Pre-print copy, forthcoming in *Environmental Values*, Accepted Feb. 27, 2022.

A SCALE PROBLEM WITH THE ECOSYSTEM SERVICES ARGUMENT FOR PROTECTING BIODIVERSITY

Katie H. Morrow
University of Pittsburgh
Email: khm17@pitt.edu

ABSTRACT

The ecosystem services argument is a highly publicised instrumental argument for protecting biodiversity. I develop a new objection to this argument based on the lack of a causal connection from global species losses to local ecosystem changes. I survey some alternative formulations of services arguments, including ones incorporating option value or a precautionary principle, and show that they do not fare much better than the standard version. I conclude that environmental thinkers should rely less on ecosystem services as a means to defend biodiversity, and that attention should be focused on additional types of value which might be attributed to global biodiversity.

KEYWORDS

Biodiversity, Ecosystem Services, Instrumental Value, Option Value, Precautionary Principle

1. INTRODUCTION

Humans are responsible for an accelerating rate of species extinctions. According to the most recent IPBES[1] report, on average, about a quarter of species are threatened with extinction

[1] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.

within each of the best-studied taxa (Díaz et al. 2019). While there is general agreement that we should try to prevent species losses, philosophers have struggled to explain how this is justified. There has been a persistent divide between environmentalists who favour instrumental versus intrinsic value defences of management objectives (e.g. the varying perspectives of McCauley 2006; McShane 2007; Justus et al. 2009; Odenbaugh 2020; Newman 2020).

This paper argues that a popular form of instrumental argument, the Ecosystem Services Argument, is unsuccessful, and the core reason for its failure has been overlooked in the literature. The Ecosystem Services Argument claims that biodiversity should be protected because biodiversity supports important ecosystem functions and services. This kind of argument is commonplace and has often been taken for granted in both academic literature and popular media.

The objection I develop to this argument form is a *scale problem*, which points to a scale mismatch between ecosystem services and global biodiversity changes. Most iterations of the Ecosystem Services Argument point to goods, functions or processes occurring within ecosystems which are putatively supported by local diversity levels. There have been relevant prior discussions about the complicated empirical support for a connection between local diversity and ecosystem functioning or services (e.g. Newman et al. 2017). This paper develops a distinct problem for the Ecosystem Services Argument, and will show that this problem is even worse. The problem arises because the argument can only support protecting global diversity if global species losses causally contribute to local species losses. But this step in the argument (which has rarely been discussed among environmental philosophers or even made explicit) also lacks support. I present conceptual and empirical reasons that undermine the causal connection between global and local species losses presupposed by the argument. So, even if appealing to services can justify protecting local species diversity, this line of argument fails to scale up to justify protecting global biodiversity.

A distinct way to put my conclusion is as follows. It is widely taken for granted that biodiversity has some instrumental value to humans. Environmentalists who object to the Ecosystem Services Argument usually claim that something is wrong with justifying the protection of nature on instrumental grounds (e.g. McCauley 2006). This is not my position. Instead, I argue that global biodiversity – i.e. the total number of species on Earth, distributed in roughly their native ranges[2] – does not have any instrumental value to humans, or at least none that is currently well-supported by empirical research. As a result, arguments which appeal to standard instrumental values cannot justify global biodiversity preservation.[3] To be clear, my contention is not that we should reject instrumental arguments in general, but that services arguments in particular are unsuccessful as biodiversity defences.

I must briefly address the nature of biodiversity before discussing its value. First, the aim of this paper is primarily to consider arguments for species conservation. For this reason, 'biodiversity' should be read as species richness unless specified otherwise. Second, for convenience, I will often write as if biodiversity were an entity, but I assume that biodiversity is instead a property (or cluster of properties) belonging to any given ecological system or area. Thus, strictly speaking, we are considering the value of the property of *being biodiverse*.

---

[2] The 'native ranges' clause is to prevent species maintained only in zoos or non-native species grown annually in gardens from counting towards biodiversity totals in the present context.

[3] By 'standard instrumental values' I mean to exclude experiential forms of value, such as subjective aesthetic value. Some philosophers consider these to be a type of instrumental value, but this issue is outside the scope of the present paper.

Historically, environmental philosophers have been wary of the view that biodiversity has intrinsic value – preferring to ascribe intrinsic value only to objects – but have assumed that biodiversity has instrumental value to humans (e.g. Oksanen 1997). If my discussion shows that global biodiversity does not have instrumental value to humans – or at least that the usual arguments for its instrumental value are unsuccessful – this suggests that a major reorientation of the discourse is in order.

I also stress that the goal of this paper is not to undermine biodiversity conservation. Rather, the goal is to encourage further reflection on popular arguments made for saving species. This paper is organised as follows. First I present the standard Ecosystem Services Argument and review some initial challenges which have already been discussed in the literature. Next I present my scale problem in more detail. After that I consider some alternative formulations of services arguments, which I argue are not much more successful than the original version. I conclude that we should continue developing alternative types of argument for protecting global biodiversity.

2. THE ECOSYSTEM SERVICES ARGUMENT

I will next summarise the Ecosystem Services Argument and review some initial problems. Standardly, ecosystem services are defined as ecosystem processes, properties or products which benefit humans. It is also possible to conceive of ecosystem services as benefits provided to any or all species. As a matter of focus, this paper will only consider anthropocentric arguments. The discussion is neutral about whether we should take an anthropocentric stance in general.

A basic version of the argument takes the following form.

1. There is a positive causal relationship between biodiversity and some ecosystem services. Biodiversity is needed to support these services; or these services would be lost or diminished if biodiversity were lost.[4]
2. These services are very instrumentally valuable; we have good reason to want to retain the services due to the human wellbeing or financial costs of their loss.
3. So, we have good reason to protect biodiversity as a means to maintain ecosystem services.[5]

Past discussion of this argument has focused on the empirical justification for the first premise. The main empirical evidence for this premise comes from the biodiversity-ecosystem functioning (BEF) research program, which includes long-term studies of the effects of different biodiversity levels on various indicators of ecosystem functioning. The initial BEF studies were manipulative field experiments in which ecologists altered the number of species in plots and then tracked properties like the plot's biomass over time (e.g. Tilman and Downing 1994; Tilman 1996; Tilman et al. 1996; Tilman et al. 2001; Spehn et al. 2005; Tilman et al. 2006; Hector et al. 2007; Hector and Bagchi 2007; Hautier et al. 2015).

