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Are human remediation efforts responsible for increases in insect abundance?

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A recent meta-analysis by van Klink et al. (2020) reports that despite long-term global declines in terrestrial insects (i.e., "the insect apocalypse" (1)), populations of freshwater insects have increased in total abundance (2). van Klink et al.'s study is unparalleled in scope, and we applaud their valuable contribution as well as the efforts of numerous people involved in collecting the long-term data used in their meta-analysis. The declines in terrestrial insect populations are indeed concerning, particularly given that insects compose ~80% of known animal biodiversity and provide many ecosystem services that contribute to human wellbeing (3,4). Although the authors have attempted to remain "cautious about generalizing these patterns", we have concerns about how they have interpreted trends for freshwater insects, and particularly how their conclusions were described by various media sources (5,6).

Specifically, we feel that van Klink et al.'s assertion that increased abundance of freshwater insects broadly reflects recovery from degradation due to "improvements in water quality" needs to be interpreted carefully and with more nuance (7). In particular, we wish to highlight three key points that should be useful for evaluating this study and any future studies examining long-term change in freshwater insect abundance:

1) increasing insect abundance should not be conflated with a 'positive' ecosystem response,

2) total aquatic insect abundance often increases following natural disturbance events, independent of environmental remediation efforts; and,

3) common and widespread human perturbations can result in increases, as well as decreases, in total aquatic insect abundance.

With respect to our first point, increases in insect abundance (or biomass or production) do not inherently reflect a positive change in ecosystems, as increased abundance often occurs in response to human perturbation, and may further exacerbate alterations to ecosystem processes. For example, inputs of contaminants to freshwaters can lead to large increases in the abundance of tolerant insect taxa, including some mosquitos (Diptera: Culicidae) and midges (Diptera: Chironomidae) (8). Because contaminants may be incorporated into insect tissues, high insect abundances can lead to further transfer and biomagnification through aquatic and riparian food webs (9). Although increases in freshwater insect abundance may sometimes reflect desirable ecosystem responses to remediation, and decreases in abundance may reflect responses to human perturbations, it is critical to acknowledge that these are not hard and fast rules.

To address our second and third points above, we qualitatively placed individual studies in van Klink et al.'s meta-analysis - when possible - into three broad categories that characterize the primary focus of the study: responses to environmental remediation efforts, responses to natural disturbance and variability, and responses to human perturbations. Of the studies we examined, many were focused on environmental remediation. The focus of these studies, which clearly support van Klink et al.'s major conclusions, included the remediation of point-source pollution and responses to landscape rehabilitation. However, a significant number of other studies were focused on long-term variability or responses to natural disturbance events such as wildfire and catastrophic flooding. While some studies within this category may reflect long-term environmental improvements, there appear to be many cases of rebounding insect populations following natural disturbances, independent of environmental remediation. Unfortunately, given the large-scale observational nature of these particular studies, it was not always possible to attribute a mechanism to the changes in insect abundance. Finally, and perhaps most importantly, we noted numerous studies in van Klink et al.'s study that were focused on changes in freshwater insect abundance in direct response to human perturbations. These perturbations comprised a variety of threats to global freshwaters including the construction and management of dams, nutrient enrichment, land use alteration, and climate change. Thus, it appears that

many positive trends observed in van Klink et al.'s analysis are related to human perturbations and natural disturbances, in addition to remediation efforts, a finding that many other shorter-term studies corroborate (e.g., 10,11).

We did not quantitatively reanalyze van Klink et al.'s time series trends within the three categories described above. However, given our expertise and familiarity with freshwaters in the western U.S., we closely examined the nine studies from this region that showed the most pronounced and consistent increases in abundance (van Klink et al. 2020 supplemental S1: 'USA West'). Although three studies in the western U.S. were indeed related to remediation efforts (Van Klink et al. supplemental refs. 122, 163/164, and 187), the remainder reported positive trends that reflected natural variation (ref. 91/92), recovery from flooding (ref. 75) and wildfires (refs. 126, 134), and responses to river impoundment and other human perturbations (refs. 129, 18). Therefore, many studies that exhibited the strongest increases in freshwater insect abundance were unrelated to environmental remediation and contradict the author's major conclusions and those of the media. These studies also underscore our first point: that increases in total abundance should not be conflated with a positive response or necessarily interpreted as a "good thing."

Freshwater ecosystems face myriad human perturbations and high rates of species extinctions (12-14). While losses of freshwater biodiversity have been clearly documented (15), van Klink et al.'s study focuses on a global trend of increasing freshwater insect abundance. At first glance, this result is puzzling; why are freshwater insect populations growing in the face of increasing threats? However, it is important to acknowledge that both remediation efforts and perturbations to ecosystems can lead to increased insect abundances. Perturbations such as elevated nutrient concentrations, climate warming, species invasions, and altered hydrology often result in simplified communities with populations that achieve higher abundances, resulting in higher overall abundance. Although van Klink et al. do briefly acknowledge that "other causes of this increase may have been climatic warming and an enhanced productivity cause by nutrient enrichment," this point was unfortunately overlooked by various media sources, and van Klink et al. emphasized the improved water quality explanation. Understanding the nuances of how insect abundance relates to multiple factors, including both human remediation and perturbation, and clearly disseminating this information to the public, will be important for the future protection and management of freshwater ecosystems.

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