Adaptive dynamics of life-history traits in harvested communities: Evolutionary responses in mixed fisheries

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Goal

To clarify whether and how the presence of co-harvested populations in mixed fisheries modifies the evolutionary response of exploited target populations.

Background and motivation

Over the past few years, concerns have risen about the evolutionary consequences of large-scale exploitation in commercial fisheries (*e.g.* Browman 2000, Law 2000, ADN workshop March 14th-17th, 2001). The high and selective mortality imposed by fisheries can cause evolutionary changes in size-dependent life history traits (Law and Grey 1989, Stokes et al. 1993, Heino 1998). This expectation is supported by observed trends of decreasing age at maturity and size at maturity in several exploited populations, such as North Sea plaice, Northeast Arctic cod, and Baltic cod (Rijnsdorp et al. 1993, Jørgensen 1990, and Cardinale and Modin 1999, respectively). These observations suggest that fisheries induce genetic changes that may be difficult to reverse, changes that will decrease the available fish biomass and thus also the long-term yield of fisheries.

With few exceptions (Gårdmark *et al.* in prep.) studies on evolutionary effects of population harvesting have neglected interactions between species and/or populations. Current harvesting practices, however, ensure that different species and populations are often caught simultaneously; this is due to non-discriminating fishing gear and to the targeting of areas where populations mix. In many species, populations mix during part of the year at feeding or spawning grounds. These mixing areas are often targeted by fisheries (*e.g.* Baltic cod (Aro 1989)), or fisheries might follow a migratory population into areas where they mix with local populations (*e.g.* herring fishery off Nova Scotia (Claytor 2000). Populations originating from different regions often have different life-history characteristics. Size-selective harvesting on mixed populations can therefore cause different evolutionary responses in the different populations. The mixing of populations therefore poses a problem for predicting evolutionary responses to harvesting.

Here, I propose to analyze how the evolutionary responses to harvesting might be altered under different types of population mixing and harvesting regimes. This work is designed as a continuation of a recent project on the evolutionary responses to harvesting in a population subject to different types of predation, conducted in collaboration with Ulf Dieckmann. In addition, the proposed research is an important application of adaptive dynamics theory that will contribute to the understanding of evolutionary effects of exploitation.

Research question

As populations of different origin often differ in their life-history traits, harvesting of mixed populations might have different evolutionary effects on these populations. If populations do not interact with each other when mixing, single-population models can be used and the evolutionary responses can be predicted by using methodology developed in earlier studies. However, there are several ecological settings in which the mixing populations influence each other, obvious examples being direct resource competition and apparent competition. Depending on the form of interaction and on the type of harvesting applied, the evolutionary outcome becomes harder to predict. For example, if individuals of two mixing populations are dependent on both population densities and if the harvesting regime cannot discriminate between these populations, harvesting could possibly initiate a co-evolutionary process in the two competing populations.

In this project I will analyze the evolutionary responses to harvesting in age-at-maturity in two age-structured populations that mix during part of the year. In particular, I will study how the evolutionary responses are dependent on

- the form of interaction between the populations and
- the harvesting regime (whether harvesting can discriminate between populations or not).

Methods and work plan

For the analysis of this problem I will construct a model of two age(/size)-structured populations that can interact and are subject to harvesting. I will then apply the techniques of adaptive dynamics to analyze the evolutionary change in age(/size)-at-maturity in response to harvesting. For each type of population interaction outlined below, I will analyze the effect of two harvesting regimes: (a) when harvesting on the mixed populations can selectively target the different populations and (b) when harvesting acts indiscriminately on both populations. In particular, pairwise invasibility plots will be constructed for each case.

The following three alternative assumptions on population interaction will be tested:

1. The two mixing populations do not affect each other. Starting with this simplest case provides baseline results to which outcomes in the following settings can be compared.
2. The interaction between the mixing populations is asymmetric, such that one of the populations influences the other negatively, but not vice versa. (Such amensalism could apply, for example, if mixing occurs when one population migrates into the area where the other population is resident and the resident population is very small compared to the migratory one, or if the migratory population is regulated by factors outside the mixing area.)
3. The interaction is symmetric, such that competition is equally strong within and between populations.

The analysis will focus on the relationship between the evolutionary outcome in the possible strategy space and the type of density-regulation, differences in life history parameters and differences in harvesting regimes.

Relevance and link to ADN's research plan

This project provides an innovative application of the theory of adaptive dynamics. Utilization of adaptive dynamics techniques for developing the theory of evolutionary effects of population harvesting is relevant for ADN's research on 'Fisheries-Induced Adaptive Change.'

The proposed research extends the application of adaptive dynamics techniques to previously untackled complex problems of evolutionarily sustainable fisheries management, thus supporting ongoing ADN projects.

This project is also related to research done by previous YSSP participants (Mikko Heino, Are Saltahug, Frode Lium, and Sondre Aanes) and strengthens the existing collaboration between the ADN project and the Department of Theoretical Ecology at Lund University.

Expected output and publications

The proposed research is planned to result in a jointly authored research paper. This work is also planned to be one of the articles in my PhD thesis, either as a manuscript or in its published form.

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