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Forum

Contemporary Evosystem Services: A Reply to Faith *et al*.

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We thank Faith *et al.* [1] for their informative and thought-provoking reply to our recent article in *TREE* [2]. We agree with several of their comments regarding the path forward for the study of evosystem services and especially contemporary evosystem services, the topic of our article [2]. Evosystem services are 'all the uses or services to humans that are produced from the evolutionary process' [3] including benefits stemming from past, current and future evolution. In our article [2], we defined 'contemporary evosystem services' as 'the maintenance or increase of an ecosystem service resulting from evolution occurring quickly enough to alter ecological processes'. Here, we briefly discuss two areas where our opinions and working definitions differ from those of Faith *et al.* [1].

One area of discord between our view and that of Faith *et al*. [1] is that we do not see enhancements to ecosystem services stemming from evolution by artificial selection as a contemporary evosystem service. Evolution stemming from natural processes that occur on human-altered landscapes and that increase ecosystem services would fit our definition, and we provide several putative cases in our original article [2]. For example, the slowing of the evolution of pesticide resistance through gene flow between farm and refuge populations of pests is a clear contemporary evosystem service that occurs in agricultural landscapes. Faith *et al*. [1] would also include the action of farmers intentionally maintaining crop diversity in fields under their definition, but we regard this as a form of artificial disruptive selection. We fail to see the advantage of lumping artificial selection with natural selection under the same heading. If the intentional maintenance of genetic diversity is to be regarded as an evosystem service, then so should other forms of manipulation leading to changes in genetic diversity, including the selective breeding of crops and livestock, and artificial evolution achieved through allelic replacement using CRISPR and older transgenics techniques. In all of these cases, humans are driving heritable genetic changes, but the action of human engineering differs markedly in mechanism and ontology from what occurs in scenarios not deliberately controlled by humans. More importantly, these cases diverge from the main message of the ecosystem services concept, which is to focus on the contributions to human wellbeing that are outside of the market system. Farmers maintaining genetic diversity are certainly performing a service to society, but we believe that calling it a contemporary evosystem service reduces the clarity of the concept.

Faith *et al*. [1] also make the interesting point that option values (such as that provided by genetic diversity) should also be included with contemporary evosystem services. In our view, this depends on whether one regards option values as an ecosystem service or as something distinct from ecosystem services. Option values have long been included in the ecosystem services concept. Daily *et al*. [4] formally recognized them as 'a premium that people are willing to pay to preserve an environmental amenity, over and above the mean value of the use values anticipated from the amenity' ([4] pp. 34–35). The Millennium Ecosystem Assessment (MEA) [5] defined option value more broadly as: 'the value individuals place on keeping biodiversity for future generations.' The original definitions from Daily *et al*. [4] and the MEA [5] focus on how humans value maintaining the option of enjoying ecosystem services in the future. Similar to other ecosystem services, option values, as defined by Daily *et al*. [4], could be modified by contemporary evolutionary processes, and contemporary evolution could alter the value humans ascribe to maintaining options for future use. In this case, rapid evolution leading to changes to option values should be regarded as a contemporary evosystem service.

Faith [6] provides a rather different definition of option value: 'option value refers not only to the unknown future benefits from known units of biodiversity, but also to the unknown benefits from unknown units.' Using this definition, Faith *et al*. [1] focus on the importance of maintaining genetic diversity to maintain 'future options' provided by living variation. Although we agree that the maintenance of genetic diversity is important for future evolution, we would not classify these option values as contemporary evosystem services because they are not the product of current rapid evolution. We feel that option values under this definition fit best under the broader evosystem services concept.

Our intent in defining and discussing the evidence for contemporary evosystem services is to provide an impetus to study the links between rapid evolution and ecosystem services. Are contemporary evosystem services of sufficient magnitude to maintain or restore many (or any) of the ecosystem services at risk owing to widespread anthropogenic impacts on ecosystems? Can recent advances in the study of rapid evolution and ecoevolutionary dynamics help us to maintain or enhance ecosystem services? We hope that this exchange will ultimately lead to advances in our ability to answer these questions and to help maintain ecosystem services that are being eroded.

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