove a desirable function; alter some characteristic of an existing, desirable or undesirable function (such as its intensity); or add an undesirable one – as it is to add a desirable function or (by some metric) strengthen or intensify an existing (desirable) one.

Productivity – the focus of Tilman's experiments – illustrates all this. This property or function and its relationship to species diversity, species composition, nutrient limits, and a host of other and possibly interacting ecological factors is probably one of the most highly studied because one of the most tractable to measure. However in and of itself, productivity is really of no value to humanity. This is easily seen by reference to the many plants that people classify as weeds. Some of them, such as kudzu in the southeastern United States, are enormously productive. Productivity is only a service when it involves the production of what people *like* – because it is good to eat, because you can build things from it, because it provides shade, because it anchors the soil, or because it performs some other, desired chore.

Even then, productivity is a service only if what is produced is in quantities that people also like. Producing either too much or too little can be a disservice. Juxtaposing production-as-service with expressions of alarm about enormously productive ecosystems illustrates this point. Eutrophication in coastal zones (briefly touched upon in Sect. 3.3.2.3 on Functions) is one of those cases for alarm. These offshore environments often arise from the anthropogenic, albeit unintentional, fertilization of algae by fertilizer that washes into their aquatic environment from upriver farms. Just like terrestrial crops and other plants whose growth is limited by the availability of nitrogen and phosphorus, the algae sometimes respond with an enormous increase in primary productivity – an "algal bloom".

However, unlike the terrestrial crops fertilized upriver, people do not eat these aquatic algae. It is ugly. Because it tends to reduce oxygen levels, it makes life hard for the fish and crustaceans that would otherwise thrive in these environs.

People like to eat those meaty creatures, not the algae. Worse, this fertilization often favors algal species that produce toxins, which harm, not just the fish and crustaceans that people like on their dinner plates, but people directly. Quite obviously, this productivity is *not* good and therefore it is *no*t an ecosystem service. Rather, it is *bad* productivity and an ecosystem *dis*service.

The production of toxins provides yet another illustration of compartmental leakage. In the context of what E.O. Wilson (2002, 126) calls “nature’s pharmacopoeia” (discussed separately in Sect. 6.5.1), Wilson (2002, 127) joins many others in lauding the production of toxins by assorted creatures as part of “biodiversity’s bounty”. But it is clear that toxin production, like primary production, is a function that is neither inherently good nor bad. Insofar as these functions are tied to biodiversity, only a logic of contextual convenience separates diametrically opposed conclusions – that biodiversity is good for people or that it is bad for people.[36]

It is worth dwelling on aquatic (including marine) eutrophication for another reason, which has to do entirely with matters of fact that bear on value claims relating to biodiversity. Human-induced aquatic eutrophication is frequently cited as a terrible bad for its deleterious effect on ecosystem services. And the bad of eutrophication is said to be the result of the erosion of biodiversity. But what is said in these contexts must be distinguished from actual evidence. In extreme cases, eutrophic zones become hypoxic (oxygen depleted); and these areas are labeled “dead zones”. A layperson would be forgiven for conjuring up a zombie movie, or a moonscape of total and desolate lifelessness, or at least in the context of a discussion about biodiversity, for thinking that this term implies a serious loss of species. But this is not so obviously the case.

The real science is much more subtle and complex. In a report on eutrophication in the Baltic Sea, marine ecologists Jesper Andersen and Janet Pawlak (2006, 13) provide some hint of the real complexity:

> In terms of the biological response to hypoxia, the lethally low concentration of oxygen depends on the species. Fish and crustaceans have higher requirements for oxygen and they react very quickly to a lack of oxygen. Other species can tolerate low dissolved oxygen for longer periods. Under conditions of hypoxia, the benthic responses involve a change from communities of large, slow-growing, slowly reproducing species to communities of small organisms with a rapid turnover rate. Hypoxic and anoxic (total lack of oxygen) conditions also may result in the formation and release of hydrogen sulphide (H_2S) from the sediments, which is lethal to higher organisms.

Unstated in this passage (and in the report) is the likelihood that the hydrogen sulphide is produced by (diverse) sulfate-reducing microbes in the sediment. Certain other microbes – chemoautotrophs capable of oxidizing hydrogen sulfide or methane for energy – are known to thrive in environments like this. These organisms, in turn, might support protozoans and metazoans, such as sponges. Of course, all these

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[36] This vexing characteristic of arguments for the value of biodiversity – that, when carefully considered, they cut both ways – is a recurrent theme. It recurs again quite prominently in the discussion of the health benefits of biodiversity in Sect. 6.5 on Biodiversity as a cornerstone of human health.

are “lower organisms”. But this derogatory classification is irrelevant so far as the diversity of species or functions is concerned. In fact, the type of benthos just described routinely occurs in the deep ocean’s seabed, which is “naturally” oxygen-depleted and lacks sunlight – signal characteristics that that environment shares with the seabed in “dead zones”. However, I am not aware of any research that attempts to determine whether benthos-resembling communities exist in “dead zones”, and if such communities do exist, what diversity of species they support.

Let’s return to the more general case of eutrophication, which does not always lead to hypoxia. Stripping away a commentary that relies more on its use of normatively loaded words than on reasons leaves this story: There are changes in the species composition in several categories – including phytoplankton, zooplankton, fish, submerged vegetation, and benthic macrofauna. Even the story for algal species is mixed and complex, apparently depending on the characteristics of the herbivores that are present.[37] Generally, the biomass of phytoplankton (and their production), zooplankton, and benthic animals on shallow bottoms above the halocline *increases*. It is not at all clear that the diversity of creatures diminishes overall. A scientifically justified claim to this effect would require a careful census of all organisms – lower, higher, great, small, and miniscule – both before and after eutrophication. Again, I am not aware that any such survey has been undertaken.[38]

“Stability” joins “productivity” as another ecosystem property that purports to be a biodiversity-dependent service. Unfortunately, discussions of how stability relates to biodiversity have a strong tendency to forgo logical consistency in favor of normative commentary.[39] The first thing to note about the stability of ecosystems is that there is no known general positive or negative correlation of this property to any kind of diversity – including species diversity.[40] Moreover, it’s hard to know what service is implied by stability, other than that of preserving the *status quo*.

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[37] See, for example, Mazumder (2009, 143–157).

[38] Nor have marine biologists whom I’ve contacted been able or willing to point to evidence for the thesis that eutrophication reduces biodiversity overall. The pervasive claim is rather that “biodiversity is degraded”. But “degraded” does not mean “reduced”, and “degraded biodiversity” has less to do with biodiversity than with an expression of displeasure with the changed composition of a eutrophic environment. The scientist mentioned in Note 49 of Chap. 3, who changes the subject from biodiversity to vibrancy, also seems to be doing no more than expressing his displeasure with eutrophic ecosystems. I suggested that the basis of his displeasure cannot be reduced biodiversity. But nor can it legitimately be reduced vibrancy. That is because neither he nor anyone else has provided a respectable account of what a vibrant ecosystem is, why vibrant ecosystems are good, and what implications this has for the Sonoran Desert and Antarctica. Exploring these issues might be interesting and valuable, but this exploration would apparently have little to do with biodiversity.

[39] The concept of “stability” has many components or interpretations – including resistance to change and resilience after perturbation. I don’t try to dissect the concept here because my discussion cuts across these multiple interpretations.

[40] The scientific literature that discusses ecosystem stability is enormous. My impression is that there is no general thesis about how stability and species diversity are related that either does not have substantial disconfirming evidence or is not so highly qualified that it essentially turns into a description of one special case study.

What really seems to be at issue with stability is that at least certain particular deviations from the *status quo* are perceived to be bad. Perhaps the most-discussed example of this is the form of stability that consists in the resistance of an ecosystem to the immigration of species new it. In what follows I largely have this particular form of stability in mind.

Two formidable problems confront those who propose that species diversity "enchances" an ecosystem's stability considered as a *status quo*-maintaining service.[41] The first, as noted just above, is an empirical matter. The preponderance of evidence simply does not support the empirically falsifiable generalization that greater species diversity diminishes the naturalization chances of a newcomer. As noted by Thomas Stohlgren and some colleagues (2003) and reiterated by ecologist Jason Fridley and his colleagues (2007, 7–10) in a survey on this topic, it is often the case that "the rich get richer".[42] Fridley et al. (2007, 10) propose a list of eight factors that might enhance an ecosystem's resistance to invasion. Only one of them has to do with its existing level of species diversity. Oftentimes, it appears that the conditions that were most likely responsible for engendering a rich diversity of "natives" are also quite welcoming to latecomers, too – and in a way that does not displace or entirely displace the early-comers.

The second problem has again to do with a failure to bridge the normative gap. The property of resistance to immigration might indeed be found to a lesser or greater degree in different ecosystems. But it is entirely unclear why this should be considered, without a great deal of contextual qualification, a "service" or (what is implied by "service") "a good". Most immigrants increase rather than decrease local and regional species diversity and relatively few result in global extinctions. So the anti-immigrant sentiment seems antithetical to a purely biodiversity-valuing point of view.[43] But aside from that, there are many contexts in which people value, not immigration resistance, but immigration acceptance. Fish and game managers routinely introduce species (particularly fish) to satisfy interests in (mostly) recreational predation.[44] Ironically, biologists intent on controlling previous, recent immigrants, introduce immigrants – known as "biological controls" – of their own.

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[41] Those familiar with the history of ecology will recognize this as a restatement of the eminent English ecologist Charles Elton's (Elton 1958, 145) famous richness-stability hypothesis:

> ··· the balance of relatively simple communities of plants and animals is more easily upset than richer ones.

[42] The phrase "the rich get richer" is stolen from the title of the paper by Stohlgren et al. (2003), which is devoted to an exposition of this phenomenon.

[43] The issue of how species diversity might increase or decrease as the result of immigrations is a complex one, which I cannot adequately address in this book. An excellent short synopsis is due to Sax and Gaines (2003).

[44] Not infrequently, wildlife managers take advantage of the phenomenon that the introduction of exotics increases species diversity without compromising the fate of natives. Reporting on Florida exotics, Burkhard Bilger (2009), cites Paul Shafland, the director of Florida Fish and Wildlife's Non-Native Fish Laboratory, as stating that:

> Florida's waterways are home to more than 30 species of exotic freshwater fish … and their total biomass nearly tripled between 1980 and 2007. Yet the number of native fish hasn't changed in that period; nor have any natives gone extinct.

In cases such as these, the ecosystem's immigrant-accepting property is valued: It enhances human endeavors and therefore meets the criterion for being an ecosystem service.

Of course, a newly arriving organism can and sometimes does upset the ecosystem *status quo* in some negative way other than by negatively affecting the ecosystem's species diversity. While a newcomer can instigate one or more new functions that are desirable, it can also precipitate a decline of one or more functions that might be regarded as human services. This possibility of declines in desirable functions might be why resistance to immigration is sometimes regarded as an ecosystem service.

This is not infrequently the basis of complaints about recently naturalized species, such as *Tamarix* species in the American southwest. As previously observed (in Sect. 3.3.2.3, Functions), according to the best experts, that plant's recent arrival and dominance in some riparian systems has not extirpated any other species. However, it does tend to change the way ecosystems function. For example, the presence of *Tamarix* promotes fires, and so the naturalization of *Tamarix* species can be said to compromise a fire-suppression function, which might be regarded as an "ecosystem service". But if it is the newly arrived Tamarix that is responsible for the disservice of suppressing this ecosystem service, then this is not the result of a decrease in species diversity nor, in any obvious way, of any other type of diversity. In other words, the changes that *Tamarix* spp. bring to the ecosystems where it settles have little to do with the biodiversity of those ecosystems.

All in all, the theory that ecosystem services are critically tied to biodiversity is singularly unpromising. The empirical evidence does not support it, for the complete body of facts includes a raft of disservices, which handicap human endeavors rather than benefit them. Also, the nature of many services places them in two broad classes of service that are extremely insensitive to diversity. The logic also does not support it, for the rationales rely on invalid inferences such as those that infer the need for biodiversity from the contribution of a single species. Even the foundational concept of "ecosystem service" seems ill-equipped to shoulder the weight of generalizations that allege the dependence of ecosystem services on biodiversity, for it does not account for the differing circumstances that sometimes make a property a service, and other times a disservice.

Finally, one plausible view of progress in ecology has clear implications that substantially deflate any remaining enthusiasm for the ecosystem service theory of biodiversity value. The value of some thing that provides a service falls off precipitously when another, more efficient (more effective for the cost) service-provider is found.[45] One need not speculate on the possibility of robotic but functionally equivalent surrogates for the current complement of service-providing organisms. For some time to come – but almost certainly not forever – humankind will rely on biological

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Bilger goes on to say:

> In 1984, Shafland spearheaded the introduction of the South American butterfly peacock bass to Florida, arguing that it would both control invasive tilapia and make a superb sport fish… "Nothing has been displaced," Shafland said. "We're just changing the carrying capacity."

[45] As noted in Sect. 2.1.1 (Concepts and categories of value), all instrumental goods are fragile in this way.

organisms, perhaps with modest genetic tinkering, to play service-rendering roles in ecosystems that are also tinkered with. But continual advances in science will increasingly demonstrate ways to rely on fewer and fewer, less and less diverse, relatively unreliable and fickle working bio-parts. As this happens, from an ecosystem service point of view, there will be an increasing superfluidity of organisms that constitute inefficiencies in the "development" of these services. As such, they will be not just dispensable, but liabilities – obstacles or at least excess baggage that humankind will be happy and perhaps even obligated to jettison and get out of the way of development that promotes human well-being. If this speculation is true, then the organisms that now are still regarded as key service-providers will, with time, join the already much larger contingent that are already of little service consequence or are disservice-providers.

Viewed from this perspective, the argument for the value of biodiversity as the basis for ecosystem services is, at bottom, an argument from scientific ignorance. The value derives from the provision of services that *so far* are not otherwise cost-effectively rendered. This is distinctly reminiscent of the argument for God's existence on the grounds that God is required to explain that which science *so far* does not. This type of theological argument is slowly but inexorably eroded by progressively more and more satisfying scientific explanations. Similarly, as science advances beyond the relative ignorance presumed by Hooper and colleagues, it will explain in greater and greater detail what minimally diverse biological elements need be retained to provide coveted services. That knowledge will enable a more and more "efficient" use of biodiversity. This will progressively diminish the service value of any great amount of biodiversity, which will be seen as more and more superfluous and more and more a barrier to progress. This line of reasoning leaves aside the completely separate assault on this value of "nature's services" by the nonbiological surrogates that technology surely will eventually provide.

Of course, one can challenge this speculation about the progress and potential of ecology. One can maintain that the functions of ecological systems are so individual, so contingent on locally unique conditions, so confounded by the myriad, overlapping spatiotemporal scales in which the myriad interactions between organisms and never-duplicated environments play out, that one cannot expect to ever arrive at ecological laws that would ground a general program of streamlining ecosystems for their service value.[46] If one is willing to embrace this radical skepticism about the possibility or likelihood of finding general ecological laws, *and* if one has a like skepticism about the likelihood of attaining a sufficiently detailed knowledge of a sufficient number of ecosystems on a case-by-case basis, then (and I believe, only then) one last argument for the proposition that biodiversity underwrites vital ecosystem services remains available. That argument, mentioned at the outset of this section, is based on precautionary prudence.[47]

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[46] An argument to this effect is made in Reiners and Lockwood (2010). See, in particular, Chaps. 2 and 10 of their book.

[47] A comment by Jeffrey Lockwood prompted me to realize the need for this discussion.

The ecologist Paul Ehrlich has vigorously pursued a precautionary argument for preserving biodiversity over the course of his distinguished career. In its original presentation with Anne Ehrlich (which predates the invention of the neologism "biodiversity"), the Ehrlichs do not base the argument on radical ecological ignorance. In fact, they (Ehrlich and Ehrlich 1981, 95) confidently posit that the link between rates of extinction (and hence, one might suppose, rates of species diversity loss) and ecosystem services is ironclad:

> … *all* [ecosystem services] will be threatened if the rate of extinctions continues to increase…[48] [italics in the original]

On the other hand, an assessment of technology as stuck in a state of more or less permanent incompetence is already part of the argument. According to the Ehrlichs (1981, 96), technology at best can supply a "partial substitution" for a lost ecosystem service, for the ecosystem "nearly always does it better".

A more recent version of the Ehrlichs' thesis retains the earlier one's dismal assessment of technology's capabilities. However, the previous confidence in the tight link between biodiversity and ecosystem services gives way to a confession of ecological ignorance – at least as the current state of the art. With another group of distinguished colleagues, Paul Ehrlich (1997, 101) states that

> No one knows precisely which, or approximately how many, species are required to sustain human life; but to say… that "there is no credible argument … that … all or even most of the species we are concerned to protect are essential to the functioning of the ecological systems on which we depend" is dangerously absurd. Until science can say *which* species are essential in the long term, we exterminate *any* at our peril.[49] [italics in the original]

Given its very strong claim about sustaining human life, this passage could just as well be discussed in the following Sect. 6.4 (Biodiversity as (human) life sustainer). I discuss it here where it can get a more favorable hearing as the much weaker claim that every extinction puts humanity at risk, not necessarily for absolute survival, but for losing a relatively low-cost and effective way to provide a service, considered apart from how critical it might be.

Let's recall two considerations that burden this argument from the outset. First is the empirical consideration that the majority of ecosystem services fall into one of two classes characterized by very weak sensitivity to biodiversity. According to Ehrlich et al. (1997, 101) the "critical life support services"

> …include the purification of air and water; the mitigation of droughts and floods; the generation and preservation of soils and renewal of their fertility; the detoxification and decomposition of wastes; the pollination of crops and natural vegetation; control of the vast majority of potential agricultural pests; and partial control of climate.

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[48] While I believe that the Ehrlichs' precautionary argument is flawed, this should not be interpreted as a general criticism of their extraordinarily prescient book.

[49] My taking exception to this part of the argument by Ehrlich and his colleagues should not be misinterpreted as my taking exception to any other point in this response to Mark Sagoff's answer (Sagoff 1997) to the question, "Do We Consume Too Much?". However, it is odd that Norman Myers, a coauthor of this piece, elsewhere (Myers 1996b, 2764) expresses his awareness of one major reason why this precautionary logic does not hold up.

In this list, air and water purification, flood mitigation, and climate control (via carbon sequestration), as I said before, "are radically indifferent to which species, the number of species, or the diversity of species that provide them". Furthermore, soil renewal and waste decomposition depend on "functional groups [that] might change in composition from time to time or from place to place, [yet] tend to require species that reproduce easily, are abundant, and are unusually adaptable. They are the species whose ubiquity spans even dramatic ecosystem changes in the face of which many more vulnerable species succumb." This leaves only pollination and pest control as "critical" services that might, in fact, be vulnerable to species extinctions, because pollinators and insectivores (for controlling agricultural pests) can be specialized.

The second consideration observes the epistemological condition that some of the foremost practitioners of ecology see as defining the bleak prospects for their profession. While this view is not universally endorsed, those with a more sanguine view unburden the precautionary argument only to make it less relevant. If ecology will figure out how and to what extent the ranks of species can be thinned without any palpable effect on services, then it seems sufficiently prudent to simply follow the science.

The net effect of these considerations is to marginalize precautionary considerations: From the point of view of how biodiversity affects ecosystem services, little seems to hang on an argument from precautionary prudence for the simple reason that there is little space in which it can legitimately operate. Services such as pollination and pest control, which might be exempt from the empirical disqualification, are exempt precisely because they are performed by well-known, specialized "players". As a consequence, these services fail to avoid the epistemological disqualification. Science already knows, or there is good reason to suppose, that in the near term it will come to know "who" these specialized players are, along with their specialized requirements for survival. That knowledge, in turn, reveals which species are *dispensable* so far as the service is concerned. In such cases, what counts, so far as ecosystem services are concerned, is some modest and not particularly diverse set of particular species.

If matters of fact and epistemology relegate precautionary arguments to a nearly irrelevant corner, then a notable lack of any credible defense invites suspicion that there is none. Ehrlich et al. do nothing to elaborate, let alone justify, the precautionary logic behind their claim, "Until science can say *which* species are essential in the long term, we exterminate *any* at our peril." Declaiming (Ehrlich et al. 1997, 101) that it is "dangerously absurd" to question their precautionary stance does not constitute a credible defense of it.

Still, the defense of biodiversity's value so often devolves into precautionary exhortations that is worthwhile trying to understand in a general way why appealing to a Precautionary Principle is a hard row to hoe – even aside from its restricted "application space" in the domain of ecosystem services. The demands on precautionary logic and the difficulties in meeting them will make plain why it is not at all absurd to challenge Ehrlich et al.'s precautionary proclamation.

Many versions of Precautionary Principle are possible and many versions have been proffered. But it is relatively safe to say that no reasonable Precautionary Principle lacks certain basic ingredients. In the context of taking precautions to prevent species extinctions from disrupting ecosystem services, key ingredients are[50]:

1. **A threat of harm that is considered serious, great, or catastrophic.** It is unclear just how "serious" the harm must be to justify precautionary action. The envisaged outcome must fall outside some vague boundary that circumscribes the domain of "the acceptable". It is more clear that a principle that urges precautions against small (and "acceptable") harms would be difficult to defend because consistent adherence to such a principle would arguably result in greater harm (from paralysis) than the harms the precautions are supposed to avert. Most of us would say that we would cause ourselves greater harm by always refusing medications to avoid their side effects; or by refusing to drive to a job interview to avoid the additional risk of being in a traffic accident.

   A number of considerations bear on how serious the harm must be and how serious a threat it must constitute in order for precautionary logic to apply. They include:

   (a) The ability to avoid the harm altogether by severing the first link in an otherwise uncertain causal chain that leads from species extinction to disruption of service. In this regard, one must consider how one species might substitute for another in maintaining a particular, desired function. However questionable this might be as a general principle, many biologists regard this kind of substitution as a basic tool for conserving and restoring ecosystem functions. There is also the possibility of resurrecting species, though this possibility and its attendant controversies need not burden the current discussion. Proponents of The Natural Capital Project (for example, Goldman et al. 2008, 9446) even promote substituting entire ecosystems and habitats (under the rubrics "mitigation banking" and "habitat banking") as not merely acceptable but a positive selling point for their economically oriented doctrine.
   (b) The ability to ameliorate the harm, sometimes known as "adaptability". This is the context in which technological substitutes are relevant.[51]
   (c) The scale and pervasiveness of the harm.
   (d) How the harm is distributed, which leads to considerations of distributive justice.

2. **Some high degree of *uncertainty*.** Care must be taken to distinguish uncertainty from "mere" risk as an epistemic condition in which (European Environment Agency 2001, 170, Box 16.1) "… the adequate empirical or theoretical basis for assigning probabilities to outcomes does not exist."[52] When risks are known, a different, non-precautionary logic is appropriate for taking them into account.

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[50] This explication is indebted to Stephen Gardiner's in Gardiner (2006).

[51] See also Sect. 2.1.2.1 (Consequentialism) regarding technological substitution.

[52] For a more detailed discussion of the distinction between risk and uncertainty (and ignorance), see Sect. 6.9.2 (Risk, uncertainty and ignorance).

On the other side of the spectrum, that a harm can be (merely) imagined to occur, or that its occurrence is a logical possibility, or that its occurring is consistent with known science cannot reasonably ground precautionary action. That would be as indefensible as stretching precaution to cover small harms and for the same reason described in item (1): It would excessively inhibit actions that have a high likelihood of rendering great benefit.

Several kinds of uncertainty can be involved in precautionary logic. First, there is uncertainty in whether or not the harm will occur at all. Item (1a) bears on this kind of uncertainty by suggesting a method, already a part of current conservation and restoration practice, for substantially reducing it – perhaps to the point of making precautionary logic inappropriate.

Second, if the harm (in the limited sense of an ecosystem no longer serving a particular human purpose) does occur, there is uncertainty about how seriously this occurrence should be taken, given the other considerations in item (1) and particularly the ability to adapt (item (1b)). Ehrlich et al. make a broad claim about the futility of technological adaptation. For support of this claim, these authors refer to the failure of the Biosphere 2 experiment. But that experiment was an attempt to construct a completely self-contained, human-friendly ecosystem from whole cloth rather than an experiment in extirpating or substituting for some components of one that is already functioning. And it is certainly at odds with the Natural Capital Project doctrines such as those that permit the substitution of habitats. So the relevance Biosphere 2 to their case is marginal, at best.

Third, in addition to uncertainty about whether the harm will occur and how seriously such an occurrence should be taken, precautionary logic presumes uncertainty about what links and what sequence of links might form a causal chain leading up to an occurrence. Most discussions of the Precautionary Principle focus on this particular kind of uncertainty.[53] The precautionary argument that warns against allowing extinctions must conceive of a plausible (though uncertain) causal chain that, starting from an extinction event, leads to a deleterious effect on an ecosystem service. As I have already said, this account must rest on something more than mere logical possibility or consistency with known science.

The "sweet spot" between blind speculation and known risk is extremely difficult to find. Ehrlich et al. are not alone in failing to supply such an account. In the narrow range of cases for which it is plausible to link a service disruption to an extinction, it seems that the causal chain is typically short and well known – that is, not at all uncertain. If a particular crop relies on a particular pollinator, then with relative certainty or at least with a scientifically ascertainable likelihood, the extirpation of the pollinator will leave the crop unpollinated. Because it is so central to the precautionary case against extinctions, I will revisit this dilemma – of attempting to cast an extinction as a Pascal's wager – immediately after this list of Precautionary Principle ingredients.

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[53] Most saliently, the Wingspread Statement on the Precautionary Principle (http://www.sehn.org/wing.html) emphasizes the condition that "some cause and effect relationships are not fully established scientifically".

Finally, it is important to emphasize the epistemic contingency that attaches to precautionary logic's grounding in uncertainty. Uncertainty reflects a current state of knowledge. Should science ever find a sound basis for assigning probabilities for a causal chain leading to a harm in ecosystem services, then a discussion of risk analysis and risk management will properly supplant precautionary logic. As I have pointed out, science has already pushed beyond a state of uncertainty for some cases within the restricted, presumptive application space for the Precautionary Principle.

3. **An "appropriate" response to the threat and whether this response is merely permissible, advisable, or obligatory.** Ehrlich et al. can be interpreted to suggest that the appropriate response is to do what is possible to avoid letting any species go extinct and that this is *obligatory*, no matter what the cost. (Keep in mind that cost-benefit analysis applies in the domain of problems with understood risk, not in the Precautionary Principle's domain of uncertainty.) This exhortation is both dramatic and difficult to defend. Not the least reason for its vulnerability to objections is the fact that in some contexts such as pest control, ecosystem services are enhanced by species extirpations (local extinctions) rather than damaged by them, or so it is commonly thought. So in its unqualified form, the Precautionary Principle (on this interpretation) would seem to entail obligations that sometimes compromise ecosystem services by way of the precautionary obligation to not let any species go extinct.

The obvious response to this criticism is to insist that sometimes the precautionary obligation to prevent species extinctions applies; sometimes it does not. But far from being a defense of the Precautionary Principle, this response makes it clear how its plausibility as a general action-guiding principle hinges on an accompanying framework that provides a principled way to distinguish circumstances in which precautionary measures are obligatory, advisable, permissible, or proscribed. It is a nontrivial matter to construct such a framework; and it has yet to be done – by Ehrlich et al., or by anyone else.

These difficulties suggest that it might serve a Precautionary Principle well to retrench its domain yet further. At the cost of leaving out promising but difficult cases, one might try to define conditions that sharply qualify a candidate for precautionary prudence and that decisively rule out implausible and irrational applications of it. One obvious candidate condition is one (of the three) that John Rawls (1971, 154) proposes must qualify application of his "maximin" rule (for choosing principles of justice)[54]:

> … the person choosing has a conception of the good such that he cares very little, if anything, for what he might gain above the minimum stipend that he can, in fact, be sure of by following the maximin rule. It is not worthwhile for him to take a chance for the sake of a further advantage, especially when it may turn out that he loses much that is important to him.

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[54] Rawls' other two conditions are ones already described. One is the requirement for true uncertainty – that is, the absence of adequately known likelihoods for outcomes. The other is the requirement for serious outcomes – that is, (Rawls 1971, 154) "outcomes that one can hardly expect".

> But this is anything but a panacea. Adopting this "nothing to lose" condition as a qualifying one for precaution would rule out most, if not most all situations where the extinction of a species hangs in the balance. For in these situations, it is precisely for significant economic gain that the possibility of extinctions is routinely ignored. Think again about Sarah Palin's beluga whales.
>
> So it seems that even a much more limited program of precaution is likely to encounter serious problems.

All in all, I believe that whatever force there is behind Ehrlich et al.'s precautionary argument derives from their implicit supposition of a threshold that is the backdrop for a Pascal's wager on the removal of the next species.[55] The terms of the wager are that

(i) there is radical uncertainty about the outcome of the next extinction, no matter what the circumstances; but that
(ii) one plausible outcome is the irremediable loss of a vital ecosystem service; and that
(iii) there is little to lose by preventing the next extinction, thereby avoiding such a dire outcome.

I have argued that there are fatal objections to all three terms of this wager: So far as terms (i) and (ii) are concerned, we are most often justified in thinking that the removal of a species will have absolutely no deleterious effect. In cases where we believe that a deleterious effect might result, the belief is oftentimes not at all uncertain; we have a good handle on the likelihood with which the harm might occur. As for term (iii), there is often much to lose by doing what is needed to prevent an extinction. And finally, term (ii)'s claim for irremediable loss presumes a radically broad and unqualified inability to adapt that has, at best, fragile support.

6.4 Biodiversity as (Human) Life Sustainer

In an interview that David Takacs presents in his sociological study of how scientists conceive of biodiversity, biologist and conservationist Reed Noss (Takacs 1996, 75) says that biodiversity "is life, and all that sustains life." Not a few of the other biologists interviewed by Takacs express a similar sentiment, which promotes the value of biodiversity for reasons that range from "providing services" to "the conditions required for all life". As mentioned at the outset of this chapter, zero biodiversity would logically and with certainty remove life, though perhaps not its possibility. After all, there was a time – over 3.5 bya – when life *was* just a possibility.

At face value, the claim that biodiversity is "all that sustains life" borders on hyperbolic nonsense. The conditions for life are set by many factors that have little

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[55] Jeffrey Lockwood suggested this interpretation to me.

or nothing to do with anything biological, let alone biological diversity. To mention just a couple: The characteristics of the sun as a star and the distance of the earth from it; and plate tectonics, which drive the carbon cycle. So surely, biodiversity cannot be *all* that sustains life.[56]

One can rework Noss' statement to say that biodiversity constitutes "the *biological* or *biotic* factors that sustain life". In this form, the proposition might not be hyperbole, but it is next to useless in characterizing what biodiversity is supposed to be. The best geological and ecological evidence points to the conclusion that life will persist for a very long time under very many conditions – including the many different ones that have actually existed for the last 3.5 billion years of life on earth. This is true even in the face of extreme sorts of changes. Should all the methane currently trapped in clathrates suddenly be released, the earth would be bathed in a methane-rich atmosphere, as it was at the dawn of life. That would not offer a particularly friendly environment for most of the many respiring organisms that currently inhabit the planet. But very likely, methanogenic organisms, driven to obscurity some 2.5 bya by the photosynthesizing ones that transformed the methane-rich troposphere into an oxygen-rich one, will once again thrive.

One could rework Noss' statement in another way to restrict the biodiversity it mentions to "that which has accompanied the presence of *H. sapiens* on the planet". Its value then derives from all the biological factors that have sustained life that humanity has known from human prehistory onwards. Human presence is extremely recent, geologically speaking – less than 200,000 years – so this is a considerable restriction. Yet even during humankind's brief tenure, not just the composition of biodiversity (which species exist), but also species diversity in its proper sense, without regard to composition, have dramatically changed. These changes were largely induced by characteristically human activities and behavior. Focusing on just the direct effects on other species, conservation biologist Martin Jenkins (2003, 1177) remarks,

> There is growing consensus that from around 40,000 to 50,000 years ago onward, humans have been directly or indirectly responsible for the extinction in many parts of the world of all or most of the larger terrestrial animal species.

The component set of species has undergone transformation due to human influences. The component set of ecosystems has been concomitantly transformed. This is a matter of humanity's transformation of "the lay of the land" and of its biogeochemistry. It is the major point of the concept of anthropogenic biomes (mentioned in Sect. 5.3, The moral force of biodiversity), none of which existed 70,000 years ago. The biomes from that past time are now extinct, like many of the species that occupied them, and partly on account of the extinction of those species. In other words, whatever biological conditions have sustained life over the last 200,000 years have also sustained so many changes in life that the planet now is hard to recognize as a later biotic and environmental version of its former self.

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[56] Peter Ward and Donald Brownlee (2000) offer a more complete and fascinating accounting.

This is a serious blow to the supposition that biodiversity, just as it was at some point arbitrarily selected within the interval of human tenure, was essential to sustaining life from that point onward.

One might insist that the concern for biodiversity should be restricted even further – to the sustaining of life (just) as we know it right now in the early twenty-first century. This additional restriction finally reaches a confluence with the just-so model of biodiversity value whose attendant problems are recounted in Sect. 5.1.4 (The just-so model). In the current context, it also reaches a tautologous and therefore uninteresting conclusion: Biodiversity as we know it now is all that sustains biodiversity as we know it now.

Yet another reworking of Noss' statement would place a different restriction on biodiversity – as that which sustains not all life, but just *human life*. However, from an historical perspective, none of the transformational changes in the particular kinds that are diverse – nor the changes in their diversity – hindered humanity from emerging from a bottleneck population of perhaps 15,000 individuals 70,000 or so years ago, to grow to its current population size. Now nearing a population of 7 billion, *H. sapiens* has become the world's apex species[57] to boot. That is not just "sustaining human life". It is a spectacular flourishing of a species by any purely biological standard.[58]

To give it some degree of plausibility, I can only interpret this last reworking of Noss' statement as a way to reinterpret the threshold model of biodiversity value. That is, at some point not yet in the experience of *H. sapiens*, sufficient change (most likely reduction) in biodiversity will pass the point beyond which human life will not be possible – even though it is nearly certain that other life forms will still flourish.

The question then becomes, where is the threshold? Although the most easy-to-notice organisms, and particularly megafauna, have undoubtedly suffered easy-to-notice declines in increasingly human-dominated landscapes, *H. sapiens* clearly has not suffered as a biological species on account of that. Moreover, the planet still stands at something near an all-time earth history high point in species diversity – indeed, at an all-time high for diversity considered at almost every taxonomic level.[59] Also, we know that some species – particularly the most adaptable generalists, such as *H. sapiens* – have often survived dramatic extinction events and squeezed through

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[57] I mean "apex" in the sense of being the dominant, unmoved mover of ecosystems on a more widespread basis through a greater variety of means than any other organism.

[58] Of course, the flourishing of a species by a "biological standard" does not guarantee the flourishing of individuals of the species. The ability of human *individuals* to flourish is likely to decline if their numbers increase well beyond the current 7 billion. Also, my remark about the population-measured success of humans is not meant to imply (falsely) that *H. sapiens* outstrips all other species in this department. A comment by Jeffrey Lockwood prompted this clarification.

[59] See, for example, Dirzo and Raven (2003, 140), Purvis and Hector (2000, 214–215), and Spicer (2006, 71–78). Estimates of historical trends in diversity predominantly build on the pioneering work of Sepkoski (1982).

the narrowest of population bottlenecks. So the most straightforward inductions argue *against*, not *for*, any immediate danger to the continuation of human life.

The absence of convincing evidence that there is a threshold, let alone that one is near, suggests that the supposed threshold must be reached via an uncertain sequence of causal links. This plainly rehearses the "uncertainty" ingredient of a Safe Minimum Standard or other form of Precautionary Principle. And so, the current discussion reverts back to that one explored in the preceding section. At least one other ingredient of a Precautionary Principle – the identification of (though not a fully elaborated causal sequence for bringing about) significant potential harm – is surely present in this case. But a responsible deployment of the Precautionary Principle also requires that credible threat of potential harm be established. The evidence available today seems to fall substantially short of that standard.

Evidence for a negative feedback loop that might wildly accelerate processes leading up to the total demise of humanity would contribute to the case of legitimizing a Precautionary Principle. But with one possible exception, there is none. And speculation, based on "what if" conjectures, swings well wide of the "sweet spot" that a Precautionary Principle must find between blind speculation and known risk. Neither the mere logical possibility of a negative feedback loop nor the fact that such a thing is consistent with known science suffices in this regard.

The exception takes the form of credible evidence for the phenomenon of coextinction. This is (according to Koh et al. 2004, 1632)

> … the loss of a species (the affiliate) upon the loss of another [which can include] the process of the loss of parasitic insects with the loss of their hosts [as well as] the demise of a broader array of interacting species, including predators with their prey and specialist herbivores with their host plants.

Evolutionary biologist Lian Pin Koh and his colleagues (2004, 1633) claim to have identified some 200 such extinctions. Moreover, coextinction gains theoretical credence as a straightforward consequence of the existence of very specialized parasitic (including parasitoid) and mutualistic relationships between species. But I believe that this level of evidence does not yet rise close to the level of "credible threat to human existence".

Koh and his colleagues (2004, 1632) describe various well-known interdependences – of "pollinating *Ficus* wasps and *Ficus*, parasites and their hosts, butterflies and their larval host plants, and ant butterflies and their host ants." As Sir Robert May (1995, 16), the famous Australian physicist-turned-ecologist, points out,

> … it could reasonably be argued that for each species of metazoan or vascular plant there is at least one specialized species of parasitic nematode and protozoan, along with at least one species of bacterium and virus. Thus an estimate of plant and animal diversity can be multiplied by five, at a stroke.

How worrisome this is hinges critically on the degree of specialization, the degree to which the species are dependent on one another for their well-being (because some mutualisms are probably not critical to survival), whether the parasitic or mutualistic dependencies form cascading patterns, whether those cascades lead specifically to undermining resources or services that are vital to human existence, and whether or not there are other factors – such as the ability to express adaptive behavior that might sustain an affiliate species in the absence of its host – that might thereby inhibit a cascade or feedback loop. These critical factors are not addressed in Koh et al.'s work or elsewhere, to my knowledge.

In short, arguing for biodiversity value on the basis of a threshold for human survival does not achieve the threshold for sound practical reasoning. Abandoning the threshold model, one might argue that reductions of biodiversity might, more modestly, result in humankind's foregoing an economic bounty of services (or resources). This brings the discussion back around to Biodiversity as resource and Biodiversity as service provider – the notably unconvincing theories of value discussed in Sects. 6.2 and 6.3.

6.5 Biodiversity as a Cornerstone of Human Health

Among arguments that try to make a case for biodiversity's value, the ecosystem service one likely ranks first in frequency of occurrence, with biodiversity as resource taking second. In both categories, arguments that deal with issues of human health have recently come to dominate. Biodiversity is supposed to provide the service of safeguarding humans against infection. And it is supposed to be an indispensable pharmacological resource. I collect most of these arguments regarding health issues together in this separate section.

6.5.1 Biodiversity as Pharmacopoeia

Without biodiversity, your drug cabinet would be bare. To open the door to your drug cabinet is to open the door to biodiversity. That, in essence, is the claim made by those who urge (Newman et al. 2008, 117) that

> … biodiversity… provides us with medicines that relieve our physical suffering and treat, and in some cases even cure, our diseases.

Or (Cox 2009, 269):

> Over 50% of Western pharmaceuticals are derived from biodiversity.

Or (Cox 2009, 278):

> Historically, biodiversity has been the major source of pharmaceuticals, and today is relied on by 85% of the world's population for primary health care.

Again (Grifo et al. 1997, 131):

> Extinction of biological diversity risks the loss of the raw materials for existing and new weapons in the fight to alleviate human suffering and prevent death.

According to these authors and others, biodiversity is invaluable as an indispensable source of beneficial drugs.

I shall examine the details of arguments for this claim. But before turning to that, I wish to note an element common to all its formulations – an element that opens a window on all the maladies that plague the arguments made on its behalf. That element is a misstatement. Medicines are not derived from biodiversity. They are derived from specific plants, animals, and microbes. Furthermore, the "species richness" in the set of organisms from which medicines derive is tiny. Consequently, the claim amounts to a form of the category error discussed in Sect. 4.1.3 (Particular species), which mistakes biodiversity for some number (and in the case of providing medicines, some very small number) of particular species. This observation should end the discussion. But arguments from biodiversity's pharmaceutical value – both actual and potential – make a number of other interesting missteps, which are also worth examining.

There are two main argument threads for biodiversity's value as nature's pharmacopoeia:

1. The argument from the number of drugs that actually do owe their original discovery or current manufacture, in some part, to one or another organism. This includes the large number of folk remedies used around the world. A variant of this argument (which I take up first) starts with a premise, not about the number of drugs, but about the number of usage instances – typically in the form of number of prescriptions dispensed. The two numbers obviously convey different information.
2. The argument from the *potential* for deriving new pharmaceuticals from the huge set of organisms not yet evaluated. This includes the claim that these organisms would be indispensable for such derivation. It also tacitly includes the claim that the potential for finding medicines of sufficiently great benefit justifies forgoing other opportunities for realizing the more certain benefits of development that might impinge on the ability to find the medicine-yielding organisms.

