

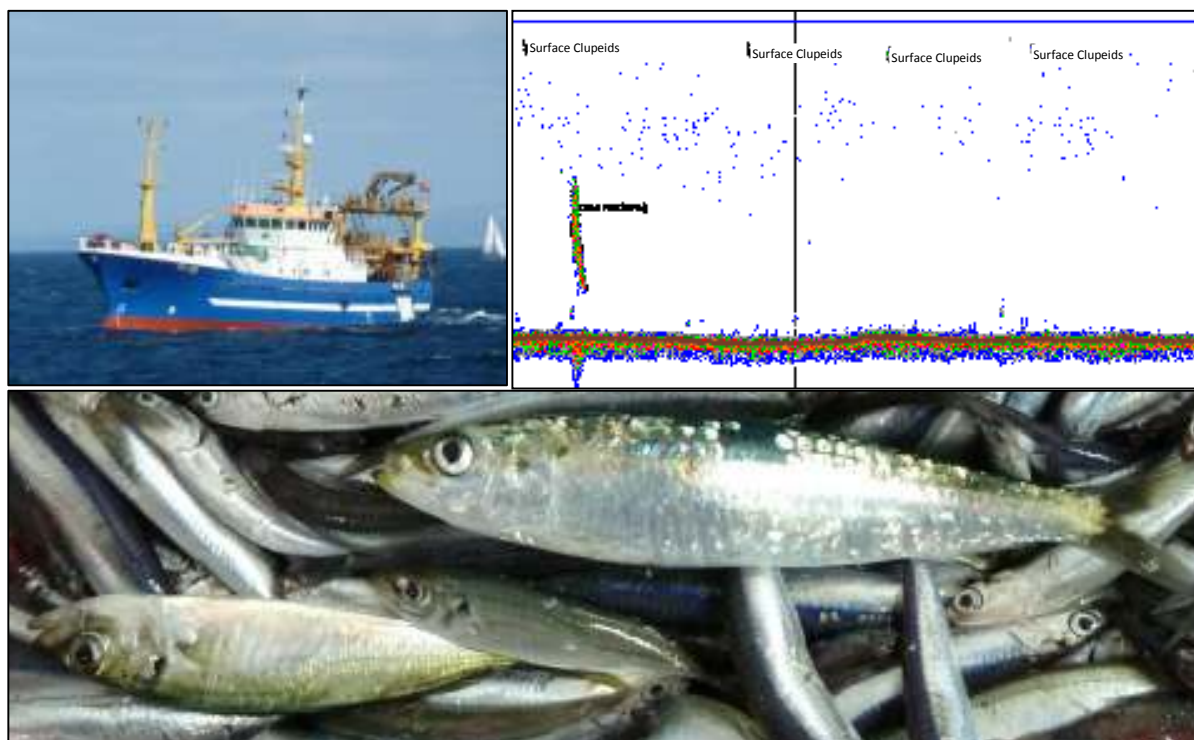
Final Report

***Programme 40:
Sardine and anchovy off Southwest
England***

Prepared by:

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Summary

The Pelagic Pair Freezer Trawlers *Wiron 1*, skipper D. Kuijt, and *Wiron 2*, skipper A. Hoek, were chartered for a multidisciplinary fieldwork programme to:

1. use acoustic methods, trawl, plankton sampling and CTD to collect information on the distribution, age and length composition, spawning and habitat of sardine and anchovy in the southwest of the UK, within the British fishing limits.
2. gain a better understanding of the population dynamics of sardine and anchovy in the Celtic Sea and Western Channel, including the interactions between the UK stocks and those farther south.

Although the survey was curtailed by engine problems experienced by one of the vessels, novel data collected during the survey suggested that a late spring, early summer spawning population of sardine is present over the Celtic Sea shelf. A large proportion of old sardine in the sampled population was also suggestive of fishing pressure currently being sustainable, but more data need to be collected to corroborate this. No adult anchovy were caught during the survey, nor were any anchovy eggs or larvae found. As this species is found regularly in these waters, and indeed specimens collected by the fishing industry from the Channel were analysed during this study, the question is left as to the spawning population from which these fish derive.

