Published 20 March 2017

EU request on distributional shifts in fish stocks

Advice summary

Distributional changes were found for 16 of the 21 fish species analysed. Half of these changes affect the relative distribution of these species across TAC management areas. The drivers for the changes in distribution of most of the analysed species are linked to the environmental conditions (i.e. mostly through sea temperature), but for some species fishing also played an important role. Changes in these drivers have caused changes in fish distribution, mediated through a number of mechanisms that are species- as well as stock-dependent. Future changes in these drivers will further affect the fish distribution and may affect more species/stocks than have currently been detected. ICES cannot predict these changes at present.

Request

The Commission wishes to be informed of distributional shifts in fish stocks that may have taken place since 1985 in relation to TAC management areas. ICES is requested to:

1) *Assess the proportion of each principal commercial species of fish (see list* [Annex A]*) that is distributed within each TAC management area established for that species, from research vessel survey and additional information.*
2) *Identify any significant long-term trends in distributional changes between TAC management areas and between stocks of the same species.*
3) *Where appropriate, identify likely drivers for such changes.*
4) *Where appropriate, advise on likely future trends.*

Elaboration on the advice

1) It has not been possible to assess the proportion of species' distribution between TAC management areas because the ranges of most species extend well beyond the area covered by any given survey (and also well beyond any single TAC management area). No current single survey can provide the data necessary to assess distribution changes in any commercial species analysed here over its entire range. Because of the difference in species catchability in the various gears used in different surveys and areas, the interpretation of variation in species abundance estimates derived from different surveys and areas is highly problematic.
2) Eight species (anchovy, cod, hake, herring, mackerel, plaice, horse mackerel, and common sole) have shifted their distribution in relation to TAC management areas since 1985. Of these, the greatest shifts occurred for hake and mackerel.
3) Environmental conditions influenced the distribution of all of the 16 species that showed substantial change; fishing (both overall pressure and effort distribution) influenced the distribution of nine species. Environmental conditions and fishing are interacting factors; both have changed since 1985 and they are likely the drivers of change. The degree to which each has caused change varies between species (and, in some cases, between individual stocks of the species).
4) Future changes in distribution are likely, but given the complexity of the mechanisms affecting the spatial distribution of fish stocks, predicting those changes with precision and accuracy is not possible. It is reasonable to assume that these changes will challenge some assumptions underlying the current management of Northeast Atlantic fisheries. Continued monitoring of the spatial distributions of fish stocks is essential to support future management.

Suggestions

It is highly likely that there will be further changes in fish distribution with consequential implications for TAC management. In addition to bottom trawl surveys, ICES will in future be able to use pelagic survey data; further information could potentially be derived from commercial catch data with high spatial resolution. Surveys for pelagic species should ideally extend also beyond the EU continental shelf and not be coincident with TAC management areas.

Basis of the advice

Background

Temperatures in most seas and oceans around the globe have risen in recent decades. Shifts, usually in a northerly direction in the northern hemisphere, have been widely documented in the distributions of many fish species and linked to the major change in environmental conditions. The European Commission has asked to be informed of any distributional shifts in fish stocks that may have taken place since 1985 (or the earliest available reliable time-series year by region) in relation to TAC management areas. Twenty-one species were considered: anchovy, anglerfish (2 species), blue whiting, cod, common sole, Greenland halibut, haddock, hake, herring, horse mackerel, mackerel, megrims (2 species), Norway pout, plaice, pollack, saithe, sprat, spurdog, and whiting. The species were examined across the following regions and time-series: Baltic Sea (from 1991), Celtic Seas (from 1993), North Sea (from 1965/1987), and Bay of Biscay/Iberian coast (from 1997).

An analysis of bottom-trawl survey information identified species with substantial changes in distribution. This was supplemented with a literature review for all species. If the analysis or the literature review found changes, the findings were used to identify the likely drivers of distribution (and therefore of change).

Environmental conditions determine the distributions of each species, but these are subsequently modified by fishing. As the exploitation of commercial fish species moves towards sustainable levels, the effects of environmental drivers on fish distribution become proportionately more important because of the declining influence of fishing mortality.

