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# Fish data from the Continuous Plankton Recorder survey

J.A. Lindley[1], N.C. Halliday[2], D.P Stevens[1]

[1] *Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, PLYMOUTH, PL1 2PB UK, Fax +44 1752 600015, JAL Tel +44 1752 633133, e-mail jal@sahfos.ac.uk, DPST Tel +44 1752 633208, e-mail dpst@sahfos.ac.uk*
[2] *Marine Biological Association, The Laboratory, Citadel Hill, PLYMOUTH, PL1 2PB UK, Tel +44 1752 633215, Fax +44 (0) 1752 633102, e-mail nch@mba.ac.uk*

The Continuous Plankton Recorder (CPR) survey has been sampling plankton in the North Sea since 1931. However the identification of the larval and juvenile fish taken in the survey has not been a part of the routine analysis of the samples. Specialist analysis of the fish was carried out between 1948 and the early 1980s but the data were available as hard copy only. As part of MarBEF, data on >60 taxa from 1948 to 1972 have been entered on a database which is now linked to EUROBIS to show the biogeographical information and the data are available for general research. Examples of the data are shown. These data provide a background on the variability of fish stocks before the recent period of rapid warming and in some cases before significant fisheries developed. Data for subsequent years will be made available as possible and work is now underway to bring the analysis up to date. This will provide time series over six decades.

Keywords. Continuous Plankton Recorder, fish, database, distribution, seasonal cycles, long-term change.

Correspondence to: - J. A. Lindley. Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, PLYMOUTH, PL1 2PB UK, Fax +44 1752 600015, Tel +44 1752 633133, e-mail jal@sahfos.ac.uk

## Introduction

The Continuous Plankton Recorder survey was started in the southern North Sea in 1931 and monthly sampling was maintained from 1932 with the intention of studying changes in the plankton and relating these to climatic and hydrographic causes and effects on the fisheries (Hardy, 1939). This has been extended in more recent time to cover higher trophic levels dependant on fish, particularly sea-birds (e.g. Aebischer et al. 1990; Frederiksen et al., 2006). The Geographical coverage of the survey extended to the Northern North Sea by the late 1930s, with first tows between Scotland and Iceland in 1939. (Hardy, 1939). The development of the geographical extent of sampling following resumption of survey operations in 1946 is summarised by Richardson et al. (2006).

The catches of fish eggs and fish larvae in the recorder samples are a valuable supplement to the data on fisheries from other sources but the specimens are frequently damaged, making specific identification difficult and in some cases impossible. The identification of specimens to finer resolution than the categories of "Fish Eggs" and "Young Fish" (including both larvae and pelagic post-larval stages) has, therefore, been a task for specialists. Coombs (1980) reported that the proportion of fish that could not be identified even by these specialists may reach 40% in some areas. However the value of the data is enhanced by these specialists measuring as well as identifying the specimens. The analysis of the fishes from 1932 to 1939 was by H.G. Stubbings and for a prolonged period from1948 to 1968 by G.T.D. Henderson. Following his retirement fish were identified by V. Bainbridge and G.A. Cooper. P.B. Hart took over from Bainbridge from 1970-1973 and then S.H. Coombs replaced him. On Cooper's retirement, work on fish larvae was continued by Coombs, R.K. Pipe, C.E. Mitchell, C.A Fosh, N.C. Halliday and J. Roskell. During the late 1970s and early 1980s the analysis of all the fish larvae was discontinued but targeted analysis for species of particular interest were maintained until 1984. More recently in response to specific funding sources, work has been carried out by Halliday on fish, particularly sand eels in the northern North Sea in relation to breeding sea birds (Frederiksen et al. 2006).

The development of methods to extract DNA from the formalin preserved CPR material was initially developed using tissue from a sand-eel (Kirby and Reid, 2002) and has been used subsequently to identify pipefish which have been occurring frequently in CPR samples in recent years (Kirby et al. 2006). This technique provides the potential to identify a larger proportion of specimens and to take the identification to a higher level of resolution than is possible with morphological examination of the frequently damaged specimens.

A list of fish taxa recorded in the CPR and of publications on the results of the analyses of CPR analysis is given in Table 1.

The data were only available as hard copy records until recently when, aided by the MarBEF MarData RMP, the biogeographical data for the analyses from 1948 to 1972 were put into a database. Now further hard copy data have been located and these data and the measurements will be put into a database in a programme funded by a contract through the Centre for Environment, Fisheries and Aquaculture Science (CEFAS). This programme will also fund the analysis of fish in CPR samples for the years in which this analysis has not been carried out. It is intended that this should be maintained into the future.