BEF studies have generally found a positive (sometimes asymptotic or saturating) correlation between diversity and measures of ecosystem functioning. However, there are questions about whether this provides evidence for a causal connection between diversity and the

[4] These claims posit a causal relationship between variables. The causal claim can be helpfully read in terms of Woodward's interventionist theory (Woodward 2003), but other theories of causation may be equally apt as long as they allow for causal relations between variables.
[5] A similar argument is reviewed critically in *Defending Biodiversity* (Newman et al. 2017) on p. 47 and following.

functioning of ecosystems, especially at larger scales. I will briefly review some main issues for the Ecosystem Services Argument, issues which are discussed at length by other sources (McCann 2000; Jax 2010; deLaplante and Picasso 2011; Newman et al. 2017). Although the problems sketched below represent important challenges to services arguments, I will argue that my scale objection is even more serious.

First, the causal interpretation of BEF findings remains challenging. One reason is that there are many distinct proposed mechanisms to explain diversity-functioning relationships, and only some of the mechanisms are causal, while others explain correlations as (merely) probabilistic outcomes or even as artifacts of study design (Doak et al. 1998; Giller et al. 2004; Loreau and Mazancourt 2013; Downing et al. 2014). More recent BEF research has moved towards designing studies to distinguish among possible mechanisms for biodiversity-functioning relationships (Hector et al. 2010; Hallett et al. 2014). However, due to the ongoing nature of this research, there seems to be no consensus about the relative importance of the proposed mechanisms across ecosystem types.

A second problem is with the external validity of classic BEF studies. Many of these studies utilise artificially simplified, small-scale experimental plots, often including only a single trophic level. In addition, many of the studies have focused on a limited number of ecosystem types, especially temperate grasslands, yet we expect that different ecosystems could respond in qualitatively different ways to diversity changes.

If the results of these studies are to inform the management of ecosystems, we need reason to believe that the same causal principle(s) describing the behaviour of the experimental plots also describe the behaviour of real ecosystems (Cartwright and Hardie 2012, chap. I.B; Marcellesi 2015). There are reasons to think this is not the case, since BEF experiments omit many factors which are known to be causally important in ecosystems (e.g. higher trophic levels; realistic community assembly processes; disturbance regimes). It is a well-known feature of ecology that patterns and processes at one scale often do not scale up nicely. A pattern observed in a single trophic level at a small spatial scale might be qualitatively different from the pattern observed in a larger system. So, results from classic BEF studies do not specify how realistic ecosystems will respond to diversity changes (Hooper et al. 2005; Brose and Hillebrand 2016). This has been widely acknowledged among BEF researchers but sometimes has been overlooked in popular reporting.

As one might expect, the BEF research program has moved in the direction of studies that focus on more realistic or multi-trophic systems (Little and Altermatt 2018; Moi et al. 2021). This includes observational in addition to manipulative studies (Hector et al. 2007) and studies of BEF relationships at larger spatial scales (e.g. Patrick et al. 2021). Very large-scale studies are increasingly possible due to remote sensing technology. Although these studies face their own statistical and interpretive challenges, we can expect that they will continue to improve our understanding of real ecosystem behaviour.

A few observations about the Ecosystem Services Argument are in order. First, we might not want our obligation to conserve biodiversity to hang on currently open-ended empirical research. Second, it remains the case the BEF research focuses on simple ecosystem functions – like productivity – which are amenable to various forms of estimation. Ecosystem functions, however, are conceptually distinct from services. Functions are the processes that occur in ecosystems as studied by core ecological science. Services are goods and opportunities provided to humans by ecosystems, like water purification, food and recreational opportunity. Ecosystem functions are not necessarily services; some, like periodic flooding or fires, can be disservices.

This adds complexity to extrapolating from ecological studies of ecosystem functions to conclusions about how to promote ecosystem services.

A final relevant issue has to do with the interpretation of 'biodiversity' in the hypothesis that higher biodiversity contributes to better functioning or stability.[6] The initial BEF studies measured species richness, implicitly assuming that taxonomic diversity is a good predictor of community-level functions. However, there is evidence that functional trait diversity better explains community-level outcomes than does the diversity of species (Mori et al. 2013; Gagic et al. 2015; Sakschewski et al. 2016; Mason et al. 2005 on functional diversity indices). This makes intuitive sense given that it is species' role functions rather than their evolutionary history which proximately explain their contributions to ecosystem behaviour (Odenbaugh 2010).[7] Therefore, to the extent that diversity is causally relevant to ecosystem functioning, it is likely the diversity of role functions rather than the number of species present that is most explanatory.

It is also known that some individual species or functional types of species are disproportionately important to ecosystem functions (on functional types, Díaz and Cabido 2001). In some cases there is evidence that one or a few dominant species, rather than diversity of any kind, drives community stability (Sasaki and Lauenroth 2011). So, setting aside for now potential external validity problems, BEF findings provide reason to protect functionally

[6] The meaning and utility of the biodiversity concept has been controversial (Maclaurin and Sterelny 2008; Burch-Brown and Archer 2017; Santana 2018). If a given biodiversity index is the best predictor of functioning, this does not entail that 'biodiversity' ought to be interpreted in the same way for all purposes.

[7] Role functions are species' behaviours that help to explain ecosystem processes. Examples include browsing and pollination.

important species but do not univocally support the assumption that modest species richness losses will cause consequential breakdowns in ecosystem functioning.

The hedge term ‘modest’ is important here, since it is clear that a major loss of species will cause ecosystem function breakdowns. For management purposes, we should focus on a degree of species loss that can be reasonably expected in the near term. In this respect, again, classic BEF experiments may not be representative of likely scenarios, since they often use many plots with just a few species. Realistic projections about biodiversity changes will help to inform our expectations and should be considered when designing BEF research.

I have challenged the assumption that modest species richness declines will be a proximate cause of lost services. However, there is also a problem in the opposite direction. Population declines among species which directly support services (e.g. pollinators and fished ocean species) or which are functionally important (e.g. keystone species, top trophic levels) can and do cause disruptions to ecosystem service provision. Population declines fall short of extinction and therefore do not affect species richness. This further shows that, if we are primarily concerned with services, species richness is an inadequate variable to focus on.