Results and conclusions

All but five species were found to exhibit some changes in their distribution.

Table 1.a–c below presents a summary of the distribution changes for each species and method that demonstrated the change. A double 'XX' implies strong support from that method, a single 'X' implies weaker support. There may be less evidence for some stocks within each species, but the strongest evidence is indicated for each species.

Table 1.a Substantial changes that affect TAC management areas.

Species	Brief description of change in distribution	Method			
		Frequency of occurence	Centre of gravity	Log-ratio	Literature
Anchovy	Expansion within the North Sea from 1990 onwards.	XX			XX
Cod	Northward shift (for the West of Scotland, Celtic Sea, and Irish Sea stocks, and for the North Sea stock).	XX	XX	XX	XX
	Northward expansion for the Barents Sea.				XX
Hake	Expansion of the distribution from the western shelf into the northern North Sea. Catch records confirm this expansion.	XX	XX	XX	XX
Herring	No evidence of large directional distribution change, some contrasting regional changes between adjacent stocks and TAC management areas.	X	X	X	X
Mackerel	Northwestward expansion of the stock.				XX
Plaice	Increase in occurrence in the northern North Sea and Baltic Sea, with a southeastward shift in biomass between the Skagerrak and western Baltic. Indication of a northward shift of the southern boundary of the species distribution range.	X	X	X	XX
Horse mackerel	No large distribution shifts, but indication of a more northerly distribution within the North Sea.			X	
Common sole	Increases in the northern extent of the range in the 1980s. Significant trend detected when comparing abundance in the North Sea and the eastern English Channel.	XX	XX	XX	

Table 1.b Changes found, but not currently affecting TAC management areas.

Species	Brief description of change in distribution	Method			
		Frequency of occurence	Centre of gravity	Log-ratio	Literature
White-bellied anglerfish	Northward and deepening distribution shift in the North Sea.	X	X	X	XX
Black-bellied anglerfish	Northeast shift off the coast of Galicia and increasing occurrence in the North Sea.	X	XX		X
Blue whiting	Large occurrence increase in the northern North Sea and west of Scotland, with periodic shifts in spawning distribution and migration routes to the west of Scotland.	X			XX
Megrim (*L. whiffiagonis*)	Changes in the regional distribution (increasing occurence in the Celtic Sea and Bay of Biscay). Northwards shift of distribution in the North Sea.	X			XX
Sprat	Shifts in distribution found in the Baltic Sea (northeastward) and in the North Sea (southward).	X	XX		XX
Whiting	No change in the area occupied by whiting. However, there is an indication of an increase in occurence at eastern and western boundaries.	X			
Haddock	The area occupied by haddock has remained unchanged for the last 15 years. Regional changes in the Celtic Sea and in the northern Bay of Biscay.	XX		X	X
Saithe	No change in the area occupied by saithe. However, there is an indication of an increase in occurence and northward shift in northwestern shelves.	X	XX		

Table 1.c None, or only limited changes found.

Species	Brief description of change in distribution	Method			
		Frequency of occurence	Centre of gravity	Log-ratio	Literature
Four-spotted megrim	No information from the trawl surveys.				
Norway pout	Some weak indication of changes at the southern distribution limit in the Bristol Channel and in the northern North Sea.	X			
Greenland halibut	No information from the trawl surveys.				
Pollack	Some changes in occurrence of the species were detected in the North Sea and the Skagerrak–Kattegat area.	X			X
Spurdog	No large distribution shifts, but some evidence of local changes in frequency of occurrence.	X			

Eight species (anchovy, cod, hake, herring, mackerel, plaice, horse mackerel, and common sole) had substantial proportional changes in their distribution between TAC management areas, or into areas not presently covered by TACs (Table 1.a).

A further eight species (black- and white-bellied anglerfish, blue whiting, megrim (*L. whiffiagonis*), sprat, whiting, haddock, and saithe) showed changes in distribution, but these did not affect proportions between TAC management areas (Table 1.b).