**Table 1.** Fish taxa identified in the CPR survey and publications where results referring to these are published.

| Taxon | Notes (ERMS identity) | References |
|---|---|---|
| Ammodytidae | Mainly *Ammodytes marinus* Raitt 1934 in the North Sea | Stubbings, 1951; Henderson, 1953; Henderson, 1961; Bainbridge & Cooper, 1971; Hart, 1974; Coombs, 1975; Coombs, 1980; Frederiksen et al., 2006 |
| Ammodytidae/ Clupeidae | Damaged specimens that could not be referred to Family with certainty | |
| Anguilliforms | Mainly *Anguilla anguilla* | Stubbings, 1951; |

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| | (Linnaeus, 1758) | Henderson, 1961; Coombs, 1980. |
| Argentinidae | Probably mainly *Argentina sphyraena* Linnaeus, 1758 | Coombs, 1980. |
| *Arnoglossus laterna* | *Arnoglossus laterna* (Walbaum, 1792) | Stubbings, 1951; Coombs, 1980. |
| Blennidae | Blenniidae | |
| *Brosme brosme* | *Brosme brosme* (Ascanius, 1772) | Stubbings, 1951; Coombs, 1980 |
| *Callionymus* sp. | Probably mainly *Callionymus lyra* Linnaeus, 1758 | Stubbings, 1951; Coombs, 1980 |
| *Chirolophis ascanii* | *Chirolophis ascanii* (Walbaum, 1792) | Henderson, 1953; |
| Cottidae | | |
| Clupeidae | Mainly *Clupea harengus* Linnaeus, 1758, *Sardina pilchardus* (Walbaum, 1792)<br>and *Sprattus sprattus* (Linnaeus, 1758) | Stubbings, 1951; Henderson, 1953; Bainbridge & Cooper, 1971; Bainbridge et al. 1974, Coombs 1980; Coombs et al 2005 |
| *Enchelyopus cimbrius* | *Enchelyopus cimbrius* (Linnaeus, 1766) | Stubbings, 1951; |
| *Gadiculus argenteus thori* | *Gadiculus argenteus* Guichenot, 1850 | Henderson, 1953; Coombs, 1980 |
| Gobiidae | | Stubbings, 1951; Henderson, 1953; |
| Gadoid Unidentified | | |

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|---|---|---|
| *Trisopterus esmarkii* | *Trisopterus esmarkii* (Nilsson, 1855) | Henderson, 1953; Coombs, 1975; Coombs, 1980 |
| *Trisopterus luscus* | *Trisopterus luscus* (Linnaeus, 1758) | Henderson, 1953; Coombs, 1980 |
| *Trisopterus minutus* | *Trisopterus minutus* (Linnaeus, 1758) | Henderson, 1953; Coombs, 1980 |
| *Gadus morhua* | *Gadus morhua* Linnaeus, 1758 | Henderson, 1961; Coombs, 1980; |
| *Glyptocephalus cynoglosus* | *Glyptocephalus cynoglossus* (Linnaeus, 1758) | Stubbings, 1951; Henderson, 1961; Coombs, 1980; |
| *Hippoglossoides platessoides* | *Reinhardtius hippoglossoides* (Walbaum, 1792) | Henderson, 1953; Coombs, 1975; Coombs, 1980; Coombs & Mitchell, 1981; |
| *Hippoglossus hippoglossus* | *Hippoglossus hippoglossus* (Linnaeus, 1758) | Henderson, 1961; Coombs, 1980 |
| Labridae | | |
| *Lampanyctus crocodilus* | *Lampanyctus crocodilus* (Risso, 1810) | Coombs, 1980 |
| *Limanda ferruginea* | *Limanda ferruginea* (Storer, 1839) (not in ERMS) | Coombs, 1980 |
| *Limanda limanda* | *Limanda limanda* (Linnaeus, 1758) | Stubbings, 1951; Henderson, 1961; Coombs, 1975; Coombs, 1980; |
| *Mallotus villosus* | *Mallotus villosus* (Müller (ex Olafsen), 1776) | Bainbridge & Cooper, 1971; Coombs, 1980 |
| *Maurolicus muelleri* | *Maurolicus muelleri* (Gmelin, 1789) | |
| *Melanogrammus aeglefinus* | *Melanogrammus aeglefinus* (Linnaeus, 1758) | Coombs, 1975; Coombs, 1980 |
| *Merlangus merlangus* | *Merlangius merlangus* (Linnaeus, 1758) | Stubbings, 1951; Henderson, 1961; Coombs, 1975; Coombs, 1980; |
| *Merlucius bilinearis* | *Merluccius bilinearis* (a Hake) (Not in ERM S) | Coombs, 1980 |
| *Merlucius merluccius* | *Merluccius merluccius* (Linnaeus, 1758) | Henderson, 1953; Coombs, 1980 |
| *Microchirus variegates* | *Microchirus (Microchirus) variegatus* (Donovan, 1808) | |

