



International Council for  
the Exploration of the Sea  
Conseil International pour  
l'Exploration de la Mer

ICESCIEM

FISH STOCKS

## FISH STOCKS: COUNTING THE UNCOUNTABLE?



Photo by BAM ([www.bam.dk](http://www.bam.dk))





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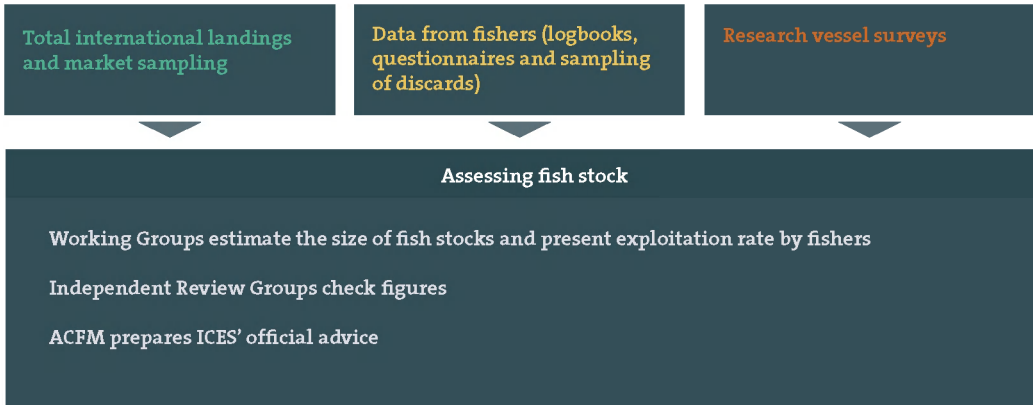
In the last few decades, fisheries scientists have increasingly warned that many fish stocks are being fished too hard. Sometimes the advice has been heeded, other times it has not and entire fisheries have collapsed – as happened with the cod fishery on the Grand Banks.

Whenever scientists have to make gloomy predictions about the fate of fish stocks, questions always arise about how they arrived at their figures and where the data comes from. In this leaflet we explain how fish stocks are assessed in the Northeast Atlantic and hopefully give a flavour of the amount of work that goes into the scientists’ stock estimates.

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

The first point is that scientists don’t try to count every single fish in the sea, as that would be impossible. Instead, they collect as much information as they can from three main sources: from landings at ports; from fishers; and from research vessel surveys. They then use these data to estimate the size of commercial fish populations such as cod, haddock, and hake.

As fish are no respecter of 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 acts as a meeting point for a community of more than 1600 marine scientists from 19 countries around the North Atlantic; scientists working through ICES cover all aspects of the marine ecosystem from marine chemistry to fish, marine mammals and seabirds. Working together with experts from other nations gives scientists the big picture of what is really happening in the sea – rather than just knowing about their own countries’ sea areas.



### Total international landings and market sampling

Fishers are out in all weather doing a difficult, dangerous job. When they arrive back in port, the fish they land give scientists an excellent opportunity to collect essential data. 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.

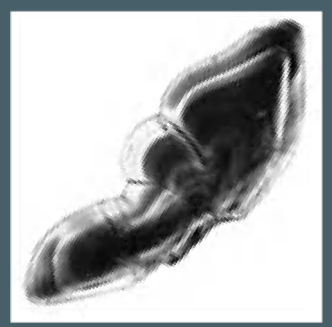
As a rough estimate, fisheries scientists generally aim to sample a minimum of around 200 fish per 1000 tonnes landed, across the ICES area. As more than 8 million tonnes of fish are landed in the ICES area every year, this means that by the end of December, in a typical year, scientists will have recorded details of around 1.6 million fish.

But scientists can also learn a lot more by being present when fishing boats land their fish. They are on hand most weeks at fishing ports, from Portugal up to the Arctic coast of Norway, sampling the fish that are landed to collect crucial data on the age, length, and breeding condition of the 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. Otoliths are the balance organs of fish and are small bones (a few mm to 3 cm long) found on either side of the brain. Under a microscope, the rings can be counted, giving 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, and a lack of older fish may signify overfishing.