Five species showed no major changes (Greenland halibut, Norway pout, four-spotted megrim, pollack, and spurdog; Table 1.c).

Table 2 Two drivers of fish distribution and species affected (from literature review).

Drivers	Species
Environmental conditions (mainly temperature)	anchovy, anglerfish (*L. piscatorius*), blue whiting, cod, common sole, haddock, hake, herring, horse mackerel, mackerel, megrim (both species), plaice, pollack, saithe, sprat, whiting
Spatial distribution of fishing effort and overall fishing pressure	anglerfish (both species), common sole, haddock, hake, herring, megrim (both species), plaice, pollack, whiting

For all 16 species that showed substantial changes in distribution, the literature indicates that the main factor influencing the locations of suitable habitats was environmental conditions, mainly through temperature (Table 2). The spatial distribution of fishing effort and overall fishing pressure affected the distribution of ten species. Environmental conditions and fishing affect distribution through, for example, the mechanisms of habitat selection, density-dependence, species interactions, demographic structure, geographical attachment, and spatial dependency.

To illustrate this, reduced fishing pressure should result in increased abundance in populations of targeted species; density-dependent processes might then cause the distribution to expand. Habitat selection, and the accessibility of suitable habitat, could dictate the actual areas that the species is able to utilize. Similarly, species interactions with predators or competitors might influence the extent to which the species is actually able to utilize particular locations. Conversely, expansion of the species distribution could be inhibited if the species is particularly dependent on specific and restricted habitats, or has especially strong geographical attachment to particular sites, such as spawning grounds. Changing environmental conditions alter habitat suitability at specific geographical locations. The area occupied in times of cooler water temperature may become unsuitable when the temperature rises. Habitat selection could then cause the distribution to shift northwards, or into deeper water, where a more suitable temperature regime may again be found. Such a shift may be initiated by variable productivity within the species' original range such that productivity is higher towards the north, or in deeper parts, of the range, and lower in shallower more southerly areas. Changes in environmental conditions and fishing are drivers of distribution change, but the effect of each driver is species and stock dependent.

Current climate scenarios project an increase in temperature and changes in primary production; there are therefore likely to be future changes in distribution. The recovery of populations as a result of reduced fishing mortality will also increase the likelihood of distribution change. The ability to accurately predict the future distribution of fish species is hampered by insufficient understanding of the mechanisms associated with drivers, and our ability to predict the drivers.

Methods

Survey data used

ICES analysed data obtained from the ICES DATRAS database covering the various bottom- and beam-trawl surveys in the Northeast Atlantic (e.g. Figure 1). The spatial coverage of the available survey data increased over time and a standard coverage was available from 2000 onwards, with some time-series extending back to before 1985. In some areas, the number of surveys also increased over time. Surveys could not be combined owing to the differences in catchabilities between them. In order to avoid any bias between surveys, only the survey with the longest time-series was chosen for each DATRAS survey area.

Although considered qualitatively in the literature review of relevant species, acoustic survey and egg/larvae survey data were not included in the analyses because there is no consistent central survey database. Analysis of these data will be possible with the completion of the ICES Acoustic Database in 2018.

