The Impacts of Fishing and Stochasticity on Saving Coral Reefs

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Coral reefs have been increasingly impacted by stresses, such as climate variability and ornamental and commercial fishing, and it is unclear how these stressors can change a highquality, coral-dominated system to a low-quality, algae-dominated system. Coral- or algaedominated systems are alternative stable states, in which one combination of environmental parameters has more than one equilibrium. To understand transitions between these two states, we reanalyze the mathematical model of coral-algae competition (Fung et al. 2011) and focus on fishing pressure (modeled by changes in algae and coral growth via grazing by fish) and stochasticity, a measure of natural variability within the system. As coral grazing pressure increased, models exhibited alternative stable states. According to our initial analysis, increasing the maximum grazing rate of algae (turf and macro) causes these alternative stable states to occur at decreased grazing pressure on corals. The macroalgae grazing rate, as opposed to the turf algae grazing rate, appears to drive the presence of these alternative stable states. In some stochastic simulations where there is only one stable equilibrium, the system spends time around a ghost attractor, the lingering transient effect due to the loss of an equilibrium. At high levels of stochasticity, we also observed coral-dominated systems beyond any predicted attractor. With respect to fishing, management should aim to limit coral-eating fish and limit the removal of macroalgae-eating fish. With respect to variability, conservation tactics that limit the variability in coral reefs may ameliorate transitions between alternative stable states or the presence of ghost "stable" states.