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|---|---|---|
| *Micromesistius poutassou* | *Micromesistius poutassou* (Risso, 1827) | Stubbings, 1951; Henderson, 1953; 1957; Henderson, 1961; Bainbridge & Cooper, 1971; Bainbridge & Cooper, 1973; Coombs, 1975; Coombs, 1980; [2] |
| *Microstomus kitt* | *Microstomus kitt* (Walbaum, 1792) | Stubbings, 1951; Henderson, 1961; Coombs, 1980; |
| *Molva molva* | *Molva molva* (Linnaeus, 1758) | Henderson, 1953; Coombs, 1980 |
| Myctophidae | See also *Lampanyctus crocodilus* | |
| *Onos* spp. | *Ciliata* Couch, 1832 | |
| *Pagellus bogaraveo* | *Pagellus bogaraveo* (Brünnich, 1768) | Coombs, 1980 |
| Paralepididae | | Coombs, 1980 |
| *Pholis gunnellus* | *Pholis gunnellus* (Linnaeus, 1758) | |
| *Phrynorhombus norvegicus* | *Phrynorhombus norvegicus* (Günther, 1862) | Coombs, 1980 |
| *Platichthys flesus* | *Platichthys flesus* (Linnaeus, 1758) | Stubbings, 1951; Coombs, 1980 |
| *Pleuronectes platessa* | *Pleuronectes platessa* Linnaeus, 1758 | Stubbings, 1951; Henderson, 1961; Coombs, 1975; Coombs, 1980; |
| Pleuronectidae | Unidentifiable to species | Stubbings, 1951; |
| *Pollachius pollachius* | *Pollachius pollachius* (Linnaeus, 1758) | Henderson, 1953; Coombs, 1980 |
| *Pollachius virens* | *Pollachius virens* (Linnaeus, 1758) | Stubbings, 1951; Henderson, 1961; Coombs, 1980; |
| *Raniceps raninus* | *Raniceps raninus* (Linnaeus, 1758) | |
| *Scomber scombrus* | *Scomber scombrus* Linnaeus, 1758 | Henderson, 1953; Henderson, 1961; Bainbridge & Cooper, 1971; Bainbridge et al. 1974, Coombs, 1975; Coombs, 1980; Coombs & Mitchell, 1981. |
| Scopelidae | Neoscopelidae | |
| *Sebastes* sp. | *Sebastes* Cuvier, 1829 | Bainbridge, 1965; Bainbridge & Cooper, 1971; Henderson, 1953; Coombs, 1980; * |

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|---|---|---|
| Soleidae | Mainly *Solea solea* (Linnaeus, 1758) in the North Sea and *Microchirus (Microchirus) variegatus* (Donovan, 1808) in the western English Channel and south-west of Ireland. | Stubbings, 1951; Henderson, 1953; Coombs, 1980 |
| *Stomias* spp | *Stomias* | Henderson, 1961; Coombs, 1975; Coombs, 1980; Henderson, 1953; |
| Syngnathidae | Mainly *Entelurus aequoreus* | Coombs, 1980, Kirby et al. 2006, Lindley et al. 2006 |
| *Taurulus bubalis* | *Taurulus bubalis* (Euphrasen, 1786) | |
| *Trachinus vipera* | *Echiichthys vipera* (Cuvier, 1829) | Stubbings, 1951; |
| *Trachurus trachurus* | *Trachurus trachurus* (Linnaeus, 1758) | Stubbings, 1951; Coombs, 1980 |
| Triglidae | | |
| Unidentified | | |
| *Urophycis chuss* | *Urophycis chuss* (Walbaum, 1792) | |
| *Zeugopterus punctatus* | *Zeugopterus punctatus* (Bloch, 1787) | |

[1] Plus contributions to *Annales Biologiques* by Henderson (1961- 1968), Bainbridge and Cooper (1969, 1970); Hart and Cooper 1972): Cooper (1973- 1976), Robinson (1977); Coombs (1978), Coombs and Mitchell (1979, 1982); Mitchell and Coombs, 1980, 1981); Fosh and Halliday (1984); Fosh and Keen (1985), Roskell ( 1986a, b)

[2] Plus contributions to *Annales Biologiques* by Coombs and Pipe (1979,1981); Pipe and Coombs (1980).

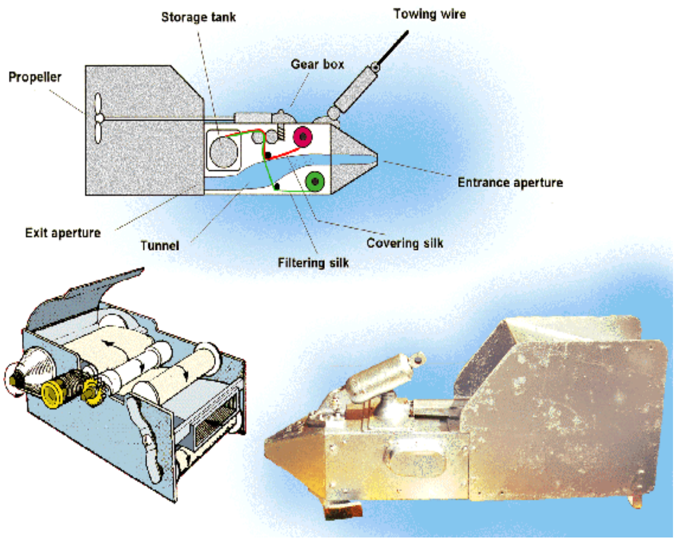


Figure 1. The Continuous Plankton Recorder currently in use.