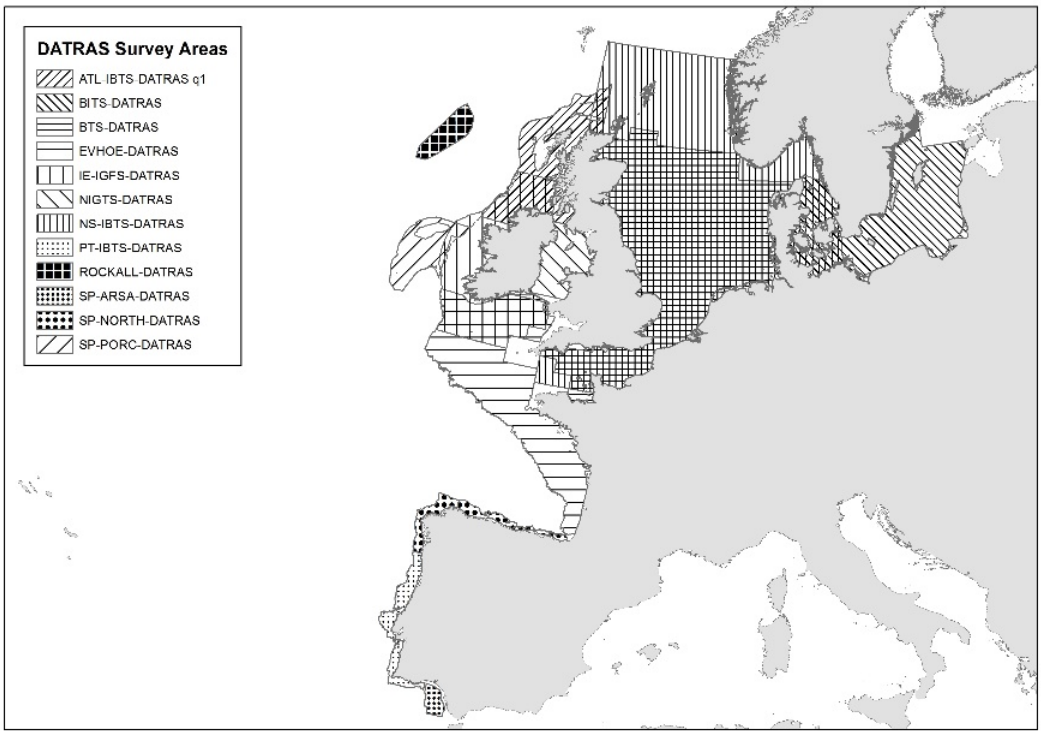

Figure 1 Spatial distribution of some trawl survey data from DATRAS used in the analysis of hake; illustrating the heterogeneity and overlaps of spatial coverage of trawl surveys.

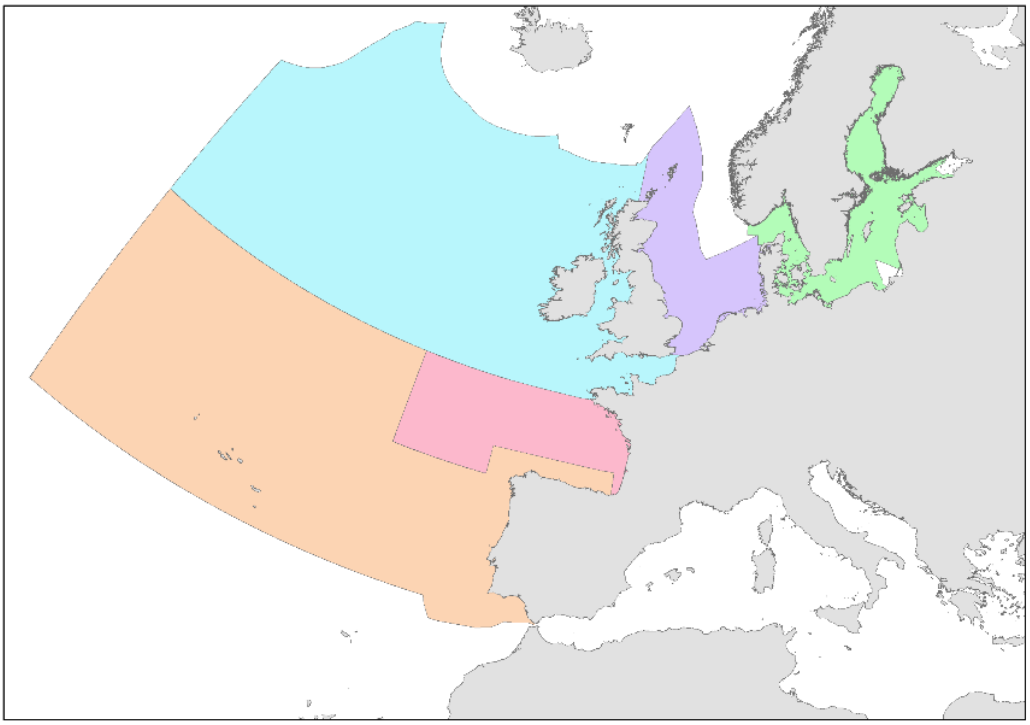

Figure 2 The five EU TAC management areas for hake:. EU waters in areas 2a and 4 (purple), 3a and EU waters in Baltic (green), 5b, 6, 7, 12 14 (blue), 8a,b,c,d (pink), 8c, 9, 10 and CECAF area 34 (orange).