As serious as they might be, the above problems for the Ecosystem Services Argument are not the primary reason the argument fails. BEF research is ongoing and we can expect future research to provide further evidence about how biodiversity declines will affect ecosystem processes. Even as future research brings more clarity, the standard Ecosystem Services Argument will not be successful because of the scale problem, which I will present next.

3. THE SCALE PROBLEM

The scale problem shows that any standard-form services argument cannot be successful, regardless of the details discussed above. If standard services arguments are sound, they give us reason to protect the species diversity of individual (token) ecosystems in order to protect the services provided to humans by those ecosystems. But biodiversity loss is a global phenomenon. The argument under consideration is meant to support preventing global species losses. This goal is only justified if we add a further premise to the argument, stating that global biodiversity losses contribute to biodiversity losses within individual ecosystems.

Here is a reformulated Ecosystem Services Argument, which makes the implicit premise and the intended conclusion explicit (additions are italicised).

1. There is a positive causal relationship between *local* biodiversity and some ecosystem services. *Local* biodiversity is needed to support these services; or these services would be lost or diminished if *local* biodiversity were lost.
2. These services are very instrumentally valuable; we have good reason to want to retain the services due to the human wellbeing or financial costs of their loss.
3. *Global biodiversity losses will cause local biodiversity losses.*
4. So, we have good reason to protect *global* biodiversity as a means to maintain ecosystem services.

For the purpose of this discussion, ‘local’ scale entities, processes and properties occur at the scale of an individual ecosystem. Throughout, I have opted to use phrases like ‘local biodiversity’ to avoid equivalent but cumbersome phrases like ‘the species richness within individual ecosystems’. Local-scale phenomena here contrast with much larger-scale phenomena, like those characteristic of landscapes, continents or the whole globe. Although I recognise that precisely individuating ecosystems is a problem, I assume that we can distinguish between ecosystem-scale and global-scale phenomena clearly enough to assess the argument at hand.

First, I will state why the above argument is in tension with some relevant empirical findings. Second, I will explain on a conceptual level why we should not expect the above argument to be sound.

The link between global and local species losses is a matter of empirical investigation. Surprisingly, some large meta-analyses have concluded that although global diversity is declining, local species richness has not on average been declining (Vellend et al. 2013; Dornelas et al. 2014). Intuitively, this is because the ranges of some species are expanding while the ranges of others are shrinking, such that in some areas the total diversity is increasing or not changing.

It is certainly the case that local biodiversity is declining in some places as ecosystems collapse or are removed for development. Various urban locations, monocultural agriculture sites or sites of recent deforestation will be characterised by low biodiversity levels. So, the conclusion cannot be that there are few sites which have experienced biodiversity loss. Instead, the claim is that the increasing rate of global extinction has not so far contributed in a consistent manner to local biodiversity losses within some studied ecosystems.[8] Critical responses to the cited meta-analyses point to the prevalence of human-influenced sites and question whether the meta-analyses sample a representative set of studies, among other methodological features (Gonzalez et al. 2016; Cardinale et al. 2018).

[8] See the exchange between Cardinale (2014) and authors of the Dornelas et al. study.

The previously cited meta-analyses report changes in biodiversity composition even in areas where net loss was not detected. As previously discussed, there are reasons to believe that species richness is less explanatorily relevant than more sophisticated measures of biodiversity change (Hillebrand et al. 2018). So, the moral is not that there is nothing to be concerned about. Rather, arguments which focus on species richness may not capture more salient features of biodiversity change.

It is an empirical question to what extent local systems are experiencing species richness declines – and, apparently, a question which is not fully settled to the mutual agreement of ecologists. But even if species richness were declining at a majority of sites, it is a further question what caused the declines. Human land use, climate change and sometimes biological invasion seem to be the main causes of major local biodiversity reductions. Unsurprisingly, studies which track land use detect a much greater degree of local species loss (Newbold et al. 2015). This further supports my claim that the global extinction rate is not what is primarily driving local biodiversity changes.

I have outlined some empirical questions surrounding the extent to which local species richness is declining. In addition, I suggested that the global extinction rate is not the main driver of local changes, even where species richness is declining. The reason this is possible may be further clarified by applying the distinction among within-system, between-system and total diversity, termed α-, β- and γ-diversity respectively. Think of a landscape consisting of a patchwork of different communities. In this example, α-diversity refers to the diversity of species within a local community, while β-diversity quantifies the spatial heterogeneity – the differences in composition between communities. And γ-diversity refers to the total number of species within the landscape. BEF research has mostly investigated α-diversity, and standard services arguments appear to have α-diversity in mind, since they claim that services will be lost as species are lost from ecosystems.

The conceptual problem is that constant or increasing levels of α-diversity are consistent with decreasing levels of β- and γ-diversity. This can occur as a result of declines in between-system heterogeneity – i.e. when the composition of different local communities becomes more similar. If all that matters causally is α-diversity, then there is no reason not to maintain local diversity via homogenisation. This is at odds with the conservation goals of preserving distinctive local communities and maintaining the total number of species at larger scales (Lean 2021). Therefore, again, there is a scale mismatch between the services argument, which cites a putative causal role of α-diversity, and the intended conclusion which is to protect global diversity.

It is also possible for α-diversity to decline much more quickly than γ-diversity, which is what happens when an area is deforested. Extreme local declines in α-diversity are a concern from the perspective of service provision. But again the proximate cause is human activities, not the global extinction rate.

At best, the Ecosystem Services Argument would show that the number of species at a given location ought to be maintained, regardless of the identity of those species. Yet environmentalists agree that rare or unique species should be given special priority as a part of biodiversity conservation (Deliège and Neuteleers 2015; Lean 2021). We also usually think that introduced invasive species do not count towards biodiversity conservation goals.[9] Thus, we

[9] Lean (2021) discusses a similar set of issues as applied to invasive species.

seem to value compositional heterogeneity, not just the total count of species at each location. As I have now argued, the services argument cannot justify this preference.

