QnAs with Alan Hastings

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Theoretical ecology uses conceptual and mathematical models, computer simulations, and data analysis to study ecological systems. Alan Hastings, a Distinguished Professor of Environmental Science and Policy at the University of California, Davis, has contributed significantly to the development of this field over the past four decades. Much of his research uses mathematical models of population dynamics to explore various applied ecological problems, including natural resource management and invasive species control. He also founded the journal *Theoretical Ecology* and coedited *The Encyclopedia of Theoretical Ecology* (1). His contributions to theoretical ecology have earned Hastings numerous awards, including the Robert H. MacArthur Award from the Ecological Society of America in 2006 and election to the National Academy of Sciences in 2016. In his Inaugural Article (2), Hastings developed a framework for studying a common problem in fisheries management. PNAS spoke with Hastings about his career and current research.

PNAS: Your doctorate is in applied mathematics. How did you decide to study problems in environmental science?

Hastings: The problems [in ecology] are really interesting; they're difficult and they're important. As a graduate student, I took all of the coursework that a graduate student in ecology would have taken. My thesis was all about problems in ecology. So even then I was working at the interface between mathematics and ecology.

PNAS: What motivated you to launch the journal *Theoretical Ecology*?

Hastings: I thought that in previous journals, if they were focused on ecology, contributions in theoretical ecology were not necessarily receiving the attention they deserved, and journals that were focused on mathematics, or more broadly on issues of theoretical biology, did not necessarily focus enough on theoretical ecology. Having an outlet that was focused specifically on theoretical ecology would allow for a better review process in a forum that would encompass the range of theoretical ecology. Contributions can be as mathematical as they need to be, but there can be contributions that have no equations at all.

PNAS: What was the purpose of the *Encyclopedia of Theoretical Ecology* (1)?

Hastings: The goal there was to get broad coverage of issues in ecology. We had a range of contributions that focused on both ecological topics and methods topics, and ranged from broad areas, like applied ecology, to quite specific areas, like ecological stoichiometry.

Alan Hastings. Image courtesy of Alan Hastings.

PNAS: Your Inaugural Article (2) examines how the presence of multiple species influences the results of models of fisheries management. Why did you choose to investigate this issue?

Hastings: One reason is that it's a natural extension of earlier work on single species. Work from almost 20 years ago (3) showed in a simple, strategic model that under some specific assumptions, yields for a fishery managed in traditional ways, having to do with control of harvest, would be matched by a fishery managed using marine protected areas, where in a certain percentage of the habitat no fishing was allowed and in the rest of the habitat potentially all of the fish could be caught. Another reason is that there have been problems with multispecies fisheries, in particular the groundfish fishery on the west coast of the US. If your fishing gear is not selective, the fishing effort that would give you the optimal yield for the species of interest may drive another species' population to zero through bycatch. That limits the overall fishing effort to below the optimal effort that would give you the maximum sustainable yield for the target species, if there were no protected areas.

This is a QnAs with a recently elected member of the National Academy of Sciences to accompany the member's Inaugural Article on page 8927.

PNAS: How do marine protected areas compare with traditional management methods in your multispecies model?

Hastings: Our model assumes that the bycatch species—the so-called "weak stock"—has lower recruitment, but higher adult survival than the target species, so it's helped more by the marine protected area. This is in fact exactly the situation that occurred with the United States west coast groundfish fishery. So if you manage using marine protected areas, you could get the same yield for the target stock that you would get if you did not have to worry about the weak stock. Another way to put it is you could get a higher yield of the target stock with marine protected areas than you would with effort control while still maintaining the weak stock in the system.

PNAS: What is unique about the model you used in the Inaugural Article (2)?

Hastings: I'm not aware of other specific models for marine protected areas with multiple species, except for some that looked at more detailed interactions [between the species] involving trophic interactions. We're actually ignoring interactions between the species, but just comparing the effect of the marine protected area on two different species with different life histories. And by isolating out what we think are the key issues, we're able to obtain some general results on the use of marine protected areas for fisheries involving multiple species that are caught by the same gear. We are at the strategic end of modeling where we get results that are robust, but don't necessarily take into account details of a specific situation.

PNAS: What is the next step in this line of research?

Hastings: The approach that's outlined here makes a number of specific assumptions: we ignore species density dependence; we looked at species where the adults are relatively sedentary and the juveniles are widely dispersed. We'd like to understand how relaxing those assumptions would affect the result. Another would be to look in more detail at some specific situations, and so to parameterize the models using that kind of approach. One issue that comes up is that we would want to include more detailed aspects of life histories, of dispersal behavior, and of economic and fishery responses as well.

1 Hastings A, Gross L, eds (2012) *Encyclopedia of Theoretical Ecology* (Univ California Press, Berkeley, CA).

2 Hastings A, Gaines SD, Costello C (2017) Marine reserves solve an important bycatch problem in fisheries. *Proc Natl Acad Sci USA* 114:8927–8934.

3 Hastings A, Botsford LW (1999) Equivalence in yield from marine reserves and traditional fisheries management. *Science* 284:1537–1538.