ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

Fish stocks: counting the uncountable?

“ The reduced fishing in recent years has allowed many fish stocks to begin to rebuild. ”

For decades, fisheries scientists have warned that many fish stocks are being fished too hard. Sometimes the advice has been followed; other times it has not, and entire fisheries have collapsed – as happened with the herring fishery in the North Sea in the late 1970s and the cod fisheries in the Grand Banks and Kattegat in the early 2000s. Fortunately, reduced fishing in recent years has allowed many fish stocks to begin to rebuild.

When scientists make predictions about the fate of fish stocks, questions arise about how they arrived at their figures and where the data come from. In this leaflet, we explain how fish stocks are assessed in the Northeast Atlantic and give insight into the types of science and information that goes into scientists' stock estimates.

How do scientists know how many fish there are in the sea?

It is impossible for scientists to count every single fish in the sea. Instead, they collect as much information as they can from three main sources: landings at ports, fishers, and research vessel surveys. They then use these data to estimate the size of commercial fish populations such as cod, haddock, and hake.

As fish do not respect national boundaries, scientists from around the North Atlantic coordinate their work under the umbrella of the **International Council for the Exploration of the Sea (ICES)**, which acts as a meeting point for a community of more than 4000 marine scientists from twenty countries around the North Atlantic and adjacent seas as well as from marine institutes around the world. Scientists working through ICES cover all aspects of the marine ecosystem from marine chemistry to fish, marine mammals, and seabirds. Working with experts from other nations gives scientists the bigger picture of what is happening in the sea – rather than just understanding their own countries' marine areas and interests.

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Total international landings and market sampling

Scientists have an excellent opportunity to collect essential data for fish stock assessments when fishers land their catch at port. At the simplest level of detail, the official international landings figures give scientists a basic idea of how many fish have been caught – although this does not include fish caught and discarded at sea. Scientists are on hand throughout the year at fishing ports, from Portugal to the Arctic coast of Norway, sampling the landed fish to collect crucial data on the age, length, and breeding condition of the fish.

Fisheries scientists aim to sample a minimum of 200 fish per 1000 tonnes landed across the ICES area. As more than 8 million tonnes of fish are landed in the ICES area annually, by the end of the year scientists will have recorded details of approximately 1.6 million fish.

How old is a fish?

Similar to the way that trees lay down rings in their trunks every year, most fish also lay down rings in their otoliths, which are small, hard, calcium carbonate structures located behind the brain in bony fishes (cartilaginous fish such as sharks and rays do not have otoliths). Under a microscope, the rings of an otolith can be counted, revealing the fish's age.

Fish are aged to give an indication of the health of the stock. A broad range of ages signifies a healthy stock. A lack of young fish could mean poor spawning success in a particular year, while a lack of older fish may indicate overfishing.

Data from fishers

In addition to sampling at fishing ports, scientists board commercial fishing boats to sample catches, record the discards – unwanted fish and other marine life thrown overboard – and tag and release fish to gain insight into their movements, preferred environments, and lifespan. For more than a decade, fishers in the North Sea have also been filling in questionnaires recording their perception of the state of key fish stocks; this information is considered when preparing the ICES advice.

Another store of information is the fishers' logbooks, which the scientists can use to determine how many hours it took to catch the fish they have landed – the so - called catch-per-unit-of-effort (cpue) data. If the amount of effort required to catch fish goes up, this may indicate that fish are becoming more scarce.

Finally, fishing vessels are occasionally hired by scientific institutions to make dedicated research cruises to add to the findings collected on the scientists' research vessel surveys.

Research vessel surveys

Research vessel surveys are an essential source of information for scientists and a vital cross-check of the data gathered from international landings and on-board sampling on fishing boats. On research vessel surveys, scientists sample both demersal (bottom-living) fish such as cod, haddock, hake, and plaice; and pelagic (surface-living) fish such as mackerel and herring.

