Reply to: Empirical pressure-response relations can benefit assessment of safe operating spaces

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Moving past thresholds towards understanding complex ecosystem dynamics undergoing global changes: a reply to Lade et al.

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We very much welcome the discussion started by Lade et al.[1] on the important common goal of devising effective ways of managing global change impacts on ecosystems. We also agree with their call for a more diverse tool-kit and continued development of environmental management options. However, we disagree on the ubiquity of thresholds in ecosystems, and remain skeptical on how they may be used as a framework in ecology and environmental sciences. We are therefore grateful for the opportunity to reply to each of their four main statements.

(1) We do agree with Lade et al. on the fact that "[t]here is extensive experimental and observational evidence of threshold dynamics" , and acknowledged this in our article[2]. We argue, however, that a list of "positive" cases alone is insufficient to motivate the adoption of the threshold concept for management. The issue of publication bias against non-significant results is a general phenomenon in science[3,4], but is especially likely to affect studies of threshold/tipping behavior because the alternative outcome "no threshold observed" will likely not suffice as basis of a stand-alone case study publication. Hence, we do not know the proportion of possible cases the experimental and observational evidence for threshold dynamics comprises or, as we put it[2], whether the evidence in support of tipping behaviour is the tip of the iceberg or if it is, in fact, the entire iceberg. A great advantage of our analysis is that it uses data that were not explicitly assembled to test for thresholds, thus reducing the risk of bias. We would like to reiterate that the main conclusion of our synthesis is not that thresholds do not exist, but rather that they are hard to detect in observational data and therefore difficult to use for risk management.

(2) Lade et al. then argue that "[e]ven in the absence of precise information on threshold location, awareness of the risks associated with potential thresholds can promote risk-averse decision making and promote collaboration". We agree that there is evidence from behavioral experiments that the uncertainty of threshold location can result in precautionary definition of a management goal. However, in those studies, the existence of thresholds and consequences of their transgression was known beforehand, which, as we showed with our analyses, is rarely the case in natural ecosystems. In fact, the way thresholds are used in actual setting of management goals, often leads to exactly the opposite outcome. Scientifically recommended thresholds for sustainable fisheries are regularly exceeded by total allowable catches and when - due to uncertainty - a range of thresholds is given, the quotas are set towards the upper limits[5,6]. Similar attraction to the maximum is observed in intensive agriculture, where pesticides are used at highest tolerated quantities, even if they could be reduced by half or even more without detectable loss of yield or increase in weeds[7] and even though the negative impacts on

rare species are known[8]. Fisheries and agriculture are two striking examples that show that, just like speed limits on roads, environmental "limits" have the unfortunate tendency to become "targets". Lade et al. close this paragraph by warning that ignoring thresholds "risk[s] potentially damaging and irreversible consequences", and a "misguided expectation that ecosystems will recover". We would like to highlight that our recommendation was not to ignore thresholds, and we are very aware of limits to ecological recovery, even in simple stressor –response settings[9]. Instead, we are worried that with too much attention directed towards threshold transgression and tipping behaviours, other equally damaging changes will remain unnoticed, because they appear slow and gradual. By focusing on the prevention of non-existent or not-identifiable forcing thresholds, we may end up involuntarily accepting locally deleterious effects and underestimating gradually shifting baselines.

(3) We agree with Lade et al. that "acceptable" or "tolerable" limits can be defined with or without tipping behavior. As we describe above, we fear that setting such limits is in itself problematic given political power relations and the attraction to the maximum. We also question what such a tolerable limit may be, for example, in the urgent matter of biodiversity loss. Setting a local or regional limit to species loss does not reflect that many local systems experience biodiversity gains[10] (potentially transient and based on imbalanced immigration-extinction dynamics[11]). Side-stepping the profound ethical and moral question of what level of species loss is "tolerable", any threshold of net loss will not capture compositional turnover as the major aspect of biodiversity change[11-13]. When extending to the global scale, defining safe operating spaces is challenged by the enormous variance of the responses that we observed even under low pressure levels (that is, close to the reference state). At both global and local levels, we reiterate our main conclusion that a strong focus on threshold-type responses marginalizes the importance of other, more complex, nonlinear dynamics under global change. Thus, we do not share the optimism in Lade et al.'s argumentation that conservative safe operating spaces under uncertainty are appropriate or even operable in the political discourse for local management practice. Earth's ecosystems are arguably the most complex systems that we must understand, and non-linearity, which is more encompassing than the special case of thresholds, is the larger feature, along with, e.g., multiple feedback mechanisms (both stabilizing and destabilizing), high-dimensionality, chaos, stochasticity, and applied problems of error and uncertainty. The important logical point that we make is that thresholds are only one possible phenomenon—and not an essential one—belonging to the larger problem of ecosystem dynamics driven by global change.

(4) We couldn't agree more with Lade et al.'s advice to use meta-analyses and other review synthesis efforts more consistently to characterize the evidence base for ecosystem management[14]. A major strength of these efforts is that they allow quantification of the variance in potential responses, which enables interventions to be based on the breadth of evidence rather than single contexts. Such synthesis efforts can help identifying limits to recovery[9] or – as in our study[2] - investigate preponderance of threshold signals in global change studies. Therefore, in contrast to Lade et al., we also do not see the definition of safe operating spaces as a major focus of such synthesis efforts, but rather we recommend they are used to support the development of empirically quantifiable effect metrics for a wide range of potential response types in a global change context.

In conclusion, we share with Lade et al. the aim to establish viable management structures to mitigate global change impacts, which remains a complex endeavor given the plethora of feedback mechanisms and non-linear dynamics in natural ecosystems. We are also grateful for their constructive and dialogue-oriented approach to our results, which provided us with an additional opportunity to clarify our results. We restate that the low detectability of thresholds from data – independent of whether it is because threshold transgression is less common than we thought or because they are masked by low signal to noise ratios – requires to shift focus from policies dominantly based on thresholds to policies that accounts for gradual changes and potential large impacts for even small pressures.

References

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