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Marine reserve networks for non-equilibrium metacommunities

Changes in fishing practices have promoted the depletion of commercial stocks around the world and caused significant damage to marine habitats. Recent empirical studies have shown that marine reserves can play an important role in reversing these harmful effects. Equilibrium metapopulation models predict that networks of marine reserves can provide similar benefits so long as individual reserves are sufficiently large to achieve self-sustainability, or spaced based on the extent of dispersal of the target species in order to maintain connectivity between reserves. However, these guidelines have not been tested in non-equilibrium models that exhibit spatial and temporal variability typically seen in natural marine communities. Using a spatially-explicit predator-prey model whose predictions have been validated in a marine system, we show that current guidelines are not optimal for trophic metacommunities. In equilibrium metacommunities, there is a community-level tradeoff for designing effective reserves: networks whose size and spacing are smaller than the extent of dispersal maximize global predator abundance but minimize global prey abundance because of trophic cascades, whereas the converse is true for reserve networks whose size and spacing are larger than the extent of dispersal. In non-equilibrium metacommunities, reserves whose size and spacing match the extent of spatial autocorrelation in adult abundance escape this community-level tradeoff by maximizing global abundance and persistence of both the prey and the predator. These results suggest that using the extent of adult patchiness instead of the extent of larval dispersal as the size and spacing of reserve networks is critical for designing management strategies.