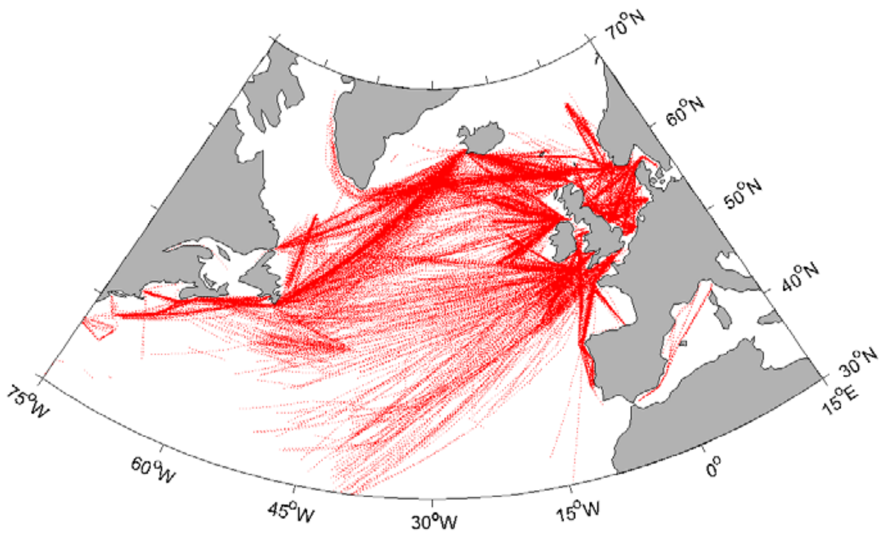


Figure 2. The distribution of CPR sampling in the North Atlantic and adjacent seas.

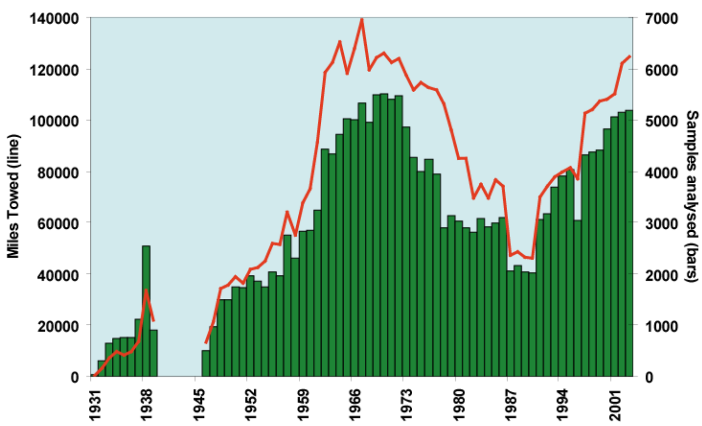


Figure 3. Distance (nautical miles) towed and samples analysed by the CPR

# Methods.

The CPR as used in the routine survey of the North Sea and North Atlantic (Figure 1) was designed by Hardy (1939) and has been unchanged except for minor alterations to the external body to correct for instability at towing speeds higher than those normal when the original was devised (Batten et al. 2003). The sampling aperture is a 1.27mm square opening at the front of the machine. The water is filtered through a band of silk gauze with mesh size ~ 270µm. The gauze is wound on by a drive powered by an impeller and the gauze with the retained plankton is covered by a second band and the sandwich of plankton between two layers of gauze is compressed by rollers and rolled into a storage tank where it is preserved.

The recorders are towed by ship-of opportunity, usually merchant ships on regular routes. As far as possible a tow is taken on each route in each calendar month. The distribution of samples is shown in Figure 2. The geographical coverage and hence numbers of samples has varied from year to year according to the funding available. (Figure 3.)

On return of the CPRs to the laboratory, the gauze is divided into sections representing 10 nautical miles (18km) of tow during which $3m^3$ are filtered. The positions and times of the mid-point of each sample are calculated from data provided by the ship. Normally alternate samples are analysed. The method of analysis of samples is described by Batten et al. (2003). Total numbers of “Young Fish” and “Fish Eggs” are counted in the last stage of analysis.

Samples in which fish have been recorded are re-examined by a specialist (and in some cases the adjacent “non-analysed” sample have also been examined”. The specimens are identified where practicable to species but often a higher taxonomic level is the best that can be achieved, and the specimens are measured.

The routine data processing procedure with the hard copy data was to calculate mean numbers per sample for 2° latitude x 1° longitude rectangles for each month of sampling and then to use those data to calculate mean values for the larger standard areas shown in Figure 4). The rectangle and standard area values can then be used to calculate annual mean values, mean values for each calendar month over multi-year periods or long term mean values. Other combinations of rectangles were used for specific purposes and examples of the use of both standard areas and “customised” areas can be seen in Coombs, 1980. The ability to manipulate data on databases will make extraction and processing of data more flexible.