Complaints that instrumental arguments cannot distinguish between native and non-native species have been made previously. For example, concerns have been raised that services arguments would justify introducing species or even replacing ecosystems with artificial technology if this results in better performance of functions or services (Deliège and Neuteleers 2015; Newman et al. 2017, sec. 2.7 ff; Desjardins et al. 2019). Concerns have also been raised that if biodiversity or species richness is the main locus of value, then we might have a counterintuitive obligation to increase the number of species at any location rather than to protect the native species (Santana 2017).

My presentation of the scale problem explains why these are persistent concerns. Some authors have implied that these problems affect instrumental arguments as such. However, on my assessment the root of the issue is that the Ecosystem Services Argument operates at the wrong scale. Protecting native diversity and rare species is warranted assuming that our goal is to protect compositional heterogeneity at larger scales and to protect the total number of species globally. But because services arguments have focused on processes and properties at the scale of individual ecosystems, they have no bearing on these potential larger-scale goals. The unintuitive consequences of the argument arise because of this misalignment.

4. ALTERNATIVE SERVICES ARGUMENTS

The argument I have discussed so far is what I characterised as the standard version of the Ecosystem Services Argument, which connects α-diversity to ecosystem services or functions. However, there are other forms of service argument, and one might wonder if they avoid the preceding objections. In this section I present four alternative formulations and argue that they do not fare much better than the original.

Conjunctive argument

The first reformulation is a conjunctive argument which appeals to the roles of individual species in conjunction rather than to the roles of diversity per se. This argument claims that since many individual species support important services, considering all of these services collectively gives us reason to preserve biodiversity in general. This results in an argument with fewer empirical limitations, since the services provided by individual species are often easier to detect than the services supported by biodiversity as such.

An argument of this form has recently been endorsed by Jay Odenbaugh (2020), though what I provide here is my own summary.

1. Many individual species support important services such as pollination, food provision, drug development, attracting tourism, etc.
2. These services are very instrumentally valuable and will be lost as the relevant species are lost.
3. The collective instrumental values of individual species give us good reason to protect global biodiversity.
4. So, we have good reason to protect global biodiversity.

This kind of argument is subject to the ‘patchiness’ objection (Newman 2020). Briefly, according to this criticism, although many species have important uses, there are also very many species which have no apparent uses to humans. The existence of useful species does not provide an instrumental reason to protect non-useful species. If we already know which species support services, then from the standpoint of protecting those services, we should focus on trying to protect just those species with known use value.

A common reaction is that instrumentally-important species may rely on mutualist or food web relationships with other species. This gives us reason to protect those other species. But keep in mind that the total number of species on Earth swamps the number of species which directly support services. Moreover, some service-providing species are generalists, so they do not rely on the presence of other particular species. So it remains a problem to account for the instrumental value of the vast majority of species.

Although the argument is not sound as stated, there is a straightforward way to improve it. The strategy is to add a precautionary principle which can support protecting species without currently known uses.

Precautionary conjunctive argument

A precautionary version of the above argument is as follows.

1. Many individual species support important services such as pollination, food provision, drug development, attracting tourism, etc.
2. These services are very instrumentally valuable and will be lost as the relevant species are lost.
3. We are not in a position to know which species may turn out to provide important services.
4. So, by a precautionary principle, we have good reason to protect global biodiversity.

There have been many different formulations of precautionary principles.[10] The principle relevant here is one which states something like, 'we should take steps to prevent serious negative consequences, even when the likelihood and exact nature of those consequences is unknown'. Thus, the idea behind this argument is that we should try to stop species losses in order to prevent possible future harms, even ones we cannot now foresee.

There are several reasons this precautionary conjunctive argument may not be compelling. First, one might think that we *are* in a position to know which organisms are likely to be useful; that we have good reason to believe the majority of species are not useful; or that we have reason to believe that many of the most useful organisms, e.g. ones with agricultural applications, are in the least danger of extinction (Maier 2012, chap. 6). For example, we have good knowledge about which plant species are edible by humans. Where we lack such knowledge, it is plausibly because the species are uncatalogued, rare, remote from humans or difficult to cultivate, making them unlikely candidates to become important food sources. So, you might think this argument relies on a false generalisation about our state of knowledge. Precautionary arguments in general have been subject to criticism. Some philosophers argue that precautionary principles are misguided because they seem to advise a strategy of risk avoidance, a strategy which is impossible to implement and contrary to ordinary practical reasoning (e.g. Newman et al. 2017, chap. 3). Ordinarily, people are willing to accept a small chance of major harm in exchange for a likely moderate gain, suggesting that most people do not accept a

[10] There is a large literature on the precautionary principle. Some starting points are Manson (2002) for an overview; Steele (2006) for a favourable discussion; Newman et al. (2017, chap. 3) for a discussion critical of the principle.

principle that states we should take action to avoid all potential future harms (Sober 1986). If you share this kind of reservation about precautionary principles, then you will not find the above argument effective.

This argument avoids the scale problem since it concludes directly that we should try to preserve all species in order to avoid risks of future harm. However, if we have evidence that some species do not have instrumental value to humans, the argument seems to allow that we no longer have reason to protect them. Problematically, the argument only justifies protecting all species to the extent that we have incomplete knowledge about the consequences of their loss. We would expect that our impetus to protect all species will decrease as we gain better scientific knowledge. So, this argument does not capture the intuition that global biodiversity decline as such is undesirable, irrespective of our state of knowledge about the uses of particular species.

Option value argument

Next I will consider an argument which appeals to the option value of species. Erik Persson defines option value as '[t]he value something has because it provides an alternative way of promoting something else that has instrumental and/or end value' (Persson 2016: 167).[11] When multiple species can potentially sustain the same service, those species have option value. We value the fact that these species are intersubstitutable because they provide some insurance against losing services in the event that one species is lost. In general, we value the existence of alternative options because they leave room for more choices or new preferences in the future. Here is my summary of Persson's option value argument for protecting biodiversity:

---

[11] This is distinct from the technical sense of 'option value' in economics.

1. Many individual species support important services such as pollination, food provision, drug development, attracting tourism, etc.
2. These services are very instrumentally valuable and will be lost as the relevant species are lost.
3. In many cases, multiple species support the same service.
4. When multiple species support the same service, we have good reason to protect all of them because of their option value.
5. So, we have good reason to protect all species which support services.
6. So, we have good reason to protect global biodiversity.