I take up each thread in turn. First thread (1), which runs along actual use of medicines.

There is an obvious gap between a number representing how many organism-derived drugs there are or how many organism-derived drug instances are dispensed by pharmacies (on the one hand) to the supposition that the beneficial use of drugs would diminish and human suffering thereby increase as a consequence of a severely diminished diversity of species (on the other hand). To see why, I start by looking at the numbers in the "numbers premises".[60]

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[60] It is worth noting that it takes serious historical research to classify a drug's origins – that is, to determine whether or not a critter or plant somehow led to its development. Drugs initially derived from organisms are often completely synthesized for commercial production. There are several other tricky problems in coming up with summary numbers, as Grifo et al. (1997, 135–140) discuss. These problems are dealt with in different ways (or not at all) by different authors. This makes it very difficult to compare numbers between surveys. An additional difficulty is that the identities of the top drugs change dramatically from one decade to the next. The work by Grifo and her coauthors is based on 1993 data. That is why I supplement their results with more recently available data.

What are the numbers? Let's first look at the numbers of prescriptions dispensed. Pharmacognosy expert David Newman and his colleagues (2008, 117) cite a 1997 study by biologist Francesca Grifo and her colleagues (1997), based on 1993 data from the commercial U.S. healthcare industry information vendor IMS America:

> In the United States… half or more of the most prescribed medicines come from natural sources, either directly, or indirectly when these natural compounds serve as models or as chemical templates for new drugs.

What Grifo et al. (1997, 136) actually state is that

> 57% of the top 150 brand names prescribed in [the 1993 time period] contained at least one major active compound now or once derived or patterned after compounds derived from biological diversity.

E.O. Wilson (2002, 118–119) recites a 40% ballpark number, without citing any reference. It might well be based on data more recent than Grifo's. The differences in these numbers, though not insubstantial, do not affect my consideration of them.[61]

To be clear, I am (first) talking about the number of dispensed prescriptions, not the number of drug types prescribed, nor the total sales or profits. Also, as suggested by Newman et al. and as reflected in Grifo et al. (1997, 137, Table 6.2, "Origins of Top 150 Prescription Drugs"), I interpret "comes from nature" to mean "natural product" or "semi-synthetic" drug – that is (Grifo et al. 1997, 136), a drug *not* "entirely synthesized without specific reference [via either discovery or current manufacture] to a compound found in nature".

This immediately raises the question: To what organisms are we indebted for this cornucopia of drugs? Wilson's answer (2002, 118, 119) – that it is due to "wild species" – is at once a red herring and quite misleading. It certainly does not address the overriding question: Is there any credible reason to believe that reductions in biodiversity of the sort that E.O. Wilson and others foretell will threaten human health and welfare because of the health-benefiting drugs that we might consequently forfeit?

That question is addressed by Grifo et al.'s analysis of 1993 drug data. The summary (Grifo et al. 1997, 138, "Table 6.3: Derivative Organism"; 144ff., "Appendix to Chapter 6: Origin of Pharmaceuticals Index") show that the "derivative organisms" from which the top five drugs (again, in the sense of "most frequently prescribed") partly derive are *Equus caballus*, *Ovis aires*, *Penicillium notatum*, and "various mammals", with number 4 on their "Top 5" list being completely synthetic. That is, the top featured organisms are the common domesticated horse – specifically, pregnant mares, whose urine is the main ingredient of the estrogen supplement premarin (PREgnant MARes' urINe); the common domesticated sheep, for the anti-hypothyroid hormone drug synthroid (levothyroxine); and Sir Alexander Fleming's famous, ubiquitous, and easily cultured bread mold, which continues to be the inspiration and source of a variety of semi-synthetic, *Penicillium*

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[61] Yet earlier studies report a 25% figure, but they are restricted to drugs whose derivative organisms are plants, not animals or microbes. But even the highest figure of 57% does not deflect the thrust of my argument.

species-based antibiotics, most notably amoxicillin. Grifo et al. give part credit to "various mammals" for ranitidine (Zantac), a drug in the class of H_2-receptor antagonists for treating gastrointestinal reflux. Ranitidine's connection to animals is somewhat tenuous. Zantac's development by the pharmaceutical firm Glaxo was by rational drug design, based on their model of the histamine H_2-receptor. Evidently, mammals such as rats and dogs played a role as laboratory subjects for initial screening for effects. The number 4 drug in Grifo et al.'s survey is nifedipine, an antianginal that is an all-synthetic affair. This "Top 5" list is unrepresentative only in its emphasis on animals and microbes, as opposed to plants, which tend to dominate the rest of the "derived from nature" list.

A survey using more recent (2008) data shows major changes in the drug lineup. But the collection of "derivative organisms" gives a similar impression. In this survey, the cholesterol-lowering statin atorvastatin (Lipitor) now dominates prescription dispensing numbers. *Penicillium* spp. (*P. citrinum* and *P. brevicompactum*) once again figure in the derivation list, this time as the organisms from which compactin, the first known statin, was isolated. Ethnobotanist Paul Cox (2009, 274) appears to suggest that red yeast from rice can also claim part credit for statins. The analgesic hydrocodone (Vicodin), in various formulations, is also now a dominant drug. It is a semi-synthetic opioid derived from naturally occurring opiates in *Papaver somniferum* (the opium poppy) – one of the most widely and easily cultivated plants in the world. Amoxicillin from *P. notatum* continues its dominance in the world of antibiotics. Premarin has fallen away with the discovery of life-threatening side effects. Zantac has yielded to omeprazole (Prolisec) and esomeprazole (Nexium, a mixture of D- and L-isomers of omeprazole), which like ranitidine (Zantac) has, at best, a tenuous connection to living organisms.

In short, the facts do not merely fail to support but strongly contradict Wilson's general claim, to the effect that some significant amount of wild biodiversity is a cornerstone of medicine. Some "wild species" do offer up interesting bioactive molecules. But domesticated ones often do, too. And in any event, that is not the issue. Simply put, an extinction far more massive than even the most dire predictions from such experts as Wilson would, with near certainty, leave us with domesticated horses, domesticated sheep, bread mold, rats, dogs, and poppies.

Of course, the proposition that 50% (or so) of the prescriptions dispensed are derived from organisms is not equivalent to the proposition that 50% of the pharmaceuticals are so derived, though sometimes (as with Cox 2009, 269) the two are conflated. The latter proposition is therefore worth an independent look to see if it might ground a more convincing case for the need for some non-trivial amount of biodiversity.

Unfortunately, this other way of accounting for drug usage is not up to the task, either. According to the World Resources Institute, of the 119 plant-derived drugs used worldwide in 1991, just 90 of the 270,000 described plant species and perhaps 320,000 estimated different plants (according to Spicer 2006, 27) can be credited with even a peripheral role. Grifo and her coauthors (1997, 136, 138, "Table 6.3: Derivitive Organism") find 86 drugs in the top 150 (for the United States) that derive from some living thing. But many organisms are counted multiple times. All told, just 20 different species appear on their list (excluding *H. sapiens*, which is listed as a "derivative organism") plus "various mammals", which I infer refers to lab animals used for testing. This is hardly an impressive representation of the 10–100 million organisms that dwell on the planet.

Those who nevertheless persist in trying to make the case for "biodiversity as pharmacopoeia" pursue two auxiliary lines of argument. The first one abandons the numbers to present a sequence of anecdotes about "biodiversity-derived" drugs or just bioactive molecules and their benefits or potential benefits. This is accompanied by tales of bioprospecting, and exciting drugs-in-the-works. Examples (of unproven drugs) that find a place in almost every discussion include a possible cure for leukemia (fucoidan from various brown algae), promise for those suffering with HIV-AIDS (calanolide A from *Calophyllum langigerum* and *C. teysmannii,* cousins of the rubber tree*)*, and anti-malarials from *Artemesia annua* (sweet wormwood).[62]

Discussions such as these draw in a larger entourage of organisms. Unfortunately, this approach relies on the excitement that these anecdotes generate, rather than even modest, let alone convincing, inductive evidence for the case that our pharmacopoeia and consequent good health relies on some significant amount of biodiversity that is in danger of being lost. Some of the excitement comes from a small number of exceptional stories of biomedical sleuthing – involving the near-disappearance of a species with possible biomedical value. These stories are very popular and receive a large number of tellings. The story of *C. langigerum* and calanolide A is one such story.[63] But the more common stories are about species that are common and abundant and often easily cultivated – such as wormwood and a raft of the brown algaes.

Another significant quantum of excitement comes from pharmacologically active materials that are stimulating scientific imaginations, but in fact are not efficacious medicines whose benefits outweigh their harms. Mention of this also belongs with the discussion of the argument from potential medicines, below. I include it here because the organisms involved are already known and identified; and they are routinely misrepresented as evidence for the medicinal value of these organisms.

Pumiliotoxins, initially isolated from *Dendrobates pumilio* (Panamanian poison frog) and subsequently found in many other Dendrobatidae, are typical in both the amount of enthusiastic interest that they generate and their failure to actually become viable medications. Their myotonic and cardiotonic effects – that is, their ability to affect heart contractions – has resulted in ubiquitous citing of these toxins as showcase examples of potential medicines in the future's medicine cabinet. Underemphasized and often unmentioned is the toxicity of these alkaloids, which has precluded their

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[62] To be clear, a tiny number of successful drugs do derive from unexpected organisms; and recitations of their stories are legion. One cannot avoid encountering mention of *Taxus brevifolia* (Pacific yew), which yielded the chemotherapeutic mitosis inhibitor paclitaxel (Taxol). Nor can one fail to read about *Catharanthus roseus* (rosy periwinkle), which yielded vinblastine and vincristine – also mitotic inhibitors and also effective against cancer (in their case, Hodgkin's lymphoma).

[63] It is difficult to avoid the story of calanolide A. It is featured in Newman et al. (2008, 131–132) and Wilson (2002, 123–124). Nor does Cox (2009, 271) neglect its mention.

entering even Phase I (safety) trials for actual medical use (Chivian and Bernstein 2008c, 214). Epibatidine has a similar story. Initially discovered in *Epipedobates tricolor* (Ecuardorian poison frog), it was found to be a powerful analgesic in mice. Unfortunately, epibatidine itself is far too toxic to give to humans. Derivatives of it have not fared much better. Abbott Labs got the farthest with their ABT-594 (Tebanicline) (Chivian and Bernstein 2008c, 215). But it had too many adverse gastrointestinal side effects to make it out of Phase 2 trials.

The pumiliotoxins and epibatidine are the rule, not the exception. The vast majority of bioactive substances never even make it to clinical trial.[64] A pharmacological profile is required (at least by the FDA in the United States), and more often than not, it is too unpromising to proceed. The substance must be tested for first acute toxicity and then short-term toxicity (2 weeks to 3 months) in (typically) at least two species of nonhuman animals. Further testing in animals can require up to several years, because not all adverse effects present quickly. These tests are often failed, too.

Those substances that do make it to trial almost never make it past Phase I (safety and dose) or Phase II (short-term effectiveness and side effects). And although it is surprisingly difficult to find consistent data on the success rates of clinical trials, a 50% figure seems to split the differences of the few available numbers. Since this percentage applies to each one of the three trial phases, one might expect something like a 12.5% rate of success for the tiny number of substances that pass pharmacological and toxicological tests to make it into initial clinical trials. This is merely to say that the excitement surrounding this research is not equivalent to, or even remotely supported by, evidence that human health depends on the organisms involved.

A second auxiliary line of argument for "biodiversity as pharmacopoeia" focuses on "traditional therapeutics". More than medicines in industrialized regions, these remedies rely on a variety of organisms, some of which are threatened. Moreover, people in the industrialized world increasingly embrace folk remedies. Here is how Peter Canter and his colleagues (2005, 180) (the source for similar comments by Meyerson et al. (2009)) set out the case for this:

> The World Health Organization has estimated that more than 80% of the world's population in developing countries depends primarily on herbal medicine for basic healthcare needs. The use of herbal medicines in developed countries is also growing and 25% of the UK population takes herbal medicines regularly. Approximately two thirds of the 50 000 different medicinal plant species in use are collected from the wild and, in Europe, only 10% of medicinal species used commercially are cultivated. There is growing concern about diminishing populations, loss of genetic diversity, local extinctions and habitat degradation. Well-known species threatened by wild harvesting include *Arcostaphylos uva-ursa* (bearberry), *Piper methysticum* (kava), and *Glycyrrhiza glabra* (liquorice). Between 4000 and 10 000 medicinal species might now be endangered.

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[64] A summary of the United States drug approval protocol can be found in Chin and Lee (2008, 32–33).

The last claim about the number of "medicinal species [that] might now be endangered" is apparently derived by projecting another estimate – that 8% of all plants are threatened – onto the subgroup of plants that are regarded as medicinal (on the accounting of Schippmann et al. 2002, 4). Also worth mentioning is that Canter includes "aromatic" plants used in perfumes as contributing to "medicinal species". That might inflate the accounting for medicinal value, strictly construed. On the other hand, the number might be deflated because based on plants (no animals or microbes) alone.

Putting these admittedly relevant details aside, this account by Canter joins similar ones in skating past the single most important consideration in the matter. That is the question of the efficacy of these "medicines" – that is, whether or not they are actually promoting human health beyond the psychological benefit of the ministrations of traditional healers who typically dispense them. And if they do have some real salutary effect, there remains the question of whether their pharmacological benefit exceeds that of other, easily produced medicines. It is a sad circumstance that not a few have been found to be poor alternatives for other medications that are often ignored, even when they are available, in favor of the less efficacious ones. For example, ecologist Mark Tanaka and his colleagues (2009) express concern that, "... in Nigeria, witchcraft and traditional remedies of unknown efficacy are widely employed as treatments for malaria, instead of, or delaying access to, modern medicines of proven effectiveness." This is aside from the separate concern, expressed by these authors, for the outright toxic effect of other traditional medicines, which contain heavy metals, for example. In any case, the answers to these questions regarding efficacy are far from clear.

Nor is the increasing over-the-counter use of traditional herbal remedies in industrialized countries credible evidence for their efficacy. Efficacy is not proven by popular votes, which are often cast with unawareness of toxicity and side effects. For example, Schippmann et al. (2002, 214) raise the concern that

> ...many herbal remedies like ginseng (*Panax quinquefolium*), gingko (Gingko biloba), valerian (*Valeriana officinalis*), kava (*Piper methysticum*), or St. John's wort (*Hypercum perforatum*), very popular in the West, are more toxic than previously believed, and present dangerous interactions with prescription drugs...

Of course, these points – regarding a pharmacuetical's efficacy, the absence of adequate or even more effective alternatives, and whether its benefits extend to people generally – are not restricted to "traditional" medicines. They apply quite generally, so that even if the gap between drug numbers and biodiversity were bridged, this would still not secure the argument that connects pharmacological benefits to substantial biodiversity.

But in the case of a traditional medicine especially, even if all these formidable obstacles for establishing medicinal value were surmounted, there might still be good reason to refrain from using it as a medicinal resource. Those reasons have to do with the consequent threat to the medicine-supplying organism or to its environment on account of its extraction for medicinal use. In fact, with alarming frequency some set of organisms, if not biodiversity, is put at risk by intense use of traditional medicines, independent of their merit. There is meager evidence for the efficacy of some number of them, such as the Chinese use of the horns of various rhinoceros spp. for fever, convulsions, and delirium; the bones of *Panthera tigris* (tiger) for joint ailments; and the gall bladders of *Ursus* spp. (Asiatic black bears) for liver ailments and headaches. Musk glands from *Moschus* spp. (musk deer), in enormous demand for various Western homeopathic medicines as well as for perfume, is of similarly questionable benefit.[65]

The use of a resource need not entail using it up. But it is a real danger, and an imminent one in cases such as the ones just cited. Attempts to ameliorate this risk by resorting to medicinal agriculture can exacerbate other risks associated with the "land conversion" that accompanies all commercial agriculture. The conversion typically banishes many or most of the organisms that formerly made a home in that piece of real estate. Additionally, the medicinal plants will often be exotics where they are planted. Some will likely escape and become "invasive weeds". *H. perforatum* (St. John's wort), for example, has acquired this prejudicial label in both Australia and Canada (Newman et al. 2008, 153) – though when examined without prejudice for their status of as "aliens", their effect on biodiversity is uncertain. In other cases, there is the risk of transforming natural areas into industrial gardens. Precisely this is apparently under consideration for *Pseudopterogorgia elisabethae*, a soft coral that produces pseudopterosins, which have use in topical anti-inflammatories (Newman et al. 2008, 146). These examples collectively point up the possibility of a direct conflict between the sometimes marginal human health benefits that derive from organisms-as-medicinal-resource on the one hand, and the welfare of the medicinal organisms themselves, other organisms that might suffer for their cultivation, and the extractive environment, on the other.

Furthermore, in some cases, the use of traditional medicines is in all likelihood directly responsible for *declines* in human health. This appears to have been the case for the outbreak of severe acute respiratory syndrome (SARS) in southern China in 2002 and 2003. It seems likely (Li et al. 2005) that horseshoe bats in the genus *Rhinolophus*, sold in Chinese markets for use in traditional medicines as well as food, constituted the original reservoir of the SARS virus.

I now finally turn to the second of the two main argument threads for biodiversity's value as nature's pharmacopoeia – the case for biodiversity as an indispensable source for *future* medicines (item (2) at the start of this section). This argument is typically posed as the specter of losses in biodiversity that will forever deprive humans of the means to assuage their pain and cure their ills and will therefore condemn the human race to eternal, disease-ridden desperation. Built on conjecture, this is an argument of last resort.

Many writers present this argument, but none better than E.O. Wilson. He (Wilson 2002, 125) asks his reader to consider a two-dimensional matrix.

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[65] On top of this, the question of general, long-term, and indispensable benefit is brought into sharp focus by such dominant drugs as Lipitor and Prolisec (and Nexium) in the United States, where their availability might well encourage people to make diet-related decisions that contribute to the continuation and proliferation of the maladies and that make these drugs attractive.

The vertical dimension comprises a list of the millions (Wilson modestly says "thousands") of species of plants, animals, and microbes. The horizontal axis identifies all possible functions (though Wilson does not explicitly or immediately restrict these functions to medicinal ones), which he suggests are in the hundreds. Wilson then asks his reader to imagine filling in this matrix.

Thinking uncritically, one might imagine every cell filled in, producing Order(1 million species) × Order(1,000 functions) = Order(1 billion) gifts of nature. Thinking more critically, the matrix gets very sparse and the cornucopia suddenly gives way to leanness. That is because several considerations prune away several large chunks of the matrix.

First, while domesticated animals such as horses and sheep figure prominently in supplying a few widely used pharmaceuticals in medicine cabinets now, wild animals, or at least non-sessile wild animals, do not figure prominently in the search for new medicines. An impression to the contrary might come from the most problematic medicinal exploitation, recounted above. While megafauna tend to be the targets in the best known anecdotes, this is likely to be a matter of human observational and emotional bias. It is not unlikely that people tend to find exploitation of such animals more disturbing than exploitation of plants, with a concomitant increase in the degree to which animal exploitation registers in human awareness.[66]

In fact, the featuring of horses and sheep in a few superstar medications notwithstanding, few non-sessile animals figure in medicine overall. As Cox (2009, 269–270) notes, there might be good reason that

> … both scientists and indigenous peoples direct the majority of their attention to sessile organisms, particularly plants and marine invertebrates. While perhaps the immobility of such organisms facilitates ease of mapping and subsequent recollection, it appears that sessile organisms also produce the most potent bioactive molecules.

Cox (2009, 270) goes on to explain that

> Sessile organisms must mediate their interaction with the world – including parasites, predators, and competitors – primarily with chemicals. Evolutionary pressures have selected for toxins that fulfill this protective role.

In one telling stroke, this consideration lops out from the original matrix the preponderance of rows for non-sessile animals. Among the organisms lopped out are all arthropods – the vast majority of non-bacterial organisms on the planet. This points up a serious deficiency of the matrix representation. Its implication of "equal opportunity" for each cell's pharmacological potential is not realized.

Moreover, the equal opportunity supposition is confounded, not just by differences between kingdoms (such as Plantae) and phyla (such as Arthropoda), but also by the

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[66] A similar principle might also diminish the visibility of the exploitation of fungi. The collection of *Ophiocordyceps sinensis*, the caterpillar fungus, on the Tibetan Plateau for medicinal purposes has exploded with a 5–30-fold increase in its commercial value (since the 1980s), with uncertain effects on that organism and its habitat.

similarities between species within genera and even between genera within families. It is not uncommon for different but closely related species to manufacture very similar or even identical bioactive molecules. Precisely these similarities are the pivot points of exciting and oft-repeated tales of losing an organism that initially appeared to be the sole source of some bioactive compound. This is true of calanolide A, which was found in *Calophyllum teysmannii* when its source in *C. lanigerum* seemed to vanish (Newman et al. 2008, 131).[67] It is also true, for example, of diazonamides, anticancer agents originally found in one species of sea squirt from the genus *Diazona*. That species could not be relocated after the initial assay. However, other species in the genus were eventually found to produce the same compounds.

Of course, the tellers of these "narrow escape" stories wish to persuade us that, with the disappearance of each organism, we risk losing the drug that might save our life. That possibility cannot be eliminated *a priori.* But time after time, the stories instead illustrate the unlikelihood that any organism has a monopoly on the manufacture of a coveted molecule. This is anecdotal evidence, but only by way of reinterpreting the original anecdotes with greater clarity. It is anecdotal evidence that even the decimation of biodiversity is unlikely to substantially diminish the very modest pharmacopoeia it offers.

Second, serious consideration is due to the magnitude of the time and effort that is required to fill in whatever portion of the matrix that remains. Newman et al. refer to the adaptive evolution of life over the past 3.5 billion years as a field version of combinatorial chemistry. As a consequence, they (Newman et al. 2008, 118) sanguinely proclaim "that in many cases clinical trials have already, in essence been done".

Nothing could be further from the truth. Medicines for humans require preclinical pharmacological and toxicological testing followed by clinical testing with human subjects. This takes huge resources in the forms of funding, the dedicated expertise of research scientists, and most importantly for this discussion, time. For the testing of drugs for human use, the first 3.5 billion years count for naught. Screening technologies might improve and become more efficient. But the best of these technologies cannot make the trials go faster. The time required for them is not a matter of technological limits at which new technology can chip away.[68]

The time required for careful testing is not the only time constraint that is largely unchangeable. For species that are actually "in the wild", there is the significant challenge of finding and collecting individual organisms. It is hard to imagine major new efficiencies in such efforts that do not have the side effect of destroying what is sought as the result of gross, habitat-altering incursions into the homes of the target organisms that this would require.

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[67] As mentioned in Note 63, calanolide A's story is ubiquitous in the literature. See also Wilson (2002, 123–124), who recounts a somewhat different version of its tale.

[68] I hope that my description, earlier in this subsection, of the rigors of the pre-trial and trial protocols give some sense of how formidable these hurdles are and how seldom they are surmounted.

Third, there is good reason to suppose that expertise in molecule modeling and in molecule synthesis will improve. This is not to say that rational drug design – using such techniques as combinatorial chemistry and computer-aided design – and fabrication is a perfect substitute for fortuitous discoveries in the natural world. It *is* to say that whatever balance there is between the two approaches is likely to inexorably tilt more and more towards rational design as pharmacologically-inclined biomolecular engineers get better at it.

Finally, insofar as the argument for biodiversity as a potential medicinal resource is an economic one, it must soberly account for the vanishingly low probability that the medicinal benefits will actually be realized. That vanishingly low probability entails a vanishingly small expected net present value, which a cost-benefit analysis must weigh against the expected net present value of the benefits of economic development forgone in order to ensure the protection of the medicine-yielding natural resources. The economic analysis, when honestly done, does not appear to give the answer that environmentalists want. A big hint that this is so comes from "big pharma", whose sole *raison d'être* is economic gain. As Cox (2009, 270) complains,

> … there is no large pharmaceutical firm that currently bases a majority or even a significant component of its research program on searching for new molecules from rainforests.

Pharmaceutical firms ignore two salient considerations that contravene the pursuit of medicines "in nature": They have no interest in the possibly greater benefits of developing a promising locale in some way that might conflict with extracting drugs from it. Nor do they have an interest in avoiding the harm that might be done to the natural environment in pursuing a drug residing in some one of its residents. This builds into their assessment a significant bias towards developing medicines "from nature". Despite this, the pharmaceutical industry generally finds that it does not pay to include species-harboring areas in their asset portfolio. Of course, insofar as species-harboring areas have other, highly beneficial uses that do not accommodate the continued presence of these species, the economic rationale to retain them as a potential medicinal resource is only diminished.

Considerations previously presented in this subsection further weigh against an economic case for preserving biodiversity for its potential medicinal value. Much medicine "from nature" comes from domesticated species, ones that *can* be domesticated, ones that can be cultured or cultivated, or from new creations that are the product of selective breeding and genetic modification. Medicines initially found "in the wild" are subsequently synthesized. As for the discovery of new compounds, the apparent redundancy of their production by various different species appears to allow that a great extinction is more likely to increase the difficulty of finding them rather than to cause them to be lost entirely. And to extract their medicinal value, the species that remain need only be represented by a few individuals in zoos, aquaria, or seed banks (see Chivian et al. 2008, 201).

Taken together, these multiple considerations militate heavily against incurring the cost of preserving large populations of a large number of species in the wild for their quite marginal medicinal potential.

6.5.2 Biodiversity as Safeguard Against Infection

Not all human diseases are caused by infections, but a great many are, including a great many serious ones. According to the World Health Organization, more than one quarter of all human mortality is due to infection.

The notion that biodiversity helps to protect humans against infectious disease is, on the face of it, very odd. After all, infectious agents[69] – pathogens and parasites – are themselves organisms. For once, it would be accurate to say that they constitute a very large component of biodiversity – in the sense that these categories encompass a stunning diversity of organisms. In the most straightforward way, it seems that people would lead far healthier lives if this "component of biodiversity" were summarily extirpated. Of course, care must be taken *not* to say that biodiversity makes people sick. That is done by the huge set of organisms that make their enormous overall contribution to species diversity.

The pathogens and parasites that directly infect people represent only one aspect of the diversity of organisms that conspire to cause the human misery of disease. The direct agents of infection often, even typically, require the support of other species. Ecologists Ryan Hechinger and Kevin Lafferty (2005, 1059) performed studies that provide evidence for the sensible hypothesis "that rich communities and high abundance may foster parasitism."

This means that the pathogens and the parasites that infect people are not the only organisms whose absence might benefit human health. That is because the epidemiological situation is almost always more complicated than merely putting a "bug" together with a person. About 60% of all infectious agents reside and multiply in other animal hosts, known as "reservoirs", before being transmitted to people (Molyneux et al. 2008, 287). Infectious diseases involving transmission of the infectious agent from nonhuman vertebrates to human hosts are known as "zoonoses". Moreover, the transmission is often not direct, but via a vector – yet another animal – most commonly a cold-blooded arthropod or mollusk. In a particular place and for a particular vector-transmitted zoonotic disease system, a *variety* of host species, pathogen and parasite species, and vector species can be present to create a complex dynamic involving the interactions among the various populations of multiple species in these three functionally characterized groups. Different pathogens present in a disease system can even interact – as the result of their varying and sequential effects (morbidity and mortality) on the hosts that they share.

The complexity does not stop there. Yet other organisms that do not enter directly into the epidemiological equations affect populations of the species that are the direct players in the disease cycle. Predators might prey on some one or another of

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[69] In this subsection, I use "infectious agent" to mean "agent that can infect individuals of the species *H. sapiens*". Many pathogens and parasites infect nonhuman creatures, but not humans. The group of infectious agents involved in diseases known as "zoonoses" infect humans as well as other creatures.

these species.[70] Plants might provide suitable breeding habitats or food for other, more directly involved players.[71] Changes in the mix of all these species or in their varying populations enter into the dynamic. As I will suggest, extirpating oak trees in the northeastern United States might go a long way towards reducing the incidence of Lyme disease there – even though oaks are not hosts, pathogens or parasites, or vectors for this disease.

Finally, changes in the habitat of a place – typically wrought by human activities – impinge on these populations and consequently on the dynamics of their interactions. This almost always produces some change in rates of human infection. So this is the mazy route that is implicitly traversed by the oft-expressed proposition that "ecosystem disturbances affect human health via changes in biodiversity".

An enormous gap separates "ecosystem disturbance" from "bad effect on human health". Ecosystem disturbances can affect the mix of organisms involved in human infections, with some consequent effect on human health. But this says nothing about whether the health changes are for the better or for the worse. Nor does it say anything about whether these changes are accompanied by increases or decreases in the variety of the organisms involved. Nor does it determine even whether these effects on other organisms are the cause of human ill health or are collateral damage.

All combinations of better/worse and increased/decreased biodiversity occur. Sometimes the "biodiversity changes" are simultaneously both up and down within the same disease system. This happens when decreases in predators result in increases in the prey species that constitute disease reservoirs. Even then, the effect on human health is uncertain. That can depend on such other factors[72] as the "competence" of the reservoir species – that is, its relative ability of this nonhuman host to infect a vector that subsequently transmits the pathogen or parasite to a person. Reduced predation that results in an increase in a prey species that is a particularly

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[70] An example of how "outsiders" can dramatically affect the incidence of infection is the relative absence of predators of *Peromyscus leucopus* (white-footed mouse) in the fragmented and converted forestlands of the eastern and central United States. *P. leucopus* is an especially competent reservoir of *Borrelia burgdorferi*, the Lyme bacterium. Large populations of this mouse therefore increase the likelihood that local populations of the local tick *Ixodes scapularis* (black-legged tick) will be infected by biting them, and will subsequently bite and infect people. This zoonotic disease system and a few others involving Lyme disease are among the most thoroughly studied and most discussed. See Molyneux et al. (2008, 305–306), Rapport et al. (2009, 44–45), and Thomas et al. (2009, 232–233). I return to Lyme disease later in this subsection.

[71] An example is the intentional introduction of *Erythrina micropteryx* (immortelle tree) into Trinidad from Peru in order to shade cocoa. *E. micropteryx* also created a home for various bromeliads, which in turn, provided water reservoirs for the breeding of the malaria vector mosquito *Anopheles bellator*. See Molyneux et al. (2008, 297–298), Thomas et al. (2009, 232–233), and Dobson et al. (2006, 714–715). I return to this example, too.

[72] These other factors can make things extremely complex. Dobson et al. (2006, 716) discuss tick-borne encephalitis. In this particular case, the effective pool of pathogens to which humans are exposed is "diluted" only by the *combination* of two host reservoirs – one small, the other large, both at high density – which produces the desired protective shield for humans.

incompetent disease reservoir could be a boon to human health. Causal chains are also linked – or unlinked – by dint of such circumstances as the timing or sequence of events, which have little bearing on which creatures interact in a "disease system", their number, or their diversity.

This kind of complexity, which quickly transcends mere diversity of organisms and even biological diversity more broadly conceived, makes analyses that revolve around biodiversity appear frivolous – a distraction from the real epidemiological science of complex disease systems. Yet, not only does "biodiversity" figure centrally in the discussion of these systems, it is often promoted to titular status. Mere inclusion of a paper (Molyneux et al. 2008) on "Ecosystem Disturbance, Biodiversity Loss, and Human Infectious Disease" in a book with the title *Sustaining Life: How Human Health Depends on Biodiversity* will lead, or actually, mislead, many readers into thinking that losses in biodiversity jeopardize their health. But one need not rely on this inference when the authors introduce their paper by citing Rachel Carson's words (from an April 13, 1963 broadcast of *C.B.S. Reports* on *The Silent Spring of Rachel Carson*): "Man is a part of nature, and his war against nature is inevitably a war against himself." Insofar as the war is a war against biodiversity and the consequences have to do with rates of human infection, that proposition is, quite simply, false.

But the "dependence" of humans on "biodiversity" for their health and the consequent adverse health affect of biodiversity "loss" is not just a story that one must piece together from cryptic headlines. Experts often stake out their general claims – that greater biodiversity is protective, that reduced biodiversity is riskier, and that, notably, "habitat modification" precipitates such risk – quite explicitly, clearly, and directly. Ecologist/epidemiologist Andrew Dobson and his colleagues (2006, 718) state that there is

> …a strong selfish motivation to conserve biological diversity – our health may depend upon it.

and (Dobson et al. 2006, 714):

> … it may be sensible to conserve biological diversity for the purely selfish reasons of protecting human health.

and again (Dobson et al. 2006, 717):

> … significant threats to human health may be buffered by the presence of a diversity of other species.

Ecologist/economist David Rapport and his colleagues (2009, 50) are eager to "underscore how biodiversity can buffer exposure to disease" and further "underscore how habitat modification can facilitate disease".

As Keesing et al. (2006, 489) explain, there is significant confusion surrounding the term "dilution effect", although these authors might well add to it. They propose to define "dilution" in terms of the "net effect" of "a decrease of disease risk due to an increase in diversity". Unfortunately, using this definition has the effect of skipping past the most critical empirical question – of whether or not the change in diversity causally affects infection rates (the alternative that the definition builds into itself), or is merely correlated with infection rate changes.

It is unfortunate that what these scientists choose to "underscore" is both terribly incomplete and terribly prejudicial. It is only by failing to also underscore a raft of inconveniently contradictory evidence that they make the thesis of an inverse relation between biodiversity and infection rates appear plausible.

The remainder of this subsection has two parts. It first samples some of the science to illustrate how the argument succumbs to fallacies of accident by ignoring essential conditions and facts that bear on the case. It then concludes with a brief characterization of the real complexities of disease dynamics, focusing on zoonotic systems. I think that a sense of the actual epidemiological science, stripped of unjustified inferences from it, helps to make clear why the strategy of arguing from biodiversity to simple disease-protecting conclusions is a nonstarter.

I start with Dobson et al.'s (2006, 714) relatively straightforward presentation of the case for "biodiversity reducing disease risk". These authors focus on zooprophylaxis, the introduction of animals to divert disease vectors from people to other animals. Zooprophylaxis is a fancily named version of the "bite him (the nonhuman animal), not me (the person)" trick.

On what grounds, exactly, do Dobson et al. suggest that biodiversity reduces the risk that persons will get infected? They argue by induction from precisely one case; and this showcase example of how biodiversity benefits human health is *Bos primigenius* – the domesticated cow. They urge their case along by suggesting that the status of cows as sacred in India might be due to the disease protection that they supposedly confer.

I am mainly concerned with the informal and inductive logic that these authors use to go from the proposition that people who keep cattle have less risk of malarial infection to the proposition that biodiversity protects against disease. But before examining this logic, I should note that not a few serious studies provide strong evidence against the premise. Among them, one study (Bøgh et al. 2002) found that the protective barrier apparently afforded by cattle to cattle owners was, in fact, a matter of their greater wealth (and consequently, better access to good health care) relative to non-cattle owners. Another study (Saul 2003) found that while the cattle diverted mosquito bites, they also afforded such copious blood meals that mosquito populations flourished along with rates of (mosquito) survival. Once again, there was no prophylactic effect due to the cattle. Many other factors and conditions bear on whether or not cows in the vicinity are protective shields for humans. One factor is that cattle harbor a large variety of diseases that are transmissible to humans, including (Pelzer and Currin 2009) cryptosporidiosis, *Escherichia coli* infections, giardiasis, leptospirosis, Q fever, ringworm, salmonellosis, and tuberculosis.[73] The many factors and conditions that bear on the proposition that cattle are protective shields make it hopelessly and misleadingly simpleminded. The discussion of some of the intricacies of host/pathogen/vector dynamics at the end of this subsection should make plain why this it so.

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[73] In fact, Rothschild et al. (2001) present evidence for *M. tuberculosis* in bison dated 18 millennia ago. This suggests that the disease originated in cattle or their ancestors.

In short, the major premise's truth value is questionable, at best. Momentarily putting that aside, a couple of interrelated questions arise. Answering them requires a reasonably clear rendering of the hypothesis for which the allegedly protective benefit of introduced cattle is supposed to be evidence. The hypothesis seems to be: "The introduction of populations of nonhuman species that are alternative blood meals for a vector of a human disease decreases the vulnerability of people as blood meals, thereby decreasing the incidence of the disease in people." Given that, the first question is: What are the implications of this hypothesis for recommended human behavior and action? One obvious answer is one that authors on this topic never mention: Wherever vector born diseases adversely affect human health, one should introduce some one or more decoy species that will divert the bites of the vectors.[74] In other words, this is a call for species introductions that serve a human health purpose.

The second question, which comes in two versions, can be viewed as a corollary of the first: What, exactly, does the introduction of cattle (or other species) have to do with biodiversity? Or: how can the observed phenomena be understood in terms of biodiversity? The answer to the first version of the question is "not very much". To the second version, the answer is "not very well". It is not biodiversity that is the decoy for mosquito bites, but those large, domesticated, turf-compacting, flora-removing, water-fowling, methane-burping ruminants. To characterize the situation as a matter of increasing biodiversity via the introduction of that creature is to commit one of the category mistakes discussed in Sect. 4.1. This is another point at which the discussion really should end. But I will play along and past the category mistake to make a number of additional observations, which point up how the argument is built on fallacies of accident (discussed in Sect. 2.2.3).

Not all examples of zooprophylaxis involve domesticated animals. Nor do all of them involve species introductions; many involve species extirpations – for example, getting rid of creatures that are disease reservoirs. I shall expand my discussion to include extirpations and "wild" creatures, shortly; but for now, I confine my attention to the introduction of domesticated creatures and cultivated organisms. Considered in one way, moving a bunch of bovines into the neighborhood clearly has a rather marginal effect on biodiversity. It is marginal because there is no dearth of cows (or almost any other domesticated organism) and so certainly no increase in global biodiversity by herding them into a new location. So far as local diversity is concerned – without taking into account the effect that a beast such as a cow has on other creatures in its vicinity – there is at most an increase of precisely one otherwise extremely abundant and common species.

Of course, this incremental effect on local species diversity is far from the end of a story involving bringing in the cows. Taking into account how cattle affect the fate of other organisms and the most basic characteristics of their residence makes the biodiversity picture far more complicated. Recall Sahotra Sarkar's (unsubstantiated)

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[74] This suggestion takes its cue from the World Health Organization, which for decades has urged a more modest version of this proposition. Bøgh et al. (2002, 593) remark that it "has recommended the use of cattle for zooprophylaxis as a protective measure against malaria since 1982".

claim that cattle increase biodiversity by maintaining the Keoladeo wetland (Sect. 4.1.1, Wilderness). This type of claim might gain credence from some studies, though not always ones free of conflicts of interest – such as a study (Marty 2005) claiming that grazing cattle can maintain native biodiversity in vernal pools in the western United States.[75] And sometimes, a single, sentimental favorite species can hang on, courtesy of four-legged mowing devices.[76] But the overwhelming body of solid evidence does not point at all towards such a clearly sanguine conclusion about bovine effects on biodiversity or the natural environment – a marquee case of disregard for countervailing evidence.

Some of the best documentation for bovine influence on biodiversity comes from the western United States. There, livestock grazing nearly matches the combined effect of mining and logging in contributing to the demise of over one-fifth of all species that are federally classified as threatened and endangered. That includes fully one-third of all endangered plants (Wilcove et al. 1998, 610). And although species diversity might not be affected by a change in the species mix, one study (Kimball and Schiffman 2003), showing that native plants tend to be quite vulnerable to cow herbivory as compared to non-native plants, makes clear that cows alter the mix.

The causal influence of cows on grazed turf are multiple and, in combination, often dominant: The direct effects on other species include competition for forage (with bighorn sheep and pronghorn, for example), blowing the cover for ground-nesting grassland birds (such as mountain plovers and at least two species of grouse) and small mammals (such as prairie dogs), and the systematic extermination of potential bovine predators such as wolves. This leads to indirect effects on species that have a predator, competitive, mutualist, or commensal relationship with one of those directly affected. Among animals, that includes black-footed ferret, swift fox, and Mexican spotted owl (Miller et al. 1994, 678–679; Salvo 2009). Among plants, it includes flora that cows prefer *not* to munch on.

Cattle are responsible for wholesale modifications of habitats, which are hard to view in the sanguine way that the creation or maintenance of a wetland might be. The effects on riparian habitats are dramatically transforming. These include deposition of pathogens in streams, as well as increases in nutrient levels, turbidity, and temperature – all of which affect the viability of a host of aquatic creatures ranging from invertebrates through amphibians to fish. Grazing alters the morphology of stream banks – downcutting them and reducing their stability, as well as the number and quality of pools that salmonids (among other fish) depend on. Grazing changes stream hydrology by increasing runoff and changing flow patterns. At the same time, it exposes bare ground, which is compacted and more easily eroded. Woody and herbaceous plants suffer (Belsky et al. 1999).[77] On the other hand, algal populations in the stream tend to flourish. So do populations of nonnative plants – typically

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[75] This study was done on behalf of The Nature Conservancy, which has a large stake in accommodating cattle interests.