To sample fish on or near the seabed – for example cod or haddock – scientists use bottom trawls in the same way that fishers do; however, this is where the similarity between commercial fishing and survey techniques end. Whereas fishers target hotspots and continually try to upgrade their fishing gear to maximize their catch, fisheries scientists have a different intention. Their main aim is to collect a representative sample, a snapshot of the fish in an area. Scientists also need to compare their results with previous years to follow trends, so it is vital that they use the same fishing gear each year rather than continually improving it.

To bring order to this process, ICES has divided the Northeast Atlantic into a grid of rectangles of 1 degree of longitude by 0.5 degrees of latitude. Scientists pick random points within each rectangle and trawl for a standard period, usually half an hour, to collect a sample. Each year, virtually every ICES rectangle in waters shallower than 300 meters is sampled in this way. In key areas such as the North Sea, each rectangle will be sampled a number of times – requiring a massive international effort.

The largest and longest running bottom trawl survey is the ICES International Bottom Trawl Survey (IBTS), which focuses on the North Sea and has been carried out annually since 1966. The survey takes place in spring and autumn and involves research vessels from Denmark, England, France, Germany, Ireland, the Netherlands, Norway, Portugal, Scotland, Spain, and Sweden. Working through ICES, countries have agreed to trawl sections of the sea using the same standard trawling gear. In a typical year, these vessels spend in total more than 400 days at sea for the IBTS survey, making more than 1200 sampling trawl hauls.

After the IBTS survey, scientists pool their data and, akin to piecing together a giant jigsaw puzzle, produce an overview of the yearly rise and fall of fish populations in the North Sea.

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Trawling through the sea

One of the main trawls used for bottom trawl survey work is the GOV trawl, which collects data on the major demersal species: cod, haddock, whiting, Norway pout, and saithe. The net also samples some of the main shoaling or pelagic species, including herring and mackerel. The design and operation of the GOV trawl is coordinated by ICES, and all countries involved in the International Bottom Trawl Survey in the North Sea use the GOV trawl with an internationally agreed specification. For surveys of flatfish species such as plaice and sole, the main gear used is the beam trawl. The beam trawls used are based on the commercial beam trawls used by fishers.

Other surveys concentrate on deep-sea fish and some use video cameras that are towed across the seabed to count *Nephrops* (commonly called Norway lobster).

In acoustic surveys sound is used to monitor fish stocks, particularly pelagic stocks. Research vessels run survey tracks all over the Northeast Atlantic using sophisticated echo-sounders that fire a pulse of sound into the water and detect the presence and size of fish schools from the returning echoes. Because it is difficult to accurately distinguish all fish species from the seabed, acoustic surveys tend to focus on pelagic fish such as herring, sprat, capelin, mackerel, sardine, and anchovy. Acoustic surveys are also used to determine when certain fish leave the seabed. For instance, cod in the Norwegian and Barents seas often leave their usual seabed habitat, particularly at night.

After many years of acoustic surveying, scientists have a good idea of the kind of echo the different species give; trawl hauls are carried out to verify the findings of the acoustic gear. To illustrate the effort that goes into these surveys, the annual Northeast Atlantic blue whiting acoustic survey involves research vessels from five countries, spending a combined total of 97 days at sea.

Most commercially important fish, such as cod and mackerel, spend their early life stages as eggs and then larvae, floating among the plankton. To sample them, scientists tow very fine-meshed nets across huge areas of sea and record the number of eggs and larvae they find. As the number of eggs is proportional to the number of adult fish that produced them, scientists can count the eggs and larvae of fish, such as mackerel and herring, and they have yet another way of estimating adult fish population sizes.

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Turning raw data into advice

After painstakingly collecting thousands of records of fish from all over the North Atlantic, scientists then use mathematical models to combine all available data to provide an understanding of how the fish populations have developed and how fisheries have impacted them over time. The models are chosen to give the best possible agreement between the observations (the data available) and their interpretation (the development of the fish population and its exploitation).