The measurements of fish can be used to split the counts into size classes to define the spawning/hatching times areas and subsequent dispersal (e.g. Bainbridge and Cooper (1973). The results can also indicate changes in the size composition of the pelagic stages taken by the CPR

# Examples of results

The geographical distributions of fish in the CPR survey have been described in many of the publications listed in Table 1. The extent of the oceanic distributions and the abundance of the blue whiting (*Micromesistius poutassou*) in the north-eastern Atlantic and *Sebastes* spp. (redfish) in the north-western Atlantic were little known until the CPR survey extended to cover these areas. The overall distributions of these in the period 1958-1972 described by Coombs (1980) are shown in Figure 5 (adapted from Corten and Lindley, 2003)

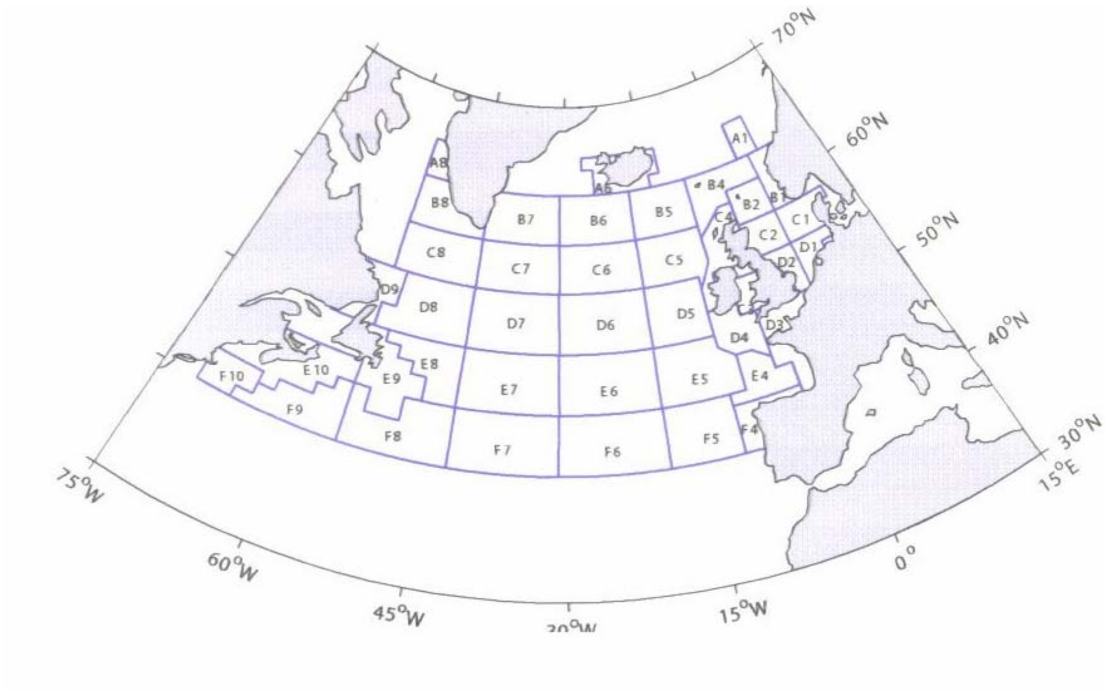


Figure 4. Standard areas of the CPR survey

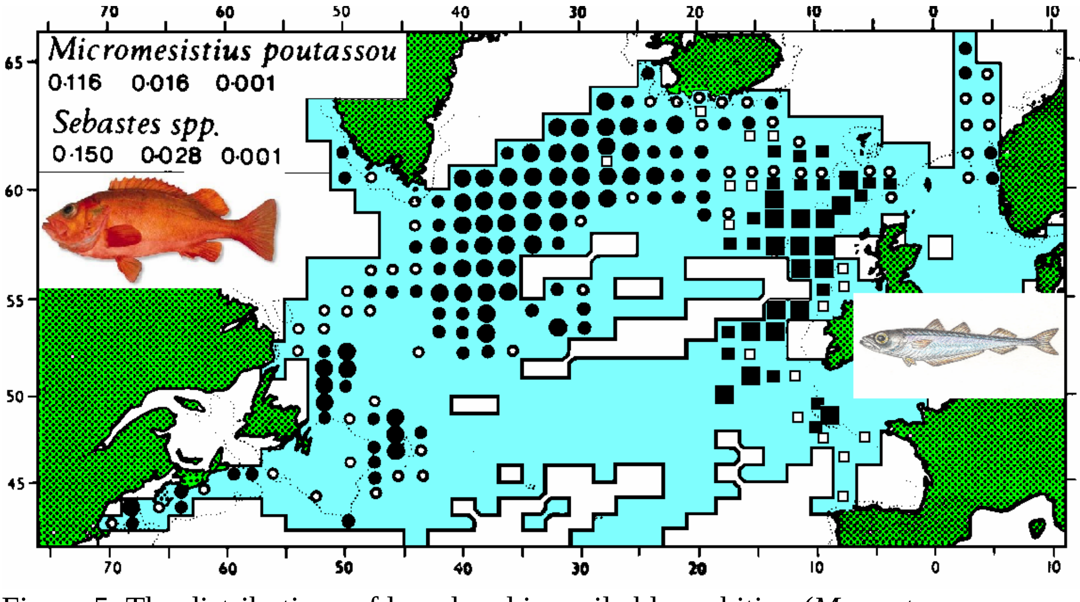


Figure 5. The distributions of larval and juvenile blue whiting (*M. poutassou*, squares) and redfish (*Sebastes* spp., circles) in CPR records 1958-1972 after Corten and Lindley (2003).
Images- http://www.seafoodfromnorway.com/binary?id=14929; (Redfish), http://www.fishin.fo/showroom/fishin/ew/media/Fiskar/drawing_svartkaft.jpg (blue whiting),