[76] See Nash (2009), which describes biologist Stuart Weiss lauding cows as "keystone herbivores" and the saviors of *Euphydryas editha bayensis*, the bay checkerspot butterfly.

[77] For the effects on upland habitats, see Belsky and Blumenthal (1997).

as a result of their relative resilience to trampling and their ability to take advantage of altered fire regimes. And the claim has been made that cows create pockets of standing water that provide breeding opportunities for some insects (including disease vectors) as well as amphibians who are pleased to dine on those insects.

All things considered, the jury is out on the net direct and indirect effect of cattle grazing on biodiversity. The issue is further confounded by the fact that different grazing disciplines (when, where, in the company of what other beasts, and in what numbers the cattle are grazed) might have different effects on the grazed habitat. But I have gone into these details to emphasize what the perceptive reader will already have realized: This discussion is entirely irrelevant to the proposition that biodiversity has a positive effect on human health. For even if cattle do provide a zoonotic decoy for some human disease vectors, and even if untold numbers of creatures of untold numbers of species sprang up in the footprints of every bovine, this would do absolutely nothing to show that biodiversity is zooprophylactic. Rather, it would show that the introduction of one species both moderates a human disease and fertilizes the biodiverse tree of life. The matter of human health and the matter of biodiversity would be correlates that happen to stem from the same cause. But the biodiversity would otherwise have absolutely no connection to the health benefits for humans.

Therefore, Dobson et al.'s argument for the health benefits of biodiversity is completely based on the fallacy of correlation – except insofar as it can be shown to rely on one common domesticated beast. So much the worse for their argument if it turns out that cows figuratively trample biodiversity as a consequence of their literal trampling of the turf on which they graze. When scientists such as Dobson join E.O. Wilson in agonizing over a possible Sixth Great Extinction, it is doubtful that they have in mind the urgency of saving domesticated cattle.

This brings me back around to the truth value of Dobson et al.'s major premise. Are there circumstances in which introduced cattle exacerbate instead of ameliorate disease? To answer this question, it helps to consider the disease-affecting properties of cattle introductions with dynamics that differ from those in the sort introduction that occupies Dobson and his colleagues. Molyneux et al. (2008, 306) relate that

> In Uganda… the expansion and movement of cattle populations into areas previously inhabited by native ungulates (a large group of mammals that have hoofs, e.g., antelopes and cows), combined with the invasion of abandoned cropland by the nonnative plant *Lantana camara*, is believed to have contributed to changes in tsetse fly (*Glossina*) distribution that initiated epidemics of African sleeping sickness (ASS) in the 1980's… …the introduction of cattle… provided a highly competent reservoir host for a subspecies of the parasite that causes ASS, *Trypanosoma brucei rhodesiense*. *G. fuscipes* is a generalist vector that will feed on cattle, as it will on any available host. The movement of cattle in Uganda continues to this day to influence the spread of sleeping sickness in that country.

Unlike Dobson et al. and Molyneux et al. do not praise diversity-enhancing additions of *Bos primigenius* and *L. camara* (Spanish fig, an intentionally imported ornamental) to Uganda. It suits their (Molyneux et al. 2008, 306) particular purpose to point out that these are "nonnative alien and invasive species". However, this classification is entirely beside the biodiversity point. At least, it is beside the point for Dobson et al., who suggest that cows might be the sacred heroes (or heroines) of disease prevention.

Within a broader purview of domesticated beasts (beyond just cows) and cultivated crops, the biodiversity literature mostly portrays these organisms as health villains rather than as health heroes. Various species of the genus *Sus* (pigs) seem particularly adept at transmitting various diseases to people. They stand accused (and perhaps convicted) of this accomplice role in connection with irrigated rice fields, home to various *Culex* spp. mosquitoes that harbor the viral pathogen for Japanese encephalitis in various parts of Asia (Molyneux et al. 2008, 301–302); and in connection with fruit orchards in Malaysia, where Nipah virus-infected pteropid fruit bats find sustenance (Molyneux et al. 2008, 303–304).

In the first of two ironic twists, closer scrutiny of the scientific literature reveals its tendency to hold up as villains not just the pigs but also "human encroachment on biodiversity". This is "science-speak" for the observation that when people move into the vicinity of a diverse collection of creatures, there is a significant likelihood that the new neighbors will be carriers of pathogens and parasites capable of infecting humans. In other words, this is evidence that a large and diverse collection of creatures is generally bad for human health.

There are few completely reliable "rules" of ecology. Rapoport's rule is probably as reliable as any – at least for terrestrial (as opposed to marine) systems. It states that biodiversity increases as the distance to the equator decreases. As a corollary, this rule also applies to parasitic and infectious diseases (PID's): The diversity of PID's is greatest in low latitudes (Guernier et al. 2004). So it is not surprising that human infection rates are highest in the tropics. The straightforward conclusion is that, so far as infections are concerned and on a global scale, biodiversity is bad for human health. In fact, it is very bad.

In a second ironic twist, this is probably good news for biodiversity. That is, it is good news if it encourages people not to venture into and change the habitat of creatures that might make them sick. It could also be bad news for biodiversity if it encourages people to venture forth anyway, while trying to exterminate any and every living thing that might play a role in the causal chain that ends in human infection. As mentioned in Sect. 2.2.4 (The fallacy of correlation), this is the inclination of villagers in Cameroon who view the preemptive extirpation of both species of *Pan* and of *G. gorilla* – local primate neighbors who carry the Ebola virus – to be in their health interest.

I have pursued at length the example of cows and other domesticated creatures viewed as offering health protective services. A second example comprises a family of narratives. These narratives do not involve the intentional introduction of a species, which characterized as "greater biodiversity", is supposed to serve as a prophylactic shield against human infection. Instead, they start from the intentional modification of habitat. The most frequently encountered variant involves deforestation, and so that is what I take up. A typical story line threads its way through changes (not necessarily reductions) in local biodiversity that result from the changed habitat. The story concludes by noting an increased incidence of human infection. This (Molyneux et al. 2008, 297) is taken to be inductive evidence that "deforestation increases the risk of human infectious disease".

Of course, deforestation is a radical form of "habitat conversion", which inevitably leads to changes in the array of species that reside in a place and in their relative numbers. Equally true is that sometimes, species that are bad for human health move into deforested or fragmented areas. The standard arguments "underscore" these cases. Thus, in a number of cases in Southeast Asia and Amazonia, wholesale removal of trees has favored *Anopheles* spp. over the previous, more benign mosquito residents. The newcomers are more effective transmitters of the more virulent species of malarial *Plasmodium* (genus) parasites (Molyneux et al. 2008, 295–296). Similarly, the removal of trees in Cameroon has shifted the balance from one snail species, *Bulinus forskalii*, which hosts a relatively non-virulent schistosome (a trematode), to *B. truncatus*, which effectively hosts *Schistosoma haematobium*. This latter schistosome readily infects the human urinary tract (Molyneux et al. 2008, 297).

Is this inductive evidence that "deforestation increases the risk of human infectious disease"? The appearance that this is evidence is sustained only if one ignores the real causal factors that bear on these cases. In the case of the malaria vectors, one might think that much more depends on *how* the deforestation is done. If it is done in a way that also ensures continued good drainage and that reduces or eliminates the standing water that favors malaria-carrying *Anopheles* spp., then, apparently, the influx of those species could be avoided. Perhaps the lesson is that care must be taken in *how* deforestation is carried out, with particular attention given to installing proper drainage systems. Another possible lesson is that consideration should be given to planting forests where there are malarial outbreaks as a means of reducing their frequency or intensity. I shall say more about reforestation and revegetation shortly.

More to the point of claims for the health-preserving effects of biodiversity: is this inductive evidence for the proposition that a change in biodiversity increases the risk of human infectious disease? The evidence presented does not suffice to answer this question with assurance. But with high probability, the answer is, again, no. If there has been a mere shift in the relative size of the populations of different species of mosquitoes, and no species have been locally extirpated, then these circumstances say nothing about whether the *diversity* of species has changed. Even if, in particular places, the more benign species are entirely displaced by more aggressive *Anopheles* spp., then these latter species might more than make up for the local loss of the previous resident species. Again, the local diversity would be undiminished. And finally, there is no indication that, in any case, the mosquitoes that previously dominated locally went globally extinct. Under any of these conditions, even to say that a "component of biodiversity changed" is, at best, a very confused and confusing way to say that, although the effects on diversity are entirely uncertain, the particular combination of creatures in a specific local mix has changed.

What are we to make of the Cameroon snails? In this case, unlike the mosquito case, no additional *sine qua non* for the outbreak of disease is immediately evident. *B. truncatus*, the snail principally responsible for urinary tract schistosomiasis, likes sun-exposed water bodies; the relatively benign *B. forskalii* does not. So one might think that this is a case in point for the thesis that deforestation causes disease.

But not when one considers what has been left out of the story. There is no general law of nature or one special to ecology that says that vector species favored by deforestation are more likely to transmit disease.[78] In fact, just the opposite is sometimes true. *Re*forestation can, just as legitimately (or really, illegitimately) be said to *in*crease the risk of human disease. I have already noted (Note 71) how the introduction of *Erythrina micropteryx* (immortelle tree) into Trinidad did just that – by providing suitable habitats for bromeliads, which in turn provide suitable breeding habitat for *An. bellator*, a malaria vector. If this case is mistakenly said to not count, for the irrelevant reason that *E. micropteryx* is an "alien" in Trinidad, then other examples will serve.

One such example is the reforestation of New England – with "native" trees. It is fair to say that it is the reforestation in that region that has led to a serious risk of Lyme infection there. This synopsis of the plot – which starts from the reforestation – might come as a surprise to those familiar with the usual narrative, which skips over the reforestation prequel and begins with the fragmentation of the reforested landscape by roads and other human structures associated with towns. (This disease system is briefly described in Note 70).

Predators and, more generally, larger animals higher up in the trophic structure tend to have relatively small populations merely by virtue of the demands of their trophic position. They also tend to require relatively more contiguous territory to meet their dietary needs. As a result, these creatures are disproportionately affected by the fragmentation of their habitat. It is this relative reduction in predators and larger competitors of *Peromyscus leucopus* (white-footed mouse) that is said to have produced a surge in populations of that small rodent. As it happens, *P. leucopus* is also an especially competent reservoir of *Borrelia burgdorferi*, the Lyme spirochete bacterium. Therefore, the presence of large populations of this rodent increases the likelihood that local populations of *Ixodes scapularis* (black-legged tick), the Lyme vector in this area, will be infected and will in turn infect people. To repeat, according to the usual, truncated version of the story, forest fragmentation causes Lyme disease.

The Lyme disease system in New England and Lyme disease elsewhere are perhaps the most heavily researched zoonotic disease systems in the world. One need not plunge into gory details of the science to notice that the usual narrative contains prejudicially selective "underscoring". It begins with the arbitrary starting point: It is a story about the ills of biodiversity-reducing forest fragmentation, not the ills of regenerating a forest. More central to this discussion, there is no law of nature that says that the small species favored by fragmentation will be more competent reservoirs of the disease. In fact, another small species, *Sceloporus occidentalis* (Western fence lizard) predominates as the target of tick bites in the United States Pacific and southwest regions (Rapport et al. 2009, 45).[79] These creatures are not particularly susceptible to Lyme infection, and so probably

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[78] There *is* speculation about this – to the effect that generalist vectors that have fewer strong biting preferences and that therefore are more likely to bite people, tend to be the pioneers in the modified landscape.

[79] In that part of the American West, the principal tick is *I. pacificus* (Gubler et al. 2001, 225).

reduce the frequency of Lyme disease in western U.S. ticks and therefore, in western U.S. humans, too.

Finally, it also should be noted that a much larger animal, *Odocoileus virginia* (white-tailed deer), not *P. leucopus*, is the primary host for ticks in the northeast, though not a particularly competent reservoir for the Lyme bacterium (Gubler et al. 2001, 225). This fact connects back to the prequel story, which reveals reforestation to be a prior cause of Lyme disease in the U.S. northeast. Research suggests that, at the root, the real culprits are the acorns of *Quercus* spp. (northeastern oaks). Ecologist Clive Jones and his colleagues found that populations of *I. scapularis* surged eightfold in acorn-rich plots, perhaps as the result of the deer spending more time enjoying the repast in acorn-rich environs. Densities of *P. leucopus* also surged with the abundance of mast, as did their Lyme infection rates in this tick-rich environment (Jones et al. 1998, 1024–1025). With this, the risk of human infection also increases. Applying the logic of convenience that infects the standard narrative to this more complete narrative might lead to the conclusion that *Quercus* spp. are bad for human health. This logic would target those grand trees for extirpation in areas where they nourish the nonhuman hosts that put humans at risk for Lyme disease. In fact, because they do not move and are slow growing, oak trees would be easier targets for extermination than deer, mice, or ticks. This consideration combines with the economic bonanza of valuable building material to make it likely that the removal of oaks is the most economically efficient means of reducing Lyme risk to humans in the U.S. northeast.

I cite one other example of the planting of native vegetation that has led to disease outbreaks: In several Mediterranean countries, including the southern Jordan Valley, cases of zoonotic cutaneous leishmaniasis surged as the result of planting native Chenopods (plants in the goosefoot family). The newly vegetated landscapes provided good homes for both rodent hosts – *Psammomys obesus* (sand rat) and *Meriones tristrami* (Tristram's Jird, on the *IUCN Red List of Threatened Species*), and the phlebotomine sandfly vectors for protozoan parasites in the genus *Leishmania*. This "biodiversity" was unwelcome and led to the uprooting of the recently reintroduced plants and the destruction of the rodents' burrows (Rapport et al. 2009, 50).[80] The habitat modification, in turn, led to the reduction of the cutaneous leishmaniasis. Evidently, habitat modification can cut both ways. In Jordan, the choice was to do the equivalent of uprooting oaks in New England.

As I said at the outset of this subsection, the notion that biodiversity forms a kind of infection-shielding cocoon for humanity is very odd on its face. Some initially odd-seeming hypotheses do turn out to be true. But what is known in disease science – the uncut, unexpurgated version – suggests that the cocoon hypothesis is not so lucky. In fact, it seems doomed to be a nonstarter. With an eye towards giving a sense of why this is so, I conclude this subsection with a glance at some of the science of zoonotic disease systems that involve vector transmission.

Some zoonotic disease systems involve a parasite with a complex life cycle that requires a diverse collection of host species. The life cycle of such a parasite

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[80] See also Kamhawi et al. (1993).

proceeds in a sequence of stages. Each stage requires one particular species of mollusk or vertebrate host. This is common for trematode flatworms, which "flow" from one species of host to the next, quite often winding up in a vertebrate. The cycle starts with a free-swimming ciliated miracidium, which enters a mollusk, where the miracidium produces sac-like sporocysts and possibly rediae, the embryonic form. These latter mature into cercaria – the larval form with a swimming tail, which propels it into a second host – typically another mollusk, a copepod, or a vertebrate carnivore (amphibian, fish, bird, or mammal). It develops into an adult there, or possibly within yet a third host. A third host is typically a vertebrate carnivore, which receives its unwanted visitor by eating the second host. The trematode cannot survive the extirpation of any one of its specialized host species.[81] But clearly, the final vertebrate host, which could be *H. sapiens*, would be healthier for the absence of any of the trematode's upstream hosts. This is a case where a variety of hosts is not just conducive to vertebrate infection; it is essential.

The epidemiological equations for zoonotic disease systems show that multiple factors are critical for determining the incidence of human infection. Many factors have nothing to do with the number of species of host, pathogens or parasites, or vectors.[82] Entering into the equations are: the rates of encounter between each vector and healthy individuals of each of its human and nonhuman host species; the varying rates of transmission for each vector/host pair, given the probability of transmission on an encounter; densities (not just abundances) of the (one or more) vector species; properties of the multiple hosts that affect the efficiency of their transmission of an infection directly (not via a vector) from one host individual to another of the same species; the properties of the various hosts that affect the direct transmission of the infection from one host individual to an individual of *another* species; and whether the transmission in each of these various cases follows a frequency-dependent or a density-dependent paradigm. Each of these multiple factors must be added to the already non-trivial epidemiology that describes a simple one pathogen/one host system. For each host, the epidemiological equations must take into account its rate of recovery, mortality, and whether or not (or to what degree) recovery removes an individual from the pool of susceptible individuals. Changes in any one of these many factors, and even the precise sequence in which the changes occur can affect human infection rates, and whether they increase or decrease. Finally, causal factors for many of these changes can be changes in the populations of species that are not hosts, pathogens or parasites, or vectors. This includes, at the extreme edges, the introduction or extirpation of species.

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[81] Hechinger and Lafferty (2005) focus on such a system in which birds are the ultimate vertebrate host.

[82] I mostly follow community ecologist Felicia Keesing and her colleagues (2006) in giving some sense of the various complexities of species interactions that, in the end, determine human infection rates.

Consider various ways in which the introduction of a species into a disease system can – and in some cases have been observed to – increase the incidence of disease:

1. A new predator induces populations of its prey to pack themselves more densely in areas that offer the best protection without necessarily changing the size of the prey's population. If the prey species is a pathogen host, this can increase rates of encounter between infected and susceptible host individuals, thereby providing a larger and more fertile breeding ground for the pathogen.
2. A new species is a food resource or a mutualist for a nonhuman disease host or vector, leading to a more robust population of a key infectious agent.
3. A new host species is a far more competent reservoir for a disease than any host previously present, leading to far higher incidence of the pathogen or parasite in vectors that transmit it to people. This is part (but only part) of the story of the Lyme bacterium hosted by *P. leucopus*. As another example, the rabies virus cannot be sustained in humans alone because humans rarely communicate the disease directly to each other. Introduce *Procyon lotor* (raccoon) and rabies becomes viable (Keesing et al. 2006, 491).
4. A new host species, even if not a particularly competent disease reservoir, helps sustain vector populations that still feed copiously from competent reservoirs. This is the role of *O. virginia* (while-tailed deer) in some Lyme systems such as the well-studied one in the northeast U.S. It is also the role of *Cervus elaphus* (red deer), the primary host of louping ill, whose transmission vector is *I. ricinus*, another tick. The number or density of deer must be just "right". Too low, and the tick populations decline. Too high, and the deer draw too many bites from viremic hosts, such as *Lagopus lagopus scotica* (red grouse) (Keesing et al. 2006, 494).
5. In a disease system in which interspecific transmission rates exceed intraspecific transmission rates, a new host species increases the prevalence of infections in all nonhuman hosts through interspecific transmission. There are several examples of this, including rabies once again: Populations of *Canis adustus* (side-striped jackal) in Zimbabwe could not support rabies, except via frequent re-inoculation by rabid domesticated dogs (Keesing et al. 2006, 492).
6. An additional vector increases disease risk. The presence of two tick vectors of Lyme disease in California – *I. spinipalpis* and *I. pacificus* (Western black-legged tick) – increases the risk of Lyme disease relative to areas where only one tick species resides. Similarly, two mosquito vectors of West Nile viral encephalitis – *Culex tarsalis*, which feeds on birds and maintains high rates of avian infection, and *C. pipiens*, which bites both birds and people – are jointly responsible for high human infection rates (Molyneux et al. 2008, 307).

Of course, adding a nonhuman host species to a zoonotic disease system does sometimes cause a "dilution effect". And sometimes a dilution effect reduces rates of human infection. When the newcomer is a relatively incompetent carrier or transmitter of the disease in question, it can supply enough of a vector's blood meals to reduce the disease's overall transmission to humans. But the effect is not a matter of the mere presence of the “decoy” species. I have given many examples to show that a salutary result hinges critically on multiple properties of all the organisms involved in the disease system. This includes whether or not the dilution effect is more significant than the increase in pathogen populations that a new host might foster (point (4) in the list above).

This range of possibilities provides some better perspective on the notion that the diversity of species is prophylactic medicine. Posed as an unqualified generalization, this proposition is quite categorically false. Mostly, the diversity of species is quite irrelevant to the question of how much disease spreads to humans.

Sometimes more species can reduce human infections. Sometimes more species can increase human infection rates. Whether or not people get infections is determined by conditions and causal chains that either wind up directing pathogens and parasites into human bodies; or not. The “right” conditions for infection can involve more or fewer species. But the number and diversity of species in the causal chain leading up to infection is entirely irrelevant as a causal factor in itself. This is another way of getting back to saying that, in the end, the proposition that biodiversity serves to protect human health is based on a category mistake.

6.6 Biodiversity as Progenitor of Biophilia[83]

In “biophilia” we have a neologism to pair with “biodiversity”. In fact, pairing these two concepts is exactly what E.O. Wilson and Stephen Kellert – the two most distinguished and vocal proponents of “the biophilia hypothesis” – set out to accomplish.

The term “biophilia” might have originated with Erich Fromm’s use of it as a “normal biological impulse” or state, which he contrasted with the “psychopathological phenomenon” of necrophilia. This usage is somewhat removed from the notion that Wilson (1984) later popularized in his eponymous book. But in retrospect, Fromm’s explication (Fromm 1973, 406) can be seen to contain the seeds of Wilson’s later extensions:

> Biophilia is the passionate love of life and of all that is alive; it is the wish to further growth, whether in a person, a plant, an idea, or a social group.

Fromm here allows biophilia to be a projection from a person’s love of her own life and her love of other individual persons, to loving the life of other organisms (plants) and (metaphorically) the life of social groups.

Wilson (1996, 165) cultivates this germ of an idea into the definition of biophilia as the speculative hypothesis that there exists “the innately emotional affiliation of human beings to other living organisms”. In the fertile mind of Kellert (2005, 49), it

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[83] My thinking on this topic owes much to an unpublished paper that Dan Haybron presented in a 2008 conference and in subsequent verbal and email conversations with him.

develops and branches into "the inclination to value nature". Based on this speculation, Wilson and Kellert fear great psychological damage will accompany great damage to biodiversity. Wilson (1996, 170) exhorts

> psychologists… to consider biophilia on more urgent terms. What, they should ask, will happen to the human psyche when such a defining part of the human evolutionary experience is diminished or erased?

Several major obstacles stand in the way of connecting biophilia to biodiversity. A cursory glance at the two rather different definitions already cited reveals the first of those obstacles. The definition of biophilia, like that of biodiversity, is anything but clear. The various definitions of various proponents and even the same proponent at different times are not obviously equivalent. Second, biophilia is pure speculation. There is no direct or clear evidence for the existence of biophilia, however defined. Proponents urge that the principles of evolutionary psychology are amenable to its existence. But it is a long way from saying that something is consistent with natural law to saying that it, in fact, exists or must exist. The third difficulty has to do with connecting biophilia to any good connected with "the natural environment" for current-day humans. Let us grant for a moment that biophilia exists and that the principles of evolutionary psychology can account for its coming into existence. Even then, the mere "fact" of an evolved tendency – even one that for a long time conferred adaptive advantages – does not, by itself, make that tendency good or worth nurturing *now*. This point is obvious, for example, from human tendencies to harm or flee a person whose appearance is unfamiliar and solely on that account. One needs to beware of committing genetic fallacies.

The first three difficulties might already be fatal for the biophilia hypothesis even before any attempt is made to connect it to biodiversity. But the fourth and fifth difficulties might make them nearly irrelevant: Even if there were a clear definition of biophilia – for example, as a collection of conative or affective tendencies, or as a collection of functional capabilities; even if there were convincing evidence that these tendencies or capabilities actually exist and came to be built into human genes in the evolutionary course of things as adaptively advantageous characteristics; and even if there were a convincing argument to the effect that these tendencies constitute a good that ought to be nurtured in the lives of people now, then there remains a fourth challenge, which resembles the one faced by the ecosystem services paradigm of natural value: Insofar as biophilia is taken seriously, it appears to value, at best, a seriously fractured and truncated natural world, which thereby makes permissible behavior and actions that might lead to this result. Finally, even if *this* obstacle were surmounted, there remains the fifth and final challenge of leaping across the chasm that still separates *biodiversity* from biophilia.

Why would any significantly biodiverse state of the world be needed to satisfy biophilic inclinations? I will suggest that the biological diversity required for the purpose of nurturing biophilic tendencies appears to be vanishingly small. I will also suggest that, insofar as biophilic needs are thwarted by aversive reactions, biophilia points towards extirpating elements that would otherwise be threatening. And more generally, the demands on environments for nurturing biophilia (as specified by its advocates) are so minimal that they entail the superfluidity of anything that would pass for a truly natural environment.

My discussion focuses on the first (definitional) and the fourth and fifth (biophilia-natural good and biophilia-biodiversity spanning) problems. However, I touch on the second and third by way of getting from the first to the last two.

Let's reconsider the definition. Wilson (1996, 165) elaborates the brief one already cited by saying that

> From the scant evidence concerning its nature, biophilia is not a single instinct but a complex of *learning rules*… The *feelings* molded by the learning rules fall along several emotional spectra, from attraction to aversion, awe to indifference, and peacefulness to fear-driven anxiety… When human beings remove themselves from the *natural environment*, the learning rules are not replaced by modern versions… [italics added]

As Wilson uses the term "feelings", it seems to be an umbrella covering both conative tendencies (preferences, wants, desires, and urges) and affective ones (approval, pleasure, fulfillment, happiness, and the like). He makes clear that these "feelings" have, as either their object or source, "the natural environment".

The meaning of "learning rules" is more elusive. Wilson's explication of this phrase gives a sense that he believes that these are genetically encoded dispositions or tendencies whose presence is the result of the adaptive advantages they have conferred upon humans living in the cultures of their societies. They are rules in the sense that they might or might not be invoked – depending on the availability of a proper environment to stimulate or encourage their use. I believe that it is in this sense, too, that both Wilson and Kellert refer to them as "weak". This interpretation is reinforced by Kellert's apparently interchangeable use of "weak genetic tendencies" and "learning rules". Kellert (2005, 49–50) muddies these waters by also tossing into the stew "genetically encoded values" and "the inclination to value nature", which he appears to regard as additional equivalents of "learning rules". I make sense of these phrases as ill-chosen alternative ways to characterize affective "feelings" (again) of approval and disapproval.

One aspect of the definition of biophilia as learning rules quite directly subverts the case for biophilic value as a good for people and as a good for natural environments (difficulties three and four). While the speculative theory of the genesis of biophilic feelings posits their evolution as beneficial to the species *H. sapiens*, they are not necessarily feelings that are pleasant or that a person would desire to have. And they are not necessarily of benefit to nature. Wilson (1996, 167–169) writes at length about aversive reactions to snakes. Kellert (2009, 118) suggests that biophilic values have a "negativist perspective", which manifests when "snakes, spiders, large predators, swamps, steep precipices, lightning, and others" incite "apprehension and avoidance" or even "aversive reactions" that "provoke abusive behavior".

In sum, Wilson and Kellert seem to agree on a definition of biophilia as a set of dispositions towards "the natural environment". The dispositions include affective ones that incline humans towards both positive and negative feelings towards natural objects. Also involved are conative dispositions that incline humans to desire or seek out some things natural and to avoid others. Affective dispositions and conative ones can mix in any combination. Sometimes people are inclined to seek out – in order to destroy – natural objects that evoke negative feelings.[84]

A key phrase in Wilson's elaborated definition is "the natural environment". A lot rests on this phrase because it must be understood in a way that helps to fill the gap between biophilia and some coherent view of the natural world. It must also be understood so as to bridge the chasm between biophilia and biodiversity. So how is "the natural environment" to be understood? Kellert says some things about "nature" that shed light on this. For him "nature" is an enormous umbrella and many things camp out beneath it. Among them is "self-sustaining nature", which he takes to be more or less equivalent to "relatively undisturbed nature". This includes (Kellert 2009, 101–103) everything from what one some might call "wilderness" to (perhaps surprisingly) urban parks and gardens where human-made structures are not excessively intrusive. But for Kellert (2009, 104–111), "nature" also covers "domesticated nature", which includes your pet dog and the potted plant in your cubicle; also "neighborhood or community nature", which is the unbuilt, manicured lawn-covered space between your house and your neighbor's. In essence, nature is roughly anything nonhuman not made in a factory. Furthermore (Kellert 2009, 99),

> … the term *natural diversity*… encompasses any form of direct, indirect, or symbolic experience of the nonhuman world. [italics in the original]

Here, I presume that Kellert is not promulgating a tenet of Berkeleyan idealist metaphysics wherein real things are (literally) conceived as boiling down to collections of our ideas-as-symbols of them. Rather, I think it safe to assume that he intends to describe some kind of *experience* of natural diversity. He takes that experience to be equivalent to experiential contact with anything nonhuman and not made in a factory – although that description might be challenged were that aforementioned manicured lawn a "Roundup-ready" variety.

I now turn to the problem of how one might get from the biophilic starting point, so defined, to an affirmation of the value of biodiversity (the chasm of problem five) by way of finding a "good" in biophilia. But before doing that, a few words are in order about evidence for biophilia as a descriptive hypothesis about innate tendencies that are the product of evolution. This is the second difficulty mentioned above,

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[84] In an unpublished paper, Dan Haybron perceptively distinguishes between a "weak" version versus a "strong" version of the biophilia hypothesis. The weak form supposes a desire – a mere liking. The strong, more tenuously conjectural version of the hypothesis supposes a need. My treatment presumes something in between – a desire whose fulfillment is actually beneficial, whether or not this constitutes the satisfaction of a full-fledged need. I believe that something like this intermediate form is what is most easily extracted from the writings of biophilia's proponents.

Haybron also distinguishes between mere "contact with nature" versus some more significant "active engagement with nature", wherein a person engages in a way that involves acute skill, knowledge, and awareness. Both of Haybron's distinctions (weak versus strong and mere contact versus engagement) are important for a full understanding of the scope and limits of the concept of biophilia. However, these distinctions are peripheral for my central and more limited purpose of determining whether there is any way to connect biophilia (in any form) to biodiversity.

These qualifications owe to personal correspondence with Haybron on his work.

stripped of any normative veneer. Wilson's definition of biophilia (cited above) concedes "scant evidence" for it. Indeed, he presents no independent evidence for it at all. In lieu of that, he (Wilson 1996, 166) states that biophilia is a logical implication of evolutionary theory; it is, as he says, "compelled by pure evolutionary logic". Unfortunately, the "logic" is a story about how people (as well as Old World monkeys and apes) might have come to be leery of snakes. While informed by Wilson's formidable grasp of evolutionary biology, this is really a "Just So" story – an unfalsifiable genesis narrative about how cercophithecids and hominines might have acquired such a trait as a consequence of the adaptive advantages that it might have conferred upon them.[85]

Even if Wilson's "Just So" story is accepted without question, it still does not answer a critical question. That question concerns whether or not the biophilic trait is still functional in modern humans. "Evolutionary logic" might lead one to speculate that, given the societies and environments in which people have now lived for thousands of years, the trait has, for some time, not conferred much advantage. Could it therefore have become largely vestigial? A credible answer to this question requires evidence.

Kellert gets past genesis stories and tries to address the need for evidence, presenting a number of studies to this end. But their cogency in support of biophilia is underwhelming. This is partly because, as he (Kellert 2009, 107) admits, "Few of these studies have been rigorously conducted." It is also partly because, rigor aside, their results do little to support the normative burden that is subsequently placed on them. As I shall show, they have little to do with "self-sustaining nature" and apparently nothing at all to do with biodiversity.

For the sake of further discussion, I suppose that Wilson's "Just So" story of biophilia's genesis solves the second difficulty. With regard to the third difficulty, let me also provisionally suppose that biophilia is not (yet) vestigial in humans. This lets me move on to normative part of the third difficulty, which has to do with extracting some kind of value from this allegedly non-vestigial tendency. Is the exercise of biophilic tendencies by people a good and furthermore a good that accrues to people in and only in a "natural environment"? The mostly anecdotal evidence that Kellert presents might at first make one think so. That "evidence" is largely a tale about the apparently pleasant effects that "nonhuman things not made in a factory" have on people – a walk in a park, greenery outside a hospital window, grass instead of concrete between adjacent houses.

But even if one receives Kellert's evidence with uncritical acceptance, chinks already begin to appear in the biophilia-based case for nature being a good for people. Kellert (2009, 106) inadvertently helps to identify one chink in the course of making his case on the grounds that "natural lighting, natural ventilation, [and] natural materials" in buildings "enhance worker comfort, satisfaction, [and] physical and mental well-being." This makes it apparent that, whatever benefits Kellert

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[85] I am here using "Just So" in the sense of Rudyard Kipling's account of the genesis of the camel's hump and the leopard's spots. This is but a very distant relative to the "just so" model of the calculus of biodiversity value, described in Sect. 5.1.4 (The just-so model).

believes might accrue from the exercise of biophilic tendencies, the need for "something nonhuman not made in a factory" might well be supplanted by "something nonhuman that *can* be made in a factory if it adequately simulates a 'natural environment'". This raises the general question of whether or not "the real thing" is indispensable, so far as the satisfaction of biophilic tendencies is concerned. On Kellert's account, this seems quite doubtful. Kellert (2009, 102) also supposes that aesthetic benefits follow from biophilic tendencies. Insofar as these tendencies are satisfied by such fabrications as potted plants and Kellert's criteria qualify artificial ones, this is another case in point.

A second chink in Kellert's case – for biophilia as the basis for the good of nature – has to do with his (and Wilson's) acknowledgement that nature is not always so good for people; that it is not always pleasant or attractive; and that it threatens us and leads to very unpleasant, aversive reactions. It is difficult to understand how snakes, dark forests, and animals that threaten to eat us can be understood to evince the kind of positive affiliation on which biophilia advocates build their case. It seems that, in the name of biophilia, one is committed to say, "so much the worse for snakes, dark forests, and big toothy animals."

The last observation merges into the fourth difficulty, which is whether or not biophilia is a credible basis for valuing the natural world. The first part of biophilia's answer seems to be that the whole of nature cannot be regarded as valuable, since at least those elements that biophilic inclinations reject must likewise be rejected and therefore excluded. So in the absence of other considerations, biophilia seems to endorse a very "patchy", human-selected and architected view of the natural world, at best. At least, a more sophisticated argument is required to break the connection between natural value and an affirmative orientation whose focus is narrow and restricted to the relatively small portions of the natural world that people are likely to regard as human-friendly.[86]

I leave off an exploration of what such an argument might look like in favor of examining the fifth and final obstacle – the chasm between biophilia and biodiversity – that most directly relates to the central topic of this chapter. This chasm is, I think, unbridged; and most likely, unbridgeable.

E.O. Wilson doesn't even attempt a bridge. In a kind of Chewbacca defense, he (Wilson 1996, 170) leaps without explanation from a speculation on the possible psychological implications of limited opportunities to exercise biophilic inclinations directly to a lament about the global loss of biodiversity. Does loss of biodiversity figure importantly, or even in some limited way in the loss of such biophilic opportunities? Wilson offers no argument at all to persuade us that it does. Moreover, given the

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[86] The most promising such argument is one that Dan Haybron develops in the unpublished paper mentioned in Note 83. It makes the conjecture that some active engagement with nature might be essential for the full development of certain human capacities, which in turn, are part of a fully realized human life. Unfortunately, Haybron explicitly excludes dispositions that do not have a pro-orientation towards nature; so he is not taking in the full compass of biophilia, as I understand it. However, I see a potential for this approach to bring the negative dispositions back into the biophilic fold, and even strengthen Haybron's case as a consequence.

sorts of “natural diversity” that, on his account, suffice to provide such opportunities, it would be extremely surprising if the loss of even the entire 30% of species that Wilson and others consider at risk would have any palpable biophilic effect.

If anything, the existence of a bridge between biophilia and biodiversity is made more dubious by Kellert’s attempts (Kellert 2009, 106–109) to deal with the difficulties that Wilson ignores. Kellert’s arguments are plagued by difficulties that fall into several categories. First, virtually all the arguments for the benefits of exercising biophilic tendencies are so easily satisfied that they make no meaningful requirement on even “self-sustaining nature”, let alone biological diversity. That a window looking out on a tree is better for a surgery patient than a window looking out on a brick wall; that domesticated animals make nice companions; that potted palms are welcome additions to cubicles at work; that natural lighting is favored over fluorescents; that groomed parks are nice places to walk; that suburban developments featuring more “open space” are favored over ones that do not: none of these things have any, even remote connection to biodiversity in the sense that makes environmentalists such as Wilson lament the Sixth Great Extinction. It is difficult to imagine how even adding a *Seventh* Great Extinction would affect our ability to have far more than enough biological diversity to have potted plants and natural lighting.

Ethnobiologist Alain Froment (2009, 213) puts it this way:

> Psychologically, the contemplation of a “natural” landscape is recognized as excellent for mental health, but biodiversity is not a factor here. First, most of the landscape, such as a garden or the countryside, is not “natural”, but humanized. Second, viewing an environment poor in biodiversity, such as bears on the Arctic Circle, may be more mentally beneficial than a rich environment like a jungle, which may cause anguish in some. For the “civilized” world, forests (from the Latin *foris*, “outside”) are savage (from the Latin *silva*, “forest”) and wild jungles (from the Hindi *jangal*, “uninhabited space”) can generate anxiety. There is, then, no direct correlation between the relaxing role and comfort provided by nature, and wealth of biodiversity.[87]

Second, the exercise of some biophilic inclinations militates directly *against* biodiversity. People want clear ponds and fast-moving streams (Kellert 2009, 102). That is a strike against inviting beavers “back in”; for some, it is strike three after the first two strikes of chewing on trees and flooding farmers’ fields (Taylor 2009).[88] The many creatures that elicit aversive responses would not do so if they were extinguished. Many people do indeed feel the beckoning call of “nature”, which they satisfy with behavior that is detrimental to biodiversity. The inclinations of off-road vehicle users in the American West come immediately to mind. These people truly appreciate the majestic backdrops – in fact, regard them as essential – for the pleasures of their “habitat-converting” sport. So much the worse for the creatures that once lived there.

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[87] Of course, beholding a Polar bear in close proximity might be substantial cause for anguish, too. This observation doesn’t so much undermine Froment’s point as it underscores the more damaging one for biophilia – namely, that it has no respect for biodiversity.

[88] For more on the various services and disservices that *Castor Canadensis* offers, see Sect. 6.3 (Biodiversity as service provider).

The third and last point connects back to Wilson's lament for the loss of biodiversity. Even if one grants each and every biophilic benefit and even if (contrary to fact and even Kellert's account) each benefit requires "relatively undisturbed nature" in Kellert's sense, then these benefits still are easily and readily available in a world undergoing the kind of mass extinction that E.O. Wilson and others decry. There is no solid case for the proposition that biophilic tendencies really exist. Nor is there a solid case for the proposition that, if they do exist, then their exercise constitutes an integral part of human flourishing. But even supposing the truth of these propositions, biodiversity – at least the sort of significant biological diversity that truly concerns biologists and environmentalists, as opposed to having natural interior lighting or a nice lawn to separate you from your neighbor – would be entirely dispensable for biophilic benefits.

The unbridgeable gap between biophilia and biodiversity is not held open by an imagined theoretical replacement of the experience of biodiversity by a functioning set of Delgado buttons. Nor does the gap persist on account of a supposed prospect for replacing the current biodiverse state of the world with some other one equally biodiverse. The problem is that real biodiversity is mostly and perhaps entirely irrelevant to biophilia.

6.7 Biodiversity as Value Generator

Several accounts of biodiversity value attempt to locate it as a kind of meta-value, which derives from its capability and performance as a value-*generating* engine. The forestry biologist and philosopher Paul Wood, for one, tries to make a case for biodiversity's value as primarily a matter of its being, more specifically, a *biodiversity*-engendering engine. He (Wood 2000, 51–57) tries to avoid the obvious apparent circularity in this proposition by saying that the biodiversity-engendering capabilities of biodiversity constitute a tertiary value which is a precondition for the secondary value of adaptive evolution, which in turn, is a precondition for maintaining a range of biological resources, which is biodiversity's proximate value. I address the question of circularity shortly.

Bryan Norton (2001, 90–94) also talks about creativity as the core value of biodiversity. He (Norton 2001, 90–91) has in mind

> … the processes that have created and sustained the species and elements that currently exist, rather than … the species and elements themselves.

His discussion is opaque about whether biodiversity is the cause or the effect of this creativity. But it is plausible to interpret his position as essentially that of Wood – namely, that biodiversity is the fuel for a process that engenders more biodiversity whose components are good stuff (resources) or have good properties (offer services).[89]

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[89] As in Sect. 6.3 (Biodiversity as service provider), I utilize the consensus definition of "ecosystem services" offered by Hooper et al. (2005, 7).

Sahotra Sarkar (2005, 103) seems to bark up much the same value tree as Wood and Norton when he speaks of diversity as engendering a kind of valuable “novelty”, by which he means something that “will contribute something new to science”.[90]

This proposal for biodiversity’s value is unconvincing in light of two observations. First, in its several variations, the value of biodiversity-as-value-generator devolves into the value of what is generated. Going “one level up” does not remove the burden of justifying the value of whatever is generated at the lower level. Of course, finding that what is generated is valuable lends legitimacy to the claim that whatever is capable of ensuring a steady supply of that value-laden product is itself valuable as a means to that end. But Wood, Norton, and Sarkar all suggest that what biodiversity generates is … biodiversity. That is, according to them, biodiversity is valuable as a means to the end of biodiversity.