Limitations in relation to describing species distributions

No one species had a uniform survey covering the whole range of its distribution or across each of its TAC management areas, and some species ranges lay almost completely outside the limits of any available surveys (e.g. there were no available data on Greenland halibut). Where survey coverage is split between a number of surveys with differing characteristics (e.g. sampling design, catchability) it is difficult to compare absolute changes between the survey areas. If the separate surveys align with the TAC management areas then it is not possible to tell whether changes are biologically real or caused by survey artefact. This issue is illustrated for hake with bottom-trawl survey coverage (Figure 1) and TAC management area (Figure 2); note particularly the boundaries in the southern Bay of Biscay and to the north of Scotland.

In addition, survey goals and objectives have evolved over the years, and the fishing gear has occasionally been changed. Species-specific catchability varies between surveys, and on occasion within surveys. This causes problems in generating consistent species abundance indices, and may particularly be the case for pelagic species (and those associated with rocky habitats, such as pollack) when primarily based on bottom-trawl surveys.

Despite these issues, the analysis of trends in data collected through a standardized and consistent protocol can allow the detection of major changes in distribution, especially for non-pelagic species. ICES analysed available bottom-trawl survey data for the species listed in the request (except Greenland halibut for which no data were available) and produced the following outputs for each species:

i. trends in frequency of occurrence based on presence/absence in ICES rectangles within each DATRAS survey area; temporal trends were tested for significance;
ii. centre of gravity of modelled biomass based on survey data with associated latitude and longitude trends within each DATRAS survey area;
iii. relative changes in abundance (log-ratio) between adjacent DATRAS survey areas; temporal trends were tested for significance.

All codes and data can be found on the GITHUB website https://github.com/ices-eg/WKFISHDISH and in the DATRAS database.

Species were described as having “substantial changes in distribution” if they conformed to at least one of two criteria: (1) a large, continuous, and directional change in distribution was identified from the analyses and/or in the literature review, and (2) a change in distribution was found within a survey area that resulted in subsequent changes in the relative distribution across TAC management areas.

The literature review searched for evidence of distribution change and took account of the two main drivers (i.e. environmental conditions and fishing) and the mechanisms, including habitat selection, density-dependence, species interactions, demographic structure, geographical attachment, and spatial dependency for each species. The review covered all relevant waters within the Northeast Atlantic.

Sources and references

ICES. 2016. Report of the Working Group on Fish Distribution Shifts (WKFISHDISH), 22–25 November 2016, ICES HQ, Copenhagen, Denmark. ICES CM 2016/ACOM: 55. 197 pp.

Annex 1

Table A1 Scientific names of the 21 analysed species.

Common name	Latin
Anchovy	*Engraulis encrasicolus*
Anglerfish – white-bellied black-bellied	*Lophius piscatorius* *Lophius budegassa*
Blue whiting	*Micromesistius poutassou*
Cod	*Gadus morhua*
Common sole	*Solea solea*
Greenland halibut	*Reinhardtius hippoglossoides*
Haddock	*Melanogrammus aeglefinus*
Hake	*Merluccius merluccius*
Herring	*Clupea harengus*
Horse mackerel	*Trachurus trachurus*
Mackerel	*Scomber scombrus*
Megrim - four-spotted	*Lepidorhombus whiffiagonis* *Lepidorhombus boscii*
Norway pout	*Trisopterus esmarkii*
Plaice	*Pleuronectes platessa*
Pollack	*Pollachius pollachius*
Saithe	*Pollachius virens*
Sprat	*Sprattus sprattus*
Spurdog	*Squalus acanthias*
Whiting	*Merlangius merlangus*