To make population estimates, the countries involved in each fishery send their scientists to ICES working groups. Different groups focus on different fish stocks in particular regions, such as the Arctic, the Baltic, the Bay of Biscay, and the North Sea. At the working group meetings, experts pool their information on the stocks, run the mathematical models, and compare the results with their knowledge of the stocks. Besides making population estimates, the working groups also make catch forecasts at different levels of fishing intensity for the coming year.

In the next stage, the working groups' stock estimates and forecasts are reviewed by independent scientists. The reviewer's comments and the working group reports are then passed on to ICES Advisory Committee (ACOM). This committee is comprised of scientists from each of the ICES member countries, and their job is to turn the estimates and forecasts into ICES advice.

ICES provides its advice to public authorities in charge of fisheries policy, such as the European Union, the North Atlantic Salmon Conservation Organization (NASCO), the North East Atlantic Fisheries Commission (NEAFC), and to the governments of the 20 ICES member countries.

ICES role is to provide scientific advice. It is then the role of the commissions and governments to weigh the social and economic implications of the advice provided.

What's in the advice?

ICES bases its advice on the principles set out in international agreements on sustainable fisheries. One important consideration is that there should be enough fish left in a stock – after fishing and deaths from natural causes – to spawn a healthy new generation the following year. With this in mind, ICES has set minimum levels below which stocks should not be allowed to fall.

ICES uses two reference points as the lower limit for biomass: the biomass limit (B_{lim}) and the precautionary biomass limit (B_{pa}). The biomass is the total weight of a fish stock. The biomass limit is the lowest level to which a stock should be allowed to fall; below B_{lim} the stock is so small that the number of young fish and adults capable of spawning is likely to be seriously reduced. The future of the stock is then in jeopardy, and in a worst-case scenario, it may never recover to its former levels.

Because estimating the biomass of a fish stock is inherently uncertain, the same is true of the estimation of the biomass limit. To account for this uncertainty and to keep the stock well away from the danger zone of B_{lim}, ICES sets a precautionary biomass limit (B_{pa}) as a buffer above B_{lim}. The better the data on the stock, the smaller the buffer zone between the two limits needs to be.

For example, scientists set the lower limit (B_{lim}) of spawning-stock biomass, or total weight of mature fish, of North Sea cod at 70000 tonnes and the precautionary biomass level (B_{pa}) at 150000 tonnes. For a healthy stock and a sustainable fishery, the stock should be above 150000 tonnes. Below this value, alarms should sound and fishing pressure should be reduced to allow the stock to recover, and the stock should definitely not be allowed to fall below 70000 tonnes, as it has done in recent years (see Figure 1).

Currently, North Sea herring is in a better state, although it has had a rollercoaster ride in the past. Back in the early 1960s, the spawning-stock biomass was approximately 1.8 million tonnes before it crashed to 47000 tonnes in the late 1970s. However, with better management and favorable environmental conditions, it has recovered to more than 1.8 million tonnes in recent years, well above the B_{pa} (see Figure 2).

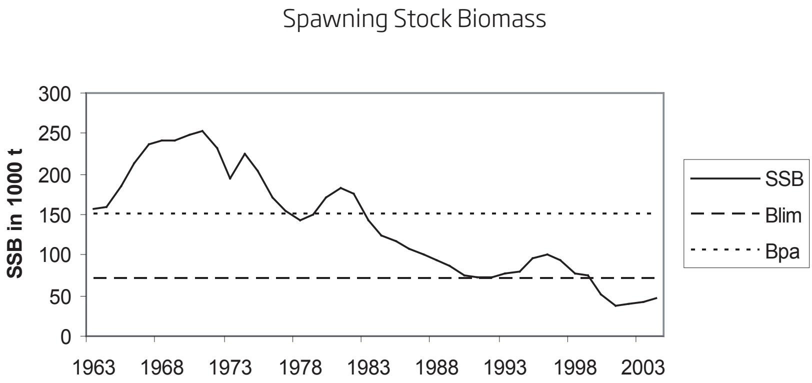


Figure 1

The North Sea cod spawning-stock biomass over time with ICES reference points: B_{lim}- the lowest biomass limit, and B_{pa}- the more precautionary biomass limit that acts as a buffer above B_{lim}. North Sea cod's spawning-stock biomass was around B_{pa} in 1963, and it increased substantially before falling below B_{pa} and B_{lim}. In such situations, ICES advises that fishing mortality should be reduced in order to achieve a spawning-stock biomass that is above such limits – simply to safeguard the stock.