All three advocates seem to realize that this point in their argument remains far from a successful conclusion. Wood pushes ahead by saying that ultimately, generated biodiversity constitutes resources. Norton says (among a dizzying assortment of other things) that the generation of biodiversity is a kind of productivity. For Sarkar, it is (again, among other things) the “stuff” of biological science. In each instance, the case must ultimately be anchored in these ends. Unfortunately, there is ample reason to be skeptical that any of these proposals is a reliably firm final anchor for value.

Norton’s notion of productivity is a non-starter, for as discussed in Sect. 6.3 (Biodiversity as service provider), there is both bad and good productivity. Perhaps the most promising of these proposals is Wood’s – that generated biodiversity is tantamount to generated resources. But it is hard to see how diversity in itself constitutes a resource, except by courtesy of the entities that constitute the diverse set; and Sect. 6.2 (Biodiversity as resource) shows how tenuous is the case for connecting these two different things. Often recited is the proposition that (for example) a new species is a kind of “raw material”, which necessarily gives humankind new options for constructing solutions to problems. After all, the more and varied kinds of raw materials, the more design choices we have.[91]

The very phrasing of this recitation prejudices the issue by suppressing a couple of questions that admit contravening answers. First, what good reason is there to believe that, say, an encounter with a new species is likely to present itself as a resource for humankind’s use rather than as an impediment to humankind’s general good – say, by eating resources, by carrying a previously unknown disease, or by just getting in the way of human development? A novel organism is not necessarily a benign hammer waiting to be picked up when humankind discovers a nail that it

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[90] This statement is part of Sarkar’s theory of “transformative value”, discussed separately in Sect. 6.10 (Biodiversity as transformative). His statement also suggests the value proposition of biodiversity as contributing to human knowledge. That topic is also treated separately – in Sect. 6.8 (Biodiversity as font of knowledge).

[91] I am indebted to Jeffrey Lockwood for forcing me to clarify, tighten, and properly qualify my argument here and in the remainder of this section.

can drive. It could just as well be a malignant hammer that picks itself up and whacks away at human well-being.

The second question is twin to the first. To what extent does the recitation presume a strictly additive conception involving a continual adding to a stockpile, each element of which (and its quality as stockpiled resource) does not otherwise change? This picture is at war with itself. It presumes a creative dynamic that generates new resources; upon their creation, the dynamics fall away and the resources enter a static state in which their resource-providing qualities are thereafter frozen.

By asking these two questions, one can see that the plea for novelty rests on an unsupported and perhaps unsupportable assumption – namely that the new will serve humans at least as well as the old. The plausibility of this assumption requires a picture of an evolving world in which resources are continually replenished; services continue undiminished, uninterrupted, and perhaps even augmented. But from a naturalistic perspective (which I suppose those who promote the novelty thesis to have), no purpose, and particularly, no benign or human-benefiting purpose, can be justifiably presumed. And no resource can be assumed to be immune to some novel circumstance that transforms it into something entirely unhelpful, a burden, or worse.

One could legitimately ask why it is not just as likely that the creative forces of nature might create a nightmare world for humans – say a world with a methane-dominated atmosphere (again), or one that contains a crafty predator with a taste for human flesh – as that it create a paradise. Just over 70,000 years ago, one nightmare scenario (though probably not predominantly biotic in origin) did play out, and it brought the recently emerged species *H. sapiens* to the brink of extinction (Ambrose 1998, 2003).[92] But so far as I can tell, an unbiased review of geological history does not favor one "creative" possibility over the other. Moreover, the question of whether or not "the creative forces of nature" favor or disfavor the retention of biodiversity is open. The current biodiverse state of affairs (not the diversity of it, *per se*) notably features an apex species with a penchant for re-engineering everything around it for what it perceives to be its own considered, near-term benefit. Taking that into account points towards the likelihood that those creative forces will lead to a novel state of significantly diminished biodiversity.

The second observation of the two mentioned at this section's outset derives from the notion of trying to evade the preceding criticisms by taking the forces of "creativity" or "novelty" seriously as independent bearers of value that do not ultimately depend on the value of the novel resources or services that they create. It is possible that there is a case to be made for this. But the rationale is not obvious, I cannot construct it, and none of the above-cited authors even attempt to sketch such a case. Why should something have positive value just because it is new? Why should novelty be more valued than what we have now? No satisfactory answers are forthcoming.

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[92] See Note 5 in Chap. 5 for a brief account of the paleontological background for this.

Sarkar might at first appear to offer an answer to this question by suggesting that novelty feeds scientific knowledge (which I discuss separately in Sect. 6.8, Biodiversity as font of knowledge). But further reflection reveals how precarious this position is. An opportunity to study the natural world undoubtedly serves a deep-seated human need to know about the world. But there seems to be no reason think that one kind of world – say, a more biodiverse one or one with a greater rate of novel creature creations – would serve that need better than one in which biodiversity wildly fluctuates and sometimes (perhaps around now) plummets, with an attendant decrease in the rate of novel creations. The point of inquiry is to understand how the world works, whatever its dynamics, whatever the engines of change, and whatever the current or future state of biodiversity.

Moreover, the notion of "novelty" is pliable in a way that just as legitimately permits one to argue that a dramatic reduction in diverse biotic and biota-encompassing kinds would provide the most novel of circumstances. Though successors to kinds that are now being swept aside might take some number of human generations to fully evolve (an issue that I address separately below), this does not detract from the novelty of actually being at the start of such a dramatic biotic event. Moreover, even the first incremental step in "recovery" would be more novel – and possibly far more novel – than maintaining the *status quo*. Realizing this, in turn, makes it easier to call into question the independent value of novelty, as I already have.

Finally, something should be said about the diversity that might arise out of current extinctions. If a great extinction event is indeed now underway, by most accounts, it differs in some significant respects from previous ones. For example, it probably involves a greater preponderance of plants; and many of the facilitating conditions can, in some measure, be traced to the behavior and activities of one species that did not exist during any prior great extinction. Therefore, it, it is risky to draw any inferences based on induction from previous such events. With that as preface, consider the suggestion, sometimes made, that current reductions in kinds of species constitute the single most powerful way to encourage the generation of entirely new kinds in every category of biodiversity. On this account, a great extinction should be welcome as a way to renew and refresh biodiversity – a way to attain a diversity of diversities, strung out along the planet's timeline.

The standard response is to dismiss this suggestion as a clever but insubstantial argument, which surreptitiously and illegitimately trades geological timeframes for shorter, more human-relevant ones measured in numbers of human generations. In the short term relevant for people, it is said, we are screwed out of biodiversity. But this is a misleadingly incomplete account of what is actually going on. It is true that full recovery – in the sense of re-attaining a similar level of species diversity in the largest organisms most palpable to humans – is likely to be measured in expansive timeframes. But adaptive changes in many organisms will occur (and are now occurring) quite rapidly; in some cases, these changes will engender (and are engendering) new species; and these near-term, species-engendering changes will be (and sometimes are) accelerated by some of the same forces that are simultaneously causing the extinction of other organisms. In other words, it is likely that, despite the extinctions, biodiversity overall will not suffer nearly so much in the relatively near future as one might think by focusing exclusively on the extinctions.

For example: There is increasing and increasingly compelling evidence (for example, Sax et al. 2007; Vellend et al. 2007) that species immigrations can and do trigger rapid selective adaptation and rapid changes in phenotypical expression. Possible mechanisms include (viable) hybridization, "disruptive selection" of natives (whereby traits at the extremes are favored significantly over intermediate ones), and the adaptive transformation of the immigrants in their new and geographically disconnected environment (which can lead to allopatric speciation).[93] Various of these mechanisms significantly push the evolution of plants, which are disproportionately vulnerable to current-day extinction pressures. For example, in studies of *Hypericum perforatum* (St. John's wort), ecologist John Maron and his colleagues (2004) find evidence that evolution can sometimes be quite rapid for a recent "transplant" that finds itself in a novel environment. Jason Sexton and his colleagues (2002) examined the (in)famous case of "invasive" tamarisk in the U.S. southwest and found "surprisingly high levels of genetic variation. This along with other factors, such as persistence long enough to experience adaptive evolution", they (Sexton et al. 2002, 1652) say, grounds a "potential for evolutionary increases in invasive traits and plasticity" that may "greatly influence their future invasiveness" (Sexton et al. 2002, 1658).

In the realm of animals, entomologist Anna Himler and colleagues (2011, 254) report that the invasion of an invader – *Bemisia tabaci* (sweet potato whitefly) by a *Rickettsia* bacterium – induced a dramatic shift in the whitefly phenotype, whereby it "produced more offspring, had higher survival to adulthood, developed faster, and produced a higher proportion of daughters". Biologist Olivia Judson (2008a) relates a variety of other cases of rapid evolution, some of which do not involve recent immigrants. But one that does is the assisted immigration of *Podarcis sicula* (wall lizard) from the Croatian island of Pod Kopište to nearby Pod Mrčaru. Geographically isolated in their new island getaway and perhaps on their way to allopatric speciation, these creatures quickly evolved cecal valves. This "suggests [to Judson] that arrival in a new environment can result in dramatic changes to an organism within fewer than 40 lifetimes."[94] She (Judson 2008a) concludes that:

> At least one other lesson can be drawn from all these studies. Natural selection has its most dramatic effects when an organism's environment is perturbed in some sustained way – prolonged droughts, the arrival of species that compete for food, warmer winters, the use of pesticides. If we humans continue to increase our impact on the globe, we're likely to see lots more evolution. And soon.

This kind of evidence suggests that some novelty emerges quite quickly in rapidly reproducing and adapting organisms. Consider that the preponderance of the

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[93] See Sax and Gaines (2003) for a description of hybridization processes.

[94] This figure overshoots the number reported by Herrel et al. (2008, 4793), the source for Judson's account of *P. sicula*. Those researchers document 30 generations of the lizard, which emerged over the course of a 36-year study.

planet's organisms – lizards are one speciose group, but insects account for something like half the planet's non-bacterial species – meet this description. This means that one can plausibly expect some considerable amount of novelty to emerge within the lifetime of currently respiring humans, some within a few generations, and much more within human historical frameworks. Something like "full recovery" of diversity within the most species-diverse groups might well occur, and well within the "lifetime" of the human species. And very likely much of this recovery will occur well before current events become ancient history.

These considerations tend to be lost in frequent recitations that, according to the geological record, it takes from 5 to 10 million years to "recover" from a mass extinction event (Kirchner and Weil 2000). More recent work (Brayard et al. 2009) on the Permian extinction event – which finds that ammonoid cephalopods recovered in something more like 1–2 million years – might call for a reevaluation of the larger numbers.[95] While still long, the shorter timeframe is significantly shorter by virtue of falling more comfortably within the likely lifetime of the human species.[96] But it is still two orders of magnitude longer than human historical timeframes, which one might suppose to be on the order of 10,000 years.

I revisit the topic of timeframes for recovery from a great extinction event in Sect. 7.3 (Biodiversity value in human timeframes). For now, let's suppose that something that one might be willing to call "full recovery" of the diversity of life forms might span the entire lifetime of our species. How much weight should this carry? The answer to that question, I believe, must find the relative weight of two other considerations. The first consideration is one that I suggested above: Much evolutionary working out is already well under way, likely at accelerated rates; and much recovery of diversity is likely to occur well within human historical timeframes – though perhaps among organisms (such as reptiles and insects) that some might (unjustifiably) tend to disregard or discount. The second consideration reconnects with the love of novelty expressed by Wood, Norton, and Sarkar. It involves a sober and unbiased assessment of the extent to which this love can be justified, given a sober and unbiased assessment of whether novel modes of being bode ill or well. This assessment is strongly reminiscent of the basic conundrum of evaluating diversity itself: As Cowper's poem (Sect. 2.3.2, The value of diversity in general) brings home, there is good variety; but there is also bad variety. Much the same can be said about novelty.

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[95] But once again, inductive caution is called for.

[96] In the background of my discussion is a picture of species lifetimes that looks something like this: According to some standard estimates, the average lifetime of invertebrate species (or at least marine invertebrates) is 5–10 million years, plant species around 3.5 million years (Niklas et al. 1983), small mammals perhaps 2.5 million years (van Dam et al. 2006, 687), and megafaunal mammal species such as *H. sapiens* around perhaps 1 million (May 1995, 14). For mammals, longevity honors of 16 million years go to such smaller members of the class as mole and dormouse (Liow et al. 2008, 6099). Within this temporal framework, *H. sapiens* is still at the beginning of its run on the planet – begun around 200,000 years ago. Combined with the uncertainty in "recovery" times (in the narrow sense that prejudicially excludes the vast majority of rapidly evolving organisms), which might be shorter than previously supposed, these numbers make it plausible to suppose that people might be around to witness a "full recovery" of a major extinction event.

All things considered, it is hard to avoid an ironic suspicion that Wood, Norton, and Sarkar are not so much interested in novelty as in the polar opposite, the *status quo*, which they are highly disinclined to see upset. One might speculate that these advocates of biodiversity-as-novelty-generator trip over their view that creativity is acceptable so long as it does not alter the current, particular biodiverse state of affairs whose peculiar mix of kinds in various biological categories (not necessarily their diversity) more or less satisfactorily meets human desires and needs for resources and services.

6.8 Biodiversity as Font of Knowledge

Biodiversity is often cited as the subject of biological study and therefore as a rich source of human knowledge. This suggestion already came up (in the preceding section) by way of Sarkar's views on "novelty". More famous is E.O. Wilson's trope of the "Great Encyclopedia of Life", which was inspired by the words – now ubiquitous in discussions about biodiversity – of his friend and colleague, the chemical ecologist Thomas Eisner (1982). Eisner was writing less about knowledge, considered abstractly as a human good, than with the relish of a genetic engineer (at a Monsanto Symposium) about the genes that he would like to see diced and spliced into genetically improved models of organisms:

> As a consequence of recent advances in genetic engineering, [a biological species] must be viewed… as a depository of genes that are potentially transferable. A species is not merely a hard-bound volume of the library of nature. It is a loose-leaf book, whose individual pages, the genes, might be available for selective transfer and modification of other species.[97]

Wilson steers Eisner's vision of biodiversity as raw material for biotechnological bounty towards what some might regard as higher ground. He does this by borrowing heavily from the Shannon-Wiener information-theoretical tradition of measuring biodiversity (touched on in Sect. 4.1.2, Measures and indexes). In this tradition, biological entities – for Shannon-Wiener entropy it is species; here it includes genes as well as species – as bits of information. It is but a short step from there to reimagining these bits into a vision of a fabulous library in which they are the contents. Wilson (1992, 151) asks us

> … to imagine… that all the diversity of the world were finally revealed and then described, say one page to a species… … this Great Encyclopedia of Life would occupy 60 meters of library shelf per million species.

He asserts (Wilson 2002, 131) that

> Each species… offers an endless bounty of knowledge… It is a living library.

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[97] Wilson (1992, 302) also quotes this passage, but he (1992, 381) cites the wrong paper and does not reveal the genetic engineering context in which the passage occurs.

And so on. This vision haunts almost every one of Wilson's writings about biodiversity. It also appears in the writings of Holmes Rolston (1988, 98–99), who closely mirrors Eisner's characterization of organisms as constituting a "genetic library". From these origins, the vision appears to have achieved a life of its own, whereby it regularly finds its way into other work, typically without reference to its originators.[98] As one example among many, the philosopher Jeremy Bendik-Keymer (2011, 15), drawing on Rolston, picks up and imaginatively embellishes the library trope:

> If a species is like a book in the library of life, an evolutionary story that is distinct and unique, the genus to which it belongs is a genre of books, for instance, books of sonnets. Its family is then a kind of literature, e.g., poetry –in other words, a section of the library, not just a book in a stack. If, for instance, a species went extinct, but much of its family remained, then the Earth would still have a considerable record of the evolutionary achievement that allowed species such as it to exist. We might miss this particular book of poems, but we would still have poems. Species like it could continue to evolve, since the family would be intact. But if the family goes extinct, then the chance of continuing evolution along anything like the species's line is gone. In other words, by our mass extinction voiding sections of nature's library, we are erasing whole areas of evolution.

Unfortunately, neither Wilson, nor Bendik-Keymer, nor any of the many who have utilized this trope on behalf of biodiversity have given serious consideration to whether or not it is capable of the normative lifting for which it is pressed into service.[99]

Surely some caution is in order insofar as the basis for the trope's power lies in the assumption that all knowledge constitutes a good. One should beware of granting, without qualification or reservation, that any knowledge is worth pursuing or that it is worth pursuing at any expense. The repugnant aim of a project to determine how, most cost-effectively, to torture people is a serious reason not to pursue it. The vacuous aim of a project to count the precise number of pushups that an individual *Sceloporus occidentalis* (western fence lizard) performs over the course of its lifetime (in contrast to studying the role that this signaling behavior plays in a western fence lizard's life) should suffice to raise questions about its worthiness. Still, it seems safe to say that no one would seriously question the pursuit of biological knowledge generally or knowledge of biodiversity in particular on grounds of repugnant purpose, vacuousness, or any similar obvious objection.

It is certainly true that the biological world as it exists today, and specifically, the diversity of kinds in the world right now, is largely unexplored. Focusing just on species diversity, only around 1.5 million species or so have been documented. Few among these have received extensive study. By conservative estimates, the 1.5 million

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[98] Perhaps another indicator of how uncritically the trope is often tossed out is that some authors acknowledge Eisner by way of Wilson's incorrect citation.

[99] In this context, Bendik-Keymer offers a logically separate argument having to do with the familiarity of the existing contingent of organisms. I will not address that argument here except to note one obvious weakness, which derives from the fact that the vast majority of organisms are not known and therefore completely unfamiliar.

known species are less (and most likely, considerably less) than one-sixth of the actual total of 10 million or perhaps many more.

However, the untapped bits of knowledge locked up in these organisms is but one type of knowledge that one can hope to have about the biological world. Much, too, could be learned from a vastly changed biological world that contained a significantly different set of species with significantly different population sizes (abundances). Minimally, this alternative would provide an unparalleled perspective on biological systems, which now are necessarily viewed (advances in paleoecology notwithstanding) largely through the highly biased lens of their current and very recent states. It is highly likely that the new perspective would immediately suggest new relationships in nature that are currently hard to discern. Just as likely, the new state of the world would reveal that some relationships that now seem hard and fast are, in fact, highly circumstantial and evanescent anomalies.

Also, the very processes involved in bringing about such an altered world (of differently composed and even reduced biodiversity) would be a rich source of knowledge that could not be tapped except by observing them unfold. What better way would there be to study previous extinction events, whose geological remove makes their reconstruction – necessarily on the basis of scant and patchy evidence – a complex puzzle whose solution might be forever underdetermined by the evidence? Ecologist Dov Sax and his various colleagues make similar observations with regard to species immigrations and their role in the extinction of "native" species.[100] These are "experiments" that could not otherwise be conducted over such large spatial and temporal scales. They permit scientists to observe ecological and evolutionary processes in action and with unprecedentedly direct access to how and at what rates these processes unfold.

This is not to say that humans should intentionally go about exterminating species in a morbid grand experiment. It is to say that if human behaviors that are an integral part of valuable human projects impose adaptive pressures, and if those adaptive pressures push some organisms towards extinction, remix others, and create yet others via speciation, then this provides an opportunity to develop an understanding of these processes that might not otherwise present itself.

There might be criteria that justify a preference for knowledge that accrues from the study of currently extant organisms frozen in time, in their current assemblages in their current environments, to knowledge that accrues from the study of flux in all these things. But I am not aware of any discussion that even raises the question of this tension, let alone argues that one or another set of criteria constitute a legitimate basis for determining the answer. In short, with all due respect to Shakespeare and Dante, the problem with the library of organisms is that its value for promoting knowledge can be realized in ways that do not include merely trying to keep every single volume on the shelf.

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[100] According to Sax and his colleagues, the best evidence shows that the role of invaders in extinction is constrained by many factors bearing on the characteristics of the invader and those of the members of the target community. For discussion of the knowledge-advancing role of species invasions, see Sax and Gaines (2008) and Sax et al. (2007).

6.9 Biodiversity Options

As mentioned in Sect. 6.2 (Biodiversity as resource), Daniel Faith (2007, §1 and §3.2) proposes a conservation axiology based on option value. James Maclaurin and Kim Sterelny, both philosophers of biology, pick this idea up where Faith (2007) leaves it off. In fact, they try to run with what they call (Maclaurin and Sterelny 2008, 154) "The Option Value Option", not as an adjunct to other considerations, but as the sole basis for valuing biodiversity.

I focus my discussion of "biodiversity options" by scrutinizing Maclaurin and Sterelny's account.[101] I justify this focus by the fact that, for all the peculiarities of their approach, these authors are among the few who bring to the discussion a solid scientific grounding, who concern themselves primarily with applying option value to biodiversity, and who go beyond the briefest of gestures along the lines of: "We should keep our options open." Their treatment is also a reasonable basis for a general reassessment of "The Option Value Option" – that is, whether or not option value, properly understood, is a suitable candidate for representing some part of biodiversity's value.

Maclaurin and Sterelny (2008, 154) offer a quick definition of option value:

> [Option value] is the additional amount a person would pay for some amenity, over and above its current value in consumption, to maintain the option of having that amenity available for the future, given that the future availability of the amenity (its supply) is uncertain.[102]

Perhaps this definition is a little too quick. At best, it is misleading insofar as it differs in several fundamental respects from standard definitions of "option value" in the primary economic literature.

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[101] Maclaurin and Sterelny's treatment of option value (Maclaurin and Sterelny 2008, 149–171) is the subject of Chap. 8, "Conservation Biology: The Evaluation Problem". Chapt. 7 on "Conservation Biology: The Measurement Problem" is preparatory material for Chap. 8's exercise in evaluation. In toto, this treatment of value – their version of *What's So Good about Biodiversity* – occupies over one-fifth of their book, whose remainder is devoted to a detailed scrutiny of their titular definitional question, *What is Biodiversity?*

I am not centrally concerned with how these authors answer the "what" question. However, I believe their treatment of the "value" question is influenced by and very likely partly derailed by building the value into the "what". According them (Maclaurin and Sterelny 2008, 174), the concept of biodiversity is based on species richness (so far, so good), which "… has to be elaborated in different ways for different biological purposes". With "biological purpose", Maclaurin and Sterelny are not referring to some "creative design". Rather, they quite straightforwardly mean, "the purpose of a biological investigator trying to establish some ecological relationship". But this, in turn, means that biodiversity is whatever a biological researcher would like it to mean, so that an ecological relationship established in the research can be said to be about biodiversity. While this in no way trivializes the research or its results, it does seem to trivialize the concept of biodiversity as the basis for a sweeping norm.

[102] Although Maclaurin and Sterelny omit quotation marks and a citation, their definition of option value is, word for word, that of van Kooten and Bulte (2000, 295).

First, it is couched in terms of a premium over "[an amenity's] current value in consumption". Although some economists presume that this "premium" must be positive, others show how, in fact, it can be negative, positive, or undefined; and moreover, that it can be negative even with risk-averse individuals. Calling an amount of money that you would demand in compensation "a premium", which implies an amount you might be willing to pay, prejudices the discussion. Second, the "premium" is, in fact, relative to expected consumer surplus. Expected consumer surplus is not (as supposed in the above definition) the "current value", but rather the *expected* value of future consumption.[103] Third, their definition implies that "the current value in consumption" is a kind of single, fixed price tag. But this is not at all the correct picture. Option value is really defined by reference to expected consumer surplus. Expected surplus is not a single price tag attached to an entity. Rather, it is a statistic computed from values that vary in various possible realized states of the world, taking into account the probability with which each state might be realized. Fourth, their definition, which characterizes the situation as one in which "the future availability of the amenity (its supply) is uncertain", obscures, if not falsifies, the working assumption of most definitions of option value. According to them, the supply is entirely *certain* because determined by the dichotomous choice to conserve or not to conserve. Supply is (assumed) assured by conservation; it is (assumed) zero in the absence of conservation.[104] Fifth, the definition fails to properly attend to the kind of uncertainty that does give rise to option value, according to many economists. That is uncertainty in a consumer's demand for the good, which might or might not be conserved. For better or for worse, in some possible states of the world, the consumer might not want it at all.

Maclaurin and Sterelny give an equally quick definition of quasi-option value.[105] Their acknowledgment of this separate category of economic value is a credit to their discussion because quasi-option value more rarely escapes the confines of specialized economic treatment. But while quasi-option value has a conceptual common ancestor with "garden-variety" option value,[106] it differs fundamentally in explicitly incorporating into the decision model an intertemporal framework, an

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[103] Economists routinely *translate* the expected consumer surplus into the *present value* of expected surplus by applying the "social discount rate". This discount rate is an ethical hornet's nest that a lack of space advises against touching here. But even the present value of expected consumer surplus is the (expected) value of *future* consumption – albeit in current dollar terms.

[104] Though as mentioned further on in the main text, some treatments of option value do allow that the supply of a resource (such as biodiversity) is not fixed by a choice of development path.

[105] This is the term that Arrow and Fisher (1974, 315) used to introduce the concept. However, other economists, such as W. Michael Hanemann, point out that what Arrow and Fisher call "quasi-option value" is an alternative interpretation of what Weisbrod (1964) originally called "option value". So Hanemann (and some others) use the term "option value" to discuss what Arrow and Fisher and most other economists call "quasi-option value". *Caveat lector*.

[106] Weisbrod (1964) gave rise to the literature that covers all forms of option and quasi-option value.

expectation of acquiring new information, and some notion of “irreversibility”.[107] Unfortunately, the authors’ Rumsfeldian characterization of this (Maclaurin and Sterelny 2008, 156)[108] – that quasi-option value requires ignorance, not too much ignorance, not too little ignorance, but just the right amount – is rather far removed from the actual theory of quasi-option value that one encounters in the economics literature.

In short, it appears likely that Maclaurin and Sterelny use the terms “option value” and “quasi-option value” to discuss something rather different from what economists discuss in these terms. Divergence from strict economic theory is also evident in the comfort these authors express (Maclaurin and Sterelny 2008, 154) in collapsing garden-variety option value and quasi-option value into a single concept despite the fact that the two notions are based on very different models possessing very different properties. The end result is an unfortunate situation that is nonetheless emblematic of option value-based arguments for biodiversity: If one sticks to definitions of “option value” and “quasi-option value” that fall within the compass of what one finds in the technical economic literature, then there is little reason to think that biodiversity would have some positive amount of it. It is only by first misconstruing what these terms mean, but tacitly assuming an equivalence of these meanings with standard economic ones, that Maclaurin and Sterelny’s argument joins many others in achieving some initial appearance of credibility.

This state of considerable confusion is not entirely unsurprising, and the responsibility for it does not originate with Maclaurin and Sterelny. The concept of option value is actually a collection of diverse concepts; and they elude unified understanding even within the field of economics.[109] Though in a minority, some economists (for example, Freeman 1986, 163; Hanemann 1984, 14) dispute whether it is a legitimate, distinct, and useful category of economic benefit – contending that it is

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[107] See, for example, Hanemann (1984) for a discussion of this. Unfortunately, as previously noted, Hanemann adds to the general confusion by insisting on using the term “option value” to refer to what Arrow and Fisher (1974) originally called “quasi-option value”.

[108] I have in mind the theory of epistemic categories propounded by United States Defense Secretary Donald Rumsfeld in a Department of Defense News Briefing on February 12, 2002:

> … as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say, we know there are things we do not know. But there are also unknown unknowns – the ones we don’t know we don’t know. [from the official transcript, http://www.defense.gov/transcripts/transcript.aspx?transcriptid=2636]

[109] This is not only my assessment, but also the assessment of the community of economic theorists. The debate about which (if any) conceptions of option value are actually equivalent, which are more general, and which better capture something real and useful in economic theory and practice are ongoing and apparently still unresolved. Some participants in the debate even question whether option value, under any reasonable interpretation, has standing as a legitimate, independent category of economic value. See, for example, Cory and Saliba (1987), whose “Requiem for Option Value” sounds the dirge for the concept of option value, at least as a component of natural value. Hanemann (1984, 14) comes to much the same conclusion.

In addition to the problem of finding a convincing theoretical basis for option value, it appears that there is no good independent way to measure it. Of course, someone persuaded that option value were a theoretical chimera would not be surprised by the seeming impossibility of assessing its magnitude.

merely an artifact of different ways of computing net benefits. Other economists more specifically find that this suite of concepts has limited application to environmental conservation and is more or less uninteresting in this domain. Even among those economists who agree that option value is “real” and it that it has some general application to nature and the environment, there is disagreement about its most basic properties. For example, my exposition of the concept accords with many economists’ conception, according to which option value can be negative (even for a risk-averse individual); but other economists deny that this is possible.

Also, many if not most definitions of option value in the economics literature defy rather than embody the intuitions of non-economists such as Maclaurin and Sterelny. For example, conservationist arguments routinely presume that option value is awarded for avoiding the risk of not conserving. But as economists define it, option value is not so much an expression of risk aversion as it is a choice between different ways of distributing risk. In fact, it is easy to see how circumstances can make conservation the risky choice. Finally, and relating to this last point, it seems that option value, in common with other categories of economic value, has no particular characteristic tendency to favor environmental (or biodiversity) conservation over environmental (or biodiversity) destruction.

In sum, there is considerable evidence to suspect that Maclaurin and Sterelny’s nomination of option value to carry the banner of biodiversity’s value is based on serious misconceptions and is seriously misplaced. The seeming unawareness of what it actually takes to demonstrate positive option value for biodiversity is especially concerning. Therefore, this section departs from other parts of the book by devoting some detailed attention to what is really involved in the underlying economic concepts of option value and quasi-option value. This should give some better idea about what sort of argument is required in order to establish that either kind of value attaches to biodiversity. And it should make plain how far short of meeting these requirements claims about the option value of biodiversity fall.[110]

First, I explicate the concept of garden-variety option value, henceforth (for the most part) simply “option value”. I then show why skepticism concerning its application to the conservation of biodiversity is justified. I repeat this two-part exercise for quasi-option value.[111] In between, I briefly comment on the epistemological vocabulary that enters into these economic discussions.

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[110] I am aware of no other similar discussion, accessible to non-professional economists, in the environmental and conservation literature.

[111] I must forewarn the reader that my presentation barely scrapes the surface of the conceptual issues that concern option value and quasi-option value. The literature on these two concepts is enormous. Large, too, are the gaps between the accounts of professional economists of how, exactly to define and use it. The economist Richard Bishop (1986, 134), one of the most distinguished contributors to the option value debate, observes that the discussion of option value is “often very technical and confusing”. This is a grand understatement. Compounding the problem is the fact that economists sometimes are not the most lucid writers and that they do not adopt a uniform vocabulary or formulation for even the most basic concepts. A full understanding of the controversies requires facility in the concepts and tools of microeconomics, which this book cannot hope to introduce. As a consequence, I cannot provide a general survey or even a broadly balanced analysis.

6.9.1 Option Value and Conservation

As discussed in Sect. 2.1.2.1 (Consequentialism), neoclassical economics posits that satisfying human preferences, no matter their object or reasons (if any) for being held, is what ultimately matters. So it must be for option value, a term that the estimable economist Burton Weisbrod (1964) introduced in a seminal paper. He proceeded by way of a story that is rather odd (to my way of thinking), but which nonetheless captured the imagination of many economists. The story concerns a park run as a business by a private concern.[112] Despite being run with all possible efficiencies, the business is a losing proposition based on the people who actually show up to visit. Moreover, there is every indication that it will remain a loser. Despite this economically gloomy picture, Weisbrod grasps for an economic straw that would yet justify preserving the park. He (Weisbrod 1964, 472) finds it in

> … the existence of people who anticipate purchasing the commodity (visiting the park) at some time in the future, but who, in fact, never will purchase (visit) it. …they will be willing to pay something for the option to consume the commodity in the future. This "option value" should influence the decision of whether or not to close the park and turn it to an alternative use.

In other words, Weisbrod suggests that in the park's "option value", we might find a legitimate basis for boosting its total economic value. This hitherto hidden component of economic value is ensconced in the preferences of persons who anticipate visiting the park, though (as Weisbrod allows) they might (or indeed, actually) never do so. These preferences occur in the context of an ability to ensure the certainty of this environmental good's supply in the face of what economists call "uncertainty in demand".[113, 114]

Some context for option value as a category of economic value is provided by relating it to existence value, mentioned at the end of Sect. 2.1.2.1. Although existence value, unlike option value, does not depend on uncertainty, in another basic way, these two categories of economic value are nevertheless kissing cousins.

Therefore, the restricted goal of my discussion is to suggest how fragile the concepts are by pulling on a well selected few of the main discussion threads connected to them. For those wishing to plow deeper into this fertile ground, I recommend beginning with Weisbrod (1964) for the seminal idea, Arrow and Fisher (1974) for the original and lucid explication of quasi-option value, and any of the several papers on the subject by W. Michael Hanemann (see references, including Fisher and Hanemann (1986)), who is unusually clear in his thinking and writing on this subject.

[112] Fortunately, this description does *not* really apply to Sequoia National Park, despite the fact that Weisbrod (1964, 471) finds this conceit "useful for the… exposition".

[113] The literature on option value is extraordinarily convoluted on the relationship of uncertainty in demand and uncertainty in supply. I attempt a high-wire balancing act that synthesizes considerations relating to uncertainties in both domains.

[114] This interpretation – in terms of garden-variety option value – is just one of two main schools of interpreting Weisbrod's suggestive but vague story. As already noted, Arrow and Fisher (1974), Hanemann (1984), and Fisher and Hanemann (1986) see quasi-option value as an alternative interpretation.

This is so especially on Weisbrod's formulation, according to which those who anticipate visiting might (or as he says, in fact) never actually do so. Option value and existence value are both types of "passive use" or "nonuse" value, in the parlance of modern economics.[115] In other words, they are both passive ways of "consuming" a resource. In Weisbrod's story, visiting the park is the predominantly non-rivalrous and non-exclusive way of "consuming"[116] the park. This contrasts with its rivalrous and exclusive consumption as a source of timber or granite. When I "consume" an environmental good for its existence or option value, I do not diminish its value to you (consumption in this way is non-rivalrous). Furthermore, there is not a way to exclude you from enjoying the good for its existence or option value. Nor can you be kept from doing this more or less simultaneously with me (the resource is non-excludable). For Weisbrod, it appears that the major respect in which option value differs from existence value is that the former has some pretense of being about a desire (however uncertain) for eventual consumption (even when, *a la* Weisbrod, that desire is never actually consummated), while the latter does not. From this perspective, a non-economist might conceive of existence value as the limiting case of option value when the latter's *un*certainty about demand for a resource fades into the *certainty* of a kind of consumption that is confined to human imagination.

I now continue with a somewhat technical explication of Weisbrod's intuition in the context of a conservation problem, which focuses on a place that can undergo more or less of the kind of development that can affect biodiversity.[117] The ecological euphemism for this is "habitat conversion". The wetland is to be paved over for condominiums. The forest is to be cut down to build those condos. The river is to be dammed (transforming a segment of free-running water into a lake) to provide electricity to the condos. These kinds of conversions oust populations of long-time nonhuman residents. Let's assume that this means that these projects decrease biodiversity. An alternative to pursuing these sorts of development projects, which would realize their economic value in a way that is both rivalrous and excludable, is a conservation project that might possibly preserve the biodiversity.

Let's presume that biodiversity can be quantified and suppose that a quantity $q = Q$ of biodiversity is at stake.[118] The quantity actually conserved can be $0 \leq q \leq Q$. Suppose further that a certain conservation project P will ensure, *with certainty*,

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[115] This classification predominates but is not universal among economists. See, for example, Vining and Weimar (1998, 322).

[116] I follow economists in using the word "consume" to indicate all uses and even, according to standard economic usage, non-uses.

[117] I am not aware of any other analysis of garden-variety option value with a like focus. However, there have been attempts to apply quasi-option value to biodiversity in the economics literature – for example, Fisher and Hanemann (1986).

[118] Economics lives by this kind of quantified representation, which I model closely on what one encounters in the technical literature. As the discussion in Sect. 4.1.2 (Measures and indexes) there is a major danger in doing this. The choice of what is measured and the weighting of various measurements build in their own set of value assumptions, which thereby evade scrutiny as value judgments.

that $q = Q$. On the other hand, not pursuing the conservation project (~P) makes it equally certain that $q = 0$. It is doubtful that these assumptions reflect the actual workings of the world. But they are part of a typical framework for defining option value.

The framework assumptions mentioned so far amount to asserting that there is no uncertainty in supply. To P or not to P (that is, to P or to ~ P) – that is the dichotomous question. The answer to it entirely determines q as either Q or 0.

This certainty in supply is part of most economic models of option value. However, option value cannot arise without uncertainty. Many models of it focus entirely on uncertainty in demand; some smaller number incorporate awareness that supply, too, can be uncertain.[119] In the context of our biodiversity conservation problem, demand uncertainty means that certain features of various possible states s of the world can influence Ms. Consumer's *demand* for some level of biodiversity q. These features include[120]:

- Her income (y). In some possible states of the future world, Ms. Consumer loses her job or she loses her life savings in bad investments. Her income plummets, which causes her demand for any level of biodiversity $q > 0$ (along with her demand for most other goods) to likewise plummet. On the other hand, she might win the lottery.
- The prices p_i for various goods i that are complements for the consumption of q – such as the cost of transportation to where q can be "consumed". A fourfold increase in the price of fuel to get to the park might put a significant dent in Ms. Consumer's demand.
- The prices p_j for various goods j that are economic substitutes for q, such as the cost of satisfyingly realistic holographic presentations of wildlife or even goods that compete for the consumer's delight. Deep discounts at the local boutique spa might make getting a facial massage and aromatherapy far more attractive than trying to get up close and personal with q in the personae of mosquitoes, skunks, and bears. Or medications that might derive from the creatures spared by a conservation project might, by the time that they are developed and marketed, be more expensive than alternatives that are born of rational drug design.
- Conditions c_k that affect level of utility that the envisioned consumption of q will actually afford Ms. Consumer. It is possible that she will find Weisbrod's park thronging with rude, rowdy, music-blaring yahoos, outnumbered only by the mosquitoes feasting on every inch of exposed (and even unexposed) human flesh. That might take a bite out of her demand, too. Even aside from these obnoxious possibilities, her terrible sense of direction might result in her getting lost and lead to a frightening, even near-death experience. Or by the time of her actual visit, her bad and worsening knees might prevent her from getting out of her car. On the other hand, by the time of her prospective visit, park officials might have

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[119] Freeman (1986, 154–155) is as clear as any economist in allowing for both supply and demand uncertainty.

[120] This list is drawn from various sources, including Plummer and Hartman (1986), Freeman (1986), and Hanemann (1984).

clamped down on rowdy miscreants, sprayed for mosquitoes, and constructed trail signs that make it virtually impossible for a literate person to get lost; and successful knee surgery might have made her more mobile than ever.

On the other hand, if the primary value of the biodiversity lies in its potential pharmacological value, then this condition of being the source of a valuable drug dominates its level of utility.

I encapsulate these ideas by saying that the conditions c_k are ones that affect the "quality" of biodiversity.

- Ms. Consumer's very preferences (reflected in the shape of her utility function u()) might change even if the above-listed factors remain constant. She might change her mind about just how much she likes biodiversity. She might come around to thinking that she is much happier not exposing herself to the possibility of getting lost. She might decide that the risk of severe sunburn, poison oak rashes, and insect bites is too much to bear. Or, on second thought, the prospect of making do without running hot water and flush toilets is just too awful to contemplate. This change of heart is not difficult to understand. Even now, most of her friends incredulously ask why she would voluntarily submit to such indignities when, with far less effort and similar expense, she could go to the spa for that aromatherapy and a facial massage. In short, Ms. Consumer's preferences might themselves change and be different in different possible states of the future world.

Subsequent states of the world might vary in any one or more of these conditions. In the economic model for option value, a possible state s of the world is essentially just a possible state of demand. Combining the prices of complement and substitute goods, the composition of states is expressed by:

$$s = \left(y, < p_1, \ldots, p_i, \ldots p_n >, < c_1, \ldots, c_k, \ldots c_m >\right)$$

for some collection of prices p_i on n complementary and substitute goods, and some other collection of m demand-influencing ("quality") conditions c_k.

Suppose that u() is a utility function that expresses Ms. Consumer's preferences as a function of factors that might influence her demand. Suppose further that y_q is the net of income and costs associated with the quantity q of biodiversity. Since the model supposes that the choice of doing or not doing the conservation project entirely determines the quantity of biodiversity q to be either Q or 0, respectively, y_q is just the net cost/income of P or ~P, assumed to be independent of s. That is:

$$y_Q = y_P$$

and

$$y_0 = y_{\sim P}$$

Note that a lot is hidden inside y_q. In particular, preserving $q = Q$ entails the opportunity costs of forgoing all the benefits of development that $q = 0$ would permit. Reserving the stock of a resource for future consumption often precludes its immediate and possibly wealth-compounding investment in alternate lines of development – those condos, for example. These potential benefits foregone constitute the conservation project's opportunity cost. Though it is not the only factor that affects the value of y_P, this alone could diminish y_P (or increase $y_{\sim P}$) and it could even make y_P strongly negative.