A fish otolith



“SCIENTISTS HAVE 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.”

### Data from fishers

As well as sampling at fishing ports, scientists are also out on commercial fishing boats sampling catches, recording the discards – unwanted fish and other marine life thrown back overboard – and tagging and releasing fish to gain an insight into their travels, preferred areas and lifespan. In recent years, 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 within the official advice from ICES.

Another store of information are the fishers’ logbooks, which the scientists sometimes use to work out how many hours it took to catch the fish they have landed – so-called Catch-Per-Unit-Effort data. If the amount of effort to catch fish goes up this could indicate that fish are becoming scarcer. Finally, fishing vessels are sometimes hired to make dedicated research cruises to add to the findings collected on the scientist’s research vessels.

### Research vessel surveys

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

To sample fish on or near the seabed – such as cod or haddock – scientists use bottom trawls in the same way that fishers do. But then the similarity blurs. Whereas fishers target hotspot areas and continually try to upgrade their fishing gear to maximize their catch, fisheries scientists have a different intention. They don’t want to maximize their catch but instead collect a representative sample, a snapshot of the fish in an area. They also have 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.

The Irish Research vessel RV Celtic Voyager (foreground) and the French research vessel RV Thalassa (background) on a joint survey  
Photo courtesy of the Marine Institute, Ireland



Using the GOV trawl to sample fish in the ICES area. Photo by Henk Heessen, RIVO

To bring order to the fish-sampling process, ICES 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 300m is sampled in this way. In key areas such as the North Sea, each rectangle will be sampled a number of times – a massive international effort.

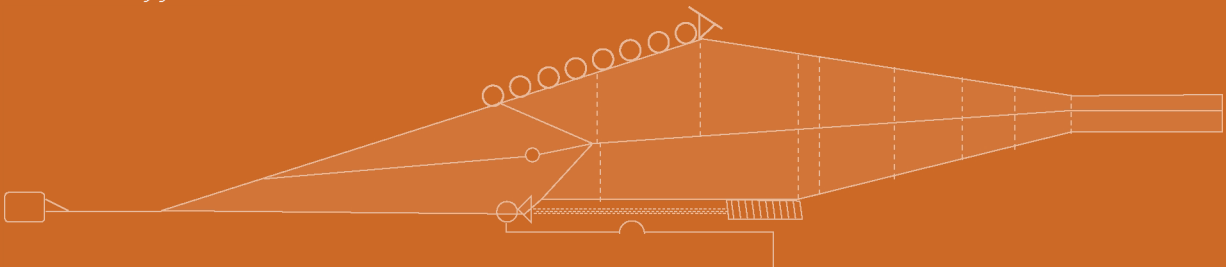
The biggest, and longest running, bottom trawl survey is the ICES International Bottom Trawl Survey (IBTS) which focuses on the North Sea. The survey takes place in spring and autumn and involves research vessels from Denmark, England, France, Germany, the Netherlands, Norway, Scotland, and Sweden. Working through ICES, countries have agreed to trawl sections of the North Sea using the same standard trawling gear. In a typical year, their vessels spend a total of more than 300 days at sea on the IBTS survey, making more than 800 sampling trawl hauls.



To bring order to the fish-sampling process, ICES divided the Northeast Atlantic into a grid of rectangles of 1 degree of Longitude by 0.5 degrees of Latitude

### Trawl surveys

One of the main trawls used for bottom trawl survey work is the GOV trawl which is used to collect 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 Surveys 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 in surveys are based on the commercial beam trawls used by fishers.





“THERE ARE ALSO SURVEYS FOR DEEPEA FISH AND EVEN SURVEYS USING VIDEO CAMERAS THAT ARE TOWED ACROSS THE SEABED TO COUNT *NEPHROPS*.”

After the IBTS survey, scientists pool their data together and, like piecing together a giant jigsaw puzzle, they are able to get an overview of the yearly rise and fall of fish populations in the North Sea. The IBTS survey has proved to be so valuable that since 1997, it has been extended to include winter surveys down the west coast of UK and Ireland and down through the Bay of Biscay to Gibraltar – a huge undertaking.