Year-to year changes in abundance and distribution can be described and analysed. For example Bainbridge and Cooper (1973) showed changes in the distribution of blue whiting between 1948 and 1970. Abundance peaked in standard area B5 in the late 1950s, in area C5 in the early 1960s and numbers increasing in D5 the most southerly area in the late 1960s (Figure 6).

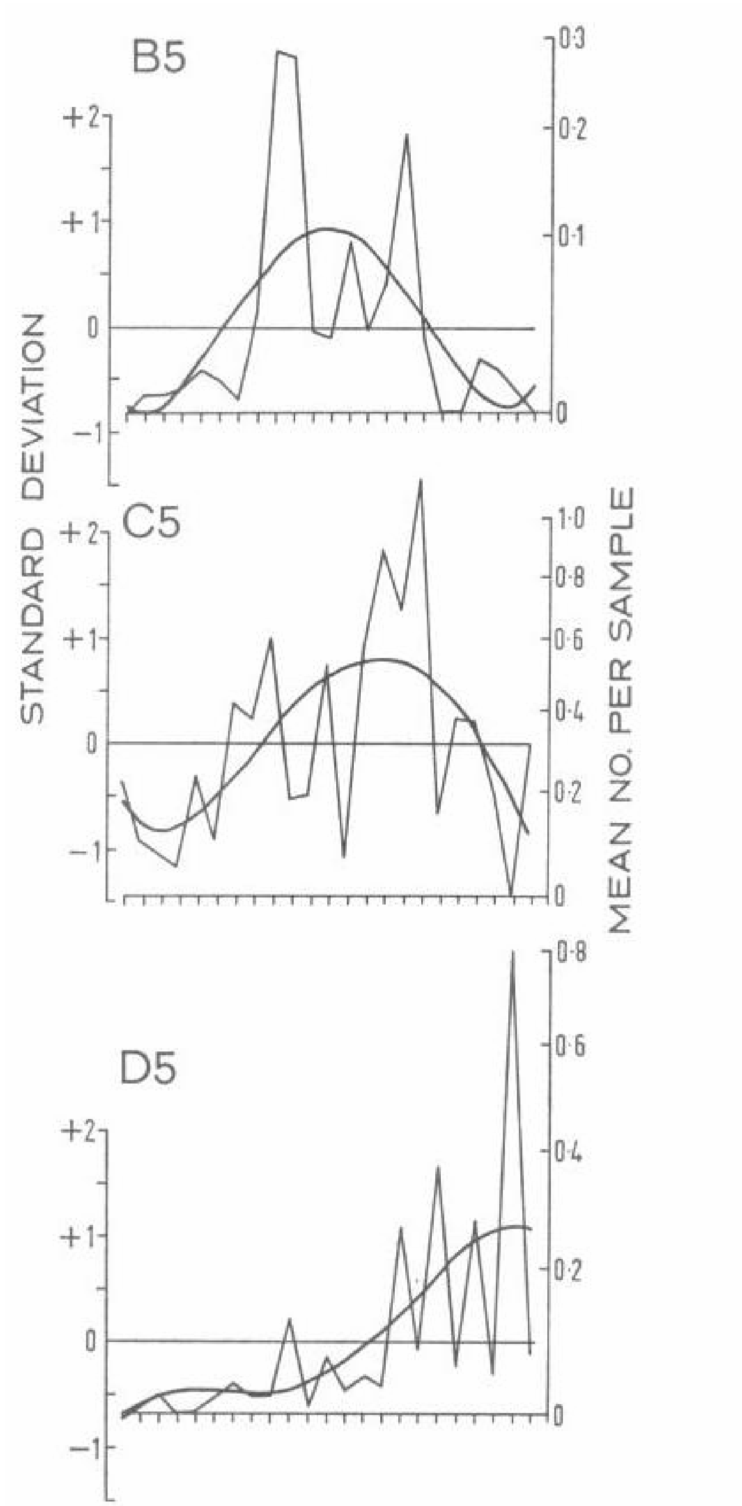


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Figure 6. Changes in abundance of blue whiting in standard areas B5, C5 and D5, 1948-1970 (after Bainbridge and Cooper, 1973).

Mean seasonal distributions can also be plotted. Although the planktonic stages of fish population may only occur in the CPR for a short period in any given area, multiple populations with different seasonal cycles (e.g. herring) or regional differences in the breeding season (e.g. mackerel) result in presence of the species over prolonged period (Bainbridge et al., 1974). The mean monthly distributions of early mackerel larvae in CPR samples for 1948-1967 are shown in Figure 7.