In this framework, one can characterize the utility U to Ms. Consumer of a certain state s of the world, which influences her demand for quantity q of biodiversity, as:

$$U = u\left(y_q, s \mid q\right) \qquad \text{where '} \mid \text{' means "given the following condition(s)"}$$

As s has been defined, uncertainty about which state s of the world Ms. Consumer will find herself in gives rise to uncertainty in her demand for q. It is good to keep in mind that this is a simplification, which ignores the less frequently considered source of uncertainty about her demand for q: u() itself might not be fixed (last in the list of demand-affecting factors above).

Now suppose that each state s occurs with probability π_s such that $\Sigma\pi_s = 1$. Note that this apparently mundane condition implies a startlingly strong epistemic claim: The set of all relevant alternative states is known and so is the probability of occurrence for each state in this complete set. Continue to assume that the supply of biodiversity is certainly Q with the conservation project P and it is certainly 0 without it (~P). Then the expected utility EU_P for Ms. Consumer with P is the sum of the utilities for each state s, weighted by that state's probability of occurrence:

$$EU_P = \sum \pi_s u\left(y_P, s \mid q = Q\right)$$

On the other hand, her expected utility $EU_{\sim P}$ in the absence of the project (~P) is:

$$EU_{\sim P} = \sum \pi_s u\left(y_{\sim P}, s \mid q = 0\right)$$

So much for the preliminaries. To see how uncertainty figures in creating option value, let's start by assuming that there is none – and particularly, that there is no uncertainty in demand. This is equivalent to saying both that Ms. Consumer's utility function u() is fixed and that u() is constant-valued in s. That is, Ms. Consumer's demand for any level q of biodiversity, like its supply (though contingent on the choice of P or ~ P), is fixed and certain:

$$U_P = u\left(y_P, s \mid q = Q\right) \quad \text{for every state s}$$

$$U_{\sim P} = u\left(y_{\sim P}, s \mid q = 0\right) \quad \text{for every state s}$$

In this case, the *expected* utility EU in each case is trivially identical to the utility for any, arbitrarily selected state:

$$EU_P = U_P = u\left(y_P, s \mid q = Q\right) \quad \text{for every state s}$$

$$EU_{\sim P} = U_{\sim P} = u\left(y_{\sim P}, s \mid q = 0\right) \quad \text{for every state s}$$

because (per the tentative assumption of demand certainty) the utility for any state s is the same as that for any other state.

What would our certain demander pay up front – that is, *ex ante* – for the conservation project? Assuming that she is an individual of the species *Homo economicus* – that is, she is a preference maximizer who evaluates any set of alternatives by doing a cost-benefit analysis according to the rules of neoclassical economics – she knows the price. That price is the "option price" OP, which satisfies:

$$u\left(y_P - OP, s \mid q = Q\right) = u\left(y_{\sim P}, s \mid q = 0\right) \quad \text{independent of state s}$$

OP is the answer to a single question that spans the entire set of possible states s. Beware: we still have not gotten to "option *value*".[121]

Whether OP is positive, negative, or zero depends on the shape of Ms. Consumer's utility function u().[122] That is, it depends on whether u() is higher or lower when the amount of biodiversity is some nonzero quantity Q versus 0. Ms. Consumer might prefer a more biodiverse world. In that case, $U_P > U_{\sim P}$, which means that she would pay for the conservation project (OP > 0). But nothing *a priori* justifies assuming that her preference is for a more biodiverse world. Nor does any contingent matter of fact about the world have this universal implication. And in fact, she might strongly prefer the benefits of development and regard a nonzero level of biodiversity as an obstacle to that more desirable state of affairs. In that case, $U_P < U_{\sim P}$, and she would *demand payment* to allow the nonzero amount Q of biodiversity (OP < 0). Of course, if $U_P = U_{\sim P}$, then she will not be inclined to lobby either for or against conservation.[123]

The option price OP is one way to price the conservation project P. There is an alternative approach to pricing the project, which hinges on the answer to a different

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[121] Unfortunately, in one of a number of terminological confusions that plague this topic, what Weisbrod calls "option value" in his paper is now called "option *price*" by most, if not all economists, who follow the usage of Krutilla et al. (1972). I follow this now-more-common usage.

[122] As Plummer and Hartman (1986) help to explain further along in the main text, this concept of option price differs in significant respects from the concept more familiar from options in stock and other real markets. See Note 130.

[123] I cannot account for the statement in van Kooten and Bulte (2000, 296) that "OP… is always positive", unless these authors are fixated on the narrow sense of option that applies to stocks. Otherwise, their claim would seem to require *a priori* justification of a proposition that is a contingency and that can tip either way. Empirically, one finds that development (no conservation) sometimes *is* preferred. In such a case, a consumer would demand payment for allowing the conservation project. That is, the option price would be negative. None of this depends on how risk-averse or risk-welcoming the consumer might be.

I detail this because, as previously mentioned, van Kooten and Bulte (2000) appear to be a primary economic reference for Maclaurin and Sterelny (2008). I have not encountered another explicit statement of this erroneous assumption. But it is possible that this assumption is nevertheless implicitly made by those who argue for the (positive) option value of the natural world. If it is (erroneously) supposed that there is no downside (negative option value), then the case basing conservation decisions on option value will (illegitimately) appear much more palatable.

question: The alternative imagines Ms. Consumer dwelling separately in each of the possible states s of the world. For each state, it asks her as part of that state, what amount would she be willing to pay (or demand in payment) for enjoying (or suffering with) a quantity q = Q (versus q = 0) of biodiversity in it. The number of questions is equal to the cardinality of the complete set of possible states s. The answers to these questions jointly produce an *ex post* (versus the previously described *ex ante*) valuation in the sense that each separate valuation is contingent on one particular state being realized and Ms. Consumer's projecting herself into it. This amount satisfies an equation that looks suspiciously like the one for option price:

$$u\left(y_P - CS_s \mid s, q = Q\right) = u\left(y_{\sim P} \mid s, q = 0\right) \quad \text{for a given state s}$$

CS_s is what economists call the "consumer surplus" for state s.[124]

Of course, so long as one presumes that the value of the utility function u() itself is fixed and that its value does not vary from one state s of the world to another, Ms. Consumer will pay (or demand payment of) the same amount CS_s in any state s in order to arrange for (or tolerate) q = Q. This resembles the situation for OP. However, OP is the answer to a single, *ex ante* question, and is therefore the same for each state *by definition*. By definition, the answer to the option price question is found by asking Ms. Consumer what she is willing to pay up front for the conservation project, independent of state. In contrast, each CS_s is the answer to an *ex post* question that is contingent on state s being realized.

So far, CS_s only happens to be the same in each state as a consequence of the tentative initial assumption about a matter of fact – that no difference in any possible state of the world affects Ms. Consumer's demand. This assumption entails that it doesn't matter which state s she projects herself into: Her consumer surplus will be the same in every one. As a consequence, the probability π_s with which each state occurs is irrelevant and the *expected* consumer surplus ECS is identical to CS_s for any state s:

$$ECS \equiv \sum \pi_s CS_s = CS_s \quad \text{for any state s}$$

Obviously, under the conditions so far specified – which make Ms. Consumer's demand for biodiversity certain and the supply of biodiversity also certain – the equations that define CS_s and OP make them identical for all s. Therefore, the expected consumer surplus ECS and option price OP are identical, too.

I am finally in a position to state the definition of "option value". Option value is (after all that complexity) quite simply the option price OP less the expected consumer surplus ECS.[125] Since OP and ECS are identical under the assumptions so far made, they entail (under those assumptions) that the option value of biodiversity is nil:

$$OV \equiv OP - ECS = 0$$

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[124] While this definition might look somewhat unfamiliar, it encapsulates similar (though notationally different) definitions in, for example, Plummer and Hartman (1986, 458), Freeman (1986, 160), and Vining and Weimar (1998, 327).

[125] This definition of "option value" is widely accepted among economists.

I have already shown that option price can be either positive, negative, or zero – that is, indeterminate in sign. Option value can be any of these, too. But clearly, something must be uncertain for option value to be nonzero.

Suppose that some combination of the demand-affecting factors listed above makes Ms. Consumer's demand for biodiversity depend on which state of the world is actually realized, so that generally, $CS_{s1} \neq CS_{s2}$ for different states s1 and s2. In this case, it might be thought that paying the option price up front is a kind of insurance that reduces risk. But this is not your normal insurance, in which one knows with near certainty the undesirability of, or negative demand for, the state of the world for which the insurance payout compensates.

Paying an option price OP up front that is greater than the expected consumer surplus ECS is not insurance, but rather a matter of trading one uncertainty for another. Of course, by paying OP, regardless of which state s of the world obtains, Ms. Consumer avoids the consumer surplus lottery. She might be so inclined by considering that the lottery would typically require her to pay a very high price for a level $q = Q$ of biodiversity in a state of the world in which she finds that this level of biodiversity highly desirable.

But things might turn out in a way that makes the high level of $q = Q$ of biodiversity highly *un*desirable for her. That, in turn, makes her choice to not enter the consumer surplus lottery itself a bet with its own risks – for she might wind up paying a lot for something that, as it turns out, is repugnant to her. Specifically, paying OP is a bet that the state of the world will turn out to be one in which her demand for biodiversity is, in fact, high. In this case, the price she pays *ex ante* for a high level of biodiversity $q = Q$ is lower than she would have paid *ex post*. It is also a bet that Ms. Consumer will *not* end up in another state of the world in which biodiversity $q = 0$ is more desirable to her than $q = Q$. Viewing things retrospectively from that possible world, she will see (*ex post*) that she erred by not *demanding* payment for allowing a conservation project that ensured $q = Q$. In this alternative world of unwanted biodiversity, Ms. Consumer would regret having paid a positive (option) price for it. In other words, paying the option price up front is also a gamble. Like any gamble, it can be lost.

I now show informally, by way of example, how option value can be negative or indeterminate. In other words, the difference between OP and ECS is not so much a matter of risk aversion as it is a matter of preferring one kind of risk to another. In fact, the examples illustrate how risk aversion can cut either way.

Initially, consider four states that vary in just one demand-altering variable – namely, the "quality" (as perceived by a consumer) of the quantity $q = Q$ of biodiversity.[126] Suppose that there are two "components" to this quality. One component has

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[126] The choice of a model that contains more than two possible states is significant. There is a substantial body of theoretical work based on a two-state model that suffices to make most of the points that are salient for my discussion. This theory demonstrates how option value can be negative or positive – depending on a consumer's risk preferences and on the shape of her utility curve. My treatment leapfrogs over this work to a more realistic multi-state model, which also illustrates how option price and therefore option value might be neither positive nor negative, but indeterminate.

Table 6.1 A hypothetical set of states reflecting uncertain demand for biodiversity based solely on the uncertain "quality" of a given level of biodiversity

State (s)	s1	s2	s3	s4
Probability (π_s)	0.19999	0.40001	0.39999	0.00001
Surplus (CS_s)	−700	−10	360	10,000

to do with the experience of actual encounters with various creatures.[127] The other has to do with the possibility of Q amount of biodiversity yielding some very valuable drug.[128] Table 6.1 shows the four states, the probability that each will occur, and the consumer surplus for the conservation project in each state.

In this example, a 60% supermajority of the time, the consumer surplus for conservation is negative (states s1 and s2). Moreover, there is a one-in-five chance that the surplus is very negative (s1). However, there is also a good but less-than-even chance of a substantial positive surplus (s3). And there is a tiny chance – 20,000 times less likely than the very bad outcome of s1 – of a stupendously large positive surplus (s4). The story behind this example could be: In s1, development (for which the biodiversity is sacrificed) turns out to be an excellent investment and pays a handsome dividend. In s2, development does okay and better than conservation. In s3, people find that they really like to be around the mosquitoes, skunks, and bears. And in s4, a conserved plant is found to produce an alkaloid that, without side effects, provides immunity to leishmaniasis. The numbers in Table 6.1 are cooked to yield $ECS \approx 0$, just because zero is an easy number to think about. But the basic story arguably reflects possible real-world economic probabilities and valuations (within the limits of economic modeling).

To find the option value of Q amount of biodiversity, one needs to find the fixed (state-independent) option price OP that is willingly paid with the knowledge of which states are possible and the knowledge of how likely it is for each state to occur, but without knowing which state does, in fact, obtain. In this example, since $ECS = 0$ and $OV = OP - ECS$, option value $OV = OP$. As a consequence, the question of whether $OV > 0$ has the same answer as the question of whether $OP > 0$. This lets us focus on the question of whether or not, under these conditions, a consumer would willingly pay *anything* up front for the conservation project. Such willingness would confer a positive option value on Q.

So what is the option price (which is also the option value) in this case? Plainly, most of the time (states s1 and s2 combined), the quantity Q of biodiversity is *not* demanded. In fact, there is a substantial chance (in s1) that Q is considered a very bad thing. Given this, would a consumer be willing to pay something for the slight chance at a jackpot payoff (s4), or even a fairly good, but less-than-even-chance at very good outcome (s3)?

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[127] The "experiential value" of biodiversity is separately examined in Sect. 6.11.

[128] Biodiversity as pharmacopoeia is explored in Sect. 6.5.1.

Does aversion to risk push the price into positive territory or the opposite? One way to understand risk aversion is in terms of its equivalence to the diminishing marginal utility of income. A risk-neutral consumer is indifferent to the marginal utility of her income. But a risk-averse consumer prefers to spend income under conditions in which her income is high and her income's marginal utility is low.[129] This equivalence does not (yet) come into play because for now, I am supposing that only the "quality" of biodiversity affects demand for it. However, taking the equivalence seriously, one can see that a person's risk aversion alone does not dimininish the attraction of betting on a jackpot that is is extremely unlikely to be collected (s4). Being risk-averse comes into play only if a chance at the jackpot means substantial exposure to another, very bad outcome. That is exactly the situation in the example at hand. One must assume that a risk-averse person is just the kind of person who might decline a shot at s4 because it only comes with a substantial exposure to the very bad outcome in s2.

In a circumstance such as this, with an expected surplus of zero, would a person averse to risk be inclined to pay some positive sum in order to avoid the consumer surplus lottery? I believe that there is no determinate answer. It is plausible to think that a consumer might *demand* payment to endure exposure to the most likely outcome, which is negative, especially when there is a one-in-five chance of the outcome being very negative. Perhaps it is only a risk-*seeking* individual who, under these conditions, would pay for a chance to win the s4 jackpot.

Up to this point, I have focused on uncertainty in demand. The choice between a state-independent *ex ante* payment and payment *ex post* becomes even more murky with the introduction of uncertainty in supply. In the real world, a conservation project will not ensure a level $q=Q$ of biodiversity. Nor is $q=0$ certain in the absence of a conservation project. Rather, conservation will merely shift to the right the distribution of probabilities for q, such that $0 \leq q \leq Q$. In general, it seems that this uncertainty in the supply that remains even after a conservation choice has been made can only lead to an increased reluctance to commit funds up front for conservation. Though much more can be said about supply uncertainty, I only briefly return to it when considering income as another source of demand uncertainty.

So far, I have supposed that the "quality" of biodiversity entirely determines demand for it, as specified in connection with Table 6.1. But further complications can and are likely to arise from other factors that affect demand. For example, the price of a complement good could be a major factor. Suppose that the demand for the drug that emerges in s4 is affected by the affordability of health insurance, which might be the only or primary means for affording access to the drug. If the price of insurance were so high as to routinely make it unaffordable, then demand for the drug might diminish

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[129] For example, Freeman (1984, 3) takes risk-aversion in state s to be equivalent to the condition that

$\partial u_s / \partial y_s < 0$

Table 6.2 A hypothetical set of states reflecting uncertain demand for biodiversity as in Table 6.1, but also taking into account the cost of a complement good

State (s)	s1	s2	s3	s4
Probability (π_s)	0.19999	0.40001	0.39999	0.00001
Surplus (CS_s)	–700	–10	360	50

to miniscule levels. That would similarly diminish consumer surplus for level Q of biodiversity in s4. In this case, Table 6.1 might become Table 6.2.

Because the likelihood of s4 is so small, the expected consumer surplus ECS remains the same as it is for the Table 6.1 example – zero. But now, even a consumer fixated on the jackpot in the scenario for Table 6.1 does not have this temptation to motivate her to pay to ensure that $q = Q$.

The consumer's expected income might also have a gross effect on her willingness to pay a price *ex ante* from (perhaps) a lesser income and when no benefit is ensured, versus paying *ex post* from a greater income and when benefit for payment is ensured. Suppose that biodiversity is a normal good – that is, a good for which (at a constant price) demand increases with increasing income. Suppose also that income is likely to increase with no conservation as the result of the investment in development. Finally, suppose that some level of biodiversity is likely to remain even in the absence of a conservation project (supply uncertainty). Under these conditions, option value is likely to be *negative* for a risk-averse person and positive for a risk seeker. The world of higher income is a world of higher demand for any level q of biodiversity. At higher levels of income, the marginal utility of income is lower. A risk-averse person who prefers to spend dollars with lower marginal utility will prefer the choice of only having to pay for the good of some level q of biodiversity in a world in which she actually demands it; and then, preferably with low marginal utility dollars.

What conclusion can be drawn from all this? Economists Mark Plummer and Richard Hartman (1986, 464–465) arrive at a fair summary in their attempt to find a "big tent" version of option value:

> … "option value" has very little to do with the value of an option.[130] Instead, if a price change is proposed under uncertainty [a source of demand uncertainty that I have not put in my examples], option value is a measure of the premium or discount a consumer is willing to pay or accept to purchase the price change by making a constant payment of $\overline{S}$ [the expected consumer surplus, which I have designated 'ECS'] rather than a payment of S(T) in each state [which I have designated 'CS_s'] of the world. Although both methods have the same effect on expected wealth, the variation in S(T) [i.e. CS_s] may provide the consumer with additional benefits or harm (relative to the constant payment of $\overline{S}$ [ECS]) because the payment varies as the marginal utility of income varies.

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[130] Options on publicly traded stock differ from options on environmental goods in other obvious respects. For the former, only the option premium (representing the option value) is due up front. The option confers a right to exercise without the obligation to actually take that action. Therefore, the option might or might not be exercised later; full payment of the option price is due only if the option is exercised. The model of option value for environmental goods typically requires up-front payment of some more substantial portion – and sometimes all – of the option price. That price is presumed to include the cost of the resource-conserving project.

> In essence, option value is a measure of the value of one institution for diversifying risk relative to another… …faced with a choice between two payment methods with the same expected dollar value, a risk-averse individual will choose that method which has greater success in diversifying the risk faced by the consumer…
>
> This reasoning is very different from that originally envisioned by Weisbrod.

My treatment of the subject minimally supports a similar conclusion regarding option value as it applies to biodiversity: First, in reasonably realistic conditions involving more than two possible contingencies (possible states of the world), the option value of biodiversity, not unlikely, is indeterminate. Second, even if risk aversion is rational and warranted (a proposition that requires independent justification), this does not imply that the option value of biodiversity is positive. To put the previous point in another way, the redistribution of risks afforded by a state-independent and fixed *ex ante* payment has risks of its own. The end result can just as well be an *increase* in risk (favoring immediate "consumption" of biodiversity via development) as it can be a decrease in risk.

Third, the dependence of option value – either positive or negative – on risk preference makes it all the more difficult to reasonably invoke it as a justification for some choice. It is hard to imagine any decisive reason for why one attitude towards risk might be more rational or more justified than other attitudes. Even if a preponderance of persons adopt one attitude in preference to the others, this does not constitute a *justification*. And in fact, there will be some distribution of risk-related preferences – ranging from risk-avoiding through risk-indifference to risk-loving – in society at large. From the economic viewpoint, the sign and size of option value will depend on this variable distribution. Even in a case where risk aversion entails a positive option value, if there is no bias in society towards risk aversion, then there is no net premium for added risk.

But even if one were mistakenly inclined to suppose that a predominant preference for risk aversion in a population underwrites a moral imperative to honor such a preference, the case for positive option value remains in jeopardy. That is because, as a matter of fact, aversion to a risk diminishes as more and more persons bear it. Even for a significant risk, the aggregate of the premiums goes to zero as the risk is distributed.[131] This consideration can reduce to irrelevance risk considerations in making a decision – even when the decision affects a population whose individuals are generally risk-averse in their own personal decision-making.

It is undoubtedly a relative strength of quasi-option value that it does not build in any assumptions about risk preferences. At least in this way, it is less problematic than garden-variety option value.

One final point, which saliently bears on the application of option value to environmental or natural goods, directly relates back to its basic definition in terms of the difference between option price and expected consumer surplus. When it is positive, option value represents a premium over the expected consumer surplus.

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[131] This is the famous Arrow-Lind Theorem, due to (surprise) Arrow and Lind (1970).

Sometimes a willingness to pay this premium for a conservation project requires a risk-avoiding preference; other times it requires a risk-seeking preference. Either way, the fact that it is a premium over the expected surplus should be a source of discomfort for an environmentalist: It means that biodiversity must do *more* than compensate for the expected surplus of the conservation project. It must somehow redistribute uncertainties in a way that justifies the additional premium represented by the option value. In other words, option value places an additional burden on environmental or natural goods to show their conservation-worthiness.

6.9.2 Risk, Uncertainty and Ignorance

The discussion of option value in the preceding subsection and the discussion of quasi-option value in the next subsection adopt a usage of "risk", "risk aversion", "uncertainty", and (in the case of quasi-option value) "ignorance" that is customary in the economics literature. Unfortunately, this usage levels important epistemic distinctions, which are critical in other, related discussions – particularly discussions of the Precautionary Principle.[132]

Here is one (European Environment Agency 2001, 170, Box 16.1) possible way to restore a proper perspective, which brings those distinctions back into relief:

> …there is the familiar condition of **risk**, as formally defined in probability theory. This is where all possible outcomes are known in advance and where their relative likelihood can be adequately expressed as probabilities. Where this condition prevails, risk assessment is a valid technique…
>
> Under the condition of **uncertainty**, as formally defined, the adequate empirical or theoretical basis for assigning probabilities to outcomes does not exist. This may be because of the novelty of the activities concerned, or because of complexity or variability in their contexts. Either way, conventional risk assessment is too narrow in scope to be adequate for application under conditions of uncertainty…
>
> Many case studies… involve examples where… appraisal laboured not only under a lack of certainty as to the likelihood of different outcomes, but where some of the possibilities themselves remained unknown. Here, decision-making is faced with the continual prospect of surprise. This is the condition formally known as **ignorance**. Even more than uncertainty, this underscores the need for a healthy humility over the sufficiency of the available scientific knowledge and, crucially, for an institutional capacity for open reflection on the quality and utility of available bodies of knowledge…
>
> Once it is acknowledged that the likelihood of certain outcomes may not be fully quantifiable, or where certain other possibilities may remain entirely unaddressed, then uncertainty and ignorance, rather than mere risk characterise the situation. The adoption of robust, transparent and accountable approaches towards the various aspects of risk, uncertainty and ignorance can be identified as one crucial means of regaining public confidence in regulatory decision-making. [bold in the original]

It is useful to see how these epistemic categories relate to the previous (and subsequent) discussion of economic value. Cost-benefit analysis in general, and the

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[132] See Sect. 6.3 (Biodiversity as service provider) for a discussion of the various elements that enter into Precautionary Principles.

concept of option value in particular, are built on the notion of expected net surplus and related notion of "expected" values. Expected values are assessed on the basis of some high degree of epistemic assurance concerning what states of the world can possibly obtain and with what respective probabilities. To put this in another way, the most clearly legitimate domain of economics is the domain of decision-making under *risk*, according to the above set of definitions. Insofar as this epistemic condition is not satisfied – because uncertainty or ignorance (both defined as above) is involved – economics wanders out into territory where its base assumptions do not apply.

In light of this, the entire discussion of option value in the preceding subsection should be read as a discussion of economic value under standard conditions of economic risk, not uncertainty, strictly understood. Part of this point's importance will become apparent in the discussion of quasi-option value, which follows.

6.9.3 Quasi-option Value and Conservation

Quasi-option value attempts to go beyond the domain of decision-making under risk (strictly understood) to decisions made under uncertainty or ignorance or both (again, strictly understood). In this respect, it represents a substantial extension of the framework for economic analysis. There are several other respects in which the defining framework for quasi-option value radically departs from the framework for cost-benefit analysis generally, and from the framework for garden-variety option value particularly.

I highlight these distinguishing characteristics of the quasi-option value framework in developing an account of how it applies to a conservation problem that resembles the one that focused the discussion in Sect. 6.9.1 (Option value and conservation).[133] Once again, the problem is to choose whether to conserve or to develop some place that harbors some amount of biodiversity.

Time element. First, the decision model explicitly incorporates a time element that is fundamentally absent from the framework for garden-variety option value.[134] I adopt the classic formulation (of quasi-option value), in which there are two decision points separated by a period of time, period 1. Period 2 is a time period that follows the second decision point. One can easily imagine how this decision model could be extended to more than two decision points.

Irreversibility. Second, the model applies only to development that is assumed to be "irreversible".[135] "Irreversibility" is a slippery concept. Here, it suffices to suppose that the quasi-option framework applies only in cases where, in some sense,

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[133] I follow the seminal formulation of Arrow and Fisher (1974), as further articulated by Hanemann (1984), Fisher and Hanemann (1986), and Hanemann (1989).

[134] Hanemann (1984) and elsewhere emphasizes its temporal element as a distinguishing feature of quasi-option value.

[135] The "irreversibility" assumption for quasi-option value is typically introduced by way of an informal example. For Arrow and Fisher (1974), it is the building of the Hells Canyon Dam on the Snake River on the Oregon/Idaho border in the United States. It is never carefully defined. Most explications of quasi-option value beg the question of what "irreversible" means by stating that it means "reversal would be extremely costly" (Vining and Weimer 1998) or something similar.

development in period 1 cannot be undone in period 2. That is, it applies only when one can assume that development is forever. This assumption is itself tied to specific assumptions about costs and benefits in period 2, which I visit momentarily.

The irreversibility requirement for quasi-option value precludes its application to some decision problems. But the specific concern here is with the conservation of biodiversity. Is development, as it affects the conservation of biodiversity, irreversible?

It is plausible to suppose that more development means less area for at least some species; and that the species-area relationship makes it plausible to conclude that less area means lower levels of biodiversity.[136] So let us grant the premise that development leads to extinctions or extirpations of local populations. Let's also grant for this discussion the stronger claim that "lower level of biodiversity in a developed area" means "*permanently or irreversibly* lower level of biodiversity". Then, insofar as development permanently reduces biodiversity, it passes the irreversibility test.

In sum, the working assumption is that development in period 1 reduces biodiversity. This, in turn, entails forgoing for all time the benefits (and costs) that might otherwise have accrued to the amount of biodiversity that the development permanently removed. These conditions jointly constitute the "irreversibility" of development and they are elaborated below, under **Costs and benefits of information and irreversibility**.

Information. The role of information in reducing uncertainty (strictly understood) is explicitly recognized. It is assumed, quite plausibly, that more information is available to inform decisions made at the second of the two decision points. By the time of that second decision, the benefits and costs experienced or uncovered as a consequence of the first decision are better known. New benefits and new costs might be uncovered. Also, better estimates might be found for the likelihood of realizing any benefit or cost (whether newly discovered or not). In other words, information gathered between the two decision points can change the computation of the expected value of development versus that of conservation.

Couched in the epistemic vocabulary of the immediately preceding subsection, quasi-option value is a creative suggestion for how to frame cost-benefit analyses (based on conditions of known risk) under conditions of true uncertainty (when the probabilities are not well known) and ignorance (when the range of possibilities is not well known).

Controversy surrounds the important question of whether or not information critical for making the best second decision can derive from development undertaken in period 1. It is unclear why this is at all controversial. Surely, sometimes, something can be learned about the net benefits of investing in a development proposal

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Unfortunately, "irreversible" admits multiple meanings; running them together can and probably does undermine clear discussion.

For a valuable start at picking apart the concept of irreversibility, see Manson (2007).

[136] This crude analysis is the basis for much reasoning about extinction rates, which He and Hubbell (2011) have recently called into question. Insofar as this principle is an unsure basis for diversity estimates, it removes one plausible basis for thinking that quasi-option value analysis applies to the real world.

by undertaking some part of it. This implies that at least some learning is or can be endogenous to the decision problem. It also implies that the quasi-option value framework might well justify undertaking development in period 1 specifically in order to provide information that could inform a more nearly optimal choice for period 2 – a choice that might also prove to be more nearly optimal for both periods taken together.

Therefore, it is somewhat baffling that a number of theorists presume that the information that informs decision 2 must concern only the existence or magnitude of *conservation benefits*. And furthermore, this information is presumed to flow from research that is exogenous to the decision problem. In cases that concern the conservation of biodiversity, the rather weak rationale for these presumptions (Fisher and Hanemann 1986, 178) is that relevant information about the properties of indigenous species will not come from developing their habitat; rather the information will flow from research that is undertaken quite apart from the development decision and the framework for making it. But this argument ignores the fact that engaging in even partial development can help to assess how much benefit the development might actually provide as well as the magnitude of costs that might become apparent as a result of some partial failure to conserve.

The question of whether and to what extent endogenous information plays a role in the framework for quasi-option value is significant. That is because observation of how actual development in period 1 goes could play a significant role in informing the second (and any subsequent) decisions regarding how much to develop. Therefore, this information could be the basis for deciding at the first decision point to proceed in period 1 with some development (as opposed to none) or with a greater rather than a lesser amount. However, the answer to this question might have less effect on the basic shape of the quasi-option value proposition than some other considerations that I consider shortly.

Risk preferences. Quasi-option value radically parts with (garden-variety) option value in being completely divorced from questions of risk preference. This is a good thing insofar as it is hard to find a general justification for either a preference to avoid risk or to seek it.

Arrow and Fisher (1974, 318) acknowledge that "there is something of the 'feel' of risk aversion… by a restriction of reversibility." But wherever that "feel" comes from, the inducement to utilize newly acquired knowledge does not appear to depend on whether individuals prefer to avoid risks or to seek them. In comparison to those hard-to-justify preferences, the rational basis for incorporating into the next decision knowledge acquired after the last one has the "feel" of solid footing.

Costs and benefits of information and irreversibility. One succinct characterization of quasi-option value is that it is the value or expected value of information that is conditioned on less, rather than more, "irreversible" development.[137]

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[137] See the discussion of irreversibility by Fisher and Hanemann (1986, 179). An even more general definition of quasi-option value along these lines might be one that makes it the difference in the expected value of information along different development paths – with the conservation path regarded as an alternative , "biodiversity development" path.

The plausibility of this proposition rests on combined presuppositions regarding irreversibility and information that frame quasi-option value.

First, the framework presumes that development (itself) is forever in the sense that if undertaken, the model disallows “undevelopment”. It also presumes that the costs and benefits that arise from development are never subject to revision. Once attained, benefits continue to register as beneficial for all time; and similarly for costs. On the other hand, so long as development is not undertaken, the *possibility* of doing so later is also presumed to remain for all time.

One or another of these assumptions might give pause. But however plausible they are as independent propositions, they jointly entail that any period 1 cost or benefit, which derives from period 1 development, extend to period 2 where they apply at precisely the same levels. Then during period 2, period, these period 1 costs and benefits combine with those that derive from any additional (period 2) development.

Unfortunately, this pleasingly neat cumulative model skates past several uncongenial facts: Some investments yield compound returns whose greatest benefits are realized only long after the initial investment. Second, some investments yield unexpected benefits. And third, investments sometimes lead to other, otherwise unrealizable and even previously unknown investment opportunities. The model also overlooks the frequently encountered real-world circumstance that some investments have a limited window of opportunity. The decision not to develop now is sometimes practically or effectively reversible. All too often, though, the required alignment of will with resources occurs just once and for all time.

Second, this separation of what is separate – between the irreversibility of development (on the one hand) and the irreversibility of its costs and benefits (on the other hand) – can be applied to conservation, too. While conservation itself might be thought to be reversible – because development is always an option – its costs (for example) might not always be so. This is not just due to permanently forgone opportunities in development, which are connected to the first presupposition. For example, if, as seems likely, a more biodiverse state of a world in which humans also manage to insinuate themselves into every nook and cranny is more likely to be one with a world of frequent and severe human pandemics, then the loss in human life and morbidity might be the sort of compound loss that is never truly recouped.

Third are some surprising and unjustifiably asymmetrical presuppositions concerning exactly what information newly available at the second decision point will reveal about costs and benefits for period 2. The entire focus is on previously unknown benefits of biodiversity and its conservation, not on any previously unknown costs of keeping it around. As Maclaurin and Sterelny (2008, 154) put it:

> … as our knowledge improves (and our circumstances change) we will come to discover new ways in which species can be valuable.

Routinely ignored is a similar possibility that newly acquired knowledge – for example about how complex zoonotic disease systems work – might uncover new ways in which conserved species might come back to bite us people.

It is also routinely presumed that new information will *not* reveal ways to attain "lost" benefits by other means. For example, if it is thought that biodiversity is the future's pharmacopoeia, then we currently respiring decision-makers must consider the question of how long we can justify the conservation choice that lets us wait to uncover this benefit. This requires some realistic assessment of expectations for exogenously acquiring the knowledge to derive the same benefit within this timeframe in an alternative way – for example, by dint of fast-developing technologies for rational drug design.

In other words, whatever support quasi-option value gives to conservation relies on a particular and apparently biased view of what kind of information might be forthcoming, combined with the assumption that conservation, unlike development, does not also have "irreversible" consequences.

Time element again. The question of what kind of information a decision-maker should expect to acquire within a set timeframe has a twin – perhaps the most vexing question of all – which has to do with setting that timeframe in the first place: How long is long enough to wait for the second decision point? This question is, in turn, closely aligned with the question of what are justifiable expectations for getting information – any information – that would increase the chances of making a more nearly optimal decision (at the next decision point) for all time?

Insofar as the focus is on exogenous research, there typically is, and should be, a time limit on doing more studies and undertaking more research. This is especially true when (as in biodiversity as pharmacopoeia), the odds of finding the sought value in conserved biodiversity are known to be extraordinarily slim. It is even more true when clear and legitimate benefits from development can be identified and known with relative certainty. Moreover, when development benefits are ones that meet basic human needs – say, by turning over an enclave of nature to farmers who can feed themselves from it – there might be a strong moral case for cutting off research quickly.

It should be apparent from this exposition that quasi-option value is not really a "component" or category of economic value in the way that say, existence value or bequest value or (sometimes) garden-variety option value is claimed to be.[138] The strain of trying to cast it in this way can be felt as a kind of paradox.

Suppose (as I suggest in Note 137) that quasi-option value is cast as the difference between the expected value of future information that is available on a "conservation" development path versus the expected value of future information available on a "development" development path. Suppose that (in some scenario) quasi-option value exists, that it can be computed, and that the expected value of future information with conservation is greater than that for development. That is, suppose that the quasi-option value is non-zero.[139] Computing the expected value of

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[138] This point of view is not original with me. Some economists say much the same thing, for example Vining and Weimer (1998, 331).

[139] Unlike garden-variety option value, quasi-option value cannot be negative. Therefore, non-zero implies positive.

information along each development path requires (in the customary way for this computation) knowing exactly what pieces of information to expect and with what likelihood. If one makes the assumption of only exogenous information, then by the definition of "exogenous", this is the same for each development path. What differs between the development paths (by assumption) is how this information will benefit decision-making (that is, facilitate a more nearly optimal decision). For example, it will be known, with probability π_c, that conserved biodiversity will yield a cure for cancer. But if we really have this information, then quasi-option value collapses into a run-of-the-mill computation of the net expected value of conservation versus development. There is no need for a special category of economic value. *A fortiori*, there is no need for a separate, special computation of it. Which contradicts the intuition that quasi-option value says something that cannot otherwise be said about economic value.

This means that quasi-option value is better regarded as a rule for how best to conduct cost-benefit analyses as a multi-stage decision process. The rule directs a decision maker not to ignore the possibility that information newly available only at the second decision point will show that the optimal amount of development for *both* periods 1 and 2 is less than that already undertaken in period 1. For if this possibility is realized and if development cannot be reversed, then the decision maker will have failed to find the optimal cost-benefit solution for the two periods combined.

The meaning of quasi-option value is essentially just this framework for decision-making. For my treatment of it, there remains only to add the main formal results based on this model. The crux of these results (Fisher and Hanemann 1986, 177) is

> … that optimal first-period use of the area [to be conserved or developed] is *less* likely to be full development ($d_1 = 1$) [where d_1 means "the amount of development in period 1"] when it is possible to learn about the benefits precluded than when it is not. [italics in the original]

However, it is important to note that this result obtains only under two fairly restrictive assumptions, which the authors carefully spell out. One assumption is that all learning is exogenous to the decision problem. I have remarked that this is open to serious question. The other has to do with the linear dependence of net value on the degree of development. Built into this assumption of linearity assumption are others about the relationship of development to biodiversity and the relationship of biodiversity to value. So far as I can tell, there is no *a priori* reason to believe that any of these relationships are linear. Nor is there any empirical evidence for this, despite the fact that the incremental model of biodiversity (Sect. 5.1.1, The incremental model) is routinely adopted.

As Arrow and Fisher (1974, 319) put it, "… the effect of irreversibility is to reduce the benefits [of development], which are then balanced against costs in the usual way." This is because – again as Arrow and Fisher (1974, 317) say – "Given an ability to learn from experience, underinvestment can be remedied before the second period, whereas mistaken overinvestment cannot, the consequences persisting in effect for all time."

Let's pull back to gain perspective. I think it useful to view quasi-option value, first and foremost, as a strategy to avoid a certain kind of opportunity cost – namely, the cost connected with permanently forfeiting the use of future information in ways that might (or then again, might not) be beneficial. The circumstances are fairly specialized in two respects: First, the *forfeiture* is not a forfeiture of the information itself. Rather, it is a forfeiture of whatever benefit there might be (and there might be no benefit) from having a larger set of development paths (here including conservation as a possible development path) from which to choose. Second, the *permanence* of the forfeiture is a direct consequence of the irreversibility requirement. It entails the permanent removal of development path alternatives – specifically those that involve less development for both periods combined than would be optimal for period 1 alone.

From this perspective, it seems critical to ask whether these two specializing circumstances warrant special consideration under the rubric of quasi-option value. If one focuses on the primary thrust of quasi-option value as a kind of opportunity cost avoidance strategy, then it seems that special consideration is *not* warranted. With each decision comes *some* opportunity cost. And surely there is at least an important *moral* sense in which no action or its consequences can be reversed. Any action that significantly benefits or harms other persons is irreversible in the sense that the benefit has been conferred and enjoyed, the harm done and suffered, and the actors have behaved well or not so well.

None of these things can be undone. We moral agents are chagrined by a person's enjoyment of benefits ill gotten because, even though we can later punish the beneficiary for her methods of obtaining them, her enjoyment of them at the time can never be erased. We are equally discomfited by the pain of someone who suffers undeserved harm or misfortune, even though we can later relieve her suffering by empathizing with her and perhaps by punishing her offenders. Neither the undeserved benefit nor the undeserved harm is ever really reversed. These considerations, no matter how obvious, are hard to capture in an economic framework in which any benefit can be removed by imposing a price; and any harm is just a price that can be reimbursed.

Furthermore, an irreducible element of human decision-making generally is that every decision is made despite the inevitability of better information that might guide a better choice later. A convincing case often can be made for more study and research. But there is also always a case, which gets increasingly compelling with time, to decide and to act. Working within the framework of quasi-option value entails a salient hazard: One might be tempted to think that it justifies an indefinite postponement of any decision that might feature a permanent removal of some development path from the collection of alternatives. But this would be a bad mistake in practical reasoning. It cannot be permissible to indefinitely postpone a decision that nonetheless could be made more optimally in light of still unavailable, but always possibly forthcoming, information.

One might object to this line of reasoning by saying that it is possible to fix the time of the second decision point. But this objection begs the question of what principles justify abandoning study and research at one particular time rather than another.

For instance, so long as new information material to the decision has not yet arrived in period 1, no condition material to the framework has changed; and in particular, there is no more justification for settling on the time of the second decision point at that point than there was at the first decision point.

It simply won’t do to say, with Maclaurin and Sterelny (2008, 154), that “as our knowledge improves… we will come to discover new ways in which species will be valuable.” I can (and, alas, do) say much the same thing about the accumulating junk stored in my garage: If I wait long enough, surely I’ll find some use for it. But I recognize that this is but a poor rationalization. It is not a justification for failing to clean out that space and put it to some obviously good use.

So long as there is no answer, let alone a convincing answer, to the question of how to set the decision points, it seems that the framework for quasi-option value is seriously incomplete. Given that it is a seriously incomplete guide to decision-making, I think that we are well advised to use it with considerable caution.

6.9.4 Specific Claims About the Option Value of Biodiversity

I now turn to Maclaurin and Sterelny’s discussion of how they think biodiversity’s value is primarily bound to its option value.