Introduction

The Fisheries Science Partnership (FSP) was established in 2003 to build relationships between fishermen and scientists, and to involve fishermen in the co-commissioning of science. The FSP is funded by the UK's Department for Environment, Food and Rural Affairs (Defra). Since it was established, the programme has undertaken numerous projects, such as investigations into fishing gear selectivity, the examination of spatial patterns and catch compositions, and time-series of relative abundance of commercial species. A full description of the development, aims and reports of the FSP programme can be found on the Cefas website (www.cefas.co.uk).

This report presents the results of a one-off programme on sardine and anchovy off Southwest England. The project was an ambitious programme in which the commercial pair-trawlers *Wiron 1* and *Wiron 2* were chartered to undertake a multidisciplinary survey to investigate different components of the population dynamics of the two pelagic species in UK waters, including by collaborating with and building upon the expertise from the skippers.

Motivation

Several regionally important pelagic fisheries operate in the southwestern Approaches (ICES divisions VIIe-j, VIIIa). Traditionally, the main commercially exploited pelagic stocks have included mackerel (*Scomber scombrus*), horse mackerel (*Trachurus trachurus*), sprat (*Sprattus sprattus*) and herring (*Clupea harengus*). In recent years, however, there has been an increase in

both commercial landings and catches in fishery-independent surveys of both anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) around the British Isles.

Given the concern over the stock of anchovy in ICES subarea VIII, more accurate studies on this species in subarea VII are required to determine whether separate stocks exist, or whether there has been a northward shift in the distribution of the single stock. Anchovy are now being taken by UK fisheries, mainly for export to continental Europe.

The sardine stock in the Celtic Sea has also increased, and currently it forms the basis of a locally important fishery (colloquially referred to as Cornish sardine). Information to hand suggests that there are subpopulations within the NE Atlantic sardine stock. Indeed, the Cornish sardine ringnet and driftnet fishery has recently been tested against the Marine Stewardship Council Principles and Criteria for Sustainable Fishing. The assessment team made a specific recommendation that studies be undertaken in collaboration with UK research agencies to clarify the existence and seasonal distribution of local sardine spawning populations. Currently, even the most basic knowledge of the biology of these species is limited.

Background

Sardine and European anchovy are lower-trophic-level pelagic species whose northernmost distribution is in the Northeast Atlantic, specifically in the waters around Great Britain. Anchovy and sardine are generally associated with warmer, southern European waters (the so-called Lusitanian ecoregion).

Information on sardine in British waters is relatively limited. However, anecdotal evidence suggests that European sardine, locally also known as pilchard, have been targeted by a dedicated inshore fishery in Devon and particularly Cornwall during warmer periods from at least the late sixteenth century (Southward *et al.*, 1988) with annual catches of up to 5000 t (Cushing, 1957). The first survey and probably the only dedicated fieldwork on both adult sardine and their eggs and larvae in the northern part of the distribution (Cushing, 1957) explored various aspects of the population dynamics in the Channel. Large numbers of eggs were found mainly in May and June, particularly in the western Channel, suggesting that the area is a preferred spawning site for the species (Cushing, 1957).

Further anecdotal evidence suggests that at the end of the 19th century, anchovy were also caught regularly by the winter sprat fishery in the English Channel, along the south coast of Wales and off eastern England, sometimes in large numbers (Cunningham, 1890). Various other sources confirm that over the past century, anchovy, although generally rare in the waters around Great Britain, were periodically found in high abundance and that they are widespread throughout the area during these periods, with several distinct spawning locations.

The populations of both species in British waters clearly fluctuated dramatically over the past few hundred years. For instance, during the 20th century increases were observed in egg production between the 1930s and 1960s (Southward and Boalch, 1988; Southward *et al.*, 1988). This trend was confirmed by studies on long time-series of fishery-independent data (Beare *et al.*, 2004a, b). In addition, there has been a more-recent (from the mid 1990s) increase

in sardine and anchovy stocks in northern waters (Boddeke and Vingerhoed, 1996; Armstrong *et al.*, 1999; Beare *et al.*, 2004a, b).

