How fisheries impact behavioural evolution in Atlantic cod

May 31 2016

As seen in other animal species, fish individuals tend to react differently to a new situation. In the case of human harvest, the boldest individuals are more likely to get caught, leaving only the fearful and cautious ones to breed. But does it mean that future generations of fish will become harder to catch? This is one of the questions the BE-FISH project tried to answer.

Fish personality—consistent individual behaviour which is maintained over time and across contexts—is known to result from adaptive processes involving life-history trade-offs or physiological constraints. Concretely, a population from a single species can include individuals of the same sex, size or age which feature different behavioural traits, these traits being grouped in five major categories: shyness-boldness, exploration-avoidance, activity, sociability and aggressiveness. Various studies have demonstrated that this personality variation is heritable.

Scientists in the BE-FISH (Pace of life syndromes in fish: harvesting effects and the role of marine reserves) project have long suspected that fisheries may contribute to such evolutionary impacts in marine resources by selectively removing specific life-history traits.

Dr David Villegas-Rios, Marie Curie Postdoctoral fellow at the Flødevigen Research Station (IMR) and coordinator of the project, discusses the project results. According to him, they provide a unique link between fisheries, behavioural ecology and evolutionary biology sciences, and as such will lead the way to various national and EU projects in the coming years.

Human harvesting is a non-random activity. It often removes individuals because they are more desirable (e.g. trophy hunting) or because they are more vulnerable, as is the case for fishing. For instance, bolder individuals will enter a fishing trap more easily than shier ones. Similarly, more active fish find the nets faster than less active individuals. This means that behaviour can determine fitness.

By consistently removing individuals with certain behavioural properties, fishing practices can entail evolutionary consequences in the harvested populations. For instance, by favouring evolution towards less active phenotypes. The ecological consequences of such practices are still largely unknown but they can be maladaptive, reducing the potential for future adaptations along with the productivity of the populations.

Why do you think it is important to consider these evolutionary changes in fisheries?

Maladaptive evolutionary changes in behaviour can make the remaining individuals less and less catchable (because the more vulnerable individuals are consistently removed), which will reduce fisheries productivity.

Moreover, behavioural variation has been postulated (and sometimes proven) to co-vary with differences in life history. This is known as the pace of life hypothesis. It means that for instance, more active fish can also be those which grow faster or lay more eggs, i.e. the most productive. In practical terms, the result is that the maladaptive consequences of fisheries-induced evolution on behavioural traits can be extended to other traits that are of more interest to fisheries productivity.

If we select more active fish because they find the fishing gears more easily, and those individuals are the ones that grow faster (i.e. there is a genetic correlation between been active and growing fast), then populations may decline faster than expected.

Can you tell us more about the techniques you used to gather telemetric data?

The BE-FISH project has used acoustic telemetry to record the wild behaviour of cod. Acoustic telemetry is a largely-used technique to understand the spatial ecology and movements of aquatic organisms. We make a small incision in the abdomen of the fish, place an acoustic transmitter in the body cavity and close it with two or three stitches using surgical thread. To facilitate this process, the fish is first anesthetised with clove oil which keeps it motionless for a few minutes. When the fish recovers and displays normal behaviour (typically in 5-10 minutes), it is released into the wild again. It will transmit a unique code that reveals its individual identity as well as a depth measure.

The system is completed with a set of underwater receivers which are distributed along the study system (in our case a coastal fjord) at 3-4 meters deep, forming a dense array that records the signals from the transmitters. Basically, if the fish is close enough to a particular receiver, it will register its presence and the depth at which the fish was at that particular moment. By placing the receivers close enough to each other, we can get an accurate estimate of the true location and depth of the fish. In our study, we recorded one position every 1.5 minutes on average. The data is downloaded from the receivers and analysed twice a year.

What kind of tests did you conduct on fish and why?

In BE-FISH we investigated behaviour in the wild and in captivity. Behaviour in the wild was investigated using acoustic telemetry as discussed above. Then, in captivity, we conducted three standard tests in order to investigate animal behaviour. First, we used an open-field test to score exploration tendency. For that, fish were allowed to swim in an open 600 litres tank of saltwater and several parameters were recorded that would reflect their individual exploratory behaviour (e.g. latency to first movement).

Boldness was assessed with a novel object test. In this case, the fish, habituated to the tank from the previous test, were presented with a novel object in the centre of the tank. The reaction towards this object (latency to approach it, time in its proximity, etc.) was scored as a measure of boldness. Lastly, aggressiveness was measured by letting the fish interact with their own image reflected in a mirror. The number of approaches and the time spent close to the mirror where amongst the variables recorded in this case. By using these three tests we were able to score three of the five axes of behaviour normally recorded in animal personality studies.

What are the main conclusions from you research so far?

We are now involved in the final analyses of the project. So far we found that individual variation in behavioural traits of Atlantic cod is large both in the wild and in captivity, and that both recorded behavioural traits are repeatable at the individual level—which means that they can be termed personality traits. This alone means that behavioural traits of cod are likely to be heritable and fishing or other human activities can have a role in the population's eco-evolutionary dynamics.

We also found that behavioural traits of cod displayed in the wild are correlated at the individual level. These correlations are called behavioural syndromes and are recognised as a source of constraint in evolutionary change: traits do not evolve independently anymore, but rather they depend on the evolution of correlated traits. In other words, we found that the possibility of cod behavioural traits to evolve is reduced by 25 % on average.

What else would you like to achieve by the end of the project?

We haven't finished all the analyses but we aim to know, within the next couple of months, whether behaviour measured in captivity is correlated with behaviour measured in the wild—something that has never been done for a marine organism. This is important because researchers normally assess behaviour in captivity and make evolutionary conclusions out of it. However, captivity assays may not be representative of wild behaviour which is the one subject to selection and to evolutionary change. Testing the hypothesis that behavioural traits measured in captivity are ecologically relevant is therefore crucial.

The last analyses will also tell us if behavioural traits are linked to life history traits such as growth. This will enable us to understand if the evolutionary consequences of fishing include evolutionary change in correlated traits that reflect the productivity of the population.

What do you hope will be the project's impact over the months and years to come?

In practical terms some results have already been sent for publication to international journals.

More generally, this project will set a landmark in how we see and how we analyse telemetry data. It expands the range of possible applications and its potential since we showed how it can be used to understand eco-evolutionary processes in marine organisms. Our project also demonstrates empirically that marine organisms display animal personalities and behavioural syndromes in the wild. It provides hard evidence: now we know that fisheries-induced evolution of behavioural traits is not only possible but likely common, and that it will depend on the correlation structure of the traits.

A future challenge emerging from this project will be to understand if the patterns observed in our model species (Atlantic cod) can be generalised to most marine creatures.

More information: Project page: cordis.europa.eu/project/rcn/188220_en.html

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