CLIMATE CHANGE ECOLOGY

Some food webs like it hotter

Temperature affects the metabolic rates of species, their feeding interactions and their ability to persist in a given environment. Now research suggests that different effects of temperature on consumers and resources could cause food webs in cold climates to become less vulnerable to species loss, whereas tropical communities may be more vulnerable as temperatures climb.

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Temperature affects the vulnerabilities of different species to extinction in several ways. On the one hand, warmer areas can sustain larger populations, because more sunlight leads to more plant growth (higher primary productivity and more food available to consumers)[1]. On the other, consumers' metabolic rates tend to increase faster with warming than their feeding rates, leading to starvation at higher temperatures[2]. This limits the ability of large species to persist in hot areas. Writing in *Nature Climate Change*, Benoit Gauzens and co-authors show that these contrasting effects mean that warming could either increase or decrease the vulnerability of species in a given area, depending on how close consumer species are to their metabolic limits and on the potential for increased primary productivity[3]. Understanding how ecological communities are likely to change is crucial if we are to manage these changes and protect as many species and ecosystem functions as possible.

Fig. 1 | Clinging on. In a global dataset of tide-pool food webs, the proportion of species persisting after a disturbance increased with warming in cold tide pools but decreased with warming in tide pools from warm areas. Credit: magnetcreative / E+ / Getty

Most studies predicting the effects of disturbances such as climate change on ecological communities do not include physiological or behavioural effects of temperature. For example, temperature can affect the speed at which a species can move, and, by extension, change the size of prey that a predator of a given size can attack. These omissions mean that simulated food webs (networks of who eats whom) may accurately describe the overall structure of empirical food webs[4] while failing to predict the response of specific real communities to changes in temperature. Current food-web models predict the collapse of large species with warming[5], in contrast to empirical studies suggesting that large species may find more resources at higher temperatures[6] and therefore persist for longer.

Resolving this gap between theoretical and empirical studies is essential, as data collection for empirical food webs is extremely time- and resource-intensive. Theoretical studies offer the potential to predict changes in species persistence for many more systems than can be empirically sampled, but only if they accurately reflect real processes in the field. Recent work incorporating the effects of temperature on species' feeding interactions[7] is a step in this direction, as are efforts to estimate more accurately the parameters used in consumer–resource models[8]. Gauzens et al. add to these efforts by using a global dataset of natural food webs to compare simulated persistence along a temperature gradient[3].

More specifically, they compared network structure and the responses of species to simulated warming for a set of natural tide-pool food webs. These tide pools come from coastal areas with summer sea temperatures ranging from 11.5 °C to 28.4 °C. The researchers found that temperature did not strongly affect the network structure or scaling of body mass with trophic level in these food webs. Simulated networks can therefore accurately reproduce the structures of these networks without taking temperature into account.

A food web's local temperature did, however, affect species persistence in response to simulated warming. In colder webs, the proportion of species expected to persist after a disturbance increased, whereas in warmer webs, persistence decreased. The tipping point between the two trends was 22.9 °C — approximately the temperature of the tide pools from Madeira, Portugal. Based on previous research, this is likely to be because tropical species are already closer to their physiological limits[9] and because many biological rates scale exponentially with temperature[10]. This means that equal increases in temperature affect tropical species more severely than temperate ones.

When these analyses were repeated using simulated networks, which did not incorporate the filtering effects of ambient temperature on the natural food webs, Gauzens et al. did not observe the same trends[3]. Instead, the simulated webs had lower overall persistence and showed a roughly linear decrease in persistence with increasing temperature. The simulated networks tended to have more trophic levels and fewer herbivores per basal resource. This translates to less energy reaching top predators and could explain the lower persistence in the simulated webs. These discrepancies emphasize the importance of using natural food webs to inform simulations of future warming. Expanding models and theories such as the metabolic theory of ecology to include more complex effects of temperature (hump-shaped relationships, for example) will also help us to obtain more accurate predictions.

This study is a timely reminder that, despite recent improvements in ecological network models, we are still a long way from accurately predicting the responses of real communities (such as that in Fig. 1) to ongoing climate change. Gauzens et al. have demonstrated the potential for pre-existing temperature conditions to strongly affect whether ecological communities become more vulnerable in the future[3].

There are, of course, some caveats. As the authors state, there are important structural differences between different ecosystem types (aquatic, terrestrial and so forth) that require us to exercise caution in extrapolating these results to other systems. Moreover, Gauzens et al. used the same ranges of warming for all of the food webs in their dataset. Although cooler communities increased in persistence under these conditions, the Arctic is experiencing much greater warming than the tropics. This may mean that some colder food webs experience enough warming to cross the peak of the hump-shaped relationship and become more vulnerable with further warming.

Nevertheless, Gauzens and co-workers' recommendations for researchers to use system-specific network structures that incorporate information on species' vital rates to generate more accurate predictions are universally sound. Although following these recommendations will certainly be a challenge, it is clear that our current models are not detailed enough to accurately predict the vulnerability of ecological communities. ❐

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