Objectives

- 1 To use acoustics and biological data collected using plankton gear and fishing gear, to establish the range of distribution of sardine and anchovy within British fishing limits, to determine spawning locations and to identify the age groups in the survey area.
- 2 To gain a better understanding of the population dynamics of sardine and anchovy in the Celtic Sea and western Channel, including the interactions between the stocks in UK waters and those farther south.

Methods

The results presented in this report are based mainly on data collected during a survey conducted in June 2010. However, as the survey was curtailed by engine problems experienced on one of the vessels, we also used supplementary data on anchovy and sardine from the same area, collected by the commercial fishing fleet and during a CEFAS research programme before and after the survey.

Survey

The Pelagic Pair Freezer Trawlers *Wiron 1* and *Wiron 2* were chartered for the field programme (Figure 1).



Figure 1. FVs *Wiron 1* and *Wiron 2* (length 51.44 m) in Scheveningen harbour (Netherlands), June 2010.

As the area of interest was too large to survey at high resolution in its entirety, a provisional survey plan was drafted (Figure 2, Appendix 1), including three grids with high-resolution

sampling, one on the south coast of Cornwall (grid 1), one on the edge of the Celtic Sea shelf (grid 2) and one north of Cornwall (grid 3). Another two (southern and northern) cross-shelf transects were included to provide information on the areas in between these grids. The idea was to use the detailed information from the grids to extrapolate onto the cross-shelf transects. The entire survey was designed within UK fishing limits. The grids were located in areas of particular interest: grid 1 was situated in the key target area for the Cornish sardine fishery, grid 2 was included to determine the extent of the distribution of these species to the shelf edge and grid 3 was included because there is no information available from the area, and yet landings of sardine have been reported from there (see Figure 3).

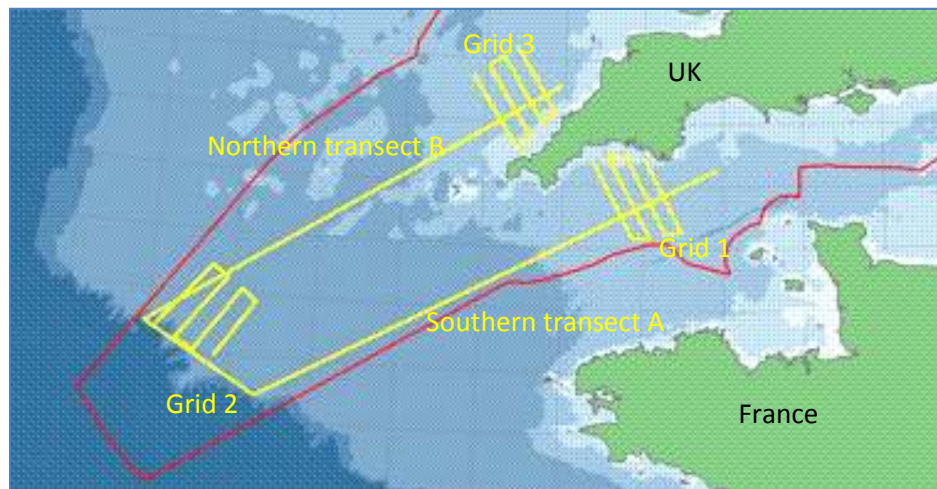


Figure 2. Provisional draft design of the 2010 FSP 040 survey (yellow lines) within the UK fishing limits (red polygon).

The fieldwork commenced on 11 June. Although commercial landings of sardine tend to be relatively small during June (Figure 3), the timing of the survey was chosen to target the sardine at their peak spawning, which has previously been reported to take place between May and July (Cushing, 1957; Coombs *et al.*, 2005). Another consideration for the timing was the ability to compare the data on sardine and anchovy in the southwest of Britain with those recorded farther south in subarea VIII (Bay of Biscay). The French have an annual survey that specifically targets both pelagic species and takes place in May.

Unfortunately, owing to a combination of adverse weather and serious engine problems on *Wiron 2*, the survey was aborted four days into the field programme and only covered part of grid 1, the southern cross-shelf transect A, one transect in grid 2, and ~70% of the northern cross-shelf transect B (see Appendix 2 for detailed cruise log).