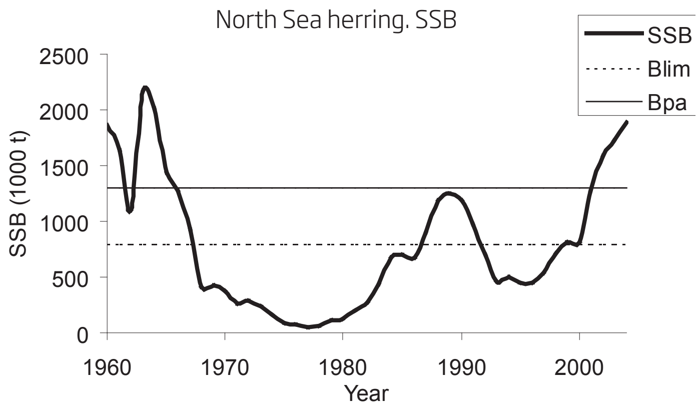
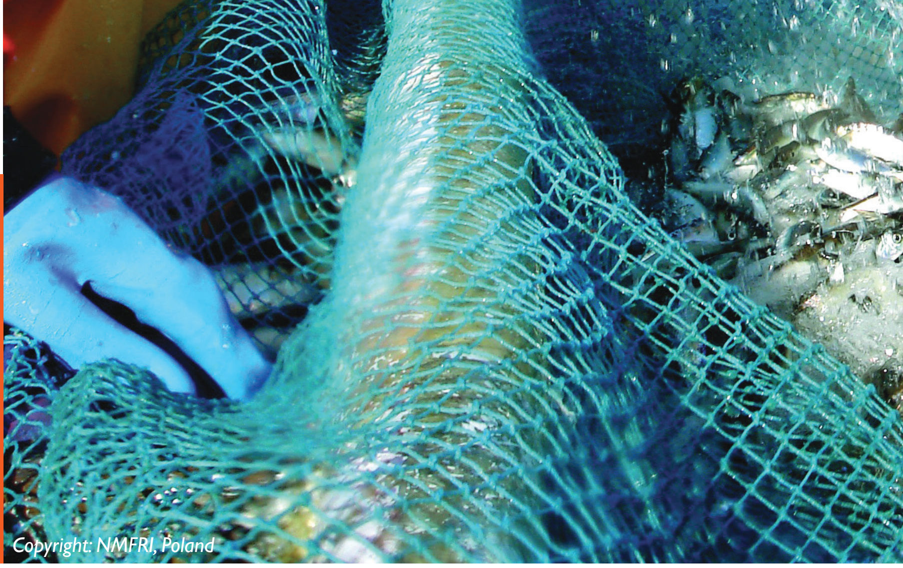


Figure 2.

The North Sea herring spawning-stock biomass over time with ICES reference points: B_{lim}, the lowest biomass limit, and B_{pa}, the precautionary biomass limit that acts as a buffer above B_{lim}. North Sea herring's spawning-stock biomass crashed well below B_{lim} in the 1970s, and it has since rebuilt to above both B_{pa} and B_{lim}.



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The future

To put Northeast Atlantic fish stocks on a more stable footing, scientists are working with policy makers to develop long-term management plans for key stocks such as cod. Rather than continuing to manage stocks on a year-to-year basis and relying on biomass limits, the long term goal is to reduce fishing pressure or maintain it at sustainable levels that allow stocks to thrive again.