Option value considerations provide good reason to protect a diversity of species that provide specific important services which would be difficult to replicate without those species. For example, I agree with Persson that option value gives us very good reason to protect a diversity of pollinating insects, given that pollination is a vital service which would be difficult to replicate without the pollinators. However, option value is only important in those cases when a limited number of species relatively directly support an important ecosystem service or function. If there is a large number of species that support the same function (e.g. the number of primary producers in many systems), these species have minimal option value, because there is no reasonable chance of losing the function if some species are lost.[12] Species become less instrumentally valuable to the extent that they are more functionally redundant. Thus, (4) holds

[12] Donald Maier makes this point more colourfully: ‘there seems to be a gross superfluidity of species – a true *embarras de richesses* – associated with the majority of ecosystem services’ (Maier 2012: 178).

only in cases where the functional role of the species is relatively uncommon. In addition, (6) does not follow from (5), given that many species do not support irreplaceable services. So, service-based option value arguments will be subject to the same patchiness objection discussed previously. They can justify protecting species that support important and relatively irreplaceable services, but they cannot justify protecting arbitrary species (such as many non-pollinating invertebrates, wild herbaceous plants, and small wild vertebrates, not to mention microbes). One might think there are various species which do not directly support a service, but which help to sustain services indirectly by virtue of their role in a community. The problem with these 'indirect' roles is that many species or communities are highly intersubstitutable from the perspective of service provision. For example, having wetlands and forests is good for water quality, but there are huge numbers of species that could make up a wetland or forest. Thus, relevant species will have low option value with respect to water quality.

I do think option value might justify protecting a diversity of ecosystems, and this could go some way to supporting biodiversity protection at larger scales. However, there will still be problems surrounding, e.g. low abundance species which do not contribute appreciably to ecosystem functions.

Global precautionary argument

The services arguments considered above have a common feature: they try to link the α-diversity within ecosystems to services provided by those ecosystems. So, the services under consideration are those generated by local processes within ecosystems (although the services might be consumed by humans either locally or globally). However, it is also possible to think of services produced at the global scale by global-scale processes. Climate stability is a plausible example of a global service – it is a service that cannot be explained at the scale of individual ecosystems.

If global biodiversity can be causally linked to some global services, the resulting argument will avoid the scale problem. Yet we currently seem to have poor knowledge about (a) what are the candidates for global services and (b) how biodiversity changes at the global scale will affect other global-scale processes. Recall, for example, that the majority of BEF research pertains to (very-)sub-ecosystem-scale processes. A major takeaway is that more attention should be devoted to these global-scale questions.

Despite the current lack of empirical information, one may construct a global-scale services argument utilising a precautionary principle. This is the final argument I will consider in this paper, and I believe it represents the most promising way forward for services arguments, although I will express reservations about the argument as it currently stands.

1. If global biodiversity losses become great, we may reach a tipping point beyond which there will be a widespread collapse of major ecosystems or large-scale biogeochemical processes and accelerating further biodiversity losses.
2. We are not in a position to know when such a tipping point would be reached.
3. So, by a precautionary principle, we have good reason to protect global biodiversity.

This argument is my attempt to update the famous airplane rivet analogy (Ehrlich and Ehrlich 1981; Ehrlich and Walker 1998). Anne and Paul Ehrlich and coauthors compare species to the rivets in an airplane. While an airplane may continue flying as rivets are removed due to redundancies, at some point, a threshold will be crossed and the airplane will experience a catastrophic breakdown. Similarly, the Ehrlichs suggest that the removal of species will eventually result in catastrophic breakdowns of ecosystem functioning. They think that preventing species losses is urgent because of our ignorance about when the breakdown will occur. As summarised, their argument is subject to the scale problem, since it focuses on individual ecosystems. My version is formulated to operate at the correct scale by pointing to potential global consequences of global species losses. Although this argument avoids the scale problem and deserves further consideration, I will argue that it is currently inconclusive.

An important difference between aircraft and ecosystems is that ecosystems can undergo major reorganisations without losing all functionality.[13] The notion of ecological collapse at work in this argument should be defined carefully (see Keith et al. 2013). ‘Collapse’ means something like an undesirable and relatively irreversible change to the state of an ecological system, particularly one which involves major native biodiversity loss or a major decrease in populations of functionally characteristic species. Climate change and biodiversity changes are resulting in ecosystem regime shifts, but this does not automatically mean that local or global-scale functions will be lost.[14] Although new ecosystem regimes are sometimes considered less desirable, even less desirable regimes can support a diverse biota and basic ecosystem functions. Thus, a collapse is an extreme kind of regime change which involves major loss of biota.

My characterisation of ecological collapse raises an issue with the causal interpretation of the first premise of the above argument. Because biodiversity losses are partly constitutive of collapse, biodiversity losses should not be treated as a separate cause of this phenomenon as

---

[13] For convenience, I will continue talking about ecosystems, but the global-scale argument predicts that there will be widespread ecosystem collapses which will affect global processes.

[14] A regime shift is a sudden, discrete change in the overall structure of an ecosystem.

perhaps suggested by premise (1). Biodiversity losses are better considered components or indicators of ecological collapse.

It is more natural to run arguments like this in the opposite direction. Climate change and human activities are in the process of wiping out whole ecosystem types and threatening others with irreversible regime shifts. Ecosystem changes are known to contribute to species extinctions. Thus, we should try to prevent ecosystem collapses as a means to prevent accelerating biodiversity losses. However, this argument presupposes that we already have reasons to prevent biodiversity losses.

Although we have good reasons to prevent runaway global-scale processes as might be caused by the climate crisis, this type of argument cannot function primarily as a justification for protecting arbitrary species.[15] The climate crisis is known to be a result of human atmospheric pollution, and although biodiversity may contribute to climate dynamics in ways that are not currently understood, the primary causal direction at the moment seems to be from climate change to biodiversity loss. So, we still need an independent reason for believing that global biodiversity loss is undesirable and that we should make a special effort to prevent species losses over and above climate mitigation efforts.

5. CONCLUSIONS

[15] Precautionary arguments related to climate change are more defensible than those previously considered, since climate change carries known serious risks to human life. There are still interpretive problems about the formulation and implications of the precautionary principle, but I think precautionary arguments which point to known risks must be taken more seriously than ones which point to the mere possibility of harms of unknown character.

