Overfishing and sustainable fishing: challenges for today and tomorrow

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During the 20th century, humans increasingly exploited the living resources of the ocean. The increase in catches was accompanied by a decrease in resources and overfishing became a widespread practice, characterized by inefficiency of the production system. In Europe, however, fishing pressure has been declining for about 15 years, and there are initial signs of recovery of exploited stocks. But to ensure sustainable fishing, it is not enough to adjust catches to the biological production of each stock. This is of particular importance given that the ecosystem approach to fisheries and the expected impacts of climate change require us to tighten up environmental requirements and rethink the concept of sustainable fisheries.

EXPLOITING THE OCEANS

People have been sea fishing for thousands of years and the first impacts are long-standing. Centuries ago, the most fragile species, marine mammals, some selachians, migratory species such as sturgeon, or shellfish beds may already have been severely affected by fishing. However, for a very long time, this activity was limited to coastal resources and a small number of carefully selected species. Vast areas of the oceans and many species have long remained unaffected by humans. At the end of the 19th century, the ocean still appeared immense, and scientists concluded that marine resources were limitless.

It was not until the 20th century that humans truly began to exploit living marine resources on a global scale. The trend, which started at the end of the previous century with the development of engines and trawls, intensified after World War II, when large industrial fishing fleets developed and gradually conquered the world's oceans (Fig. 1). Within a few decades, the total capacity of vessels increased tenfold (Bell *et al.*, 2016), and production fivefold (FAO 2018 and 2019). Production peaked in 1996, with global reported catches of 87 million tonnes (source: FAO). This figure could even be as much as 130 million tonnes if discards and illegal, unreported or unregulated (IUU) catches are taken into account (source: SAUP; Pauly & Zeller, 2015).

Since then, catch has declined sharply, mainly due to the overfishing of many stocks. The resulting loss is estimated at more than one million tonnes every year.

The increased fish catch was accompanied by a sharp fall in the abundance of exploited stocks. Several studies estimate that the biomass of large bottom feeders and some pelagic predators declined by a factor of 5 to 10 over the 20th century (Christensen *et al.*, 2003, Worm *et al.*, 2009; Juan-Jordà *et al.*, 2011). In a report based on the analysis of 1,135 fisheries, Costello *et al.* (2008) showed that the biomass of 27% of the global fish stocks has been reduced at least tenfold, including 9% whose biomass declined by a factor of 100 or more. Conversely, some species of forage fish, as well as many mollusks or crustaceans, may have benefited from a release in predation linked to the overexploitation of their predators. In the end, partly compensating for this, the total biomass of exploitable species is estimated to have declined by a factor of 2 to 2.5 on a global scale, with obvious repercussions on all food webs and marine ecosystem functioning (Gascuel *et al.*, 2019).

OVERFISHING IS NOT WHAT YOU THINK IT IS

The general public often confuses sustainability and balance, believing that nature provides us every year with a given production that we can exploit without impact. A cornucopia to satisfy our appetite. Overfishing would therefore be the equivalent of bulimia, leading us to "harvest more than the stock produces". In fact, that is not how things work. In

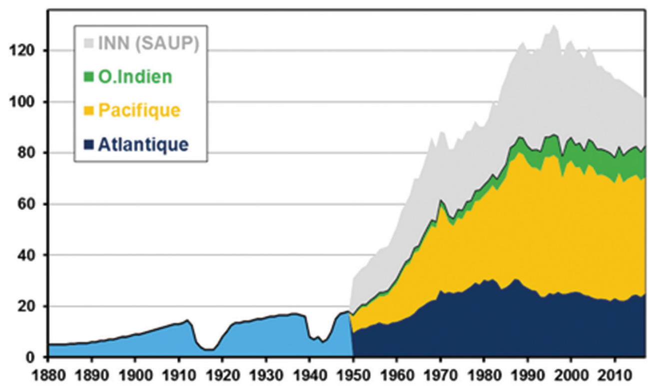

Fig.1 — Trend between 1880 and 2017 in global marine fisheries production (excluding algae), in millions of tonnes. 1880-1949: empirical reconstruction from the scientific literature. 1950-2017: data from FAO (2019) and the Sea Around Us Project (SAUP) regarding illegal, unreported and unregulated fisheries (IUU).

the absence of fishing, the net biological production of a natural population is theoretically zero. Natural mortality only just offsets the biomass gains associated with individual reproduction or growth, and the population adjusts to the carrying capacity of the environment. Inevitably, the first fisherman therefore catches more than the stock produces. This necessarily impacts the resource whose biomass decreases until the resulting reduction in intraspecific competition compensates for the increase in fishing pressure. If the latter does not increase again, then a new steady state is established.

