The scientific career of Daniel Pauly, professor at the Fisheries Centre of the University of British Columbia in Vancouver (Canada), goes a long way back. Currently he leads the project «The sea around us», named after the book published by Rachel Carlson in 1951, whose main goal is to study the impact of fishery on marine ecosystems and to propose measures to mitigate it.

Daniel Pauly has developed remarkable analysis tools such as: ELEFAN, which works with length-frequency data to study populations whose age cannot be determined; ECOPATH, a model to simulate the marine ecosystem; or FISHBASE, a database with all the information published on fish biology, which has been extended to include other marine organisms (www.sealifebase.org). He also has
adapted fishery science to developing countries, many of them in tropical areas.

Daniel Pauly has developed theories about the human impact on marine ecosystems and how to reconstruct world catches by quantifying the amount of catch that does not appear in official statistics. The *Scientific American* journal has named him one of the most influential scientists alive and he has been subject of recognition and tributes internationally. He has been recently awarded the honorary PhD by the University of Alicante, where he taught a course in the Master’s Degree in Sustainable Fisheries Management.

**How can we calculate the «ecological footprint» of fishing in the oceans?**
One way is calculating the primary production required (PPR) to sustain fishery. Basically it consists in comparing the primary production to the energy necessary to produce the captured biomass, taking into account the trophic level of catches and the efficiency of transfer between trophic levels. Our initial estimations in 1995 indicated that the PPR reached 8%, in opposition to 2%, which had been contemplated until then. Now we know that it is even higher and that, although the average is above 10%, it goes from 2% in the high seas up to 40-50% in some coastal areas. We also applied the PPR index to analyse fisheries expansion from the 50s until now, which has been very important.
When we published the study, which demonstrated the tendency of fisheries towards decreasing trophic levels – because, with time, big fishes, which are at the top of the food chain, tend to disappear faster than the small ones, in an inferior trophic level («fishing down food webs»), – I did not expect the controversy that ensued. I must admit that I was not ready. There are many examples of the reduction of trophic levels and we have compiled them on the Fishing down website (www.fishingdown.org).

Moreover, if this effect is not apparent it is because there are other factors masking it. The first of them is the expansion of fisheries. When resources become less abundant, fisheries move on to new areas, often towards the high seas, where they catch again species of high trophic level. If we do not take this phenomenon into account we might lose track of it, and the fact is that every time there is more evidence. In the science field, any theory must explain facts that have not been proved yet, or specify or polish aspects that have been previously detailed in another way. Those critics with this theory have not provided an alternative to explain trends observed in many studies.

Could it be used as an index to measure the health of the oceans?
For instance, the Convention on Biological Diversity uses the marine trophic index as an indicator of biodiversity of big fishes.

**Why is oxygen so important for marine organisms?**
Actually, we are thinking as terrestrial mammals for which oxygen is not limited. But even us die after a few minutes without oxygen, although we can last for weeks without eating. The concentration of oxygen in water is 20 to 30 times lower than in the air, water is more dense and viscous and the diffusion through membranes is much slower. In addition, the surface of gills limits the growth since it cannot grow as fast as the volume. When the body grows, the surface of gills, which conditions the amount of oxygen fish can assimilate, grows at an exponential rate of 2, but the consumption depends on the volume of the fish and it grows at an exponential rate of 3. This phenomenon explains the asymptotic growth of fish or their reproduction, among other phenomena. We can picture this situation if we try to breathe through a straw. It takes a big effort and we cannot do hard exercises such as running.

**And why is temperature important?**
Basically, because of its relation with the availability and the consumption of oxygen, since it affects mainly the basal metabolism. But also a raise in the temperature means that there is less dissolved oxygen in the water. For this reason, every species has an optimal range
temperature where it can live. A fish does not go where it will find more food, but where temperature is optimal for its growth. If besides an adequate temperature, it finds food, all the better. This explains the migration of species towards the poles or deeper waters due to global warming. It has been said that they are looking for cooler waters, but actually they are looking to maintain their optimal temperature.

You have mentioned global change. How will it affect fisheries?

It is already affecting them and will continue to do so. We are observing how surface waters are getting warmer in
most oceans except from some specific cases, such as the surroundings of the Antarctica due to ice caps melting, or some upwelling areas. There, due to the greater difference between land and sea, upwellings can intensify and bring cold water towards the surface. These areas can serve as pockets where cold water species can live.

However, in general, surface waters getting warmer is causing the migration of many species to polar areas. This phenomenon can be studied, for instance, checking the average temperatures of catches, which can indicate how the distribution of species is changing. In the future, these changes will go deeper. While in temperate areas the effects will not be very strong since some species are replaced by others, the impact on tropical areas will be terrible: each species that disappears will not be replaced. We need to keep in mind that many tropical countries are highly dependent on fishery, and that terrestrial ecosystems and crops will experience similar effects.

**How will it affect fishery?**
Each species has a distribution of optimal temperature and catch potential and right now we have very detailed models on how temperature will evolve in seas and oceans. This way, we can estimate the changes in the distribution of species and catches. In some areas, catches will remain stable or even increase, but in others, they will drop significantly. On the other hand, fish size will
decrease if they cannot migrate following their optimal temperature, since they will have less oxygen to grow.