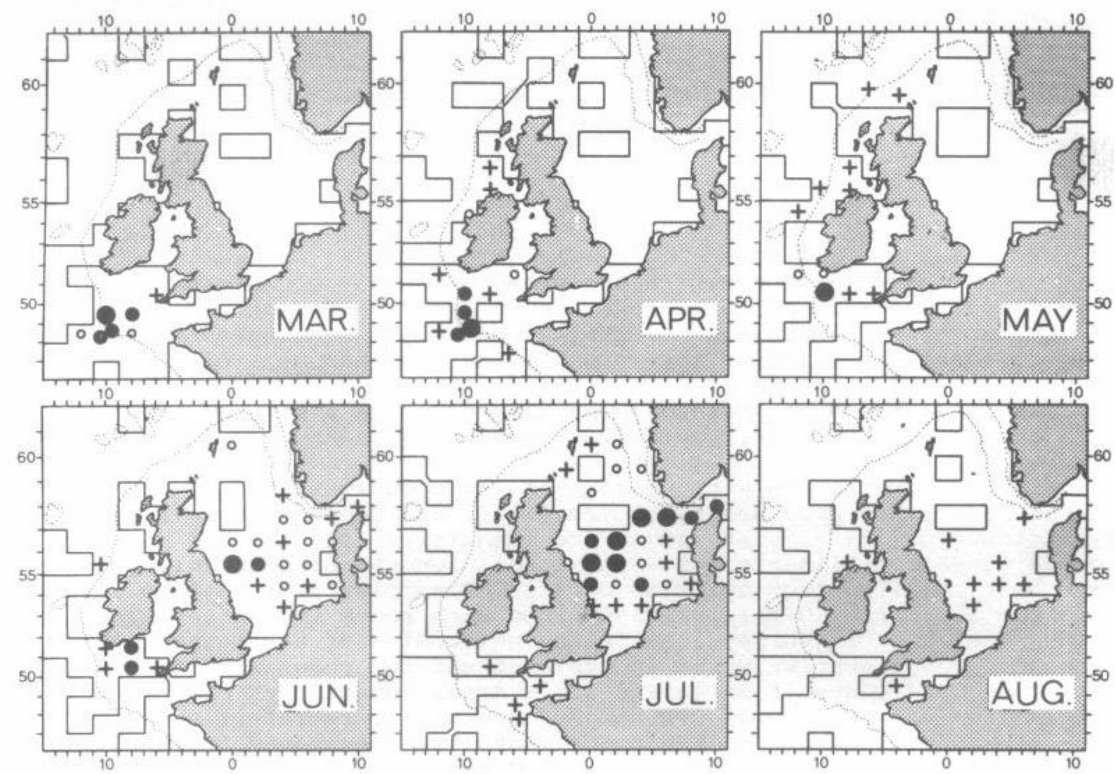


Figure 7. Monthly distributions of early larvae of mackerel (<5mm length) 1948-1967 after Bainbridge et al. (1974). + <0.09, small open circles 0.21-0.29, smaller filled circle 0.3-0.99, larger filled circle >1.0 larvae per sample.

The measurement of specimens can give an indication of the health of the population and the food value of the young fish to predators. Recently Frederiksen et al. (2006) have shown that the size of sandeels in CPR samples in the North Sea in June shows the same trend of decline as was found for fish carried by Puffins to feed their chicks (Figure 8)

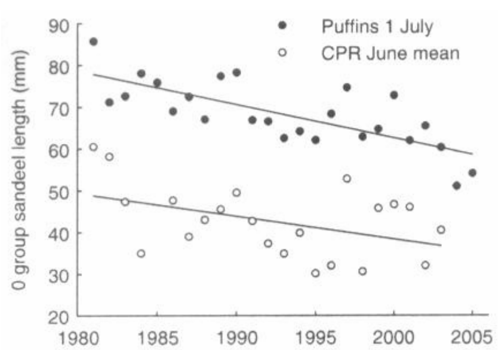


Figure 8. Mean length of sandeels from Puffins standardised to 1st July and from CPR samples in June

A recent topic of interest has been the unusual abundance of the snake pipefish (*Entelurus aequoreus*) in the north-eastern Atlantic and adjacent seas. Kirby et al. (2006) and Kloppermann and Ulleweit (2007 have described the abundance of this species to the west of the British Isles and Harris et al. (2007) have shown a much more extensive increase. Figure 9 shows the records of Syngnathidae in the CPR sample from 1958-1972 (from Coombs, 1980), the area where pipefish were reported by Kirby et al. 2006 and the records from the CPR subsequent to those included in the latter paper and the monthly numbers of specimens taken.