These authors take but one paragraph to introduce quasi-option value together with garden-variety option value. This introductory paragraph (Maclaurin and Sterelny 2008, 154) already gives substantial cause for concern when its conclusion declares that these two very different conceptions can be considered of a piece. This initial concern is amplified by their subsequent discussion, which veers back and forth between the two, but mostly loses touch with the requirements of both.

On one hand, there is the authors’ admonition to “hedge our bets, insuring against unpleasant surprises” – a risk avoidance maneuver that bears only on garden-variety option value. There is also their concern about “ignorance of our own future preferences”. This appears to be an acknowledgment that the shape of personal utility functions can change over time – one way (mentioned in Sect. 6.9.1, Option value and conservation) in which demand uncertainty can enter the (garden-variety) option value picture.

On the other hand, there is the surprising claim (Maclaurin and Sterelny 2008, 156) that “the option-value approach to conservation biology depends on our being ignorant, but not too ignorant” – a consideration that appears related to the value of information. This seems to be something about quasi-option value, but not garden-variety option value. Unfortunately, as my review of these two concepts in the preceding subsections should make clear, little can be coherently said about garden-variety option value within the framework of quasi-option value; and vice versa.

But mostly – and sadly, in this their treatment is representative – Maclaurin and Sterelny’s remarks have no clearly identifiable connection to either framework. For example, their suggestion (Maclaurin and Sterelny 2008, 155) that “The solution is to focus not on mere possibilities but on probabilities" appears to state a general, necessary condition for computing expected values in any standard cost-benefit analysis: This calculation weights the costs and benefits of each possible outcome by the likelihood of its occurrence; so both the outcome set and the probabilities must be known with some high degree of confidence. But this has nothing specifically to do with whether or not option value of either flavor figures in the analysis.

Maclaurin and Sterelny (2008, 149–157) argue that the case for the value of biodiversity must rest on the case for its option value. They present three possible ways, which they call "cases", to consider biodiversity for its option value. Whether or not they regard this survey to be exhaustive, it is clear that the authors do regard their proffered cases as exemplars and therefore their strongest evidence that option value is the key to the value of biodiversity. I therefore turn to examining these cases. Unfortunately, my examination confirms the premonitions for a less than sanguine result.

6.9.4.1 Phylogeny

In this first "case" (Maclaurin and Sterelny 2008, §8.5), the thesis under examination is that biodiversity, understood as phylogenetic diversity, has option value. The discussion by Maclaurin and Sterelny is fraught with difficulties quite aside from its problematic invocation of option value. I include these "extracurricular" problems in my discussion both because they typify what one encounters in appeals to option value and because they are too basic to be ignored.

One should expect that Maclaurin and Sterelny would launch the economic calculus of either option value or quasi-option value, incorporating phylogenetic diversity into their calculations. Phylogenetic diversity seems particularly well suited for this role, for these authors follow Daniel Faith's conception of it as a measure (of "feature" diversity, as explained in Sect. 3.3.2.1, Features). Measures are exactly the sorts of things that fit comfortably into the calculus of economics.

In the case of garden-variety option value, one should expect to see discussion of uncertainty in demand for phylogenetic diversity, computations of expected consumer surplus, and comparisons of *ex ante* versus *ex post* prices under varying circumstances. In the case of quasi-option value, one should expect to see discussion of timeframes for development and the costs and benefits of information about development – in both the standard economic sense and in the sense of "articulating a phylogenetic trajectory".

Unfortunately, absolutely none of these requisite elements are to be found. It is impossible to say whether Maclauren and Sterelny's economic reasoning is valid or not, because there is no line of economic reasoning at all that might lead to the conclusion that some positive option (or quasi-option) value attaches to phylogenetic diversity (or phylogenetic "development"). Maclauren and Sterelny (2008, 157) skip the argument, assume the conclusion – the most basic circularity fallacy (discussed in Sect. 2.2.5, Circularity fallacies or begging the question) – and assert that any speciation and any condition that encourages speciation is good insofar as it explores distinct "evolutionary possibilities":

> … in an explicitly conservation biology setting, confining our discussion to sexually reproducing organisms, and to reproductive isolation… [o]ption value explains the importance… of reproductive isolation… [This is because] Speciation allows daughter species to diverge radically in morphology, physiology, ecology, and behavior from their stem. For these reasons many people think of option value as mandating the preservation of species… every [one of which] represents a new and potentially important trajectory in a space of evolutionary possibility.[140]

With no argument concerning option value to examine, I could end my own discussion (which was supposed to be about the "case" for "phylogenetic option value") here. But it is instructive to follow along with Maclaurin and Sterelny to see how their discussion, like many others ostensibly about option value, devolves into a quite different one that begins to look like one that I've already remarked upon.

As noted just above, Maclaurin and Sterelny (2008, 139–142) adopt Faith's conception of the phylogenetic distinctiveness of one organism relative to another as the Google-mapped, shortest phylogenetic distance from one to the other. The passage just cited indicates that they also follow Faith in the dubious assumption that this phylogenetic distance is principally useful for measuring not (as one might have supposed from the name) some notion of evolutionary relatedness, but phenotypical or morphological distinctiveness. Whether justified or not, this conceptual leap leads Maclaurin and Sterelny to what they consider to be the key questions. These are: whether "all speciation represent the same amount of option value" and whether "some evolutionary trajectories represent more option value than others".

At first, it seems as though these authors (Maclaurin and Sterelny 2008, 158) might be concerned to answer their questions in a way that reprises the theme of Faith's notion that some species are more equal than others by virtue of the distinctiveness of their traits. Woe to the creature in a phylogenetically crowded neighborhood, which on that account is presumed to be morphologically and phenotypically near-identical to phylogenetic near-neighbors. To use their own examples, the authors' answers to their questions bode ill for a creature such as *Percina tanasi* (the snail darter), which has the misfortune of having evolved within a rather crowded evolutionary neighborhood – a neighborhood that does, indeed, happen to define a correspondingly compact and crowded morphospace of darters (at the genus level, which are part of the extremely speciose family of perch-like fish). On the other hand, their answers (Maclaurin and Sterelny 2008, 163) smile on *Rhynochetos jubatus* (the kagu). And sure enough, its morphospace has lots of elbowroom – presumably all vacant and available for future "evolutionary exploration".

Unfortunately, the use of Faith's notion of phylogenetic distinctiveness as a stand-in or measure for the distinctiveness of morphology or traits immediately puts this discussion on shaky foundations for the reasons first mentioned in Sect. 3.3.2.1

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[140] The foundation of their premise in distinct phenotypes is more explicit on p. 163, where they insist (again with no supporting argument) that it is critical to "attempt to represent phenotype distinctiveness".

(Features). Over the course of evolutionary history, very distant lineages have repeatedly “found” the same morphologies and other traits. There appear to be a limited number of adaptive “tricks”; different phylogenies often stumble upon the same ones – stretching from a small number of different body structures and symmetries up to the most dramatic cases of full-blown convergent evolution. A distinct phylogeny does not at all guarantee a distinct morphology or phenotype.

However, at some point, Maclaurin and Sterelny switch their pitch. They stop talking about the distinctiveness of an “evolutionary trajectory” as having a value that corresponds to the distinctiveness of its morphological *destination* in the tree of life. Rather, it emerges after further discussion that most value lies in species that are an especially promising *starting point* for a new trajectory – their “evolutionary plasticity” or “evolutionary potential” to explore uncrowded morphospaces. In fact, Maclaurin and Sterelny write as though these starting points are equivalent to “options”. And at least in their mind, this connects to option value.

Maclauren and Sterelny (2008, 158) then veer back and forth between their two notions – on the one hand, biodiversity value as plasticity and potential, and on the other hand, biodiversity value as an actually traversed trajectory – as if they were equivalent. For they go back to the latter, insisting “that we should conserve as representative a sample of evolutionary history as possible.” The authors seem to be only vaguely aware that their implicit suggestion that these two things are equivalent incorporates another unfounded assumption – that what has the most evolutionary potential also is an important representative of evolutionary history.[141]

This last assumption is simply false. There are many well-known instances where the phylogenetic isolation and phenotypical distinctiveness of a creature are the result of the dying off of nearby sister branches in the tree of life. The demise of most of an extant organism’s near relatives can be strong evidence that it shares with its extinct cousins a lack of robust evolutionary potential or that it lacks an ability to adapt to changing conditions (adaptive plasticity). The phylogenetic isolation of a creature such as the tuatara is an indication that it and its now-extinct relatives are relatively incapable of striking out on a new adaptive course. Stephen Jay Gould (1996, 72) makes this point by reference to *Equus caballus*, the modern horse – “a remnant of a remnant”, as he characterizes this species. It is, as he says, a remnant of steady perissodactyl (not just horse) decline in contrast to equally steady ascent of artiodactyls as the dominant representatives of modern macrofauna. *E. caballus* is an isolated twig at the tip of the tree of life where once was some quite bushy foliage. This certainly leaves a lot of horsey morphospace vacant. But given that that space was vacated by failed relatives, it is likely to remain unexplored in the evolutionary future.

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[141] At one point, Maclaurin and Sterelny (2008, 163) acknowledge that the snail darter might, in fact, take off on “an evolutionary trajectory… that will… make it of enormous consequence for our own future projects.” The rest of their discussion does not take this point seriously. And they do not acknowledge the worse problem, discussed in the main text, that evolutionary trajectories that rest in isolated regions of the tree of life are often that way precisely for lack of further evolutionary potential.

The authors (Maclaurin and Sterelny 2008, 163) dig themselves yet deeper into this factual hole by claiming that more recently evolved species are less "evolutionarily plastic" – and are on that account less valuable than those that are the product of an ancient speciation event. But disregarding the normative conclusion (for which no argument is offered), this proposition is also false. Some organisms are evolving, sometimes very rapidly – (as remarked in Sect. 6.7, Biodiversity as value generator) before our very eyes and likely behind our backs – as opposed to those "fossil organisms" that stopped evolving relatively long ago. The demonstrated ability of the modern quick-change artists, in contrast to the demonstrated incompetence of evolutionary stick-in-the-muds, to adapt and evolve under current conditions is strong evidence of their continued capacity to further respond to ecological change.

Let's return to the normative question. Some creatures might occupy a relatively uncrowded morphospace. Some creatures might, by some yet-to-be-specified measure, have greater "evolutionary potential" than others. Some other creatures might more "effectively represent evolutionary history". But the confusions, back-and-forths, and flaws in Maclaurin and Sterelny's narrative, which conflates all these things – distinctiveness of "traits", evolutionary longevity, and evolutionary plasticity – are largely irrelevant to the question of why any of these properties should be considered the basis for judging one organism more valuable than another. So far as I can tell, all of these properties are normatively irrelevant; and Maclaurin and Sterelny offer no reason to make us think otherwise. These properties are even more irrelevant (if that is possible) to the question of whether or not any kind of option value is involved. One will search Maclaurin and Sterelny's discussion in vain for even a hint of awareness of option value rudiments such as as *ex ante* versus *ex post* evaluation (for garden-variety option value) and the influence that new information might have on successive decision points (for quasi-option value).

Maclaurin and Sterelny, like Faith and others writing in a similar vein, do not answer the question of normative justification because they do not even ask it. And if they answer the question of how option value is connected with norms for biodiversity, then that answer is inscrutable. Maclaurin and Sterelny (2008, 163) give us only this hint about what they have in mind:

> We have imperfect knowledge of threats and opportunities the world will bring to us, and we have imperfect knowledge of how our own preferences will change over time.

The first part of this compound thought (regarding knowledge) might be relevant to quasi-option value; the second part (regarding demand uncertainty due to changes in utility functions) might be relevant to garden-variety option value. But the authors are mute on the crucial question of *how* these considerations are relevant. Furthermore, they flow from two entirely different conceptual frameworks. If, as seems possible, they are trying to combine them, it is hard to imagine what this admixture amounts to. Again they leave only a hint (Maclaurin and Sterelny 2008, 163):

> A diverse, adaptable, evolutionarily plastic biosphere is like individual health. It is fuel for success for our projects, both collective and individual.

Here, as in so many of the various attempts to link biodiversity to something valuable, the discussion comes around to some notion of "health". Unfortunately, the authors offer no argument as to why or in what respects an evolutionarily plastic biosphere is like individual health. Nor do they help us understand why and how phenotypical diversity fuels successful projects. Neither proposition is self-evident, and there is strong evidence against both generalizations: The plasticity of infectious organisms is perhaps the greatest threat to human well-being. And a small number of phenotypes associated with a startlingly small number of creatures often account for the lion's share of any category of benefit – for example the overwhelming dominance of a small number of organisms as sources of medicine. As I shall show in Sect. 6.9.4.3 (Ecological option value), Maclaurin and Sterelny themselves provide support for excluding most creatures from having a role in "ecological option value".

6.9.4.2 Bioprospecting

Maclaurin and Sterelny's discussion of bioprospecting (Maclaurin and Sterelny 2008, §8.6) takes up some lines of reasoning that Sect. 6.5.1 (Biodiversity as pharmacopoeia) examines. These authors once again neglect to present an argument. Nor can one find premises from which an argument might be constructed on their behalf. They nonetheless assert their conclusion (Maclaurin and Sterelny 2008, 167), that:

> … bioprospecting option value will weigh phylogenetically distinctive species much more heavily than those from speciose clades.

One can speculate that the authors believe that more "speciose clades" are less likely to manufacture the right kinds of bioactive molecules. But these authors present no evidence for this proposition and I am not aware of any evidence for it. The fact that some of the most common pharmaceuticals are derived from organisms such as sheep (a member of the mammal-dominating order Artiodactyla), common molds, and bacteria bluntly contradicts it.

One can also speculate that the authors believe that the more removed the lineage of an organism from that of any other organism, the more likely the organism is to produce useful bioactive substances. Once again, I am not aware of any evidence whatever for this; Maclaurin and Sterelny offer none.

Or one can speculate that the authors think that bioprospecting is like the lottery and that the winning lottery numbers are imprinted, not on distinct species, but on distinct lineages. But there is substantial evidence that bioactive molecules are often concentrated in groups of creatures that occupy nearby phylogenetic perches in the tree of life. One example is (from Smith and Jones 2004, 7841) the ">180 pumiliotoins found in virtually all anurans". This sort of evidence makes it clear that finding a bioactive molecule is not at all like a random draw from a phylogenetic deck of cards in which one would wish to have as many winning cards as possible.

Rather, the phylogenetic deck is stacked. The production of bioactive molecules is largely a matter of adaptive necessity of a particular kind of lifestyle – a need that might commonly be shared by every species in a speciose clade; but a need that is completely absent from distant and distinct clades.

In sum, it is hard to avoid the impression that Maclaurin and Sterelny fail to provide a premise or an argument for the simple reason that no defensible premise exists for an argument that might lead to their conclusion, quoted above.

Certainly nothing in their discussion of "bioprospecting option value" relates it to the framework for garden-variety option value. There is no discussion of what kinds of demand (or supply) uncertainties are in play, how these affect the difference between expected consumer surplus and option price, or how this difference varies in sign or size according to risk preference. Nor does anything in their discussion relate to the framework for quasi-option value. There is no mention of the decision framework, including the tradeoffs involved in postponing a development decision in the hope of obtaining new information that relates to the costs and benefits of possible bioprospecting outcomes and the likelihood of these outcomes.

In short, the authors do not discuss anything having to do with option value. What they offer are some considerations that are at home in a standard cost-benefit analysis in which option value (of either kind) plays no role. A case for conserving biodiversity on this basis requires evidence that the expected value of conserving is greater than the expected value of developing. That evidence, which I consider in Sect. 6.5.1, is tenuous.

It is remarkable that in the end, Maclaurin and Sterelny themselves give a dim assessment of the expected value of biodiversity from bioprospecting. They grant that there is a dismally low payoff to bioprospecting; that rational design of drugs is more efficient; that, even in the natural world, "second source" species are highly likely; that "big pharma" has largely abandoned bioprospecting for the sound economic reasons that maintain corporate profits; and that there is a very high potential for "enhancing the chemical diversity of an organism by adding to it a gene coding for alien enzymatic activity". All of this argues for assigning vanishingly small likelihoods to a better outcome, and in particular, a better pharmaceutical inventory, in a world with conserved biodiversity. It argues that, at least on these (standard cost-benefit) economic grounds, development at the expense of biodiversity is almost surely justified.

In an even more remarkable concluding twist, the authors disown the case for bioprospecting option value. This move, they say, is prompted by their belief that "ecological option value" can step into the breech to assume the burden of justifying biodiversity-as-option value. I now turn to this last "case" of option value.

6.9.4.3 Ecological Option Value

Unfortunately, there appears to be no more reason to wager that "ecological option value" (Maclaurin and Sterelny 2008, §8.7) will carry the day for biodiversity's value than that the previously examined "cases" of "option value" will do so.

The “option value” in the phrase “ecological option value” belies the fact that yet again in this “case”, nothing in Maclaurin and Sterelny’s discussion connects to the framework for either garden-variety option value or quasi-option value.

Instead, Maclaurin and Sterelny hitch their nominal option value wagon to Paul and Anne Ehrlich’s original precautionary argument whose later and more sophisticated incarnation is discussed towards the end of Sect. 6.3 (Biodiversity as service provider). Their discussion (Maclaurin and Sterelny 2008, 168) takes as premises, first, that stable ecosystem function is a good, and second, that changes in the way ecosystems work are a bad to be avoided, and that the consequence of “the removal of any species from an ecosystem risks a domino effect, leading to wholesale species loss and ecosystem breakdown.” The discussion then concludes that a very small class of animals – mostly large, furry ones with (as they say) “high metabolic demands” and “slow reproductive rates” – are far more likely than others to be the critical protectors of the *status quo*.

Though after looking at the other “cases” of “option value” it might no longer seem so odd, it truly is odd that, again, nothing said here has anything to do with option value. However, several more odd qualities in this particular discussion are worthy of brief additional comment. First, it appears that the argument is not so much pitched at conserving biodiversity as it is at preserving a small and select cadre of creatures. This position is vulnerable to being flipped on its head and considered an argument for how dispensable most creatures (for most creatures are not furry megafauna) are – that is, an argument *against* biodiversity rather than for it.

The second oddity, already mentioned, is the discussion’s turn to loosely precautionary reasoning. This divagation into precautionary territory is apparently unintentional. For the authors explicitly promote reasoning about option value as far more tractable than precautionary reasoning, emphasizing their desire to distance themselves from the latter (Maclaurin and Sterelny 2008, 185, note 7):

> … because option-value reasoning is tied to some future assessment, albeit rough, it does not depend on the decidedly controversial “precautionary principle,” beloved of green politics.

Of course, the fact that Maclaurin and Sterelny conflate their precautionary reasoning with “option-value reasoning” is not itself an argument against some version of the (precautionary) reasoning at which they vaguely gesture. But because they are unaware of having strayed into precautionary territory, they have not thought to do any of the basic preparatory work for making one’s way in that tricky terrain – including choosing and justifying choices for the key ingredients (sketched in Sect. 6.3) that go into any plausible Precautionary Principle. At most, one could say that they narrow the threat of harm to the uncertain fate of large furry mammals. But this is a long way from characterizing the nature of the harm, its seriousness, and the uncertainties involved; and on the basis of these considerations, justifying “appropriate” precautionary responses.

The end result is that, not only do these authors offer no argument for biodiversity’s value in terms of option value, they also fail to provide any viable precautionary argument. As a consequence, they wind up offering no argument at all for the value of biodiversity.

6.10 Biodiversity as Transformative

Taking a cue from some early work by Bryan Norton (1987), Sahotra Sarkar (2005, 81–87) develops the idea that biodiversity has "transformative value". Sarkar (2005, 82) defines this notion in terms that connect it directly with the nomenclature of standard neoclassical economics – as "the ability to transform our demand values". Demand values are what most economists would call "preferences". Economists tend to focus on just those demand values (preferences) that are expressed in market transactions, which (as remarked in Note 28 in Chap. 2) can be either real or imaginary. Sarkar (2005, 80) expresses some discomfort with this – asking, for example, what the market value of freedom could possibly be. As a quick cure for his malaise, he labels such values as "intangible", summarily sets such values aside, and then forges ahead with his theory.

According to that theory, to a first approximation, biodiversity has value because it can change human preferences. Sarkar is quite aware of two hazards in this position, which he calls, respectively, "the boundary problem" (Sarkar 2005, 95–96) and "the directionality problem" (Sarkar 2005, 96–98). These problems are different perspectives on the stubborn fact that a person's preferences might be changed so that she prefers the trivial to the important, the banal to the original, the excessively narrow to the sweepingly full spectrum, and even the bad to the good. The solution to these hazards, according to Sarkar (2005, 102), is to allow only transformative value that is also "systematic":

> An entity has "systematic" transformative value if we have reasons for giving it this value other than the mere fact that some individual stood transformed by it: we have a generalizable account of how it acquired such a value.

In other words, if one can offer a theory for why some thing X causes values to be transformed and the theory generalizes to many people whose values have been transformed by X, then the value of X can be regarded as "systematic" in the required sense. It passes muster according to Sarkar's theory.

Unfortunately, Sarkar's test does not and cannot do the vetting job that he assigns to it. There are good psychological theories for why a person in circumstances that make her the witness of the systematic abuse of another generally transforms the witness' values regarding trust. Saliently in western consumptive society, there are excellent theories for how commercial marketing can and does transforms consumers' values so that they prefer and acquire objects, many of which do not benefit them and which sadly sponsor much of the biodiversity-reducing "economic development" that Sarkar and other conservationists are concerned to forestall. It appears that some transformative values can be as environmentally destructive as others can be environmentally benign or beneficial.

But are these consumptive transformations "systematic" in the required sense? Unequivocally, yes. Modern neoclassical economic theory offers one of the most fully developed and systematic theories of value acquisition, which purports to shows how people, according to one model of rationality, come to prefer (for example) subdivisions to the wetland they replace. Modern marketing theory has come to an eerily sophisticated understanding of how to apply this theory. And that theory is routinely and systematically applied to transform the "demand values" of persons who, as a consequence, "voluntarily" adopt preferences to consume that which profits the corporation behind the marketing.

One might question many of the precepts on which neoclassical economics is built – saliently including its characterization of *Homo economicus* as a fully functioning rational person. But this does not disqualify that theory as non-systematic in Sarkar's sense. Sarkar says nothing to dissociate his theory from this standard version of economics. And in fact, his theory of transformative value appears to be built squarely atop it.

But there is more to Sarkar's failure to adequately qualify transformative value. For his theory does not fail just because it borrows its theoretical structure and content from economics and marketing, which notoriously can transform demand values in perverse ways. It fails more fundamentally because of a lacuna in reasoning. The mere fact that a demand or preference comes about via the systematic working of some state of affairs – whether via the omnipresence (and possibly omnipotence) of marketing or biodiversity – can never be held as an endorsement of that state of affairs. A newly acquired preference might or might not be worthy of satisfaction; its object must be assessed on its own merits. The "systematic" character of its genesis is not a legitimate criterion for making this normative distinction.

6.11 The Experiential Value of Biodiversity

In the course of making his argument for the transformative value of biodiversity, Sarkar repeatedly mentions "the experience of biodiversity". This appears for him (for example Sarkar 2005, 82, 83, 96) to have its own value – insofar as Sarkar seems to regard it as the source of "good" transformations. This notion of "the experience of biodiversity" seems ill-considered. As I observed in this book's Preliminaries, biodiversity is an extraordinarily abstract concept. It is so abstract that it is hard to say how, if at all, a person can have "experiences" of it.

When one goes out on a walk in the woods, one finds oneself encountering and having an experience of individual plants and animals – "objects" that instantiate substantial universals (in the simple ontology of Fig. 3.1). One can plausibly say that one experiences the graceful needled foliage of a neck-craning individual woody plant growing by a brook *as* an eastern hemlock – the particular kind of tree that it is; or that one experiences a particular, mellifluously whistled song *as* a Rose-breasted Grosbeak – the particular kind of feathered creature that one surmises is the star performer. Moreover, individuals of some kinds might be so numerous that the individuals quickly become anonymous and our experience of them fades into an "experience" of their kind. And as one's realization grows of the variety of these encountered kinds, one might hold on to this variety or diversity of kinds as a major or even dominating contribution to an experience of an eastern U.S. hardwood forest.

But is this an experience of *biodiversity*? Consider first a single species: Is the experience of hearing a Rose-breasted Grosbeak burst forth in song an experience of the species *Pheúcticus ludoviciánus*? Now consider several species that enter into a single moment. Is the experience of the disembodied grosbeak's song emanating from somewhere in a mixed wood of *Tsuga canadensis* (eastern hemlock), *Pinus strobus* (eastern white pine), *Acer saccharum* (sugar maple), *Betula papyrifera* (white birch), and *Fraxinus americana* (American ash) an experience of species diversity? Now consider a disjointed sequence of moments. When later on, one spots a Wood Thrush, and then a Cedar Waxwing, does one then have an experience of avian diversity? When one comes upon the unexpected yellow birch, does this enhance one's experience of tree diversity? What if "later on" is 30 years later? What if some other person, not the original observer, has the later experience?

Perhaps it is okay to say that these are experiences of biodiversity. But if they are, it is only in some very extended sense of "experience" that is stretched well beyond its customary meaning to include abstract ways of knowing, categorizing, comparing, and analyzing the world. This would be a sense "experience" that Plato could happily endorse – experience that "sees" not just the mere Platonic shadow of a particular eastern hemlock, but eastern hemlockness itself; experience that "hears" not just the shadowy sing-song tune of a particular concertizing Rose-breasted Grosbeak, but Rose-breasted Grosbeakness itself. Bringing this up a level to diversity, it would involve experience of speciosity itself, not merely experience of this species and that, and certainly not merely experience of particular barky and feathery things.

I am put in mind of Elaine Scarry's provocative discussion of justice and the value of beauty in grasping *that* abstraction. She notes (Scarry 1999, 101) that

> … the symmetry, equality, and self-sameness of the sky [taken as something beautiful] are present to the senses, whereas the symmetry, equality, and self-sameness of the just-social arrangements are not [because, among other reasons] it is dispersed out over too large a field (an entire town or entire country), and because it consists of innumerable actions, almost none of which are occurring simultaneously.

This suggests how one might legitimately say that a person is "experienced" in (matters of) biodiversity. However, this is not the same thing as to say that that person "experiences" biodiversity. More likely, that person has had a great many disjoint experiences – in the normal, non-extended sense – that involve a great variety of organisms. It is through the accumulation of these experiences, combined with a reflective understanding that integrates them, that one comes to "have experience" in the great variety of life forms. One might venture to characterize this as "experiencing" biodiversity. But this is clearly a figurative stretch of the normal sense of "experience" to something related but distinct. Less figuratively, one would characterize this as gaining an appreciation of biodiversity.

A plenitude of experiences (in the non-extended sense) might be acquired by a single person over the course of a lifetime. Someone such as E.O. Wilson who actively seeks them out might amass an impressive store of them over time – each new experience informed by, and building on, the knowledge and understanding acquired from the totality of previous ones – eventually yielding a deep-seated appreciation of life's variety. Wilson's appreciation of biodiversity – his experience in this matter – might be similar to the lifelong experience (or appreciation) of justice by a judge who, in various jurisdictions, has overseen a just and equal application of the law in many different cases that present many different circumstances bearing on their just disposition.

In fact, this extended sense of "experience" need not be restricted to a single person. It could be jointly "had" by a community of communicating observers whose individual experiences can be pooled to construct a collective picture, which all members of the community can then assemble from these various, initially disconnected pieces. In other words, the extended sense of "experience", unlike the non-extended one, admits of disjoint experiencers as well as disjoint experiences had by a single experiencer.

Clearly, these constructions of extended "experience" are at a far remove from objects that are sensible to a person at any moment in place and time – even objects-experienced-as-a-kind (for example, the feathered being-as-Rose-breasted Grosbeak). In addition to one person's non-extended experience, the extended "experience" draws on that person's memories. It draws, too, on the experiences and memories of others, conveyed in symbolic form, perhaps over the course of hundreds of years. It could even include theoretical extrapolations that let us say such things as that humankind has had "experience" of the more than 10 million species, despite having collectively encountered and catalogued just 1.5 million or so over the past few centuries.

A person certainly does experience individual animals and plants, and even many of them, and many different kinds of them in one scene at one time or in the course of a day's travel; and one is commonly aware of not just these individual organisms, but of their variety. That was part of the experience of the unseen Rose-breasted Grosbeak singing from some perch in the rich mix of trees in a mixed coniferous and hardwood forest. It is this kind of "experience" that is central to the "experience of biodiversity" in Sarkar's favored example of a neotropical forest (Sarkar 2005, 82). So let's return to the key question for this particular "experience".

Is such an experience an experience of *biodiversity*? Perhaps, but only in an extended sense in which one might "experience" criminal justice in a particular trial – upon witnessing the handing down of a sentence that seems proportional to the crime committed, given an accumulated knowledge of other, similar crimes committed in similar circumstances, disjoint in space and time, for which one might or might not have had the direct experience of the sentencing; and given some even more abstract understanding of principles of criminal justice. We might be said to have that experience, but only by virtue of evaluating what is now before us in light of a complex web of prior experiences, along with an even more complex web of abstract concepts that have to do with the nature of justice.

However, this modestly extended sense of "experience" is apparently not what Sarkar has in mind. His thinking is based on a strict dichotomy – between "direct" and "indirect" experience. He grants that some "experience" of biodiversity might be "indirect" – by which he appears to mean "theoretical knowledge". This is the sort of "experience" that comes from computing quadratic entropies or computing phylogenetically minimum-length paths to connect two points in the tree of life. But he insists (Sarkar 2005, 82–83 and in other, similar passages) that all such "indirect experience" of biodiversity is firmly rooted in the "direct experience" of biodiversity "which brings about a transformation of our demand values". He views "direct experience" to be the sort of thing that grabs us by the sensory organs, that tugs at our viscera, that dazzles us, and thereby transforms us. It is the stuff of revelatory vision – the antipode of a quadratic entropy computation.

Sarkar is driven to this dramatic but implausible conception of the "direct experience of biodiversity" precisely because of the transformative role that he requires of it. That role demands that this phrase be invested with direct and visceral qualities because, according to him, its value depends on selling us something. That is, it depends on its acting on us just like the cleverest of demand-transforming commercial marketing campaigns. Advertisements do not succeed by means of theory far removed from experience. Quadratic entropy cannot sell biodiversity.

It is possible that by insisting on this conception of the "direct experience of biodiversity", Sarkar is again led astray by the recurring error of mistaking the diversity of kinds for the qualities of some particular kinds in a diverse collection; or worse, mistaking diversity for the qualities of some particular individuals in a particular place. In that woodland walk, it is the towering presence of certain specimens of eastern white pine and eastern hemlock that most powerfully insinuate themselves into a person's experience. So too does some sense of the place – the feeling that it conveys through its quality of light and sound. This, one might suspect, is a consequence of its particular assemblage of plants and animals. But then the person walking through the woods is directly experiencing those qualities of light and dark and sound, not the diversity of organisms that collectively conspire to create those qualities.

These points are not lost on environmental organizations, which understand that some particular kinds – often the big furry animals that attract Maclaurin and Sterelny – are good "salesmammals" for natural value. But in these cases, it is not the diversity of kinds, let alone the direct experience of the diversity of kinds that is the selling point – that is, the source of demand-transforming power. Rather, it is some sort of experience of individuals of a "charismatic" kind – say, an encounter with a tiger; or an experience of a tiger as a tiger; or, at one level of indirection removed, a conjuring in the imagination of The Tiger – that is, the conception of a being that constitutes an exemplary tiger.

This criticism, of course, does not preclude the possibility that a more "indirect experience" of biodiversity might, after long and sober reflection, eventually unveil its supposed value. This is not the wakeup punch in the gut that Sarkar looks to as instrument of transformation. But I take I take it to be a succinct description of the other, less-than-compelling theories of biodiversity value covered in this chapter, which depend on some line of causal-utilitarian or precautionary reasoning, or a theory of biodiversity as a constituent of a good human life.

6.12 Biodiversity as the Natural Order

The value of biodiversity as implementing a "natural order" of things is inextricably intertwined with the just-so model of biodiversity value. Much of what I wish to say about this view of biodiversity's value is presented in Sect. 5.1.4 – The just-so model of How biodiversity relates to its value. But the remarkable prevalence and persistence of this theory of environmental value merit some additional remarks here.

The notion that the *actual* order of things is also a *natural* order permeates several venerable philosophical and religious traditions. Leibniz's version of this notion, which Sect. 2.3.2 (The value of diversity in general) visits, is unusual in pressing a view that very directly ties the value of this natural order to some great, underlying variety or diversity. Leibniz did not imagine that this actual diversity might vary from time to time. For him, the diversity of the natural world was once and for all time set by its Creator. The distinct kinds make possible the world's perfection, which consists in the natural ordering of these kinds with respect to each other.

Putting aside the static quality of Leibniz's vision of diversity, one can see how closely aligned it is with a major current of modern thinking about why biodiversity is valuable. In the updated version of the natural order story (one that admits geological and evolutionary change), the actual order is seen to have *deviated* from the natural order, which only existed at some prehuman or (on some accounts) later prehistorical or historical juncture; and the natural order could only have persisted in the absence of human interference after that. Still according to the latter-day perfectionist view, biodiversity is valuable to the extent that it exemplifies this state of perfection or one derived from it without anthropogenic inflection. Human activities can do nothing to improve on the perfect state, which, after all, was already perfect (in the relevant, natural sense); their effects can only be adulterating, except insofar as they deflect the state of nature back towards the imaginary state defined by a history uninflected by humans after the prescribed juncture of perfection. To the extent that humans cause biodiversity to deviate from the natural biological order, they compromise the natural good of the world. This sentiment is the spine of the position that holds up exotic creatures as aliens, less desirable than natives.[142]

Of course, the notion of a *natural* order carries with it the burden of understanding what makes a particular order "natural", why a natural order is a good (or at least better than an "unnatural" order), and how it should guide human choices and actions. There is not a little irony in tying biodiversity to this burden, for the notion of "wilderness" also largely hinges on some similar notion of natural perfection, which famously, humans can only "trammel", if they are not careful.[143] Hitched to the same post, the debate about the value of biodiversity plunges into the depths of the same tangled debates that once consumed the value of wilderness – debates that precipitated that latter concept's widespread supplanting by biodiversity as emblematic of natural value.

By common consensus, wilderness, conceived as a place "untrammeled by man", appears to have vanished almost completely from the planet. But so has biodiversity – insofar as it is conceived as an expression of natural order in the biological world. As remarked in Sect. 5.1.4, there is essentially no ecosystem on the planet – considered

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[142] This is not to say that the perfection of natives versus the imperfection of exotics is the *only* salvo that is routinely lobbed at the latter. It *is* to say that some substantial consternation about exotics has to do with human assistance in introducing them to their new neighborhoods, whose biodiversity is thereby rendered less "natural". I am fully aware of another claim that is now routinely made – to the effect that exotics decrease biodiversity *simpliciter*. But support for this claim as a general thesis is tenuous unless "biodiversity" is understood to mean something like "*natural* biodiversity".

[143] This is a reference to the definition of "wilderness" in the 1964 Wilderness Act in the United States.

as including its diverse community of organisms – that is un*affected* by a wide range of human activities. If the "natural order" is one in which (according to one prevalent suggestion) humans have not heavily *interfered* with the "natural progression"of the world, then this order is largely or perhaps entirely absent in the current state of the world. This makes it difficult to find grounds for thinking that the *current* order, which is evidently already a deviation from the natural order, should be defended, conserved, or even restored to some very recent state – a state that will inevitably still be marred by human-induced deviations from the natural order, which (on most perfectionist accounts) already have a history centuries or millennia long.[144]

Current-day thinkers tend to substitute the term "naturalness" for "natural order", but to all appearances, their philosophy sprouts from the same roots as that of Aquinas and Leibniz. The verbs "affect" and "interfere" (italicized in the preceding paragraphs) figure prominently in characterizations of how human influence on the "natural" world have compromised its naturalness. By the lights of some thinkers, the extreme degree to which humans have affected and interfered with nature is thought to have sufficiently destroyed the natural order so as to entail "the end of nature".[145]

The environmental philosopher Dale Jamieson accepts the basic framework in which the "end of nature" claim is made. But he believes that the rumored "end of nature" is greatly, or at least somewhat, exaggerated. While setting aside the question of how much the quality of naturalness *explains* about nature's value, he (Jamieson 2008, 164) regards naturalness to be "a matter of degree", and the degree of nature's naturalness to be an axiological barometer – that is, a salient property or characteristic that is a sound basis for judging the degree to which nature has value as nature (in contrast to its value as resource, for example). Finally, the degree of naturalness, according to Jamieson, is a function of how human influence is involved in the causal chain that led to a temporary terminus in the current state of the world. In this significant respect, he is a latter-day exponent of the perfectionist tradition of valuing naturalness,[146] which makes it important to understand the extent to which pieces of the current, actual world exemplify this property.

Jamieson suggests that assessing how much naturalness is justifiably attributable to a place must take into account what he regards as two distinct kinds of human influence, because according to him (as I explain below), these have differing effects on naturalness. To this end, Jamieson (2008, 163) tries to drive a wedge

> …between X affecting Y, and Y being a product of X. I may affect your decision about what to study in many ways, for example by providing you with information or advice that you may or may not take into account. This, however, is quite different from the case in which your decision about what to study is a product of my influence.
>
> Consider the following example. Human action affects the length of the growing season in the Great Lakes region of North America, but the fact that there are zebra mussels in the

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[144] This point stands even before any additional support it receives in the much-discussed conundrum that modern restoration practices constitute yet another means of human interference.

[145] This phrase is ensconced in, and made famous by, the title of Bill McKibben's book, *The End of Nature.*

[146] Jamieson himself is likely to balk at association with perfectionism.

> Great Lakes is a product of human influence. They were transported there by ships, and deposited along with ballast water. The distinction between these two cases (the human impact on the length of the growing season and human impact on the presence of zebra mussels in the Great Lakes) has intuitive force (or so I hope)…

Unfortunately, there are significant gaps in the logic of Jamieson's proposal. First (initially putting aside the validity of the distinction), he neglects to state explicitly *why* he thinks the alleged distinction between affecting and producing makes a difference for nature's naturalness, or for determining whether or not "the end of nature" is at hand. As he grants (Jamieson 2008, 163), if the end of nature is not at hand, this must be so despite the fact that "human influence is so pervasive that no part of nature remains untouched." Or, to put this in the terms of modern ecology, if we are not at the end of nature, this is so despite the fact that there might not remain a single biome on the planet that is not an anthropogenic biome (Ellis and Ramankutty 2008).[147]

Jamieson does not explicitly state the purpose of his distinction "between X affecting Y, and Y being a product of X". But it seems clear that he believes that it serves to separate two kinds of human influences, which differ in their effect on nature's naturalness. On the one hand, humans can *affect* nature and do so without thereby affecting its state of being natural. On the other hand, any change in nature that humans *produce* is, by virtue of that, an unnatural state, or at least a state of reduced naturalness. Establishing the relevance of this difference to the issue that motivates Jamieson's discussion – of whether or not nature is already at its end – requires one final claim of an empirical nature. This premise, which I supply on his behalf, is: The changes that humans *produce* are restricted in scope – sufficiently so (compared to changes due to people merely *affecting* nature) that the end of nature is some way off.

The second gap in Jamieson's logic is located in the alleged distinction itself rather than in its alleged implications for naturalness. As he says, Jamieson "hopes" that his readers will feel the intuitive force behind it. I suppose that he also hopes that his readers will feel the intuitive appeal of the distinction's force in bifurcating human influences on nature, along the lines I have just suggested. But he offers no supporting argument; I do not feel the intuitive force that Jamieson hopes I will feel; and no matter how hard I look, I do not see any light between X affecting Y (on the one hand) and Y being a product of X's influence (on the other).[148]

One might think that the clues for finding the light will be found in the two contrasted cases (briefly mentioned above, in the first quotation from Jamieson) of person-person interaction, which Jamieson offers as models for the two contrasted cases of human-ecosystem interaction. But I think that there is more in the person-person model to derail the analysis of the human-ecosystem interaction than to keep it on track. The interhuman interaction concerns a decision, of possibly great personal

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[147] As the main text explains, the very point of Jamieson's distinction is to enable him to say that although both forms of human influence result in anthropogenic biomes, only one reduces a biome's naturalness. See also Sect. 5.3 (The moral force of biodiversity).