Fisheries acoustics

Acoustic data were recorded to establish the distribution and abundance of the pelagic species in the area. The *Wiron 2* provided the main acoustic platform owing to its superior equipment compared with the *Wiron 1*: the former was equipped with three SIMRAD ES60 echosounders, a 38 and 120 kHz splitbeam system, a 70kHz splitbeam system and a 200kHz single beam system.

All four frequencies were calibrated at the start of the survey off Plymouth (50°17.7N; 4°12.25W at 40 m deep). Calibrating fisheries acoustic echosounders (Foote *et al.*, 1987) involves suspending a metal (tungsten carbide) sphere with known target strength below the transducers (Figure 4) and is generally performed to allow the processed fisheries acoustic backscatter data on (pelagic) fish species to be used for biomass calculations.

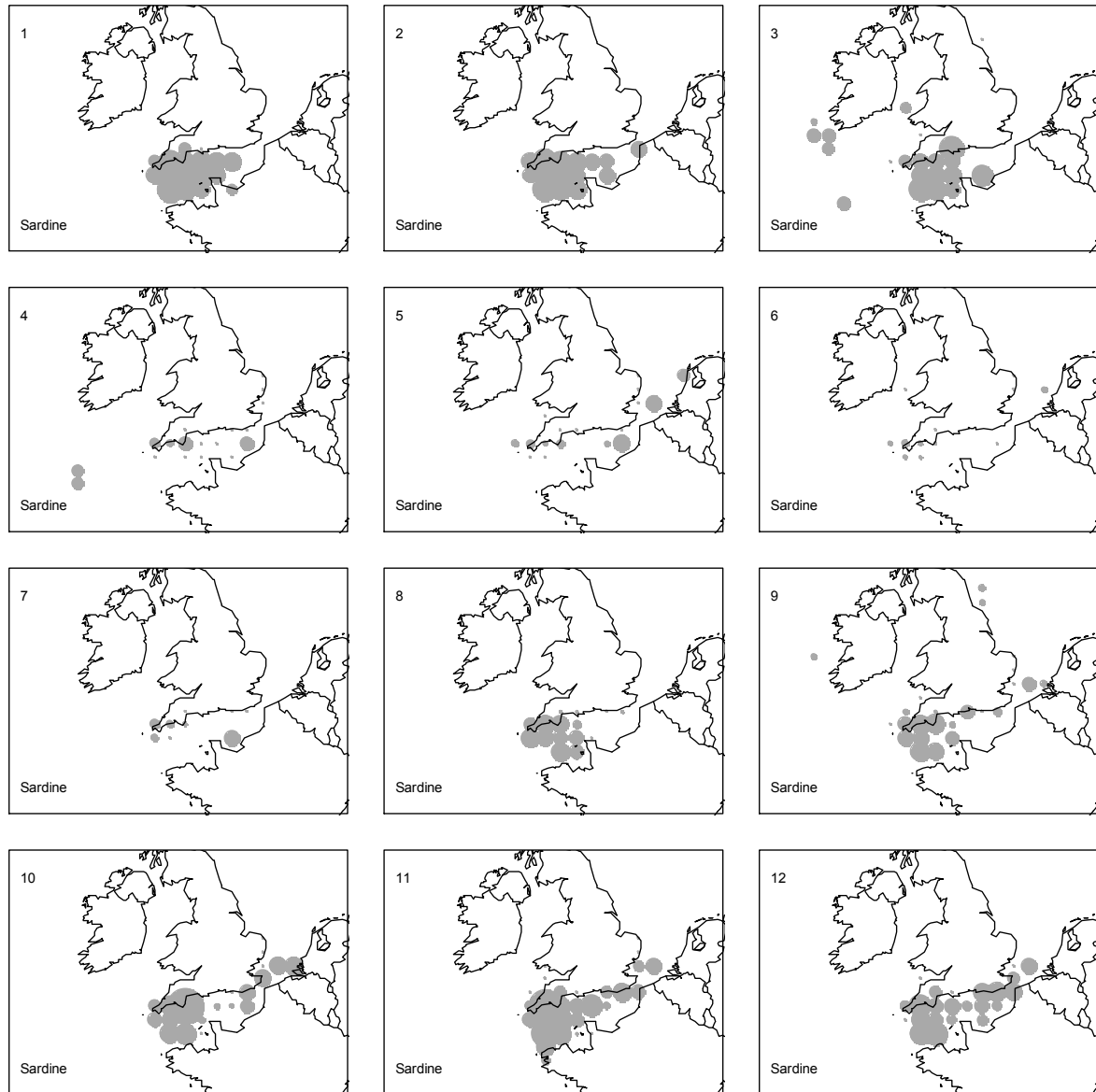


Figure 3. Sardine landings by ICES rectangle averaged per month (1-12) over the period 1982-2007. Landings include all those made by English and Welsh vessels, and by foreign vessels using English ports.