When considering biodiversity defences, it has been tempting to form the opinion that there is safety in numbers. There are a lot of proposed arguments for protecting biodiversity, and one might hope that they will generate a cumulative case for protecting biodiversity, even if each individual argument is subject to objections. A similar convergence strategy is sometimes pursued elsewhere in applied ethics. For example, one might show that many different ethical frameworks all justify respecting competent patients' decisions about their medical care. Thus, one can conclude that respecting patients' decisions is well-justified in medical ethics, even if any individual ethical framework is subject to objections.

Unfortunately, I have demonstrated in this paper that the arguments for the value of biodiversity are not as abundant as one might think. The scale problem shows that popular services arguments cannot be successful. They rest on a faulty implicit premise linking global species losses to local species losses.

In view of this, environmental philosophers should continue devoting attention to different types of value that might be attributed to global biodiversity, such as intrinsic value (McShane 2007; McShane 2017; Callicott 2017; cf. Oksanen 1997; Odenbaugh 2003; Maguire and Justus 2008; Justus et al. 2009), aesthetic value (Welchman 2020; Linquist 2020), experience value, scientific value and so on. If these types of value can be attributed directly to biodiversity, then arguments from these values may avoid the scale problem.

It is important to be more attentive to scale when discussing the values of species diversity. Ecological processes and properties are notoriously scale-dependent, and phenomena across multiple scales should be considered when discussing environmental management problems (Desjardins et al. 2019). Finally, we should devote more scientific and philosophical attention to potential roles of species richness at the global scale. For instance, more knowledge of possible feedbacks or tipping points at the global scale resulting from interactions among climate change, ecosystem changes and species extinctions would help to inform conservation decision-making.

ACKNOWLEDGEMENTS

Thanks to Colin Allen, Michael Dietrich and Marina DiMarco for reading prior drafts of this material. Very helpful discussion of my argument was provided by audience members at the virtual ISHPSSB meeting in July, 2021. Thanks also to the anonymous reviewers for prompting clarification of several points of my discussion.

REFERENCES

Brose, U. and H. Hillebrand. 2016. 'Biodiversity and ecosystem functioning in dynamic landscapes'. *Philosophical Transactions of the Royal Society B: Biological Sciences* **371** (1694): 20150267.

https://doi.org/10.1098/rstb.2015.0267

Burch-Brown, J. and A. Archer. 2017. 'In defence of biodiversity'. *Biology & Philosophy* **32** (6): 969–997.

https://doi.org/10.1007/s10539-017-9587-x

Callicott, J.B. 2017. 'What good is it, anyway?'. In J. Garson, A. Plutynski and S. Sarkar (eds), *The Routledge Handbook of Philosophy of Biodiversity*, pp. 168–182. London: Routledge.

Cardinale, B. 2014. 'Overlooked local biodiversity loss'. *Science* **344** (6188): 1098–1098.

https://doi.org/10.1126/science.344.6188.1098-a

Cardinale, B.J., A. Gonzalez, G.R.H. Allington and M. Loreau. 2018. 'Is local biodiversity declining or not? A summary of the debate over analysis of species richness time trends'. *Biological Conservation* **219**: 175–183.

https://doi.org/10.1016/j.biocon.2017.12.021

Cartwright, N. and J. Hardie. 2012. *Evidence-Based Policy: A Practical Guide to Doing It Better*. Oxford: Oxford University Press.

deLaplante, K. and V. Picasso. 2011. 'The biodiversity-ecosystem function debate in ecology'. In K. deLaplante, B. Brown and K.A. Peacock (eds), *Philosophy of Ecology*, pp. 169–200. Amsterdam: Elsevier.

https://doi.org/10.1016/B978-0-444-51673-2.50007-8

Deliège, G. and S. Neuteleers. 2015. 'Should biodiversity be useful? Scope and limits of ecosystem services as an argument for biodiversity conservation'. *Environmental Values* **24** (2): 165–182.

https://doi.org/10.3197/096327114X13947900181275

Desjardins, E., J. Donhauser and G. Barker. 2019. 'Ecological historicity, novelty and functionality in the Anthropocene'. *Environmental Values* **28** (3): 275–303.

https://doi.org/10.3197/096327119X15519764179791

Díaz, S., J. Settele, E. Brondízio, H.T. Ngo, M. Guèze, J. Agard, A. Arneth, et al. 2019. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn, Germany: IPBES Secretariat.

https://doi.org/10.5281/zenodo.3553579

Díaz, S. and M. Cabido. 2001. 'Vive la différence: Plant functional diversity matters to ecosystem processes'. *Trends in Ecology & Evolution* **16** (11): 646–655.

https://doi.org/10.1016/S0169-5347(01)02283-2

Doak, D.F., D. Bigger, E.K. Harding, M.A. Marvier, R.E. O'Malley and D. Thomson. 1998. 'The statistical inevitability of stability-diversity relationships in community ecology'. *The American Naturalist* **151** (3): 264–276.

https://doi.org/10.1086/286117

Dornelas, M., N.J. Gotelli, B. McGill, H. Shimadzu, F. Moyes, C. Sievers and A.E. Magurran. 2014. 'Assemblage time series reveal biodiversity change but not systematic loss'. *Science* **344** (6181): 296–299.

https://doi.org/10.1126/science.1248484

Downing, A.L., B.L. Brown and M.A. Leibold. 2014. 'Multiple diversity–stability mechanisms enhance population and community stability in aquatic food webs'. *Ecology* **95** (1): 173–184.

https://doi.org/10.1890/12-1406.1

Ehrlich, P.R. and A.H. Ehrlich. 1981. *Extinction: The Causes and Consequences of the Disappearance of Species.* New York: Random House.