[148] Jamieson uses "product of X" and "product of X's influence" interchangeably. The latter phrase appears at Jamieson (2008, 164).

significance, that one person (in this case, a student) makes as (one initially supposes) an autonomous rational agent. Quite clearly, the manner in which Jamieson exerts influence on that agent is an important moral consideration. Offering guidance that is not based on his own personal interest in the choice is permissible; threats are not. But none of this carries over to influencing the environment because, quite simply, it is not an autonomous agent that makes decisions that matter to it.[149]

The person-person model also goes off track considered apart from its role as a model for human-environment interactions. I believe that whatever difference there is between the two interactions hinges on tacitly transforming the student from a fully autonomous agent in the first case, in which Jamieson's role is merely "providing… information that [she] may or may not take into account", into someone or something whose freedom to decide is severely truncated in the second case, where the decision is no longer hers, but rather "a product of [Jamieson's] influence". Perhaps the student is really now a robot, which Jamieson has programmed with a certain decision procedure that yields the decision that he "recommends". Or less dramatically, perhaps the student is still a person but Jamieson has given her a drug that temporarily disables or seriously impairs her ability to deliberate in a way that properly balances all her own interests. Or perhaps Jamieson's influence on the student is more subtly coercive, by dint of his position of relative power over the student. If one resists this tacit transformation and presumes that the student remains as fully autonomous and rational in the second ("product of") case as in the first ("affected by") one, then the opening between these two cases collapses. Insofar as it is natural to say that her decision about what to study is a *product* of Jamieson's influence, it is equally natural to say that is because he has *affected* her decision.[150]

Nor does intention appear to provide an opening between "affecting" and "being a product of". In Jamieson's two human-environment interactions, both the shortening of the growing season and the presence of the zebra mussels in the Great Lakes are causally attributable, in part, to human actions and patterns of behavior. But no one *intended* to shorten the growing season; and no one intended to transport zebra mussels into the Great Lakes. Both are inadvertent and unplanned side effects of actions taken with intentions that had nothing to do with those effects. In both cases the lack of intention is clear because awareness of these specific effects and even of the possibility of their occurring – arguably a necessary, but not a sufficient condition for their being intended – emerged only after the fact.

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[149] Jamieson disagrees with this assessment, saying "It isn't obvious to me that autonomy can't be ascribed to nature." [personal correspondence] See also Jamieson (2008, 166) and Jamieson (2010, §6, "Respect for Nature"). I briefly return to this topic at the end of this section. Section 8.2.6 (What appropriate fit is not) reconsiders the position taken by Jamieson and others by way of contrast with my own, antithetical view: Insofar as autonomy can be ascribed to nature, it is devoid of key elements that ground moral respect for other *persons*' autonomy.

[150] As I have already pointed out, Jamieson (2008, 164) states that "the distinction between X affecting Y, and Y being a product of X's influence, is undeniably value and a matter of degree." But this does not cut against my point, which is that, if X and Y are chosen in a uniform way (both fully autonomous rational agents, or not), then the distinction loses its ability to do the logical work for which Jamieson employs it.

Perhaps “product” is supposed to connote “a salient result of actions or behavior”. But this interpretation does not help Jamieson, either. Both the shortened growing season and the presence of zebra mussels in the Great Lakes surely are products in this sense.

Maybe Jamieson just picked unfortunate examples, and a more felicitous choice would tease out some relevance to the distinction of intent and salient results. Suppose that the case of *producing* a Great Lakes full of zebra mussels were replaced by that of constructing a condominium in a wetland area. Condos, unlike the relocation of zebra mussels, *are* produced in the primary sense of “made or fabricated”. Their fabrication is the product of human planning and design, and therefore (unlike the transplanting of zebra mussels) intentional. Directly tied to the intentional production of the condos is the salient result consisting in the wetland’s transformation. Perhaps this combination of intent and salient result justifies saying that, while the condo project does not *affect* the wetlands, its transformation of the place is a *product* of human influence.

But this new example does not really salvage Jamieson’s goal of distinguishing those human influences that undermine naturalness from those that do not. While no one would dispute that the condos were produced and that *they* are not natural, that was never in dispute; Jamieson’s proposed wedge is superfluous in making that determination. So far as intention is concerned, no one would dispute that the condos required careful planning and design: The intent was to build condos. But one must take care to distinguish that intention from a full accounting of the salient consequences of acting with that intention. The peculiar (intentional) nature of intention is such that, when doing A ends up (also) realizing B, a person who intended to do A need not also have intended to do B. That is certainly true when she had no idea that B would come to pass as a consequence of her doing A. But it is also true when she knew B to be an inevitable consequence of A; and it is true even when she intended to do A *by* doing B. In the first case, she might acknowledge that she knew that B would follow from A. In the second case, she might acknowledge that she did B precisely in order to do A. In both cases, she might be held responsible for B. But in all these cases, she might also truthfully maintain that it was only A that she intended. So it is reasonable to question whether an intention to *produce* a condominium complex is also an intention to obliterate the wetland that it displaces.

Granted, one might say that the intentional production of condominiums (also) *produced* a transformation of the wetland – whether or not that transformation was intended. However, with equal clarity and cogency, one might say that the wetland was *affected* – in fact, greatly affected and perhaps even destroyed – by the development project. This latter characterization – in terms of the effects of human activities – is common in the ecological literature, which frequently speaks of how humans have *affected* virtually every biome on the planet by various means. These means include behaviors, which, on the one hand, have resulted in changes in climate and growing seasons in the Great Lakes region among others, and on the other hand have resulted in bringing creatures such as zebra mussels to places such as the Great Lakes heretofore unvisited by them.

Where else can the opening between "being affected by" and "being a product of" be found? What else could it consist in? On the one hand, why can't one just as easily say (*pace* Jamieson) that the changing length of the growing season in the Great Lakes region is a product of human influence as say (along with Jamieson) that the domination of zebra mussels over other mollusks in the Great Lakes is a product of human influence? On the other hand, why can't one just as easily say (*pace* Jamieson) that human behavior has affected the Great Lakes aquatic ecosystem as (with Jamieson) that human behavior affected the growing season in that region? So far as I can tell, all these cases depict states of affairs that are partly the *product* of human influence. Which is to say that all these cases depict states of affairs that have been *affected* by human actions and characteristic behaviors. Which is to say that human actions and behavior have played some causal role – a role that is, in fact, salient both for the growing season and for the zebra mussels' newfound homes.

Perhaps Jamieson is just trying to say what I suggested at the outset – that the world's naturalness – the degree to which it approximates the natural order – varies inversely as the quality, power, or degree of human causal involvement. And perhaps one should take his definitions of "produced by" and "affected by" as stipulations (not necessarily concordant with common usage) according to which the former has a higher quality, degree, and power in its deleterious effect on naturalness than the latter.[151] Still, it is hard to see what illumination this thesis throws on the value of nature. That is partly because "degree of causal involvement" is, at best, a tricky philosophical knot to unravel. This is evident from Jamieson's own cases: It is highly doubtful that there exists any straightforward or incontrovertible basis for comparing the degree of human causal involvement in the shortened growing season versus the degree of causal involvement in a hitchhiking organism establishing itself in a new locale. At the highest level of causal description, both were caused (in part) by characteristic human behavior connected with economic pursuits. But even if one could somehow disentangle degrees of human causal involvement here, there, and everywhere, why would a lesser degree of naturalness (understood in terms of degree of human causal involvement) be more perfect (and presumably more valuable on account of that) than a greater degree? Aquinas and Leibniz had an answer to this. So far as I can tell, Jamieson and latter-day perfectionists do not.

It is important to understand that the conundrum of determining "the true natural order of the world" is not one that has emerged just recently as the result of industrial-age developments (in several senses of that word). The preponderance of evidence now makes it clear that *H. sapiens* profoundly transformed every place it invaded, starting with that species' initial exodus from southwestern Africa 70,000 or so years ago. As of 1,500 years ago with the occupation of New Zealand (and Madagascar probably 500 years before that), "every place it invaded" had

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[151] This interpretation is not obvious in the ordinary meanings of "affecting" and "is a product of" or in Jamieson's exposition. But Jamieson says as much in personal correspondence: "As I use the terms, 'affecting' implies that there are other, more powerful causal influences; 'is a product of' implies that this was the only or most powerful causal influence."

become essentially "every habitable place", with the exception of a few isolated islands. By now, those too are no longer untouched by human activities.

The primary influence on ecosystems has often been exerted from the top – by the direct killing of megafauna by hunters and their eviction by agriculturalists. In a survey by marine ecologist Jeremy Jackson (2006, 28):

> Food webs were severely disrupted by the loss of almost all of the top predators and megafaunal herbivores, and patterns of vegetation changed greatly in response. The vast herds of bison in North America were partly an artifact of the elimination of all other large herbivores that had competed with bison to graze.[152] Seed dispersal and distribution patterns of Neotropical plants with large, armored seeds, whose germination depended on consumption by large frugivores, were greatly altered by the extinction of 15 genera of large herbivores; a pattern that was apparently reversed at the eleventh hour by the arrival of goats, cattle, and pigs four centuries ago. And perhaps most spectacularly, the elimination of large herbivores in Australia resulted in the accumulation of vast amounts of uneaten vegetation, which was vulnerable to wildfires, which in turn transformed much of the vegetation to arid scrub, controlled more by fires than by herbivores.

Even these dramatic human-wrought transformations do not fully convey how dim is the prospect for finding in this morass a "natural order" in the sense of "being unaffected by humankind" or "not a product, in significant degree, of human activities". In response to all these anthropogenic perturbations and multiple other non-anthropogenic forces, all of which interacted in cascading patterns impossible to unravel, virtually every ecosystem on the planet took a "development path" (to borrow the handy phrase from economics) utterly different in both small and gross detail from the path that it would have taken in the absence of human influence. Some of the more recent (industrial-age) human impingements – particularly those on the biogeochemical cycles of, for example, nitrogen and carbon – have had a rapid, globally sweeping, and deep penetration that significantly affects both terrestrial and aquatic (including marine) biota, and most likely every biotic as well as abiotic interaction worldwide. But the sort of changes that Jackson describes, though enacted over longer, millennial timeframes, had already erased any vestigial hope of reconstructing a "natural order" in the sense under consideration. And as Mann (2011) recounts, the remixing and reconstitution of ecosystems that followed on Columbus' 1492 voyage to the New World rivaled, if it did not exceed, more recent remixings and reconstitutions.

As a consequence, even if one makes the category mistake of confusing the diversity of kinds for the particular identified kinds that assemble themselves into the particular communities in the particular habitats to form the particular ecosystems

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[152] The stupendous size of the bison herds was likely also a consequence of the disappearance of bison predators. The last of the predators to vanish were the human ones – Native Americans, who in previous millennia had hunted the competing, nonhuman predators of bison to extinction. In the early sixteenth century – before epidemics decimated Native Americans – Hernando de Soto apparently did not see a single bison while stumbling around the southeast on out to the Mississippi, an area which he was the first European to see. Perhaps it was de Soto who sowed the germs of the destruction of the previously resident Native American people in that region. By the late seventeenth century, Robert de LaSalle, paddling down the Mississippi, observed that bison were omnipresent on the plains along the river. For an intriguing discussion of this, see the chapter on "The Artificial Wilderness" in Mann (2005).

that one can observe today or anytime since the beginning of human prehistory, it is hard to understand how any state of the world could qualify as the natural order or even be characterized in terms of its deviation from the natural order. The question – of how much the actual order (evaluated at any point in time after the prescribed juncture of last perfection) deviates from the natural order (understood as the terminus of an imaginary development path from that juncture taken in the absence of *H. sapiens*) – is most likely incoherent. But even if it were meaningful, we humans are utterly impotent to imagine in even the most general terms the world to which that development path would have led. That reason alone – the practical impossibility of adopting that imagined world either as an action-guiding norm or even as an action-valuing norm – is reason enough to disqualify it.

Finally, even if humankind had, or could have, or could *conceivably* have a science powerful enough to produce a picture of this "what if" world, this picture would be utterly irrelevant for distinguishing good behavior from bad. For such concepts as right action and good character necessarily apply to human moral agents confronted with decisions about how to act in this other, very different, well-peopled, current world that, for better or for worse, they actually inhabit. Morality has to do with norms that moral agents can be reasonably expected to see as applying to acting in the real world in which they find themselves. By contrast, morality has little to do with some alternative world without moral agents – including one without all those trammeling people. Norms that are centrally grounded on some such fiction literally make no moral sense. This leads to the conclusion that norms based on some ideal of natural order are not just practically impossible to adopt, they are morally irrelevant.

At this point, perfectionists tend to adopt a backpedaling strategy in order to salvage their approach. They suggest that, while there is no *perfectly* natural order, there are (as Jamieson believes) *degrees* of naturalness – that is, degrees of approximating natural perfection – and we humans should strive to achieve higher degrees. Two considerations make it difficult for this strategy to salvage credibility for the perfectionist view. First, the norm or standard that is said to admit of degrees of attainment is, as I have just argued, morally irrelevant. It is hard to see how this is remedied – that is, how an irrelevant norm could possibly be made relevant – by declaring that it admits of degrees.

Degrees of naturalness are sometimes defined by association with (or non-anthropogenic derivation from) states of the world at various earlier times. The gold standard for "naturalness" is affixed to some sufficiently early time, with naturalness becoming more and more alloyed with the compounding of human-induced deflections over time. Many choices present themselves for the gold standard: before the Pleistocene extinctions, before the deforestation of most of the world's forested lands, before the flora and fauna of most of the world's islands were dramatically shuffled by human activities and those of their companion plants and animals, before Columbus' journey, or before the introduction of vast quantities of reactive nitrogen into virtually every environment on the planet. Then again, you or I might dearly wish the time to be set (or reset) to that of our childhood world, which we yearn to repossess.

But this suggestion for setting a standard of naturalness by historical reference does little but illustrate something important about norms: The choice of a normative standard for anything cannot be arbitrary. It must be based on some set of endorsable principles that can be seen as applying to a broad range of choices, not just this one. It is very difficult to imagine any credible principle that could be used to justify the selection of one point in history over another… except by going back to a criterion relating to human influence or its absence. In that case, the successive historical references are reduced to mere tokens that, with the advance of time, mark successively more heavy and pervasive trammeling, and successively more compounding of human-induced effects successively more intertwined. That criterion, I have already argued, offers no hope of a solution. But the requirement for generally endorsable principles adds yet another reason why it is futile to build a norm out of the relative absence of human-induced effects: The absence of human influence – whether expressed by reference to some point in time or not – is singularly unpromising as a basis for any such principle because some of the most highly prized things are uncompromisingly human creations. Therefore, human influence alone cannot be held to be a normatively tainting influence.

Second, the attempt to salvage the notion of naturalness by emphasizing that it admits of degrees only serves to emphasize the moral impotence of the underlying conception. "Degrees of naturalness" seems utterly powerless to adjudicate between real and even imagined alternatives for biodiversity. Would a North America with Asian elephants tromping around as surrogates for the elephantids that existed on the continent 10,000 years ago be more or less naturally biodiverse than one without them? Coyotes have, with systematic zeal, expanded into the void left by exterminated wolves and mountain lions. Would a world in which, with equally systematic zeal, they were shot be more or less natural than one in which coyotes are everywhere? In a world in which essentially no free-flowing rivers remain, is it more or less natural to weed out creatures that thrive in the dammed legacy of sluggish riparian systems and reservoirs, while coddling the creatures whose previous habitat has vanished *in situ*?

Incoherence, practically insurmountable epistemic demands, an absence of generally endorsable principles, moral irrelevance, moral impotence: individually and collectively, these reasons suffice for abandoning the natural order approach to biodiversity's value. But these are not the only reasons. For "the natural order" to connect with "the good of nature", there must be some reason to persuade us that the natural order matters – that it is good in a way that commands moral respect. Even if (among other things) the "natural order" were a coherent concept and even if it were morally relevant (in the limited sense of offering a coherently characterizable norm that *could* apply to actual persons acting in today's actual world), there remains the question of whether it *should* apply. No matter how many iterations of fractionation, distillation, and refinement they undergo, the notions of human "product" and "effect" offer little hope as the keys to an answer.

The notion of a natural order builds on a particular and peculiar model of value, which is not peculiar to Jamieson's treatment of it. I comment briefly on it here, as preface to a more comprehensive treatment in the last chapter of this book. What makes this axiological model worthy of comment is that it typifies and sets the terms for many more general discussions of natural value, not just those concerning natural order. These terms, I think, are largely responsible for bedeviling an understanding of nature's value.

First, as I have observed, the model for natural order is a state model – one that is saliently oriented towards achieving a certain state of perfection conceived in terms of some notable absence of human influence. It is no small problem that such a state cannot, as a matter of fact, be achieved, approximated, or even imagined. There is no getting around the fact that nature has been enormously, incalculably, and unimaginably affected as a product of human activities.

This first characteristic, which has to do with the nature of a human-inhabited world, is an empirical one. The second characteristic is conceptual: According to the natural order state model, virtually all human actions and behavior that impinge on nature *by definition* cannot have anything but the deleterious effect of making the actual state of the world diverge from natural perfection. In the context of a perfectionist state model, there is something of the theory of original sin in this precept, which views as inherently damaging the living of a characteristically human life.[153] The third characteristic is that an implicit reference to historical memory is curled up inside the state model. That is, the state of perfection – or of the relative *im*perfection that is a deviation from it – is underdetermined by the state of affairs observed at any instant in time. One cannot solve for the degree of perfection without bringing into the equation the causal history of what one observes.[154] For example, and saliently, there is no general principle whereby one can distinguish between an exotic and a native organism by merely observing the current state of an ecosystem. The exotic, considered as an organism that doesn't belong, cannot be fingered without reference to observed past states (including, most obviously, a previous record of the exotic organism's absence), or by reference to observed events – most saliently human actions and activities that introduced the creature by something other than "natural" means.[155]

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[153] Of course, the theory goes on to urge that, although people necessarily sin, they ought to arrange to sin a little less.

Also, for this brief discussion, I but briefly touch on the roles of both conservation and restoration biologists in further influencing the course of the nature. Conservation biologists commonly perceive their mission as one to slow, or ideally, to stop the perceived deviation from the natural order. This is even true of to ecosystem service conservationists insofar as they deviate from a strictly economic argument to a position that defines the "natural order" in terms of some gold standard of service provision. Restoration biologists, at least in their admirably simple, initial understanding of their mission, perceive their mission as one of making history loop back on itself at an earlier point of lesser deviation. Making a case for the good of these kinds of nature-influencing projects versus the bad of other human-engendered changes these projects are supposed to rectify must deal with an obvious incongruence. See below in the main text. Chapter 8 further explores this conundrum.

[154] Of course, this might cause some to question whether this is, after all, a state model.

[155] Mark Sagoff brings home this point in Sagoff (1999). See, for example, his discussion of mute versus trumpeter swans in the Chesapeake Bay region. Even an analysis of genomes, which might link two distantly disjoint populations and implicate humans as the likely intermediary, must rely on an historical analysis of the populations and rates of change at DNA loci. See, for example, Alter et al. (2007).

A fourth characteristic applies to many, but not all, conceptions of a perfect natural order. This is a principle of permanence, which says that any human-induced deviation from perfection cannot be undone, only further compounded.[156] This is what Bill McKibben (1989, 210) calls "the permanent stamp of man". There is a tension between this principle and the conception – of inducing nature to loop back to a previous historical state – that some restoration biologists have of their mission. The tension is relieved by reference to some common-sense notion of "undoing" what was done or "putting back" what was there. But any relief in contemplating the possibility of restoring nature's perfection is temporary. For putting aside the giant leap from "putting back" in everyday life (for example, restoring to its original, perfectly judged position the potted plant that I inadvertently moved when I leaned on its container) to resurrecting an historical state of an ecosystem, the restoration must still drag along the ball of defiling human influence at the end of its historical causal chain. And the last few links of human influence, comprising the restorative reshaping, are no less significant than those that led up to its previously imperfect state.

I close this section by expanding on some earlier remarks (in connection with Jamieson's attempt to distinguish "affected by" from "being a product of") about how the natural order ties into what is called the "autonomy" of nature. This topic is important because the word "autonomy" implicitly carries the normative load of an entitlement. Those who connect the natural order to autonomy are none too clear about what this connection consists in. One might start, simply enough, with the thought that in the natural order of things, nature is autonomous. If "autonomy" with regard to nature means merely "unaffected by humans" or "not a human product", then the proposition that perfectly ordered nature is autonomous is underwhelmingly true, for it follows in a straightforward way from the perfectionist definition of the natural order. But in this case, "autonomy" fails to confer any entitlement, for it merely translates a matter of fact about the perceived absence of human influence.

On the other hand, suppose that "autonomy" has the sense in which it is customarily attributed to a person, whose autonomy moral agents are obligated to respect. This sense of "autonomy" entails that the autonomous subject have an interest in exercising the freedom to pursue an existence that that subject conceives as good for herself. As applied to the natural world, this notion of morally respect-worthy autonomy would entail that nature have similar entitlement to pursue its existence on its own terms. But since nature has no conception of a good for itself, let alone an interest in pursuing such a conception, it seems certain that nature is not autonomous in this sense, no matter how influenced (or not) by people. As a consequence, there is nothing to object to – on the grounds of "respect for autonomy" – about humans anointing themselves "masters" of a natural world that they are determined to "dominate". I return to the topic of autonomy in Sect. 8.2.6 (What appropriate fit is not), where I distinguish my own views about nature's value from those for whom nature's autonomy is foundational for its value.

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[156] Restoration biologists who take their mission to loop back to a previous historical state obviously do not fully embrace this principle.

It is also unclear whether autonomous nature is always the natural order. Whether or not that is so would seem to depend on whether the autonomy is expressed by or exercised by something that is truly natural. If kudzu in the American southeast is considered unnatural, then its expression of autonomy will not pass muster as part of the natural order. Some similar objection might be raised to exclude Eduardo Kac's biotopes (discussed in Sect. 5.3, The moral force of biodiversity). But this requirement mires the proposition in circularity: Whatever it is that expresses its autonomy is not the natural order unless its naturalness can be affirmed on the basis of assessing its autonomy. In other words, the naturalness of the starting point forever remains in doubt.[157]

6.13 Other Value-Influencing Factors

I end this chapter with a survey of some other factors that have been said to affect the value of biodiversity, while not necessarily being claimed to constitute the core of its value.

6.13.1 Viability and Endangerment

Sahotra Sarkar says that he is primarily concerned with attaching biodiversity value to places. By this, he does not so much mean that biodiversity is a two-argument function, which takes "place" as an argument alongside "diversity", as that a place presents a conservable quantum of biodiversity. In Sarkar's formulation of this thought, a place's biodiversity value cannot be assessed from (what he calls) its biodiversity *content* alone. Rather (still using his vocabulary) its value is a function of the *viability* of that content in that place (Sarkar 2005, 173–178; 2002, 136). It is unsurprising and uncontroversial that, according to Sarkar, a place with no biodiversity content has no biodiversity value. But it does seem surprising that, according to his viability requirement, the most biodiverse place on the planet also has absolutely

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[157] One of several variations on the theme of "respect for autonomy" is "respect for nature's health". The kernel of the theme is a slide from some characteristic of the human condition that commands moral consideration to a homonymous characteristic attributable to nature. Unfortunately, in the contextual shift from people to nature, all of the morally compelling considerations are left behind. Nature is simply not capable of autonomy or of being enslaved in anything like the sense in which human autonomy demands moral respect and human slavery demands moral condemnation. Nor is nature capable of having an interest in being "healthy" in a way that a person understands is a prerequisite for living her life fully and well. What is left in the nature context is a word – "autonomy" or "health" – which is a normatively suggestive but otherwise hollow shell. Ecosystem health insinuates itself at several points in the next two chapters. For an excellent discussion that largely aligns with my views about ecosystem health (but not about nature's autonomy), see Jamieson (2002, 213–224).

no biodiversity value – if its complement of biodiversity is doomed. This view defies the common perception that the value of something commands increased consideration with the realization that it might soon be lost. It is valued more, and it is appropriate to value it more, on account of the short time left in which its treasures might be regarded in any way except as fond and fading memories.

Some sense can be made of Sarkar's position if construed as dealing with the kind of triage that is a central concern of biomedical ethics and, indeed, that is a central concern of Sarkar's own practice of conservation biology. A triage protocol assumes that it is possible to classify "patients" according to their expected response to "treatment". It is especially concerned to identify patients that will not survive, despite all efforts to the save them.[158] But if this analogy is what guides Sarkar's viability doctrine, then it exposes some major logical and axiological shortcomings in that doctrine.

First, in the sorts of extraordinary circumstances that call for triage, there are compelling grounds (based most obviously, but not solely, on consequentialist principles) for letting valuable patients succumb without attempting to save them.[159] But this does not somehow demote the value of those patients, let alone reduce their value to zero. Rather, it increases the tragedy of their demise and imminent loss, and the tragedy of an inability to forestall this loss. To assign value to some thing or being based on good or bad fortune outside the valued entity's control is not just an error; it is a morally disturbing error. It is the sort of move that gives false comfort to the compulsive rationalizer. She need not confront the great value of what, in bad fortune beyond her control, is lost. Instead, she can maintain that, by the time it is about to vanish, what is inevitably lost has essentially no value whatever. In essence, Sarkar's seemingly innocent axiology writes off rather than acknowledges a morally horrible circumstance: Sometimes, we find ourselves in the position of having to sacrifice something of the greatest imaginable value (human lives) in order to retain a precarious grip on a still-valuable, though diminished world.

Sarkar would probably respond by saying that he is simply focused on right action, whose rightness, he would say, is both judged retrospectively and revealed beforehand by his optimizing, aggregating consequentialist calculus. In this calculus, a species' value (by virtue of its contribution to biodiversity) is conceived not in a

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[158] Medical metaphors generally, and the triage metaphor in particular, are not unfamiliar to the discipline of conservation biology. Its founding statements, for example, by Michael Soulé (1985), self-consciously conceive conservation biology as the discipline that restores "health" to its natural world "patients". This, I believe, is the origin of now common talk about "ecosystem health".

[159] Medical triage protocols are generally regarded, not as a more or less uniform "prescription for action" under any pressing circumstance, but rather as a class of protocols that vary according to context. Hospital emergency rooms, pandemics, and battlefields are significantly different contexts that call for different protocols. Battlefield triage protocol often rests on a four-way classification of patients in which those who have no chance of survival are in a class whose members might receive no attention at all. However, medical triage protocols for other contexts, such as emergency rooms and pandemics, often do allocate some care (beyond palliative care) to "doomed" patients. My purposes are not served by trying to split these differences.

single dimension, but as the two-dimensional “value area”, which is the integral of the value curve traced over time. To say that a species is doomed is to say that its value curve is expected to shortly plunge to zero, whereafter it contributes nothing of value. This understanding warrants ignoring such a species, from the viewpoint of a practical actor (a conservation biologist) who is supposed to work for the broadly conceived good of biodiversity at large and in the long term. That broadly conceived good is the sum of value areas under the value curves for all species over time. The greatest contribution to it comes from species whose value curve extends on indefinitely, or at least for a good long while.

In other words, Sarkar might appeal to the principles of aggregating consequentialist logic that underlie his evaluative practice. But in this context, it is important to recall that, for Sarkar, his operationalization of biodiversity is one and the same as biodiversity. What his algorithm fails to select is excluded from consideration because no other, independent basis is capable of justifying inclusion. In light of this, to be excluded from consideration is to be devalued.

This brings up a second disturbing implication of Sarkar’s axiology. It appears to sanction the view that, insofar as humanly controllable activities and behaviors are known to have already contributed to pushing some organism to the brink, a sense of relief should set in. For at that juncture, little will be lost in the final, fateful stroke that pushes the ill-fated organism over. This implication is made more disturbing by the likelihood that at some level of social organization, the institutions that sanction and fund conservation according to Sarkar’s precepts are the same as those that sanction and fund those humanly controllable activities and behaviors that have contributed to pushing some organism to the brink. Under these circumstances, one might think that it is singularly important *not* to devalue a place or its resident “chunk” of biodiversity whose imminent total demise will be ensured by continuing insults.[160]

Sarkar’s discussion is troubling in a third way, which has to do with his proposed criteria for segregating triage “patients” into disjoint classes.[161] His preferred patient-classifying tool is what conservation biologists call “Population Viability Analysis” (PVA). By Sarkar’s own admission, there is a radical lack of scientific consensus on how to use PVA in conservation, which is an unsurprising consequence of radical disagreement on what it even means. In their utter opacity, the various definitions of PVA are reminiscent of the definitions of scalar “indexes” of biodiversity itself. Researchers who propose various competing formulas for computing PVA routinely fail to connect their computation’s scalar output to some independently characterizable condition or property in the real world. In its stead is typically a vague declaration that it satisfies an intuition, which apparently varies considerably from researcher to researcher. This kind of vagueness is open to manipulation (whether conscious or unconscious) and constitutes a formidable hazard. It is a moral hazard insofar as it operates in the realm of moral decision-making.

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[160] The discussion at the end of this subsection revisits this source of malaise with triage from a somewhat different perspective.

[161] As previously noted (in Note 159), the classification of patients is a critical part of any triage protocol.

This is not the end of the troubles with Sarkar's use of viability as a value determinant. As it turns out, his views on viability are in sharp discord with other tenets of his axiology. Logic dictates that if *viability* enhances or is essential to value of biodiversity, then *endangerment* militates *against* the value of biodiversity. Generally, the more something is endangered, the less viable it is; and conversely. Sarkar defies this logic. According to him, (for example, Sarkar 2002, 147) despite diminishing biodiversity's value, its endangerment *adds* to the mandate to conserve it. And for him, the mandate to conserve is equivalent to the attribution of value. In other words, his axiology rests on principles that are essentially self-contradictory.

Of course, if Sarkar asserts both A and not-A in support of his proposition concerning how environmental value attaches to biodiversity, this misfortune in logic entails nothing about the proposition's truth value. But it does contribute to the impression of a general inattention to drawing out the implications. Most of all, it increases the aforementioned hazard that whatever "reasons" are forthcoming will be reasons of convenience rather than carefully considered ones.

Sarkar's proposal that viability is a necessary condition for biodiversity to have value toes the line of yet another contradiction. This second incongruence concerns conjoining viability with rarity and endemism (geographical rarity) as signal attributes of biodiversity value. Even if an organism has a viable population, if that population exists in just one place on the planet, then its vulnerability to extinction is elevated.[162] As a consequence, one would think that narrowly established endemics would be at the bottom rather than at the top of Sarkar's triage list, so far as the implications of his thinking about viability are concerned. Sarkar ignores this implication of his stance on viability.

My discussion of viability and endangerment has focused on Sarkar's treatment of this topic because his is one of the few in which there is an extended attempt to rationalize the inclusion of these factors in a biodiversity-valuing ethic. But Sarkar's views and his seeming unawareness of their contradictions and other flaws are widespread. He is not alone in viewing endangerment as a key element in biodiversity value. More widely known than Sarkar's discussion of the "Viability Problem" is the famous definition of "biodiversity hotspot" due to Myers et al. (and described in Sect. 4.2.2.1, Geographical rarity). The notion of "hotspot" embraces both rarity (in the form of endemism) and endangerment (in the form of a history of impingement that has already drastically reduced local vegetation) as reasons to conserve biodiversity.[163] It is unclear whether these authors intend to justify these suggestions

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[162] Most ecologists believe that this threat derives mainly from the ongoing human "conversion" of land. However, direct land conversion is not the only threat. Even an impenetrable physical barrier that circumscribes the tiny spot where a geographically rare organism lives is not an ecological barrier against such factors as changes in climate and the deposition of nitrogen.

[163] The alert reader will notice that this is something of a cheat on the definition of biodiversity as a state of affairs. I discuss causal history as a possible value-altering element in Sect. 6.13.3 (Causal factors and history). It is also useful to recall (from Note 20 in Chap. 4) that the endemism that Myers et al. consider is restricted to that of plants and vertebrates. The latter group of creatures is the subphylum of the phylum Chordata that is the most species-impoverished of the commonly compared groups on the planet. On the other hand, there is strong evidence for a high correlation of insects – from the most species-rich phylum Arthopoda – with plants.

on the grounds that rarity and endangerment are key elements of the value of a place's biodiversity. If this is not the intended normative grounding, then there appears to be none. Therefore, for the sake of this discussion, I presume that this is the intended normative grounding for their suggestions. But then those suggestions are very hard to defend.

Myers et al. do not create the tension (or flat-out contradiction) that comes from Sarkar's playing on both sides of the viability/endangerment court. But the idea that endangerment adds to biodiversity *value* does not need the disagreeable company of conflicting ideas for it to lead to another conundrum, which arises from its application to a theory of right action.[164] As I previously observed, embracing the notion that endangerment *decreases* value seems to entail also endorsing the reprehensible attitude that little or nothing is lost by ignoring that which is endangered. The notion that endangerment *increases* value has the equally uncomfortable consequence of seeming to endorse behavior that increases value via promoting endangerment. If hotspots are what really count, then other things being equal, it seems as though conservationists should do what they can to create more of them. One can imagine eliminating dispersed populations of widespread species to the point that they are endemic to a single, last remaining place where their heightened contribution to biodiversity then makes them merit our assistance in making its last stand.

Of course, this suggestion is absurd. The obvious response to it is that the doctrine of enhancing value through endangerment is intended to apply only to triage "patients" that are selected beforehand according to other criteria that those who must perform the triage cannot control. Compare: there was a bar brawl and the ambulance brought the injured to the ER. The doctrine is not supposed to justify standing outside the ER and stabbing random passers-by.

The problem with this response is that it ignores disqualifying disanalogies between the triage of biodiverse places-*qua*-patients and the triage of human patients. First, if all humans are presumed equally entitled to their health and life, then medical triage need not say anything about how this human life is more valuable than that other one. Both are presumed equal.[165] In contrast, a rational biodiversity triage protocol presumes significant inequalities of places with respect to their biodiversity value. Moreover, it is advisable to avoid stipulating that a place is "entitled" to its biodiversity. For on what grounds could a place be said to have such a right? Whatever those grounds might be, it is safe to assume that they are very different from the grounds that justifies a human's entitlement to health and life. Finally, the proposal to create more hotspots is the opposite of stabbing people – if one takes seriously the notion that hotspots really are more valuable places by virtue of the endangered condition of their biodiversity. Just as a place's value might be

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[164] Myers et al. (2000) prefer the term "threatened" to Sarkar's "endangerment". As used by these two sets of authors, the two terms appear to be synonyms.

[165] I acknowledge that a principle of utter equality of all human lives is not universally granted. Some would say that a young life has greater value than an old one; that a life endangered by the foolish choices of its owner is less entitled to be lived than the life of a person who did not so contribute to her compromised condition. To the extent that human equality it is not granted, the force of the disanalogy diminishes.

thought to be enhanced by the cultivation of a garden there, another spot might be more highly prized by virtue of its being a hotspot. By contrast, no one could legitimately claim that stabbing a person changes her value; and in particular, no one would claim that a stabbed person (the flawed analog of the hotspot) is more valuable than an unstabbed one.

Myers et al. provide just the two aforementioned criteria for assessing a place's value as a hotspot. There is the endemism of vertebrates and plants, and there is endangerment – the latter implicitly determined by induction from the amount of primary vegetation already removed. I have already touched on the difficulties of calling on endangerment to make the case for value and will not recite that verse here.

Setting aside endangerment leaves just endemism – and the endemism of a relatively small group of organism (plants and vertebrates), at that – to assess biodiversity value. As I observed in Sect. 4.2.2.1 (Geographical rarity), endemism is geographical rarity and it is simply a conceptual error to conflate rarity of any kind with diversity. So if the endemism of a species logically entails a disproportionately large contribution to biodiversity value, then this contribution must come in through a logical back door that is not legitimately part of the concept of biodiversity itself. It is also possible that those who value endemic biodiversity presume that it contingently correlated with efficiency in conservation. That is, they might think that as a matter of contingent fact, by conserving endemics one conserves more for less cost and effort; in other words, endemic species are the key to a good heuristic for the species set cover problem. But this presumption is highly questionable: A species' high degree of endemism might entail its high degree of vulnerability to unpreventable perturbations in the specialized conditions (for example, the temperature ranges of its climate or the biogeochemistry of its habitat) that make life for that species' individuals possible. If so, this would make it a bad bet for the investment of conservation resources. And, as a "marker" for high biodiversity, there seems to be no reason to privilege endemism over direct assessments of the actual diversity of species (or the diversity of kinds in any other category). Even if, as Myers et al. seem to suppose, by felicitous happenstance or perhaps by an as-yet uncovered causal connection, hotspots turned out to be extremely species-diverse places, the value of the biodiversity (or species diversity) in those places would then properly derive from the fact that they contain lots of different species, not because the species are endemic to those places or because they are endangered.

In summary, it appears that both legs holding up Myers' case in support of the proposition – that a place's biodiversity is more valuable by virtue of that place being in a hotspot – give way. I now return briefly to the notion of efficiency in conservation as somehow undergirding judgments of biodiversity value.

6.13.2 Efficiency

In the preceding subsection, I discussed the triage-like orientation that seems to be the context for the role of viability or endangerment in some conceptions of biodiversity value. In this subsection, I explore the possible derivation of this view from neoclassical economic analysis in general, and cost-benefit analysis (CBA) and (economic) efficiency in particular.

Sarkar (2005, 160) draws the connection to economic efficiency quite plainly:

> The critical consideration is that of economy (usually called 'efficiency' in the biological literature…): the representation of as many different and as a high a concentration of individual biodiversity surrogates as possible in the least number of places.

This characterization pushes consideration of biodiversity value to the very center of the neoclassical economics stage, which has to do with the efficient allocation of scarce resources. The allocation of each place is a considerable cost; and so one should strive to allocate places to biodiversity as efficiently as possible. In that way (and only in that way) can the greatest possible biodiversity benefit – conceived as the greatest possible amount of biodiversity – be achieved at the lowest possible cost.

Compare: there is the value, to me, of acquiring the stratospherically priced season tickets for my local major league baseball team. Of course, in contemplating whether or not to acquire them, I do not consider just the value of my experience of live ball games. I also think of the costs, which include that of the car that I might have to forego to attend the games (which necessarily includes the requisite $8 beer and other baseball food), and the fact that my son might have to forego a college education.[166] In considering these costs, I am now doing a CBA in which the benefit of witnessing baseball – live and well played – are weighed against its various costs (in the form of benefits foregone). But I do not confuse the value of a foregone car or of my son's education, which enter into those costs, with the value of experiencing baseball. That latter value would not change if my neighbor, about to move out of the area and unable to use his remaining season tickets, bestowed them on me *gratis*.

In short, the value of experiencing live baseball is something that I can get a grip on without reference to its cost. I can even see how some baseball experiences might have greater value than others. For example, there is more than one major league baseball team where I live and ticket prices for the two teams are not equal. As a matter of fact, the quality of my experience will differ between the two teams because one team plays the game with greater and more dedicated enthusiasm and in a more exciting style than the other. But this has nothing to do with which team's tickets are more dear.

When they talk about efficiency, it is unclear whether Sarkar and Myers et al. really take themselves to be addressing the value of biodiversity. If they are, then their discussion is based on a confusion, which conflates the value of biodiversity (a presumed benefit) with the costs of acquiring it and with the question of its most efficient acquisition. One cost of a biodiverse place might be its cost as real estate – valued for the development of something other than biodiversity. This might vary from place to place, just as the season baseball tickets vary from team to team. But this has little or no bearing on the value of the resident biodiversity, which one can safely assume varies

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[166] Prices for seats at major league games apparently have risen to this dizzying height. See Mallozzi (2009). Fortunately for my son, he has graduated college and need no longer worry about my being blinded by my love for baseball.

more or less independently of real estate values – much as the baseball ticket prices are no sure reflection of the quality of the baseball experience that they afford. The fact that a tract of biodiverse land cannot be acquired except (in some cases) at enormous expense has little to do with the value of its biodiversity.

Furthermore, the determination of economic efficiency is customarily a determination of the relative efficiency of various alternatives. This requires the computation and comparison of the economic value that each of several possible development paths is expected to realize. Couched in current dollar terms, this is the expected net present value of development along each of these paths. In this calculation, greater viability, which increases the likelihood of survival, increases value while endangerment has the opposite effect. Myers' et al. (and Sarkar, who, as I observed in the preceding subsection, also plays on the opposite side of this court) seem unaware of the devastating consequence of this consideration for the development path that attempts to preserve hotspots. The very definition of "hotspot" entails the precarious condition of its biodiversity, which in turn entails a substantially depressed expected net present value.

So in the end, it seems that conflating biodiversity value with the efficiency of acquiring it does not produce the result that Myers et al. might have hoped for. Considerations of economic efficiency appear to argue against preserving hotpots rather than for preserving them. I take that unexpected and unwelcome result to be a call to revisit the initial confusion on its own terms. To say with these biologists that the value of biodiversity varies inversely as the cost of the real estate on which it resides is not correct and not useful, and is itself an act that tends to devalue what they are trying to value.

Sarkar volunteers an observation that illuminates one of the hazards of failing to maintain a clear separation between the value of diversity on the one hand, and on the other hand, the plethora of other considerations that might enter into a conservation decision using CBA, or any other evaluation scheme, for that matter. He points out that his algorithm (sketched in Sect. 3.3.4.1, Place (again)) for iteratively accumulating a collection of biodiverse places (the places that, by his precepts, humanity *ought* to conserve) is capable of assigning radically differing biodiversity values to any *one* place – depending on an arbitrary starting point defined by the arbitrarily selected initial subset of places.[167] This initial selection is arbitrary in the sense that it has no axiological justification. It defines the initial condition for an algorithm that is itself arbitrary in the same sense: While it obviously must satisfy some intuition for Sarkar, he offers as chief justification that it is practical to implement. This does not qualify as sound axiological reasoning.