Although the weather conditions were good, the strong tidal flows (spring tide) slowed the process, but all four frequencies were eventually successfully calibrated. Between 12 and the morning of 15 June 2010, fisheries acoustics were run continuously at all available frequencies on board the *Wiron 2*. Fisheries acoustic data were also recorded on the *Wiron 1* at 38 kHz

(SIMRAD ES60) and 70 kHz (SIMRAD ES70) splitbeam frequencies. Although not calibrated, these data were recorded to provide a comparison dataset with the acoustic data from the *Wiron 2*. As the vessels steamed 5 nautical miles apart in parallel during the acoustic transect, these data provided increased qualitative acoustic coverage. First, a correction was applied to the raw acoustic data to compensate for the 1 dB triangle wave error in ES60 data (Keith et al., 2005). The corrected fisheries acoustic data were cleaned and processed back in the laboratory (Cefas, Lowestoft) using Myriax Echoview Software Version 4.9. The calibration offsets were applied to the data: in contrast to the scientific SIMRAD echosounder EK60, the ES60 has no built in calibration software, so we applied the methods described by Honkalehto and Ryan (2003) to apply correct calibration settings in the processing files.

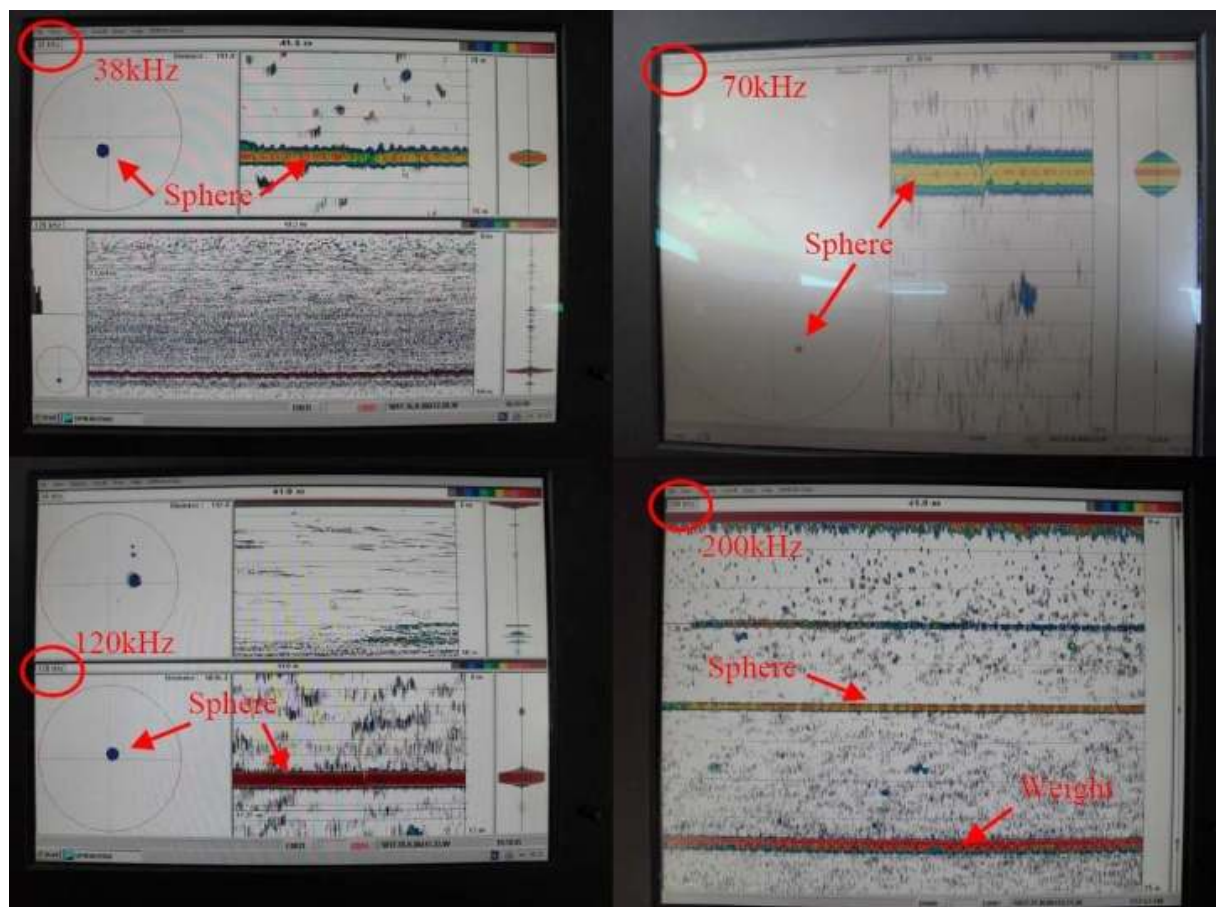


Figure 4. Screenshots of Simrad ES60 echosounder displays of the four frequencies (as indicated on the images) during the calibration process. The splitbeam 38, 70 and 120 kHz displays consist of an echogram with horizontal line (sphere in beam) as well as a cross-section of the beam in the single target window (circle with four quadrants) in which the single target (sphere) is visible as a circular mark, close to the centre of the beam. The singlebeam 200 kHz only has an echogram which shows the sphere and the weight attached to the sphere. The top line was thought to be a bit of seaweed stuck to the line and was excluded from the single target analyses. Image created by D. Delaunay.

Next, the seabed and surface exclusion lines were set and schools were selected. Owing to the very limited groundtruth information (two fishing hauls, see below) the vast majority of fish schools could not be identified to species level with certainty. However, using the limited