Ehrlich, P. and B. Walker. 1998. 'Rivets and redundancy'. *BioScience* **48** (5): 387–387.

https://doi.org/10.2307/1313377

Gagic, V., I. Bartomeus, T. Jonsson, A. Taylor, C. Winqvist, C. Fischer, E.M. Slade et al. 2015. 'Functional identity and diversity of animals predict ecosystem functioning better than species-based indices'. *Proceedings of the Royal Society B: Biological Sciences* **282**: 20142620.

https://doi.org/10.1098/rspb.2014.2620

Giller, P.S., H. Hillebrand, U.-G. Berninger, M.O. Gessner, S. Hawkins, P. Inchausti, C. Inglis et al. 2004. 'Biodiversity effects on ecosystem functioning: Emerging issues and their experimental test in aquatic environments'. *Oikos* **104** (3): 423–436.

https://doi.org/10.1111/j.0030-1299.2004.13253.x

Gonzalez, A., B.J. Cardinale, G.R.H. Allington, J. Byrnes, K.A. Endsley, D.G. Brown, D.U. Hooper, F. Isbell, M.I. O'Connor and M. Loreau. 2016. 'Estimating local biodiversity change: A critique of papers claiming no net loss of local diversity'. *Ecology* **97** (8): 1949–1960.

https://doi.org/10.1890/15-1759.1

Hallett, L.M., J.S. Hsu, E.E. Cleland, S.L. Collins, T.L. Dickson, E.C. Farrer, L.A. Gherardi et al. 2014. 'Biotic mechanisms of community stability shift along a precipitation gradient'. *Ecology* **95** (6): 1693–1700.

https://doi.org/10.1890/13-0895.1

Hautier, Y., D. Tilman, F. Isbell, E.W. Seabloom, E.T. Borer and P.B. Reich. 2015. 'Anthropogenic environmental changes affect ecosystem stability via biodiversity'. *Science* **348** (6232): 336–340.

https://doi.org/10.1126/science.aaa1788

Hector, A., Y. Hautier, P. Saner, L. Wacker, R. Bagchi, J. Joshi, M. Scherer-Lorenzen et al. 2010. 'General stabilizing effects of plant diversity on grassland productivity through population asynchrony and overyielding'. *Ecology* **91** (8): 2213–2220.

https://doi.org/10.1890/09-1162.1

Hector, A., J. Joshi, M. Scherer-Lorenzen, B. Schmid, E.M. Spehn, L. Wacker, M. Weilenmann et al. 2007. 'Biodiversity and ecosystem functioning: Reconciling the results of experimental and observational studies'. *Functional Ecology* **21** (5): 998–1002.

https://doi.org/10.1111/j.1365-2435.2007.01308.x

Hector, A. and R. Bagchi. 2007. 'Biodiversity and ecosystem multifunctionality'. *Nature* **448** (7150): 188–190.

https://doi.org/10.1038/nature05947

Hillebrand, H., B. Blasius, E.T. Borer, J.M. Chase, J.A. Downing, B.K. Eriksson, C.T. Filstrup et al. 2018. 'Biodiversity change is uncoupled from species richness trends: Consequences for conservation and monitoring'. *Journal of Applied Ecology* **55** (1): 169–184.

https://doi.org/10.1111/1365-2664.12959

Hooper, D.U., F.S. Chapin, J.J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J.H. Lawton, et al. 2005. 'Effects of biodiversity on ecosystem functioning: A consensus of current knowledge'. *Ecological Monographs* **75** (1): 3–35.

https://doi.org/10.1890/04-0922

Jax, K. 2010. *Ecosystem Functioning*. Cambridge: Cambridge University Press.

Justus, J., M. Colyvan, H. Regan and L. Maguire. 2009. 'Buying into conservation: Intrinsic versus instrumental value'. *Trends in Ecology & Evolution* **24** (4): 187–191.

https://doi.org/10.1016/j.tree.2008.11.011

Keith, D.A., J.P. Rodríguez, K.M. Rodríguez-Clark, E. Nicholson, K. Aapala, A. Alonso, M. Asmussen et al. 2013. 'Scientific foundations for an IUCN red list of ecosystems'. *PLoS ONE* **8** (5): e62111.

https://doi.org/10.1371/journal.pone.0062111

Lean, C.H. 2021. 'Invasive species increase biodiversity and, therefore, services: An argument of equivocations'. *Conservation Science and Practice* **3** (12): e553.

https://doi.org/10.1111/csp2.553

Linquist, S. 2020. 'Two (and a half) arguments for conserving biodiversity on aesthetic grounds'. *Biology & Philosophy* **35** (1): 6.

https://doi.org/10.1007/s10539-019-9726-7

Little, C.J. and F. Altermatt. 2018. 'Species turnover and invasion of dominant freshwater invertebrates alter biodiversity–ecosystem-function relationship'. *Ecological Monographs* **88** (3): 461–480.

https://doi.org/10.1002/ecm.1299

Loreau, M. and C. de Mazancourt. 2013. 'Biodiversity and ecosystem stability: A synthesis of underlying mechanisms'. *Ecology Letters* **16**: 106–115.

https://doi.org/10.1111/ele.12073

Maclaurin, J. and K. Sterelny. 2008. *What Is Biodiversity?* Chicago: The University of Chicago Press.

Maguire, L.A. and J. Justus. 2008. 'Why intrinsic value is a poor basis for conservation decisions'. *BioScience* **58** (10): 910–911.

https://doi.org/10.1641/B581002

Maier, Donald S. 2012. *What's So Good About Biodiversity? A Call for Better Reasoning About Nature's Value*. Dordrecht: Springer.

Manson, N.A. 2002. 'Formulating the precautionary principle'. *Environmental Ethics* **24** (3): 263–274.

https://doi.org/10.5840/enviroethics200224315

Marcellesi, A. 2015. 'External validity: Is there still a problem?'. *Philosophy of Science* **82** (5): 1308–1317.

https://doi.org/10.1086/684084

Mason, N.W.H., D. Mouillot, W.G. Lee, J.B. Wilson and H. Setälä. 2005. 'Functional richness, functional evenness and functional divergence: The primary components of functional diversity'. *Oikos* **111** (1): 112–118.

McCann, K.S. 2000. 'The diversity–stability debate'. *Nature* **405** (6783): 228–233.

https://doi.org/10.1038/35012234

McCauley, D.J. 2006. 'Selling out on nature'. *Nature* **443** (7107): 27–28.

https://doi.org/10.1038/443027a

McShane, K. 2007. ‘Why environmental ethics shouldn’t give up on intrinsic value’. *Environmental Ethics* **29** (1): 43–61.