Other big surveys include: the Demersal Young Fish Survey which targets plaice, sole, and brown shrimp along the North Sea coast and involving more than 1000 hauls a year; and the North Sea Beam Trawl Survey (BTS), which samples plaice and sole and involves up to 60 days and more than 280 hauls a year. There are also surveys for deepsea fish and even surveys using video cameras that are towed across the seabed to count *Nephrops* – commonly called Norway lobster or Dublin Bay prawn.

*The RV G.O. SARS – one of the Norwegian research vessels that takes part in the IBTS survey.  
Photograph by Harald M. Valderhaug*



*Collecting data on Nephrops. Photo courtesy of the Marine Institute, Ireland.*

Scientists also use sound to monitor fish stocks and, in particular, pelagic stocks. Research vessels run survey tracks all over the Northeast Atlantic using sophisticated echosounders 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. But they are also used to survey fish such as cod when they leave the seabed, for instance in the Norwegian and Barents Seas where cod 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; but to double-check they also do sample trawls to check the fish that the acoustic gear has found. As an example of the effort that goes into these surveys, the North Sea herring acoustic survey involves research vessels from more than 6 countries spending a combined total of over 80 days at sea and making over 150 sample trawls.

As well as surveying adult fish, scientists also sample fish in the early stage of their lives. Most commercially important fish, such as cod, mackerel, etc. spend their early life stages as eggs and then larvae, floating around in the plankton. To sample them, scientists tow very fine mesh nets across huge areas of sea and record the number of eggs and larvae they find. Since the number of eggs and larvae 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.



*Measuring fish on a research vessel. Photo courtesy of the Marine Institute, Ireland.*

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*Photograph from Getty Images*



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## Turning raw data into advice

After painstakingly collecting thousands of records of fish from all over the North Atlantic, the next step for scientists is to use mathematical models to transform these records into fish population estimates. Models such as Virtual Population Analysis (VPA) play a key role in this complex task. The idea behind this type of model is to back-calculate the size of a fish stock from the numbers and ages of fish that have been caught.

To make the population estimates, the countries involved in each fishery send their scientists to ICES Working Groups, which focus on fish stocks in particular regions such as the Arctic or North Sea. At the Working Group meetings, the experts pool their information on the stocks, run the mathematical models, and compare the results to their knowledge of the stocks. As well as making population estimates the Working Groups also make catch forecasts at different levels of fishing intensity.

The next stage is that the Working Groups’ stock estimates and forecasts are checked by independent Review Groups. The Review Group comments and Working Group reports are then passed on to the ICES Advisory Committee on Fishery Management (ACFM). This Committee comprises scientists from each of the ICES member countries and their job is to turn the estimates and forecasts into the official ICES advice.

The ICES advice comes out every May and October when it is given to the European Commission, other Commissions such as IBSFC<sup>1</sup>, NASCO<sup>2</sup>, and NEAFC<sup>3</sup>, and to the governments of the 19 countries that are members of ICES.

In the advice, ICES’ job is to stick to the biology. It is then the Commissions and governments’ role to weigh up the social and economic implications of the biological advice.

<sup>1</sup> International Baltic Sea Fishery Commission  
<sup>2</sup> North Atlantic Salmon Conservation Organisation  
<sup>3</sup> North East Atlantic Fisheries Commission

*Photo courtesy of the Marine Institute, Ireland*



“ICES BASES ITS ADVICE ON THE PRINCIPLE THAT THERE SHOULD BE ENOUGH FISH LEFT IN A STOCK – AFTER FISHING AND DEATHS OF FISH FROM NATURAL CAUSES – TO SPAWN A HEALTHY NEW GENERATION THE FOLLOWING YEAR.”

## What’s in the advice?

ICES bases its advice on the principle that there should be enough fish left in a stock – after fishing and deaths of fish 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.

There are two benchmarks: one called the biomass limit ( $B_{lim}$ ) and the other called the precautionary biomass limit ( $B_{pa}$ ). The biomass is the total weight of fish in the fish stock.