To further this goal, the next step is to extend ICES advice on single fish stocks towards advice in support of a more integrated approach to marine policy, which incorporates all ecosystem components and relates to economic sectors which depend on, or impact, marine ecosystems.

Data-limited stocks

To provide decision-makers with information for the sustainable exploitation of fish stocks, ICES scientists use data from both fisheries and scientific sources to make stock assessments. The mathematical and statistical techniques used to make a stock assessment are “assessment models”.

ICES works to provide advice on the sustainable use of more than 250 stocks of fish and shellfish in the Northeast Atlantic; however, more than 60% of these stocks challenge ICES scientists as so little is known about the stock and there are often no applicable management plans or assessment models. In fact, for many

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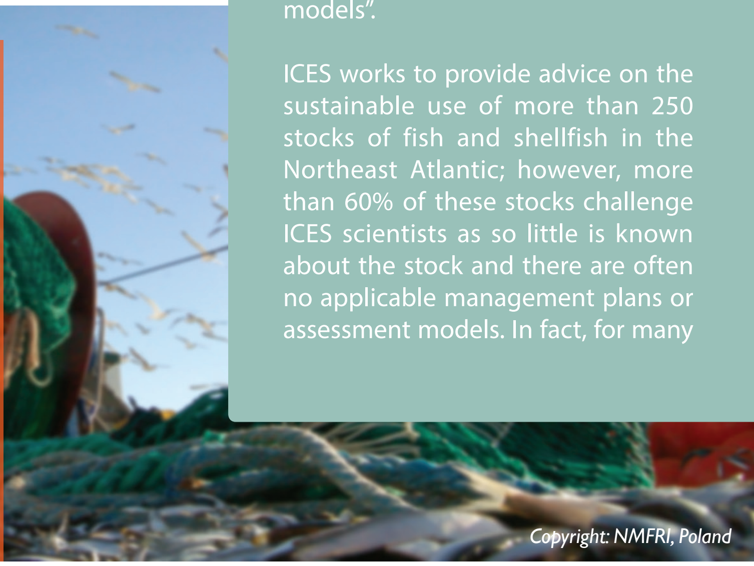

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> “ In order to provide the best available science for decision-making, the advice must go beyond the fish. ”

Ecosystem approach

Single-species fish stock assessments are one piece of the puzzle in understanding how humans interact with fish populations in marine ecosystems. In order to provide the best available science for decision-making, the advice must go beyond the fish.

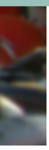
Fish are not the lone occupants of the world's oceans – they are part of the marine ecosystem, interacting closely with their physical, chemical, and biological environment, which is closely linked to land-based and atmospheric processes. Fish populations are dependent on the ecosystem to provide the right conditions for growth, reproduction, and survival. Equally, as an integral part of the marine foodweb, they provide an important food source for other animals such as seabirds and marine mammals.

of these stocks scientists can only estimate how many fish are landed at port.

In 2010, ICES began developing methods for “data-limited” stocks in an effort to utilize the data and information that are available to aid policy-makers move towards sustainable exploitation of fisheries. These methods categorize stocks based on the information available and provide an assessment method for each case.

The underlying principle applies more precaution in more uncertain situations: consequently, the less information available, the more conservative the advice. In 2012, ICES began providing quantitative advice for the majority of the data-limited stocks. This marks a great step forward in the management and conservation of many vulnerable stocks and species, including many sharks and commercially exploited species such as flounder, brill, and pollack for which few data, beyond basic biological information, are available.

ICES continually works with scientists from around the globe to further develop and test data-limited methods in support of biodiversity conservation and sustainable exploitation of fish stocks in the Northeast Atlantic.



Agriculture run-off can cause eutrophication in coastal areas, threatening key habitats for vulnerable life stages of many fish species. Since the beginning of the industrial revolution, the release of carbon dioxide (CO_2) from industrial and agricultural activities has increased, and as atmospheric CO_2 levels increase, so do the levels in the ocean.