"I am fishing more than the stock produces" is therefore only a transitional situation between two states of the stock, evolving towards a lower balance than the previous one, but which does not necessarily reflect overfishing. In contrast, a very low biomass stock, which also has low biological production, can be maintained in such an undesirable state. To this end, humans just need not to fish more than the stock produces. A balanced overfishing situation will then be maintained (at least in the medium term), regardless of possible ecosystem changes or genetic drifts. In fact, stock extinction is the ultimate case of perfect balance, in which it is a certainty that no fish will be caught – in other words, "no more than the stock produces". Everyone will agree that this is not a sound fishery management strategy!

Overfishing, therefore, has nothing to do with imbalance. It reflects a very specific situation in the fisheries sector. In any other sector, it is accepted that when the means of production increase, production also increases. More capital and labor invested leads to a growing production function. More workers and machine tools manufacture more cars.

In some areas, such as agriculture, it is accepted that production can reach an asymptotic value. More tractors in a field do not increase production indefinitely. In fisheries, the dynamics are different. Above a certain threshold, when the means of production increase, production decreases. An increase in the number of larger, more efficient vessels, equipped with more innovative electronic devices (fisheries scientists speak of increased fishing effort or pressure) leads to lower catches. The fundamental reason is that the natural resource is affected. Fish catch declines because the ecological impact is too high, because the ecological capital is affected beyond what is "reasonable".

The concept of overfishing refers to these situations of decreasing production function. In fact, it characterizes a production system that has "gone mad", a situation in which we spend more, work more, consume more diesel, etc. but fish less. It is as if, in the automotive industry, the machine tools that build cars were being supplemented with other expensive tools designed to destroy part of the production.

At the same time as fishermen catch fish, they also destroy the stock that could have been caught the next day! In other words, overfishing refers to a strange situation where fishermen must be persuaded to stay home some of the time so that stocks can replenish. Ultimately, this would actually result in higher annual catches.

Basically, overfisching situations therefore reflect the inefficiency of the production system. Fishermen are at the same time the most direct contributors and victims, as they are impacted by the low economic profitability of fisheries and fluctuating catches. Of

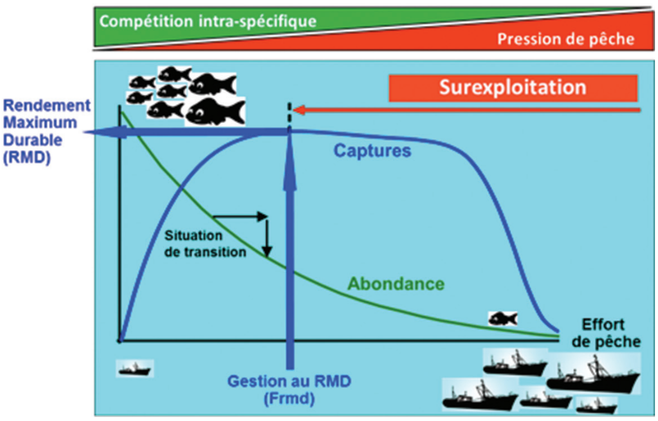

Fig.2 — Conceptual diagram of how the abundance of an exploited stock and the resulting catch evolve, for an increasing fishing effort (equilibrium curves). Concept of overfishing and principle of Maximum Sustainable Yield (MSY) management.

course, the resource is also affected, with low biomass and the truncation of demographic structures. Undoubtedly, these situations should be avoided. Although the "how" is still the subject of debate, all stakeholders in the fisheries sector agree on this principle.

As early as the 1930s, the first fisheries biologists identified the risk of overexploitation and called for a limitation of fishing effort. This idea was developed after the war, when the US government took the initiative to propose "Maximum Sustainable Yield (MSY) management" as an international standard for sound fisheries management. This standard was formally adopted by the United Nations in 1955 and enshrined in the 1982 UN Convention on the Law of the Sea (UNCLOS). For each exploited stock, the objective is to set the fishing effort at a level that allows maximum catch, as a long-term average value. Neither too few vessels, which would catch few fish, nor too many, which would leave insufficient residual biomass in the sea to sustain high catch rates. MSY management therefore ensures – just barely – that there is no overfishing.

