Biodiversity and fisheries

An uneasy marriage needed to fix shifting baselines in aquatic conservation…

The United Nations declared 2011-2020 the Decade on Biodiversity – but it may well turn out to be the decade of 'Biodiversity Crisis'. Scientists today agree biodiversity is key to the stability of human resources and the resilience of ecosystems. Politicians are beginning to face up to the realisation that major action is required to maintain biodiversity. Yet most fisheries, including some of the largest on Earth, continue to operate with a grossly oversimplified view of biological diversity. This is not sustainable and has to change.

Some 20,000 species of fish are currently known, but diversity is still severely under-documented. Data from Europe illustrates this: while more than 95% of European birds were known 100 years ago, and 90% of mammals and reptiles 50 years ago, the number of known fish species has continued to increase linearly since Linnaeus introduced the taxonomic code 250 years ago.[1] The same linear increase is seen in marine fish diversity worldwide, with 70-80 new species added every year. In very recent years, discovery rates have even accelerated.

Distinguishing between fish species is perhaps more difficult for the human eye than bird or mammal species. Developments in molecular population genetics have facilitated the discovery of 'cryptic species' (species that resemble others in external appearance but are genetically and often ecologically distinct), led to the discovery of extensive genetic differentiation within species,[2] and of speciation (the evolution of new species) as a consequence of adaptation[3] even where it was least expected, namely in the oceans.

Extensive movement of larval fish was assumed to maintain large genetically homogeneous populations in the oceans. The emerging application of next generation DNA sequencing to population-level genomic studies of fish will likely usher in yet another paradigm shift; the first results using these new methods reveal that populations are often orders of magnitude more strongly differentiated at genes relevant to adaptation than in the rest of the genome. Thousands of still unknown fish species are awaiting discovery.

Fish species diversity at peril: (left) most species of European trout are now extinct in most of their distribution range where they were replaced by hatchery trout of Atlantic origin (bottom most image). Fisheries management is mostly indifferent to this. (Right) cichlid fish of Africa's Lake Victoria. Even though 500 species are known, fisheries management treats them as a single unit. About 200 species went extinct in the past 30 years

Three decades of research on the relationship between biodiversity and ecosystem functioning have generated broad consensus among scientists that biodiversity loss reduces the efficiency by which ecological communities capture resources, produce biomass, and decompose and recycle nutrients: everything else equal, more diverse communities tend to be more productive, and the negative impacts of species loss on primary productivity are of comparable magnitude to the impacts of climate change.[4] There is also mounting evidence that biodiversity promotes the stability of ecosystems. The diversity of genotypes and phenotypes within species is as important as the diversity between species. A beautiful illustration is the population diversity in life history traits of Bristol Bay salmon in Alaska: the variation in timing of migration and habitat choice among populations of these fish dampens fluctuations in the productivity and ensures a more stable economic output of the fishery.[5]

People exert more severe stress on fish populations than on any other major taxon: 30% of marine fish stocks globally are overexploited, 60% are fully exploited and a mere 10% are considered not fully exploited.[6] Inland fish populations additionally suffer dramatically from hydropower schemes, eutrophication, loss of habitat, misguided stocking and invasive species. A large number of marine and freshwater fish stocks have been depleted to levels where the original fishery collapsed. Multi-species fisheries that have not completely collapsed have been 'fished down the food web'; a phrase used to describe the successive loss of the large predatory species first, followed by middle-sized species, leaving in the end only the smallest species that feed at lower levels in the food chain.

As stocks decline, the diversity within them collapses irreversibly through coupled evolutionary processes linked to the shrinking population sizes. Fishing drastically changes abundance relationships among species and differentiated populations, and these in turn trigger changes in genetic and demographic interactions. Many species and genetically differentiated populations of fish can successfully hybridise (e.g. all types of Pacific salmon, or all the cichlids species of Lake Victoria).

When fishing of maximum sustainable yield is applied to a mixed-stock fishery, it results in a ratchet-like extirpation of the less productive species and populations,[7] and as populations decline (be it due to exploitation, habitat loss e.g. due to eutrophication or other causes) individuals start breeding with individuals of other still abundant species, thus triggering a cascade of irreversible and rapid genetic and phenotypic diversity loss. This way fisheries and environmental change often lead to the collapse of previously differentiated species ('speciation reversal').

Research in our group has revealed that more than 30% of the 20th Century diversity of European lake whitefish have been lost irreversibly between the 1920s and today, and more than 50% of the endemic species of cichlid fish in Africa's Lake Victoria have been lost between 1980 and now. With some 200 species extinct in just 30 years, the latter case is commonly considered the largest mass extinction of animal species witnessed by scientists.[8] Nutrient pollution-driven eutrophication and fisheries related species introductions are the culprits. 30% of diversity loss has been estimated for migratory Pacific salmon too,[9] where hydropower dams on rivers and overfishing in the sea are to blame. Finally, the collapse of the Atlantic cod fishery in the 1970s was associated with the loss of genetically and ecologically distinct populations,[10] referred to as 'genetic stocks' in fisheries jargon, but as 'incipient species' in evolutionary biology.

Unpublished reports from across the world suggest these known cases represent just the tip of the iceberg, and that species and population diversity of fish is being lost at alarming rates, even before it has been documented. Compounding this problem, good documentation of historical diversity in fish stocks is extremely rare. In its absence, biologists and managers today have little means to appreciate what has already been lost. Aquatic conservation thereby suffers from a shifting baseline syndrome, as many fisheries managers do not recognise the magnitude of the biodiversity crisis. Genetic investigations of historical samples are beginning to assess the magnitude of the historical losses,[11, 12] and illustrate the potential and the necessity of using historical DNA samples for correcting our assessments of these biodiversity baselines.

So what remedies are needed to slow down the loss of fish diversity? The failure to sustainably manage fish stocks led several years ago to the establishment of the Ecosystem Approach to Fisheries (EAF). The EAF takes into account the feedback between exploited fish stocks and their environment. However, its effects on biodiversity are unclear. Managing ecosystems for some functions does not necessarily protect its component biodiversity. The paradigm shifts in population genetics and biodiversity research have been driven by increasing resolution in the available data. We now need a paradigm shift in management driven by the empirical evidence from this same data.

First, international organisations such as the FAO ought to spearhead an attempt to change the overall approach of fisheries management to include attention to fish diversity. What is needed is zero tolerance to ignoring biodiversity. For instance, by the year 2000 about one-third of the countries with significant inland fisheries reported their production only at the least detailed level of identification (the taxonomic order); even in showcase examples of good reporting, more than 80% of fish catches were reported only at genus or even just at family level. We can and need to do better if biodiversity is to be safeguarded.

Second, baseline diversity assessments have to be implemented in order to combat the shifting baseline syndrome, ideally combined with historical DNA analyses to attempt to correct the already shifted baselines. An example is the Switzerland-based ProjetLac (www.eawag.ch/forschung/fishec/gruppen/lac/index_EN).

Third, genomic and phenotypic monitoring of major fisheries is needed. In the Bristol Bay sockeye salmon fishery, samples are taken and genetically analysed continuously, and the results of mixed-stock analysis are communicated to the offshore fishing fleet multiple times per week to adjust harvest effort.[7] Such approaches have to become the standard across the globe.

Fourth, basic and applied research is urgently needed to establish the mechanisms and drivers of loss in those systems that are little studied or particularly vulnerable.

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