In the end, this scheme falls far short of qualifying as a principled system of evaluation. That dismal assessment is made all the more clear by reference to a similarly unprincipled system of criminal "justice". No one would consider satisfactory a system

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[167] This casual acceptance of varying value assignments must be distinguished from the radically different and eminently sensible observation that, as experience in assigning values grows, heightened practical wisdom might justify a re-evaluation of things previously evaluated with less experience.

that assigned guilt or innocence to a sequence of defendants according to an algorithm justified by its ease of computation, starting with a first case decided by the flip of a coin. Yet this is an exact analog to Sarkar's principles of "biodiversity justice".

It is tempting to resist this unfortunate conclusion by retreating back to the triage metaphor. In this spirit, it might be suggested that the sequence of choices does, in fact, matter – because it affects evaluatively relevant aspects of the situation on which the next triage choice is made. One is not in a position to determine – in a single, sweeping, all-knowing, godlike gesture – what is of greatest biodiversity value everywhere on the planet. Instead, one must plunge into the gritty business of trying to make the first decision, then the next, at every step, trying to save what most adds to the accumulating total value of biodiversity. A model of economic market valuations might be thought to incorporate this sequential quality. This is easily observed on the stock market ticker, where there is an incremental adjustment in market value for every transaction that is done "at the margin". More generally, the price commanded today by a commodity can float upward as demand and purchases make its supply on the market dwindle. One might say that it is no different for biodiversity. With each biodiversity transaction, one tries to buy the most with what remains to pay for it.

Unfortunately, two stubborn problems undermine this retrenchment, along triage lines, to legitimize the arbitrarily initiated, sequence-dependent assignment of biodiversity values. First, the credibility of this move is undermined by a problem that often infects consequentialist-inflected thinking: That is, it systematically blurs the distinction between a procedure for deciding how to act rightly, and a justification of the rightness of an action (however decided upon) according to some independent principle. This point pushes beyond the previous point that the triage rules themselves appear to have no principled grounding. The new point is that, even using a well-justified decision principle (which biodiversity triage is not), it is possible to arrive at a wrong decision – a decision that results in a world with less value rather than more. To put this in another way, some independent set of principles that assess the rightness of action is required to also assess the quality of any decision-guiding principle that purports to arrive, in the ponderance of cases, at a right action. No such independent set of principles accompanies biodiversity triage.

Second, insofar as the move back to triage is based on the analogy of incremental price adjustments along a series of market transaction decisions, it ignores a critical difference between the running of real markets and the running of Sarkar's place-selection algorithm. The difference is that real markets are real. For that matter, so are the shifting conditions and classification of triage patients in an ER. The transactions in a real market and the treatment of patients in an ER are actual sequences of events. This is not true of the grand hotspot scheme due to Myers et al. Nor is it true of Sarkar's algorithm, though this might initially be obscured by the fact that it spits out first this place, then that. But these are just partial results obtained before the algorithm runs to completion. In fact, Sarkar's algorithm runs to completion "on paper" and produces value assignments to form a conservation plan – which is a prelude to taking any action in the real world. Like any algorithm, it is just a sequence of steps – a recipe. But the recipe creates or purports to create, as output, a single map of biodiversity values – in a single, sweeping, all-knowing, godlike running of the algorithm.[168] As a consequence, the major support this approach derives from the analogy of a sequence of market transactions, in which each is separately evaluated in light of its predecessors, is ill gotten.

I do not have the space to further pursue this discussion of conservation triage and its relationship to "conservation efficiency". So at this point, I must refer back to the questions raised in Sect. 6.13.1 (Viability and endangerment) about whether it is reasonable to think that key guiding principles for biomedical triage also apply to the evaluation of biodiversity. But there is a final point to be made quite aside from the question of whether the triage metaphor is valid. If the object of conservationists really is to cram as many species as possible into as little and as inexpensive a space as possible, then an honest assessment of *all* means to accomplish this end is called for. Recent science has yielded some nascent understanding of which means merit consideration. For example (see Fridley et al. 2007, 4, 6), it appears that habitats with high positive Native Exotic Richness Relationships (NERR's) are ones that invite efficient packing. I cannot think of a legitimate reason why those who promote biodiversity place efficiency would not therefore want to promote the "assisted migration" (further discussed in Sect. 7.2.1) of species into such places – as a cheaper, leaner means to the end that they seek. A good case can also be made for the greater efficiency of several of the other biodiversity-enhancing suggestions in the list in Sect. 5.3 (The moral force of biodiversity).

6.13.3 Causal Factors and History[169]

In Sect. 6.12 (Biodiversity as the natural order), I discussed how the causal influence of humankind on nature is sometimes thought to degrade the natural order of things. I return to causation in this subsection, but without that previous discussion's burden of relating it to a perfectionist vision of the natural world. Here I explore the human causal contribution to a harmful state of affairs saliently characterized by some undesirable state of biodiversity. But I now understand this in terms that transcend tarnishing a perfect state of nature.

So far as biodiversity is concerned, causal influence is typically assigned at the collective level – focusing on the behavior of human societies rather than the actions of one or a few human individuals – and regarded as historically persistent.

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[168] In saying this, I'm not denying the obvious ability to re-run the algorithm at a later time; and I'm sure that Sarkar has this in mind. But a rerun merely improves, or purports to improve true knowledge of the global value map. It is the algorithm's best understanding, at the time of that latest run, of where in the world biodiversity value lies.

[169] This discussion owes much to perceptive comments by Jeffrey Lockwood, who uncovered some weaknesses in an earlier draft. It also owes to a spirited discussion with Jeremy Bendik-Keymer about the role of intent in moral responsibility.

This is of moral interest because the degree and nature of a causal role in inflicting harm can entail something about responsibility for the harm – most notably something bearing on the degree of blameworthiness for it. It can also have a role in determining what obligations there might be to mitigate the harm – to "right the wrong", according to some principle of corrective justice. Something like this picture seems to be bound into the frequently encountered claim that humankind is responsible for "harm to biodiversity".

The precise way in which causal responsibility figures into moral responsibility for any harmful state of affairs is subject to several ethical provisos. These are especially important – and tricky – for something as causally complex as the biodiverse state of the world. But the complexity of the causal role is just the start of the moral complexity. The degree and nature of moral responsibility also depends on what those with a causal role are actually aiming to do. Bearing on this question of aim or intent, but also constituting independent considerations, are: what the best experts know about the impacts of human behavior and activities, what people generally and reasonably can be expected to understand about this, what people are capable of doing to address their impacts, and even what reasonably can be expected of people's moral sensibility in such matters.[170] The thorny question of how to understand the notion of *collective* or group responsibility also intrudes. Group responsibility stands alongside group rights as one of the more vexed topics in moral theory, which unfortunately places it outside the scope of my discussion.

Finally and most fundamentally, the causal intricacies of human involvement in how a complex state of affairs comes to obtain has little moral interest unless the coming to be of that state of affairs causes or itself constitutes a harm of some kind. Few would deny that for a change in the biodiverse state of affairs to achieve moral interest requires good reasons for thinking that, not only did humans have a hand in that change, but that as a consequence of their causal role, either biodiversity itself is harmed, or other harms ensue from the change. The ubiquitous catchphrases "harm to the environment" and "harm to biodiversity" are often used so indiscriminately that even the identity of the sufferer of harm is left uncertain; this makes a complete mystery of the exact nature of the harm (born by whichever subject suffers it). The moral proposition is further obscured by routine omission of all the considerations in the preceding paragraph, even though every one is critical to a clear understanding of how causal responsibility bears on moral responsibility.

When it comes to the aim or intent of human behavior that influences the biodiverse state of the world, the presumptions that various thinkers adopt span the broadest imaginable spectrum. At one extreme, there are those, such as Jeremy Bendik-Keymer (2010; 2012), who suggest that there is *no* intent behind humanity's causal role in what he (2011, 15) calls a "disintegrating of – here a deliberately poetic term – nature's cornucopia *as we have known it"* [italics in the original]. According to him, this is the result of utter thoughtlessness or "wantonness" – quite

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[170] See, for example, Kawall (2010) for a discussion of the epistemic element in responsibility from a virtue ethics point of view.

literally, something more or less completely out of mind.[171] At the other extreme are charges that humanity is engaged in a "war against nature", that "Homo sapiens… [is] waging a war against Nature"[172] and that such a place as Hawai'i is (Wilson 2002, 43) "a killing field of biodiversity". The trope of "waging war" is a starting point for a sequence of tropes, which circulates through "the wounds on the land"[173] – the aim and expected result of warfare's assaults, against which Nature is said to be making its "last stand" (Wilson 2002, 42). It is easy to see this as the expression, from Nature's point of view, of the proposition that – either through utterly unthinking behavior, or through monstrously sociopathic behavior characterized by satisfaction in waging a cruel war – humanity is reducing the world to biotic rubble.

Typically absent in accounts at both extremes is careful attention to many of the critical points – up to and saliently including a convincing account of where, exactly, the harm lies – that would serve to anchor the thread of a moral argument.[174] The issue of intent is a crucial one in assessing the degree of moral responsibility and in assessing how reprehensible is some action or pattern of actions leading up to some harm. But the issue of harm is logically prior. Establishing that harm is actually done is a prerequisite for a causal-historical argument for any kind of moral

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[171] Bendik-Keymer's use of the term "wanton" is prone to misinterpretation. While "wanton" commonly suggests maliciousness (which necessarily involves some kind of deliberateness), Bendik-Keymer (2012, 450) explicitly excludes that element from his usage, which focuses solely on the element of thoughtlessness. Bendik-Keymer (2012, 450) attempts to address the "puzzle" of "how people can produce wanton consequences without deliberately doing so." But given his usage of "wanton", there is no puzzle about the possibility of this: It seems clear that thoughtless behavior (in Bendik-Keymer's sense of "behavior by actors who do not consider salient consequences of their actions") might produce consequences that those actors did not (deliberately) aim at (because they didn't even think of them).

[172] The first cited phrase is Rachel Carson's call to arms, from an April 13, 1963 broadcast of *C.B.S. Reports* on *The Silent Spring of Rachel Carson*:

> Man is a part of nature, and his war against nature is inevitably a war against himself.

This statement echoes *Silent Spring*'s use of the word "war" to describe human impacts on the natural world (Carson 1962, 7, 93, 99).

Carson's call to arms is taken up by Dave Foreman. The second cited phrase is part of his presentation of the position of the Rewilding Institute, http://www.rewilding.org/thesixthgreatextinction.htm. Its Conservation Fellows include such prominent conservation biologists as Michael Soulé and David Maehr, though these scientists are not on record as explicitly endorsing this way of expressing the Institute's purpose.

[173] This is Michael Soulé's characterization of nature's state, in his address, "NATURE'S ASPIRIN: A CURE FOR MANY OF NATURE'S ILLS", delivered to the Western Conservation Summit in January 2009 (available at http://www.michaelsoule.com/, with text at http://www.facebook.com/note.php?note_id=204698819568168). Soulé is one of the more prominent of myriad writers who avail themselves of the trope of "nature's many wounds" which are inflicted by many acts of "wounding nature".

[174] Bendik-Keymer attempts to avoid the issue of whether or not harm is done when a species goes extinct. He does avoid the 'h'-word, but only by way of locutions that rely on it for their normative impact – as, for example, when he (2012, 450) says: "Wanton behavior is given to destruction by the way its thoughtlessness loses touch with what matters in our world and so tends to damage it." To "damage" something is to harm it or to harm those with an interest in its intactness.

responsibility. If collective harm is established, and only if it is established, one can forcefully argue that humanity has an obligation to mitigate that harm – at the very least by reigning in the instruments that have given rise to and perpetuated the harmful conditions. But if no harm is connected with those conditions, then causal responsibility (of any sort) has no moral significance – for causal responsibility by itself does not entail anything about whether or not those conditions constitute or cause harm. This might seem to be an obvious point, but the number of narratives that ignore it counsels for making it explicit.

That the presence of humans and their activities has altered the natural world in general and its biodiverse state in particular is not in dispute. But in itself, the difference in biodiversity – between the actual, human-inhabited world and some imagined world devoid of either a human presence or of the presence of humans who nevertheless do not engage in the characteristically human activities that are causally relevant – is not a reason for believing that it constitutes a harm. This is true even if that gap is correctly characterized as largely a matter of humans being instrumental in diminishing biodiversity – for example, by playing a role in the "premature" extinction of various species.

In other words, a separate reason must be supplied to establish that the human-induced differences are harmful – because causal responsibility for those differences is neutral with respect to whether or not they are harmful. To establish harm generally requires that a subject that suffers the harm be identified. A harm is a harm *to* someone or something, or to some group of persons or things. When it comes to biodiversity, there are two classes of theory on this. The first presumes that the harmed parties are current or future humans or both. The harm consists in depriving us currently respiring humans and our yet-to-be respiring descendents of such things as ecosystem services, mankind's pharmacopoeia, some preeminently valuable knowledge, or some of the many other goods that are supposed to flow from the world's biodiversity. But on the evidence examined in this chapter, none of these things have the kind of value that is claimed for them.[175]

A different take on who or what is harmed arises from the common use of the phrase "harming biodiversity" in a context – such as "the war on Nature" – that suggests that its literal meaning is intended: As a consequence of "losses in biodiversity", biodiversity itself is harmed. After all, if you cut off my arm, I will suffer a harm as a result of its loss and you will have harmed me. This grants *literary* license to say, more generally, that a loss of some part *of* X is a harm *to* X. That includes, for example, X = a car, which "suffers" the loss of a hubcap; or X = the set of all cars on the road, which suffers the loss of mine, which just broke down. But in these cases, the "suffering" is a matter of moral indifference and the harm to the car when I remove its hubcaps does not warrant moral condemnation of my action. Much the same can be

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[175] I realize that it is impossible to prove the nonexistence of a successful argument for biodiversity's value. I also understand (and have previously noted) that some philosophers prefer to avoid the notion of harm altogether. I revisit the latter issue, particularly with respect to virtue ethics, in Sect. 8.2.6 (What appropriate fit is not).

said of biodiversity, when it "suffers" a loss or when it is "harmed". Biodiversity – that entity, which is commonly measured by the number of species – is simply not capable of suffering in any morally interesting sense. For example, it obviously is not sentient and so cannot suffer in the sense of experiencing pain. Just as obviously, it cannot suffer from the thwarting of its projects, because biodiversity has no project to thwart.

It's clear that merely establishing a human causal-historical relationship with biodiversity cannot, by itself, ground a theory of biodiversity. These difficulties – of identifying a harm, which in turn, requires identifying a subject suffering the harm – cast doubt on whether a causal-historical theory can even clear the preliminary hurdles. But they are not the only hurdles, as consideration of the other, abovementioned moral provisos reveals. Let's focus attention on the matter of intention, starting with the position at one extreme – that humankind is guilty of the kind of vicious behavior that would be involved in "waging a war on Nature".[176]

Consider: If something is done that in fact constitutes a harm, and if it is done "viciously" – in the sense of "intending cruel or violent harm" – then these factors significantly color how one views the moral burden of causally responsible parties. In the broad moral scheme of things, the nature of the intent varies. Other factors, all varying partly, but not completely independently of intent, intertwine with intent to produce a final moral assessment of culpability. One of those factors is how directly the harm is a consequence of actions and behavior. The more tenuous and convoluted the causal chain and the more that causal factors beyond human control dominate, the weaker the case for moral responsibility is generally supposed to be. Another variable, related to the last, registers the capability of agents to perceive the causal connection to the harmful consequences and to recognize that these consequences do indeed constitute a harm. Furthermore, benefits that accrue to the harming agent are commonly thought to substantially increase how reprehensible is the harm inflicted. At the most extreme, an agent's well-calibrated *aim* to benefit herself by inflicting harm on others boosts the warrant for regarding this behavior as vicious.

At the other extreme, if causing a harm is an unintended, inadvertent, and relatively indirect consequence of unknowing and oblivious behavior whose harmful consequences have no obvious benefit to the perpetrators, then the tie between causation and responsibility generally remains very weak, though it still might justify an obligation for compensating action. The tie is strengthened to the extent that (among other possible factors) specific intent, knowledge of the harmful consequences, and a view to gaining benefits that flow directly from the harm creep back into the situation.

One path through this thicket is marked by categorical signposts, which signal how intent and benefits combine to progressively strengthen the case for tying moral responsibility to causal responsibility:

1. **Unintended harm.** The causal agents act and behave to attain some benefit, but they are not (fully) aware that their action or behavior is harmful. If some harm

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[176] The analysis that follows is meant to "lead by example". It is intended to suggest some issues that merit but are rarely given sober moral assessment rather than to be a complete working out of those issues.

is done, the agents might not perceive it as a harm. Or some consequence might register as harmful in some small or insignificant degree, but absent an appreciation of its full and possibly great significance to the party harmed. In short, though harm is done, no (or little) harm is intended.

In criminal law, some cases of reckless endangerment fall into this category. However, these cases typically require that the harm be foreseeable. My definition is broader and includes cases in which even the ability to foresee cannot reasonably be expected.

2. **Collateral damage.** The causal agents are (fully) aware that among the consequences of their actions are very likely unwanted harmful ones. These unwanted harms are viewed as unavoidable in attaining a benefit, but they are not directly instrumental in attaining that benefit. This corresponds to what, in recent, military-derived parlance, is called "collateral damage". It is less clear that a harm of this kind is completely *un*intended, for the action aimed at the benefit is intended and the attendant harm is expected. Perhaps one could express this unclarity by saying that the harm is only "indirectly" intended.

   Most commonly, a case of collateral damage is not a case of willful rapacity. That is because the harm is not a means to the end of a benefit; nor does the harm itself constitute any part of a benefit. However, these exclusions do not entirely preclude rapacious behavior in which the harm, though unwanted, is seen as justified by the benefit. Picture the bank robber who "must" shoot the teller poised to trip the alarm. Even the act of scamming an elderly couple out of their pension can be viewed in similar fashion: The scammer derives no great benefit from the emotional and financial distress that she sadly "must" inflict on her gullible victims. The benefit of the scam is the money transferred from scammed to scammer. Of course, the scammer also can be said to treat the elderly couple as a (mere) means to her end. In that respect, the scam example might be said to belong to the following category.

3. **Means to benefits.** The causal agents understand their acts to be harmful, but additionally regard their acts of harming to be a means or part of a means for attaining certain benefits, though the infliction of harm in itself does not constitute a benefit. Thus, it is by means of using a hostage as a human shield that the desperate criminal protects herself and makes good her escape. But placing the hostage in harm's way has no benefit independent of that. The desperada would gladly don her invisible cloak, had she remembered to bring it along for the heist.

   This is a step beyond "indirect" intention. The use of a harmful means to a beneficial end makes it plausible to say that, in contrast to collateral damage, the harm is intended in a direct way, qualified only by the fact that the focus and motivating intent is to attain the beneficial ends. It is also plausible to say that the good of such ill-gotten benefits are tainted in some serious way by the nature of the means employed to attain them.

4. **Constitutes a benefit.** The act of harming is not just a *means* to a benefit, but *constitutes* the benefit or part thereof, and the causal agents are (fully) cognizant of this; that is, they understand that the harm to others amounts to a benefit for themselves.

> This constitutive relationship gives us leave to say that the harm is as much the focus of intent as the benefit that it constitutes. Such cases are the ones most prone to justifiable characterization as vicious.
>
> Fortunately, this kind of viciousness is probably quite rare. In the realm of criminal activity, it is the psychotic stuff of premeditated rape and murder for their own sake.

Let's now return to this question regarding biodiversity: To what extent can human causal influence be said to be vicious, insofar as it results in the loss of biodiversity? Let's grant what seems highly doubtful in light of this chapter – that loss of biodiversity constitutes a harm. Still, the only reasonable answer seems to be: almost not at all.

Down through history, most human behavior affecting biodiversity pretty clearly falls into the category (1) of "unintended harm" in the list above. It is true that for at least 70,000 years, human activities and behavior have had a major causal influence on the "development path" for biodiversity. The terrifically effective predation of megafauna – by both humans and their invited and uninvited companions – over the course of the human diaspora was undoubtedly unmindful. People also undoubtedly noticed disappearances of their prey as well as the depredations by such animals as pigs and rats that accompanied or infiltrated their communities in various peregrinations. But they adapted as best they could to any changes that required adaptation and continued going about the business of surviving and being human. In the current millennium, the most dramatic remixing and reconstituting of which organisms live where – which heavily influenced which ones survived and which ones did not – followed close on the heals of Columbus' 1492 visit to the New World. This first giant step towards recreating an ecological Pangaea was entirely "out of mind" of anyone at the time. Indeed, it was out of mind and human comprehension until the late twentieth century (Mann 2011).

Only very recently have some of these circumstances, which affect the nature and degree of moral responsibility, changed. The nature of the impacts of characteristic human behaviors and activities that have pervaded human history down to the present time are finally coming to be understood at some very coarse level. Probably – and improbably, because the story is now so well known – the very first recorded extinction in which human activity was understood to have played a role was that of the *Raphus cucullatus* – the dodo – which vanished from its last residence on the island of Mauritius sometime in the seventeenth century. Four centuries would pass until it became common knowledge (at least among those with their nose in the subject) that for 70,000 years or so, *H. sapiens* as a species (or as a global society or as a collection of societies or as a collection of individuals) has had a significant, ongoing, causal role in bringing about the current, general, biodiverse state of affairs – whether regarded for better, for worse, or neither.

General *moral* consciousness – the awareness that a causal role in species extinction could possibly have moral implications – is at least as recent. Although it should be taken for what it is – a data sample of two – Bill Bryson (2003, 476) recounts how two American birding enthusiasts – who one would think were among the most sensitively attuned in their appreciation of birds – reacted on their sighting of *Vermivora bachmanii* (Bachman's warbler), at a time when it was thought to be possibly extinct:

> Perhaps nothing speaks more vividly for the strangeness of the times than the fate of the lovely little Bachman's warbler. A native of the southern United States, the warbler was famous for its unusually thrilling song, but its population numbers, never robust, gradually dwindled until by the 1930s the warbler vanished altogether and went unseen for many years. Then in 1939, by happy coincidence two separate birding enthusiasts, in widely separated locations, came across lone survivors just two days apart. They both shot the birds, and that was the last that was ever seen of Bachman's warblers.

Bryson goes on to recount similar stories that make it clear that this sort of attitude was not confined to the United States. The last nesting pair of *Pinguinus impennis* (great auk) was likely the two birds killed by four Icelandic fishermen in 1844. The fishermen viewed these creatures as bundles of very valuable feathers, not as the last individuals of a valued species. The final, fatal blow to both the dodo and the great auk followed on a long history of hunting the birds for their eggs, skin, fat, flesh, and feathers both by humans and their animal traveling companions, including the invited pigs and crab-eating macaques along with the uninvited rats.

But even the late-developing consciousness of human implication in the extinction of one or more species is not yet a consciousness of a human-induced reshaping or general diminution of *biodiversity*. And there is a yet wider gap to an awareness that human-induced changes in biodiversity might warrant moral consideration. Even if one grants that the extinction of a species is also a diminution of biodiversity (something that might seem assured only if one considers species richness to be biodiversity's ultimate measure), whether or not it also diminishes the *value* of biodiversity or in some other way constitutes a harm is a question that can only be answered by reference to some model (in Chap. 5, The calculus of biodiversity value) or theory (in this chapter) of biodiversity value.

The anecdotes that I have related are representative of a more general body of anthropological evidence that gives little reason to think that, at least until the latter part of the twentieth century, much if any human influence on biodiversity goes beyond category (1), "unintended harm" – the weakest basis for moral responsibility. Within that category, not even the decisive requirement for reckless endangerment – that the perpetrators should be reasonably expected to foresee the harm – is met. *A fortiori*, nothing approaching viciousness can be ascribed to the behavior of humans with regard to biodiversity up until very recently.

An over-hasty look at environmental history before the late twentieth century might initially leave a different impression. For example, some attempt was made to rein in the slaughter of the great auk before the final species-fatal killings. But in fact, this was nothing more nor less than a regulatory gambit in a regional economic dispute: It expressed Newfoundlanders' regard of themselves as sole owner of this feathery economic resource and resentment of New Englanders' plunder of it. Moreover, the economic resource was understood strictly in terms of a single species of bird, not in terms of biodiversity. To cite another example – of a type of a phenomenon that has pervaded human history: The effect on biodiversity of uninvited stowaways (such as the rats that accompanied humans in their diasporas and peregrinations) can barely achieve the level of "unintended harm" – insofar as a case can be made that it was, as that category specifies, an unintended, inadvertent, and relatively indirect consequence of unknowing and oblivious behavior whose harmful consequences had no obvious benefit to the human perpetrators. This behavior does not even rise to the level of reckless endangerment, because there can be no reasonable expectation that (up to a few decades ago) the human wanderers could have anticipated any harm – even presuming that a case can be made for regarding the resulting changes in biodiversity as harmful.

But what about human behavior in the latter part of the twentieth century and later, when some understanding of patterns of biodiversity change and the connection of these to human activities and behavior have become apparent? I believe that the shift in focus to more or less the current time does little to shift which moral categories apply.

At the top of the most direct, current-day sources of human-induced changes in biodiversity stands human appropriation of land for uses that involve its radical transformation. The reasons why people appropriate turf typically have nothing to do with biodiversity and everything to do with such things as growing food, building buildings and infrastructure, and providing transport. Needless to say, every hectare of land that goes under the plow, under the foundation of a structure, or under the asphalt running up to it becomes quite a different place. So does a wide swath of surrounding land. And this change in environment is reflected in which collections of organisms do well or not so well there. In one of the more comprehensive and credible surveys that shed light on this, Wallace Erickson and his colleagues (2005) estimate that buildings and other infrastructure are responsible for the vast majority of the 500 million to 1 billion bird deaths annually in the United States alone. Human transportation continues in the grand tradition of the Columbian exchange, reshuffling the biotic deck by providing transportation for non-ticket-paying, nonhuman stowaways to places that they would not likely have visited otherwise or quite so soon. Roads and road traffic kill all manner of creatures that attempt crossings. They also are ecological walls, despite an unimpressive presence in the vertical dimension. They substantially alter the mix of organisms and hence the biodiverse state of affairs in their vicinity, not just by subdividing previously undivided habitat, but also by creating habitat edges, whose asphalt boundary creates distinctive ecological conditions quite unlike either the previously contiguous expanse or the interior of the new subdivisions.[177] Merely turning on the lights turns off the lights for some number of creatures. For example, on the Hawaiian island of Kaua'i, the threatened *Puffinus auricularis newelli* (Newell's shearwater) is threatened partly because (Mitchell et al. 2005):

> Street and resort lights, especially in coastal regions, disorient fledglings causing them to eventually fall to the ground exhausted or increase their chance of colliding with an

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[177] Forman et al. (2003) provide an introduction to a growing literature on road ecology – a discipline mostly unknown to all but those with a Ph.D. in the field. I note in passing that there's no denying that, in creating these new kinds of habitat, the diversity of habitats is increased.

> artificial structure (i.e., fallout). Once on the ground, fledglings are unable to fly and thousands are killed annually by cars, cats, and dogs or die because of starvation or dehydration.[178]

There is no more direct way to alter the biodiverse state of a place than to "repurpose" it. Yet few people are aware – or can reasonably be expected to be aware – of something as recondite as the ecology of roads and roadkill. And the appropriation of land for farming and structures, as well as our facilitating the travels of invited and surreptitiously hitchhiking plants, animals, and microbes, are little-changed, millennia-long-standing aspects of how humans have operated in the world and continue to do so.

I am not defending willful ignorance; I am not suggesting that there is not sometimes a moral obligation to acquire certain kinds of knowledge that are requisite for acting well in the world; nor am I less than enthusiastic about educating ordinary citizens about what their style of living on the planet entails for biodiversity and the natural world generally. I am certainly not defending moral permissiveness, morality by majority vote, or morality by long-standing habit. And, as I argue in Chap. 8, I think that there is a compelling case for thinking that there is something of possibly great normative significance in the great magnification of effects by the greatly increased human numbers and the vastly greater efficiency with which humans pursue their biodiversity-transforming activities.

However, I question whether there are any reasonable grounds for believing that any of these current-day activities rise much above the level of category (1), "unintended harm" – Bendik-Keymer's notion of profound thoughtlessness – again, if indeed, human-induced change in biodiverse states of affairs does constitute a harm. For none of these activities does it appear that altering the biodiverse state of affairs itself constitutes a benefit (category (4)). Nor is that alteration a means to any benefit (category (3)); for while building a road might change biodiversity, bulldozing, not the change in biodiversity is the instrument for accomplishing that end. It is often even difficult to press the charge that these activities are pursued under the dark cloud of a cold calculation of collateral damage (category (2)) when the calculators do not regard the effects on biodiversity to be "damage". Although now, in the twenty-first century, one can legitimately ask whether this might be a matter of reprehensible negligence in moral education, changes to biodiversity simply still do not generally rise to the level of individual or social consciousness as a behavior-guiding norm. At least they do not unless and until a directly noticeable and notably unpleasant effect for humans is perceived to be tied to such changes.

Viciousness simply does not to enter into the picture. I do not think that you, my reader, are acting viciously for your role – and you do have a role, at least as a

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[178] This is an extremely common phenomenon. The authors of this report apply this identical commentary to *Pterodroma sandwichensis* (Hawaiian petrel), *Puffinus pacificus* (wedge-tailed shearwater), and *Oceanodroma castro* (band-rumped storm petrel). And their concern about the effects of artificial lighting extends to other avian and even non-avian species, such as *Eretmochelys imbricata* (Hawksbill sea turtle). Other reports reiterate the same challenge to yet other species in other places – for example, St. Kilda (in the Outer Hebrides off the coast of Scotland) and the Canary Islands.

purchasing consumer – in appropriating and transforming the land on which the building in which you dwell sits, for your role in the presence of the habitat-dividing road that runs up to your front door, or for your role in appropriating and transforming the land that produces the bounty on your dinner table. Nor do I think that society at large is acting viciously by sanctioning and facilitating this individual behavior of yours, which extends to all members of society collectively.

I have focused on human transformation of the landscape for its outsize contribution to changes in the state of biodiversity. But of course, many other human activities and behaviors also affect that state. The effects of some, such as hunting, are as direct as those of land transformation. The effects of most activities tend to be less direct, though not necessarily minor. Among that majority are, for example, the production of chemicals that find their way into various organisms and the escape of fertilizers to places – for example, rivers, lakes, and oceans – that they are not intended to fertilize. But for the most part, these seem to have no special quality that bolsters their qualifications for anything beyond a weak moral tie to their human causation. If the relative indirectness of their causation has any bearing, it militates towards weaker rather than stronger moral significance.

In short, a sober assessment of the extent to which intent and benefit tie moral responsibility to causal responsibility for changes in biodiversity turns up meager grounds for thinking that this nexus has itself undergone significant change through the great swath of human prehistory down to the present. The Pleistocene megafauna of North America, the great auk, the passenger pigeon all succumbed to human activities that were focused on providing human goods, not on anything remotely resembling vicious intent. There really is little to distinguish these cases morally from an eagerness to develop the Port of Anchorage on the broad backs of belugas.[179]

In continuing a long-standing pattern of human behavior, which includes relative unawareness that it has any broad environmental significance and little sense that this behavior rises to the level of causing a harm and therefore warrants moral consideration, there is little to distinguish the case of those belugas from most any other, similar case in the last 70,000 years. However, two parallel shifts in human thinking have recently had more than a little significance for how biodiversity is regarded. First is the nascent understanding, vested mostly in a relatively small number of scientists and environmentalists, of how the effects of human behavior and activities on individual species enter into the larger biodiversity picture. The second is the rise of some strongly held, strongly promoted, but I would say, weakly justified convictions on just what that picture *should* look like. This is what is variously called, “biodiversity management”, “biodiversity development”, or what I call “the biodiversity project”, which is the subject of scrutiny in Sect. 8.1 (The disvalue of the biodiversity project).

The biodiversity project largely comprises novel experiments in species manipulation. With its emphasis on saving a shortlist of species on their way to oblivion, it includes captive breeding and the introduction of populations of creatures regarded

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[179] See Sect. 6.3 (Biodiversity as service provider) for an account of the Cook Inlet belugas.

as surrogates for previous residents. On the opposite side of the spectrum are programs to control and extirpate "pest" species. For the world's most unwanted, "specicide" (the programmatic elimination of a species), even "genicide" (the programmatic elimination of an entire genus) – for example of all *Anopheles* species of mosquitoes – is part of the program.[180] Sometimes one and the same species, such as the *Canis lupus* (grey wolf), lurches back and forth between the poles of being the reviled target of specicide for its depredations and heroic embodiment of ecosystem salvation… for its depredations. One might think that differences in geographical, ecological, and historical context might justify shifts in the status of that creature (and others) as hero or villain. But credible principles undergirding the moral relevance of these contextual elements elude coherent formulation. This kind of Janus-faced attitude, which divides a small part of the biotic world into the wanted and the unwanted, and makes the vast majority of organisms an afterthought or, more likely, lost in a sea of thoughtlessness, poses a problem of consistency for such value models as the incremental one, discussed in Sect. 5.1.1 regarding The incremental model. Serious as that problem is in itself, it has far greater significance as a symptom of a general failure to address the pivotal question of how causal responsibility for the current, biodiverse state of affairs morally sanctions *any* kind of biodiversity project.

I leave a more thorough exploration of this crucial question to Sect. 8.1.2 (Responsibility for nature).[181] However, I wish to mention a few points, which connect the current discussion of deriving moral responsibility from causal responsibility to the question of determining whether, by virtue of humanity's role in changing the state of biodiversity, humanity inflicts some harm. The first point has to do with just how precarious is the understanding of the underlying causal responsibility. This understanding commonly derives from a vague gesture at a difference in states of biodiversity – the difference in biodiversity between our actual, human-inhabited world and some imagined world without us.

The first term of this difference is or should be a matter of empirical investigation. But every scientist who works on biodiversity acknowledges how difficult it is to characterize the biodiversity in our current, actual world. This is reflected in radical ignorance of even the simplest of characterizations – in terms of the number of species of living organisms that inhabit the planet. Current estimates vary by more than an order of magnitude. Even on a far smaller scale, marine biologist John Spicer (2006, 2–4) lyrically recounts the impossibility of knowing "who" lives at Wembury Bay – Spicer's "back yard" and perhaps as intensively studied a place as

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[180] See, for example, Judson (2003). Judson's suggestion might shock those not inoculated with the biodiversity project serum, but it is entirely congruent with a much larger body of scientific, environmental, and "conservationist" writing within that project. Not atypical is its narrow focus, which excludes from view the consequences of annihilating an entire genus of insect – for example, on bats and the other insectivorous creatures for whom they are a dietary staple.

[181] One might also ask whether "biodiversity management" constitutes vicious behavior. I argue in Sect. 8.1 (The disvalue of the biodiversity project) that it is more likely that its ends are either incoherent, or coherent and lacking any sound justifying reasons; and as a means, it is ill informed, unjustifiably self-confident, and imprudent. But not vicious.

any on the planet. Still, one might plausibly say that, although current ignorance of biodiversity in our actual world is profound, one can expect scientists to make steady, if slow, progress in peeling back that ignorance.

The second term of the difference is quite another matter.[182] Characterization or evaluation of the biodiverse state of an alternative world devoid of human influence (after some prescribed juncture) or very differently influenced by humans seems an utter impossibility. One need only consider the multitude of specific changes that people have wrought directly, and which have initiated a corresponding multitude of cascading causal threads, which have woven themselves into causal webs that cannot possibly be unraveled. In every place where people have dwelled, species have been shuffled, forests cut down, watercourses altered. Every place of human habitation has been changed in its hydrology, biogeochemistry, and fire regime. There is simply no unraveling any of this, let alone all of it.

That consideration is huge; yet it is dwarfed by another: People have transformed the planet in ways that fundamentally change the terms on which any organism must struggle to live and procreate *anywhere* on this planet – not just where people have built cities, roads, or cut down a forest to farm the land. That is most evident in such changes as those in the planet's climate, the ocean's acidification, and the human-produced deluge of reactive nitrogen into the land and the planet's fresh- and salt-water bodies.[183] For an organism – even one well removed from most doings of humanity – to survive anywhere in this world is a very different proposition from what it would have been for it to survive in a world in which *H. sapiens* had never emerged, or had not been so populous, whatever that world might have looked like. This, I believe, necessarily confounds any attempt to construct a coherent norm, one that is based on how organisms would live in a nonhuman, or pre-human, or minimally human world whose biotic and abiotic structure would require a way of life very different from what the actual, current world demands of any organism here, now. As a consequence, even if human causal responsibility for the current, transformed biodiverse state of affairs were regarded as morally reprehensible, and even if (contrary to fact) it were possible to conjure up a reasonable picture of what the biodiversity of the world would have been in the absence of those human-induced transformations, there is no biological possibility of (let alone practical credibility in) posing that picture as the norm for what the biodiversity of the current world ought to be.

One can begin to get an idea of the problem by considering the question of what obligations people might have to save organisms whose way of life no longer works well in the human-altered planet on which they now live. Do people have an obligation to reverse those life-framing alterations? It seems impossible to maintain that position, for reasons that I have already suggested: First of all, it is impossible to know what that reversal could consist in, given the impossibility of unweaving the

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[182] Here I reprise some themes from Sect. 6.12 (Biodiversity as the natural order), which expressed concern for the prospects of finding some credible characterization of the natural order of things.

[183] Air currents transport and deposit atmospheric nitrogen on the land; watercourses carry nitrogen to any body of water into which they flow.

causal web. Even it were possible to define "reversal", the radical transformational nature of the human influence on the systems involved and the broad spatial extent of the resulting transformations through a long history of startlingly persistent human behaviors and activities would make reversing them an impossibility. One might think that this problem could be ameliorated by aiming at some more recent restoration target – say, within the range of a human generation's memory or the generation before that, or before Columbus and his successors began the process of re-creating an ecological Pangaea. But the justification for shooting at any such a target requires some as yet unspecified principle. It is hard to see how any principle could be anything other than arbitrary.

Even if reinventing the biotic and abiotic conditions for living an earth-dwelling life were not impossible, leveraging causal responsibility in an attempt to establish a norm would still be problematic. That is because if an organism is struggling now, one likely cause is that it finds itself in conditions that are a consequence of a very long and complex history of characteristic human activities and projects. While we-now might see ourselves as having a choice to modify some of those activities and projects or to cease and desist from some of them entirely, acting on that choice would not effect any significant change in the conditions that already obtain and that currently define the terms for most every organism's struggle for existence. In other words, what humankind can do doesn't achieve what is required to justify doing it.

On the other hand, what humankind cannot do it cannot be expected to do: The more ambitious project of actually redefining the terms for existence on this planet collides with generally accepted presuppositions concerning moral duties – that they are special and sufficiently specific to circumstances in a way that makes it possible and practical for moral agents to focus their moral attention, to make sensible decisions, and to act within the compass of capabilities that they can be reasonably presumed to have. Those capabilities do not, for example, plausibly extend to the saving of most every struggling species. But what about doing what *can* be done to "manage" the survival of struggling plants and animals whose ways of life no longer work in the current world? What about putting what few we can in zoos or arboretums? There are many reasons why, I believe, these are very bad ideas. But for this discussion, I will say only that any grounds for the responsibility to do this are seriously or entirely undercut by the fact that such heroic efforts at best achieve a temporary and brief extension of "life" for a vanishingly small number of the "living dead". And the cost of that temporary reprieve for these few is often a life that those living-dead individuals must live, which is in significant ways incongruent with the way of life for their kind.

It might be countered that when the decision is made to lay the concrete for a parking lot over the last known remaining individuals of some species of plant, or to shoot the last one or two individuals of some animal that has the misfortune of being viewed as "game", then the capabilities (for restraint) are not in doubt and the responsibility is clear. But this argument focuses far too narrowly on the last proximate act leading up to extinction. The moral significance of that act is arguably dwarfed by a longer history of anthropogenic stage-setting, which made the final act an anticlimactic denouement – the inevitable, because the only possible, resolution of the plot. One can imagine some minor variations in the details of exactly how the final act is played. But the conclusion is always the same – whether the result of a rash but intentional act, or the result of one last and fatal inadvertent insult.

The validity of the points that I am making here does not hinge on the culpability of people acting 70,000 years ago – or any time since then when awareness of both the facts of the matter and their moral implications, if any, could not be reasonably expected. It suffices that essentially all the biomes of the world are now anthropogenic biomes, and that the success, or failure, or state of being on the brink of failure, of any organism is directly related to whether or not it thrives in whichever anthropogenic biomes it calls "home".[184]

To put this entire discussion in perspective, I reiterate that many of the various stubborn barriers to understanding what causal responsibility for the current biodiverse state of affairs entails for moral responsibility are built into a state-based model, which is at the heart of the biodiversity project.

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[184] See Sect. 5.3 (The moral force of biodiversity) for a brief explanation of the concept of "anthropogenic biome" or "anthrome", as proposed by Ellis and Ramankutty (2008).