SUSTAINABLE FISHERIES, WHERE DO WE STAND?

It is now customary to refer to any situation in which the stock is not overexploited as "sustainable fishery" – in particular situations in which MSY management objectives are achieved. Contrary to what the general public often believes, sustainable fishery is not defined by an objective of balanced management preserving the resource, but by an objective of maximizing long-term catches for each stock exploited.

To achieve this goal, governments worldwide have gradually implemented measures to limit fishing effort. For large ocean stocks, accounting for most of the fish catch and often shared between different countries and fisheries, decades of experience have shown that the most effective method is to directly limit catches by introducing fishing quotas. UNCLOS has been adapted to reflect this reality, giving nations very extensive fisheries policing powers within their Exclusive Economic Zones (*i.e.* up to 200 nautical miles or about 360 km from their coastline). Since the 1980s, major developed countries have adopted increasingly restrictive quota policies. Unquestionable success has been achieved for some stocks, particularly in the USA, Australia, and Europe. Nonetheless, these successes have not been enough to prevent a dramatic rise in the global fishing effort and the multiplication of overfishing situations in most of the world's oceans.

FAO assessments (2018) show that 33% of the global stocks subject to scientific evaluation are now overexploited. Unfortunately, this figure is steadily increasing, with fishing pressure continuing to rise significantly, mainly in Asia. Other analyses provide an even more pessimistic picture. For example, Costello *et al.* (2016) estimate that, based on data from 4,713 fisheries worldwide (representing 78% of global reported fish catch), 68% of stocks are now overexploited or at biomass levels too low to fulfill MSY. The median value of fishing pressure is estimated to be equal to 1.5 times the target value and biomass is only 78% of the target objective.

Europe has long been the black sheep among developed countries. Due to a lack of shared political will in a political space under construction, fishing pressure increased until the late 1990s.

It is estimated that nearly 90% of Europe's major stocks were then overexploited, with a mean annual harvest rate of about 45% of the biomass present (Gascuel *et al.*, 2016). Fishing quotas only began to become truly restrictive in 1998, and the standard for maximum sustainable yield management was only formally adopted in 2005. Within a few years, however, the measures taken, and tighter control mechanisms have resulted in a real trend reversal. The latest available assessments (STECF, 2019) show that the harvest rate has been almost halved in the European waters of the North-East Atlantic. On average, it is now close to the MSY management objective (Fig. 3).

In parallel, the average biomass of the stocks assessed in this area is estimated to have increased by 40% for the best-known stocks, probably even more according to the partial data available on a wider scale. However, abundances were initially extremely low, and are still low, well below the level that will produce the maximum sustainable yield. Moreover, average values hide large disparities. The latest tally shows that 41% of the relevant stocks are still being overexploited in European waters of the Atlantic (STECF, 2019). Above all, there are no signs of improvement in the Mediterranean Sea, where only the iconic stock of bluefin tuna is subject to quotas. The fishing situation in Europe therefore remains fragile. Recent developments have, however, highlighted that effective action can be taken to reduce fishing pressure, thus allowing stocks to replenish. This is positive news. Providing the political will is there, we are not condemned to an inexorable decline in global fish stocks and widespread overfishing. Fish stocks can recover and be healthy again.