———. 2017. ‘Is biodiversity intrinsically valuable? (And what might that mean?)’. In J. Garson, A. Plutynski and S. Sarkar (eds), *The Routledge Handbook of Philosophy of Biodiversity*, pp. 155–167. London: Routledge.

Moi, D.A., G.Q. Romero, P.A.P. Antiqueira, R.P. Mormul, F.T. de Mello and C.C. Bonecker. 2021. ‘Multitrophic richness enhances ecosystem multifunctionality of tropical shallow lakes’. *Functional Ecology* **35** (4): 942–954.

https://doi.org/10.1111/1365-2435.13758

Mori, A.S., T. Furukawa and T. Sasaki. 2013. ‘Response diversity determines the resilience of ecosystems to environmental change’. *Biological Reviews* **88** (2): 349–364.

https://doi.org/10.1111/brv.12004

Newbold, T., L.N. Hudson, S.L.L. Hill, S. Contu, I. Lysenko, R.A. Senior, L. Börger et al. 2015. ‘Global effects of land use on local terrestrial biodiversity’. *Nature* **520** (7545): 45–50.

https://doi.org/10.1038/nature14324

Newman, J.A. 2020. ‘Biodiversity, ecosystem functioning, and the environmentalist agenda: A reply to Odenbaugh’. *Biology & Philosophy* **35**: 17.

https://doi.org/10.1007/s10539-019-9721-z

Newman, J.A., G. Varner and S. Lindquist. 2017. *Defending Biodiversity: Environmental Science and Ethics*. Cambridge: Cambridge University Press.

Odenbaugh, J. 2003. ‘Values, advocacy and conservation biology’. *Environmental Values* **12** (1): 55–69.

———. 2010. ‘On the very idea of an ecosystem’. In A. Hazlett (ed.), *New Waves in Metaphysics*, pp. 240–258. London: Palgrave Macmillan.

———. 2020. ‘Biodiversity, ecosystem functioning, and the environmentalist agenda’. *Biology & Philosophy* **35**: 16.

https://doi.org/10.1007/s10539-019-9723-x

Oksanen, M. 1997. ‘The moral value of biodiversity’. *Ambio* **26** (8): 541–545.

Patrick, C.J., K.E. McCluney, A. Ruhi, A. Gregory, J. Sabo and J.H. Thorp. 2021. ‘Multi-scale biodiversity drives temporal variability in macrosystems’. *Frontiers in Ecology and the Environment* **19** (1): 47–56.

https://doi.org/10.1002/fee.2297

Persson, E. 2016. ‘Option value, substitutable species, and ecosystem services’. *Environmental Ethics* **38** (2): 165–181.

https://doi.org/10.5840/enviroethics201638214

Sakschewski, B., W. von Bloh, A. Boit, L. Poorter, M. Peña-Claros, J. Heinke, J. Joshi and K. Thonicke. 2016. ‘Resilience of amazon forests emerges from plant trait diversity’. *Nature Climate Change* **6** (11): 1032–1036.

https://doi.org/10.1038/nclimate3109

Santana, C. 2017. ‘Biodiversity eliminativism’. In J. Garson, A. Plutynski and S. Sarkar (eds), *The Routledge Handbook of Philosophy of Biodiversity*, pp. 86–97. London: Routledge.

———. 2018. ‘Biodiversity is a chimera, and chimeras aren’t real’. *Biology & Philosophy* **33**: 15.

https://doi.org/10.1007/s10539-018-9626-2

Sasaki, T. and W.K. Lauenroth. 2011. ‘Dominant species, rather than diversity, regulates temporal stability of plant communities’. *Oecologia* **166** (3): 761–768.

https://doi.org/10.1007/s00442-011-1916-1

Sober, E. 1986. ‘Philosophical problems for environmentalism’. In B.G. Norton (ed.), *The Preservation of Species: The Value of Biological Diversity*, pp. 173–194. Princeton: Princeton University Press.

Spehn, E.M., A. Hector, J. Joshi, M. Scherer-Lorenzen, B. Schmid, E. Bazeley-White, C. Beierkuhnlein et al. 2005. ‘Ecosystem effects of biodiversity manipulations in European grasslands’. *Ecological Monographs* **75** (1): 37–63.

https://doi.org/10.1890/03-4101

Steele, K. 2006. ‘The precautionary principle: A new approach to public decision-making?’. *Law, Probability and Risk* **5** (1): 19–31.

https://doi.org/10.1093/lpr/mgl010

Tilman, D. 1996. ‘Biodiversity: Population versus ecosystem stability’. *Ecology* **77** (2): 350–363.

https://doi.org/10.2307/2265614

Tilman, D. and J.A. Downing. 1994. ‘Biodiversity and stability in grasslands’. *Nature* **367**: 363–365.

Tilman, D., P.B. Reich and J.M.H. Knops. 2006. ‘Biodiversity and ecosystem stability in a decade-long grassland experiment’. *Nature* **441** (7093): 629–632.

https://doi.org/10.1038/nature04742

Tilman, D., P.B. Reich, J. Knops, D. Wedin, T. Mielke and C. Lehman. 2001. ‘Diversity and productivity in a long-term grassland experiment’. *Science* **294** (5543): 843–845.

https://doi.org/10.1126/science.1060391

Tilman, D., D. Wedlin and J.M.H. Knops. 1996. ‘Productivity and sustainability influenced by biodiversity in grassland ecosystems’. *Nature* **379**: 718–720.

Vellend, M., L. Baeten, I.H. Myers-Smith, S.C. Elmendorf, R. Beausejour, C.D. Brown, P. De Frenne, K. Verheyen and S. Wipf. 2013. ‘Global meta-analysis reveals no net change in local-scale plant biodiversity over time’. *Proceedings of the National Academy of Sciences* **110** (48): 19456–19459.

https://doi.org/10.1073/pnas.1312779110

Welchman, J. 2020. ‘Commentary on Jonathan A. Newman, Gary Varner, and Stefan Linquist: *Defending Biodiversity: Environmental Science and Ethics*, chapter 11: should biodiversity be conserved for its aesthetic value?’. *Biology & Philosophy* **35**: 13.

https://doi.org/10.1007/s10539-019-9720-0

Woodward, J. 2003. *Making Things Happen: A Theory of Causal Explanation*. Oxford: Oxford University Press.