This also leads to ocean acidification. Algae and sea-grasses may benefit from higher CO_2 conditions in the ocean, as they require CO_2 to live, just as plants on land do. That said, a more acidic environment has a dramatic effect on calcifying species such as oysters, clams, sea urchins, corals, and calcareous plankton. When shelled organisms are at risk, the entire foodweb may be at risk.

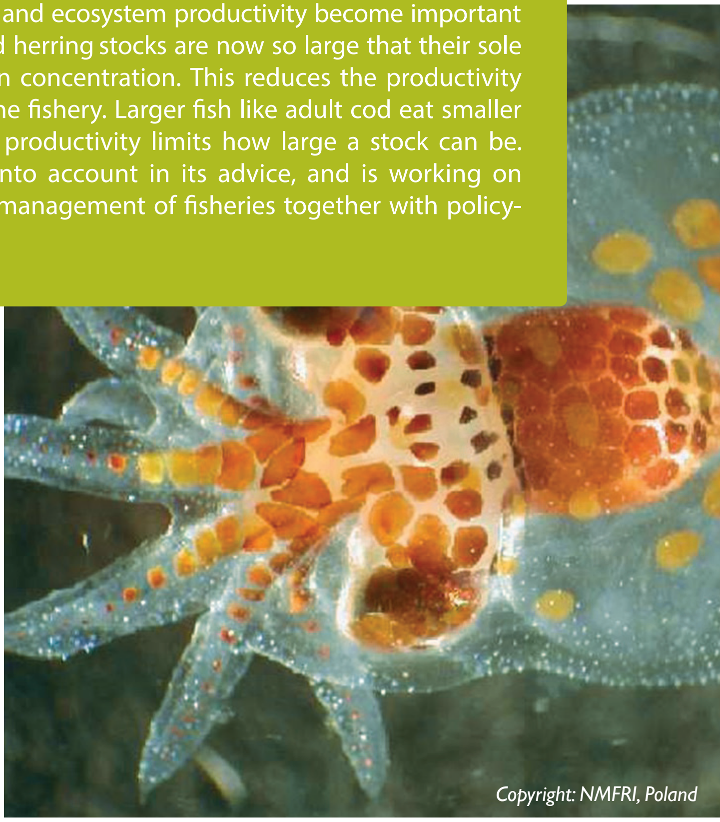
In a similar fashion, fishing activities do not solely impact on the targeted fish stocks. Fishing often results in catching unwanted fish which are discarded at sea, encounters with marine mammals, sea turtles, and other vulnerable species, as well as damage to the sea floor from fishing gear. Such impacts can accumulate and cascade throughout the ecosystem, affecting fish populations beyond the direct impact from fishing.

Therefore, integrating ecosystem considerations into fisheries advice is an active area of research within ICES and the scientific community in general. In short, to provide the best available science for decision-making, ICES is studying not only the fish, but their physical and biological environment and beyond.

“ Fish populations are dependent on the ecosystem to provide the right conditions for growth, reproduction, and survival. ”

Fish stocks compete for food

As fish stocks rebuild, food competition and ecosystem productivity become important issues. For instance, Baltic Sea sprat and herring stocks are now so large that their sole food item, zooplankton, has reduced in concentration. This reduces the productivity of the stocks and possible yield from the fishery. Larger fish like adult cod eat smaller fish like herring; therefore, ecosystem productivity limits how large a stock can be. ICES is starting to take such factors into account in its advice, and is working on the development of ecosystem-based management of fisheries together with policy-makers.



Fish stocks and climate change

Climate change may impact the distribution and productivity of fish stocks and species in the North Atlantic. For example, climate change could benefit some fish stocks at the northern border of the species' natural distribution, such as cod in the Barents Sea, where the warmer water may open new habitats and food resources.

Although the impacts of a changing climate are beyond society's control, public policy-makers can control fishing pressure in order to keep stocks healthy so they have the greatest possible chance of adjusting to a changing environment.

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