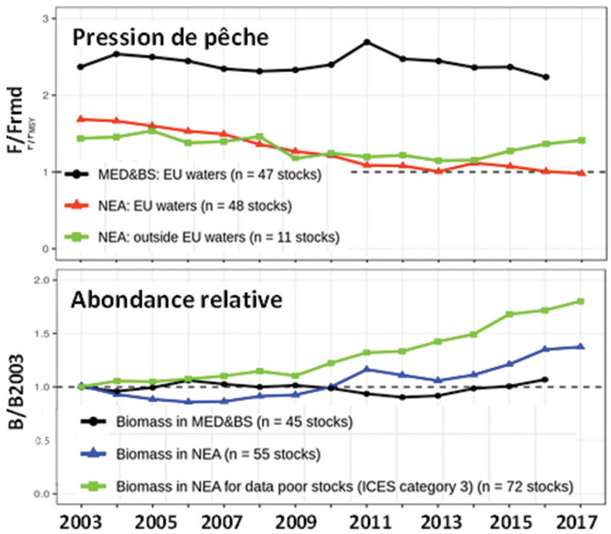

Fig.3 — Trend in fishing pressure indicators and average abundance of the stocks exploited in Europe (STECF, 2019). The indicators are calculated for all the stocks assessed by the International Council for the Exploration of the Sea (ICES). Top: The relative value of fishing pressure in relation to the MSY management objective (in the Mediterranean and the Black Sea, and in European or non-European waters of the North-East Atlantic). Bottom: Mean relative abundance compared with 2003 (in the Mediterranean, the Black Sea, and in the North-East Atlantic for well-known and data-poor stocks).

ECOSYSTEM APPROACH AND CLIMATE CHANGE: HOW DO WE ENHANCE RESILIENCE?

An essential question remains: is the progress made commensurate with the current challenges? Assuming that the MSY management standard will apply everywhere and lead to the expected stock replenishment (which is far from certain), does it really ensure long-term sustainable fisheries? There are two main considerations that raise doubts and prompt us to revisit the question of management standards.

First of all, it should be emphasized that the approach currently being implemented, in particular in Europe, was based mainly on mental representations and models developed more than fifty years ago, in the context of a monospecific approach. Implicitly, this approach assumes that managing each stock separately, according to the MSY standard, leads to a globally sustainable fishery, as if stocks did not interact with each other and all ecosystem compartments; and as if the biomass reduction imposed on every living organism had no impact on their prey, competitors or predators, and no chain effects on the entire structure and functioning of food webs. Over time, it has gradually been accepted that a broader approach, referred to as the ecosystem approach to fisheries, must be implemented (Garcia, 2003; Cury & Gascuel, 2017). This approach requires all impacts to be taken into account: those affecting each ecosystem compartment, but also food webs or habitats, and more generally, the productivity, stability, and resilience characteristics of ecosystems. There is little doubt that reducing the direct impact on each exploited stock is a major challenge in lessening the overall impact on ecosystems.

In other words, maximizing long-term catch is not enough. Paradoxically, the ecosystem approach invites us to rethink sustainable fisheries by studying the old model, and especially the curve that measures the impact of exploitation on the biomass of each exploited stock. It should be noted here that, in the absence of specific measures to protect juveniles, the MSY standard leads to a two-and-a-half to threefold reduction in the abundance of the stock in question, compared with a situation with no fishing activities. Who could guarantee that such an impact, repeated on each stock, is truly sustainable? This is all the more important since the introduction of selectivity measures would help maintain high fish catch while limiting biomass reduction. By catching only the largest fish, production could be maintained and the residual biomass left in the water could be increased substantially (Froese *et al.*, 2016).

The second major reason to rethink the management standard is climate change. This is known to have very significant impacts, not only on species distribution, but also on the productivity and stability of marine ecosystems (Cheung *et al.*, 2010; Gascuel, 2019), and these will undoubtedly increase in the future. Here, too, an upward revision of all resource protection measures is an obvious necessity. Reducing the impact of fishing, allowing resources to replenish and, more generally, ecosystems to become healthy again appears to be the best possible adaptation to the expected impacts of climate change. High biomass levels, in particular, ensure greater functional diversity, and therefore greater ecosystem resilience. Moreover, modeling shows that foregoing catch maximization, by accepting slightly lower catches, would have a double advantage.

On the one hand, reducing the generated impact would significantly improve ecosystem functioning and stability (Worm *et al.*, 2009). On the other hand, reducing fishing costs would largely offset catch loss, and thus contribute to improving the profitability of fishing (Gordon, 1954). Objectives of economic optimization or ecological resilience thus lead to accepting a situation of significant under-exploitation.

At international level, MSY management remains today the standard for sound fisheries management. Many nations still follow this standard. Europe is gradually approaching the standard performance goals, while other countries still seem a long way off, particularly in Asia or developing countries. Conversely, some countries are already going beyond this standard, adopting more cautious management standards. This is the case in the USA and Australia, for example. In the end, the situation of the different countries tells us that the concept of sustainable fisheries is not a scientific truth established once and for all. It is a social construct arising from power relations between stakeholders of the fishery sector, societal representations and values, and policy arbitration. It is a construct on which the future of the ocean depends, and which all citizens would do well to embrace.

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