Is global warming the main impact on the oceans right now?

No, it is not. Currently, the main impact is that we kill too many fish. It is necessary to decrease the mortality in fishery to recover populations and remove destructive fishing methods. With time, the relative importance of global change will increase and we need to reduce the emissions that are causing in it. But, nowadays, overexploitation is the main problem we have.

How does the perception of ecosystems change with time?
We have our experience throughout life and we can see how ecosystems change. We think that what we knew when we were young is the baseline. But previous generations thought the same. The perception we have, for instance, about the amount of fish that should be in the sea changes every generation. This means that we are not aware of all the richness we are losing. It is difficult for us to imagine how things were like before massive fishing started. For instance, a fish that was very common on the Galapagos Islands when Charles Darwin visited them now is on the list of endangered species, after being massively caught to export to the continent.
One of your most recent works is the catch reconstruction of global marine fishery. How did you do this work?

This is result of a work of a lot of people to reconstruct real fishery catches in more than 275 marine areas of 150 countries. For instance, four reconstructions have been made for Spain: one for the Mediterranean and the Gulf of Cádiz, one for the Cantabrian Sea, and two for the Balearic and Canary Islands. This project has been done because official statistics do not record catches, but landings. A part of catches is systematically not recorded, such as discards, subsistence fishing and recreational
fishing. There is also illegal fishing and undeclared catches. The tendency is to write a zero when you do not know a value, but zero is a bad estimator of a positive value that is not known. It is better to do estimations and this is the first step to evaluate all catches on a global scale. The first thing that everyone thinks is that there is no data to do that, but any human activity leaves a trail that can be followed and used to estimate the real catch. If someone can improve the estimations that we have done, we are open to collaboration.

What is the main result of this?
The most remarkable is that world catches are decreasing at a faster rate than it would seem by looking at landings only. This is our sign that global fishery trends are worrying. It allows us to get a more real picture of what we are doing to the oceans. Besides, a great effort has been made in web design so that data is easily accessible and usable to make studies all over the world. I encourage everyone to visit our Sea around us website (www.seaaroundus.org).

A few years ago, you published a study that made China to modify their catch downward.
It was a particular situation. It is a country with a planned economy and public servants had to reach the results established by government plans, so they increased their catch up to the impossible. After publishing our study, FAO published world statistics separating the data from China.
Years later, the government of China corrected the statistics downward. What we see is that, if we do not weigh in China’s catch, global catch is going down. Inflated catch caused a false perception of stability of catch that was not real.

You have pointed out that catch and the ecosystem state trends are not good. Can these trends be changed?

Of course. The trend towards catch reduction has been caused by an increase of the world fleet that intensifies fishing. It is necessary to reduce the intensity of fishing, to create more protected areas and to remove subsidies that favour the expansion of fisheries. That way, we will have more fish. A good example are the United States: they passed a law that requires the recovery of the stock biomass during a given period. If necessary, a fishing ground can be closed until its recovery is complete. There are good examples of fisheries recovery where fishery management works. When we do not achieve this, it is because we have not eliminated mortality out of fishery: it is still too high for the stock level. Such is the case of the Terranova cod: despite the fishing ground was closed, the area was still subjected to the bycatch of other fisheries or to recreational fishing. The fraction of exploited population is still too high.

What do you think about quotas?
Quotas are a good idea that can turn into a bad one quickly. As I said before, we need to limit the intensity of fishing and it might be necessary to establish a limit for catches. But afterwards, they are given to the community. Later, they are distributed individually and in perpetuity, sometimes to friends of the government. Later on, we make them transferable and, this way, big investors end up controlling fishery and we have lost control on our resources. Curiously, economists who defend the ITQ (Individual Transferable Quotas) do not refer to subsidies, which are a serious problem for the sustainability of fisheries.

Where are subsidies more important?
The subsidies are more important in Asia, followed by Europe and North America. It should be noted that, in
some fleets, crew members are subject to a regime close to slavery, which is another way of reducing costs with a similar effect to subsidies.

And aquaculture?

There are two types of aquaculture: one breeds herbivorous species such as carps and bivalvia, which is mainly developed in Asia, and is positive because it produces more fish. But there is also aquaculture of carnivorous species, such as the one we have in Europe. To produce a kilo of salmon, we need three or four kilos of fish in the form of flour and oils. This type of aquaculture is a problem because the more it develops, the less fish we have.

How important is the fishing method?
Traditional fishing is, in general, more respectful towards the environment, it produces less discards, employs more people than industrial fishing and, at the same time, it receives less subsidies. We also need to keep in mind that, approximately, a third part of industrial fishery catch is used to do flour and oil to feed animals, when they are species that could be used directly for human consumption. In any case, we should not generalise. I have seen traditional fishermen in Philippines displaying very destructive techniques that shattered coral reefs. I think the future lays on small scale fisheries that use environmentally friendly techniques.
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