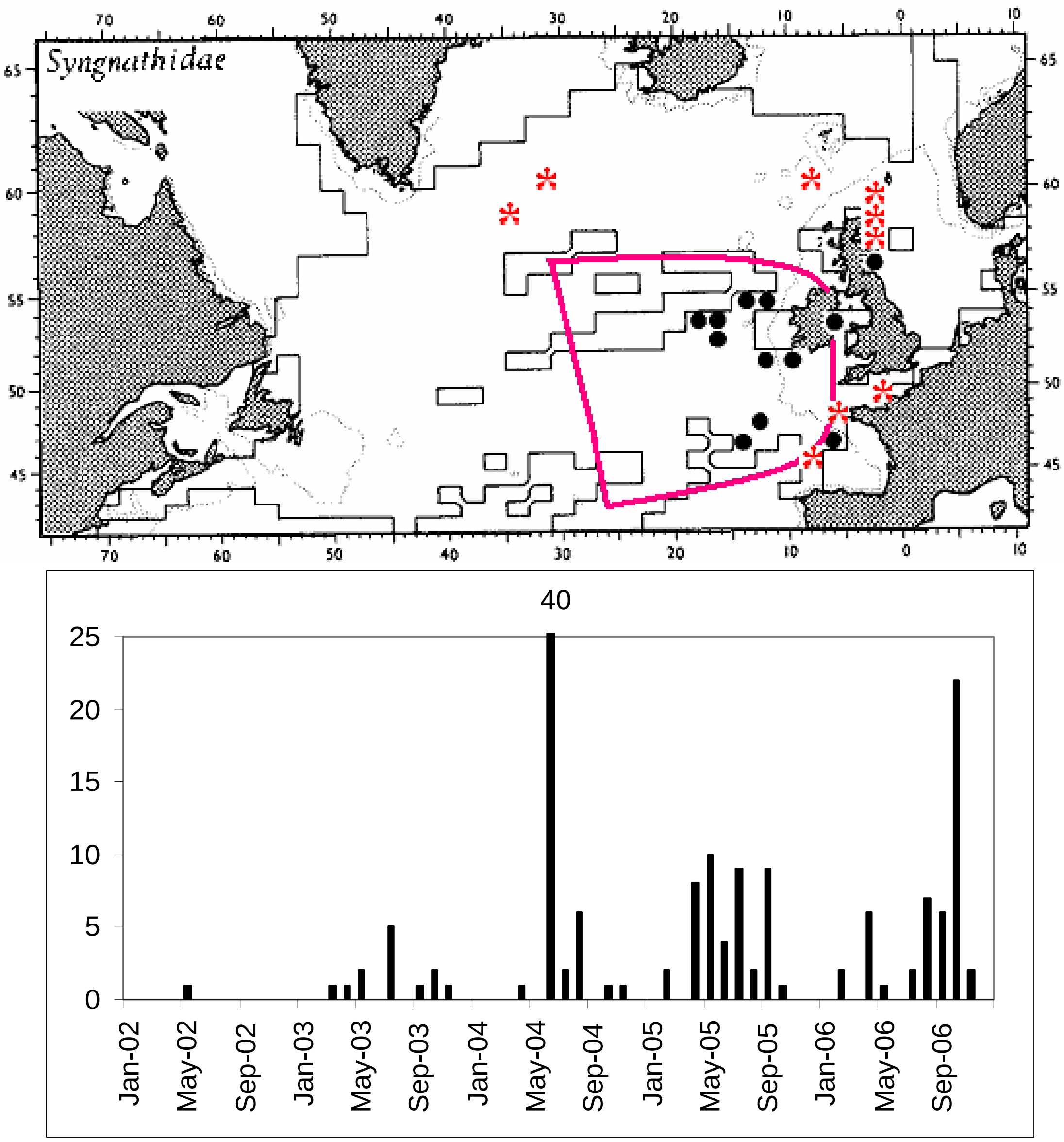


Figure 9. Above. The distribution of pipefish in CPR sample 1958-1972 ((From Coombs, 1980) with red line indicating boundary of records presented by Kirby et al. 2006) and subsequent records outside this area indicated by red asterisks.
Below. Monthly numbers of pipefish in CPR samples 2002- 2006. (2006 data incomplete)

## Discussion

The use of CPR fish data has been limited until now by the fact that they have been available only in hard copy form. The transfer of the data to database will make the data available to a wider range of potential users in a more flexible way than before. The biogeographical data for 1948-1972 is, or will shortly be available online. A more extensive database, including the measurements and the addition of the data for later years will become available within the next few years.

The changes in distribution and phenology of the plankton due to climatic variation (Beaugrand et al. 2002; Edwards and Richardson, 2004) described from the results of the CPR survey have been very far-reaching, not least in their impact on the fisheries (Beaugrand et al. 2003). The addition of the results of specialist analysis of the fish in the CPR will facilitate a range of research on the interactions between climate, plankton, fish and trophic higher levels. The addition of the fish data for the last three decades may cast further light on the causes of the increase on pipefish and blue whiting in the water the west of Britain and changes in the abundance of horse mackerel in the North Sea.  Further data on variations in the distribution, abundance and phenology of fish in the CPR survey will contribute to interpretation on the effects of climate and exploitation on fish stocks.

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