

# Paths to extinction: mode of habitat loss structures extinction thresholds and debts

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## Abstract

Species are faced with global changes that can lead to decline and extinction through one of two routes: habitat destruction, such as occurs locally with land-use change, and habitat degradation, which often occurs through larger-scale changes such as nitrogen deposition or climate change. We develop theory showing that, even when these two forms of global change have identical impact on a species' total amount of habitat, they have qualitatively different consequences for species dynamics and extinction. Using metapopulation theory and simulations, we find distinct impacts of these global changes characterized through several responses: the rate of species decline with habitat reduction, extinction thresholds, and the duration of extinction debts. Habitat degradation causes a faster decline in species when habitat reduction is low, making it particularly detrimental for rare species. Habitat destruction has smaller impacts for low habitat reduction but shows clear thresholds beyond which it surpasses degradation's negative impact; the location and steepness of the threshold depends on species dispersal, with poor dispersers having steeper thresholds. Symptomatic sampling to predict population trends is predicted to fail for both types of global change, due to thresholds (habitat destruction) and lagged dynamics that lead to extinction debts (habitat degradation). Our research clarifies why impacts of one type of global change may poorly predict impacts of the other and suggests general rules for predicting the long-term impacts of global changes based on species traits.

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