The biomass limit is the lowest level that a stock should be allowed to fall to. Below this level the stock is so small that the numbers of young fish the adults are capable of spawning is likely to be seriously reduced. This means that the future of the stock is in jeopardy, and in a worst-case scenario it may never recover to its former levels.

Estimating the biomass of any fish stock is always uncertain and this is also the case when scientists estimate the biomass limit. To allow for this inherent uncertainty and to keep the stock well away from this danger zone, ICES sets a precautionary biomass limit above this level, as a buffer. The better the data on the stock, the smaller the buffer zone between the two limits needs to be.



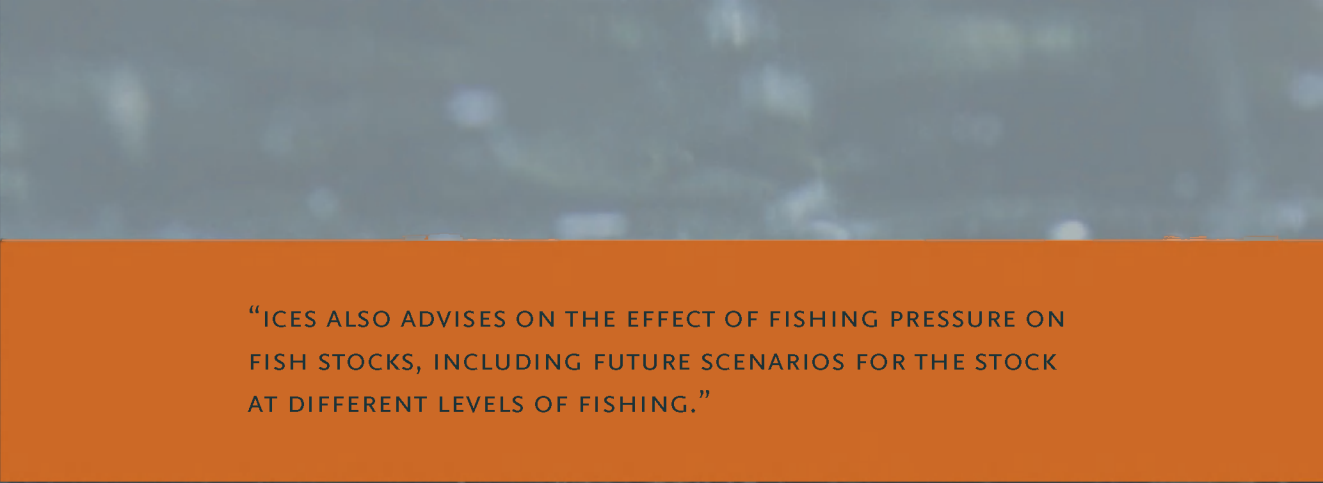
“THE BIOMASS LIMIT IS THE LOWEST LEVEL THAT A STOCK SHOULD BE ALLOWED TO FALL TO.”

*Anglerfish (top photo) by Erling Svensen  
Plaice photo by Paul Kay  
Background photo by Henk Heessen*





“FOR A HEALTHY STOCK AND SUSTAINABLE FISHERY, THE NORTH SEA COD STOCK SHOULD BE ABOVE 150,000 TONNES.”



“ICES ALSO ADVISES ON THE EFFECT OF FISHING PRESSURE ON FISH STOCKS, INCLUDING FUTURE SCENARIOS FOR THE STOCK AT DIFFERENT LEVELS OF FISHING.”

As an example, the biomass limit of North Sea cod is 70,000 tonnes and the precautionary biomass limit is 150,000 tonnes. For a healthy stock and a sustainable fishery, the stock should be above 150,000 tonnes. Below this figure the alarm bells should ring and fishing pressure should be reduced to allow the stock to recover. The stock should definitely not be allowed to fall to below 70,000 tonnes as it has done in recent years (see Figure 1).

