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Does Fishing Cause Genetic Evolution in Fish Stocks?

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Introduction

Nobody ever said it was easy being a fish. From the moment they are born, to the moment they die, they are on a knifeedge, dodging the jaws of every predator trying to make a meal of them. Their ultimate 'goal' is to survive long enough to mature and then spawn so that they can pass on their genes. But, in areas where they also have to contend with heavy fishing pressure, the odds are increasingly stacked against them.

As if to keep one step ahead of the fishing boats, many exploited fish stocks, such as cod, are now actually maturing and spawning earlier, effectively giving themselves more of a chance of reproducing before they end up on a dinner table. Taking Northeast Arctic cod as an example, in the 1930's they typically matured at 8-11 years. At the start of the 21st Century, they now mature at the earlier age of 6 to 8 years.

In the past, researchers explained early maturation as compensatory grow which happens when a stock is fished down and the remaining fish have less competition for food so they grow faster and mature earlier. But researchers now think that fishing could also be causing a genetic change in fish stocks as early maturing fish are more likely to survive and pass on this characteristic to the following generation.

Unfortunately, distinguishing between the two causes of early maturation is not easy. This is particularly so when looking for genetic evidence because the historical material on which genetic analysis could be based is limited and often not ideally preserved. Overcoming these obstacles will probably take more than a few years and in the meantime other approaches are being developed.

New approach

Recently, a new method for distinguishing genetic from growth-related changes in the age at which fish mature has been proposed. It is based on probabilistic reaction norms for age and size at maturation. In simple terms this involves using data on the age and size at which fish within a stock have been maturing to build up a picture of the range of flexibility they can show in relation to these two characteristics. Genetic changes from fishing are indicated when this range has shifted down over a number of years (for more information see Further reading below).

Progress from this technique was reviewed at the last years ICES Annual Science Conference in Copenhagen. Results from six fish stocks were presented: Northeast Arctic, Georges Bank and Gulf of Maine stocks of Atlantic cod, Norwegian spring-spawning herring, North Sea plaice and Newfoundland American plaice. All these stocks have displayed major changes in age at maturation. Analyses of maturation reaction norms in five of these six stocks show a biologically significant downward trend over time. This indicates that genetic changes in maturation tendency have occurred.

Does fishing select for smaller fish?

Although current evidence points mostly to changes in maturation, genetic changes in other characteristics are also likely. It is often suggested that size-selective fishing – taking the bigger fish out of the sea - will select for slower body growth in the long-term. Recent experiments with Atlantic silverside have shown that selecting out the bigger fish can cause significant reductions in growth (and yield) in just four generations. However, convincing evidence from the wild is lacking because growth is also sensitive to direct environmental influences. Similarly, behaviour may evolve in response to fishing pressure. For example, fishing may select for fish that are better at avoiding approaching trawls. Here the problem is that we have no historical reference material to which present behaviour can be compared.

Loss of genetic variability

Fishing can also have other genetic consequences. In small populations, genetic variability is lost through genetic drift (the random change of the occurrence of a particular gene in a population) and inbreeding. Traditionally it has been believed that loss of genetic diversity is not an issue in marine fish because of their large population sizes. Even when they are fished down to levels where commercial exploitation is no longer profitable, marine fish populations often have tens of thousands of individuals.
However, recent research is partially challenging this view. Firstly, many fish stocks consist of local breeding populations that, when fished down, may become sufficiently small for loss of genetic diversity to become important. Second, a relatively small number of individuals are responsible for production of most of the new recruits, making the genetic diversity of the population much smaller than its abundance would suggest.

Why should managers worry?

Is genetic evolution caused by fisheries something that scientists and managers should be concerned about? The answer is yes. Genetic changes may have adverse effects on fish stocks. Changes in maturation have a potential to greatly influence recruitment of young fish to a stock. Maturation incurs a reduction in body growth, and early maturation therefore occurs at a cost of reduced fertility at later ages.

Also it is often observed that eggs produced by small females have lower quality than those produced by large ones. In addition, market price of fish tends to increase with size. In species that undertake long spawning migrations, small body size may compromise ability to reach the spawning grounds. Last but not least, adverse genetic changes may not easily be reversed.

Is more selective fishing the answer?

Fisheries-induced evolution presents a new challenge for fisheries science. Does fisheries-induced genetic changes call for active management, or is it sufficient to monitor ongoing changes? How could we manage fish stocks to avoid unwanted genetic changes? Do we need new reference points? This is a research area of many open questions and few answers. Undirected lowering of fishing mortality is unlikely to be an effective management measure. It will probably slow down genetic change but not easily prevent it. New approaches are needed such as directing fishing effort to catch certain size classes, life history stages or areas. In designing new management tools that are able to cope with the issue of fisheries-induced genetic change, modelling is expected to play a critical role.

Further Reading

M. Heino, U. Dieckmann & O. R. Godø, Measuring probabilistic reaction norms for age and size at maturation, Evolution 56, 669-678 (2002)