North Sea herring is currently in a better state, although it has had a rollercoaster ride in the past. Back in the early 1960s, the spawning stock biomass, or total weight of mature fish, was around 1.8 million tonnes. The stock then crashed down to 47,000 tonnes in the late 1970s, but now with better management and favourable conditions it has recovered back up to over 1.8 million tonnes in recent years (see Figure 2).

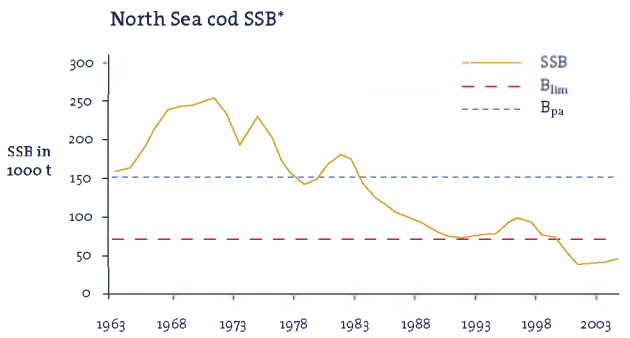


Figure 1 showing the decline of the North Sea cod stock to a level below the biomass limit.  
\* Spawning Stock Biomass (total weight of mature fish).

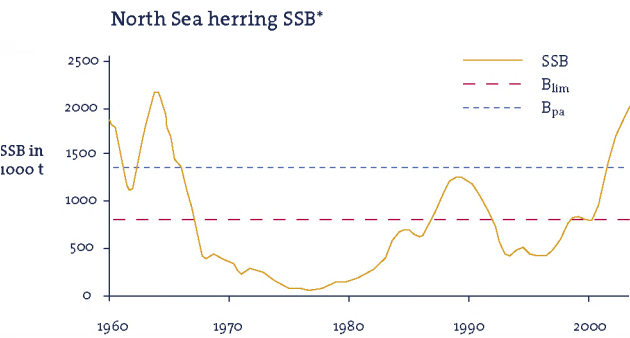


Figure 2 showing the rollercoaster history of the North Sea herring stock.  
\* Spawning Stock Biomass (total weight of mature fish).

Photos by Paul Kay [www.marinewildlife.co.uk](http://www.marinewildlife.co.uk)



“NORTH SEA HERRING IS CURRENTLY IN A BETTER STATE, ALTHOUGH IT HAS HAD A ROLLERCOASTER RIDE IN THE PAST.”

## The future

ICES also advises on the effect of fishing pressure on fish stocks, including future scenarios for the stock at different levels of fishing. This advice is complicated by the fact that fishers often don't just catch one type of fish at a time, but many. For instance, bottom-trawls for cod also catch haddock, whiting, and other bottom-living fish. So when advising on fishing pressure, scientists have to take into account the effect of fishing on these other species. ICES scientists also consider the impact of fishing on the entire ecosystem and, in particular, on non-target species such as cold-water corals or whales and dolphins.

To get Northeast Atlantic fish stocks onto a more stable footing, scientists are currently working with managers to develop long-term management plans for key stocks such as cod. The intention is that rather than just managing stocks on a year-to-year basis and relying on biomass limits, there will be a longer-term goal to reduce fishing pressure and build stocks up to the level where they are thriving again.

### Older fish mean more and healthier eggs

A young cod spawning for the first or second time will produce around 500,000–1 million eggs. This might sound like a lot but it is dwarfed by the fertility of an old cod that may spawn as many as 10–15 million eggs, which are not only bigger but also go on to hatch into stronger larvae. However, the odds stacked against a newly hatched cod are immense. On average, only two eggs out of the many millions spawned by a mature female will develop and survive to maturity.



A three-day-old cod larva. Photo by Kjell B. Døving



### Fish stocks and climate change

Scientists agree that overfishing is the main cause of recent declines in many fish stocks in the Northeast Atlantic. But climate change has also added to the pressure: warmer sea temperatures are likely to be affecting the survival of eggs and larvae of cold-water species, such as cod, and may alter the distribution of food that fish eat.

While climate change is unfortunately a wild card which can only be taken into account, managers can control fishing pressure to keep stocks healthy so they have as much chance as possible of adjusting to these changes.