available groundtruth information, expertise from both skippers, background knowledge of the species in the area and acoustic signatures, we did distinguish different acoustic marks. The results on the distribution of these categories were plotted in ArcGis (Version 9.3). Given the above-mentioned uncertainty in species identity and the premature end to the survey, we did not calculate the biomass of the pelagic species in the area for this report.

Biological sampling

On the survey the trawl was shot on two occasions (Figure 5) to groundtruth acoustic marks and collect fish for biological sampling. The fishing gear consisted of a pair-trawl, with a 15 mm sprat codend (see Appendix 3 for more details). The horizontal opening ranged from 90 to 100 m, and the vertical opening from 18 to 40 m. Technical issues with the pump meant that, once the trawl was hauled, the fish had to be winched on board the *Wiron 2* with a crane. Subsamples of the catch were taken as soon as the catch was on board in the hopper, and before the automated sorting machines had separated the larger from the smaller fish. All fish from the subsample were sorted by species, and measured to the nearest 0.5 cm total length.

Small numbers of sardine were found in the subsamples of both fishing stations. The crew had already processed the catch of the first haul when the first sardine were spotted in the subsample, so no additional samples could be taken. However, at the second station a further 109 fish were taken after the catch had been sorted by the crew for further biological sampling. Fin-clips were taken of the seven sardine from the first haul and of 93 sardine from the second haul, and were stored in 96% ethanol for future genetic work on stock identity (not part of this FSP project). The fish were then frozen in individually marked plastic bags for further biological sampling back in the laboratory.

Once back in the laboratory, the frozen sardine were thoroughly thawed and the otoliths extracted for age determination. One otolith from each fish was embedded in resin and preliminary age readings were made. The remaining otolith was stored for future work on otolith morphology (not part of this FSP project). Gonads were examined to determine the maturity stage.

Supplementary sardine and anchovy were collected from the area before and after the survey (Table 1) and were processed as above.

Table 1. Date, location, source and numbers of anchovy and sardine specimens collected for this study.

Date	Source	Location	Species	Number
Feb '10	Cefas survey (CEND04_10)	Irish Sea	Anchovy	198
April '10	Falmouth Fish Selling Co. Ltd	Western Channel, Falmouth Bay	Anchovy	30
April '10	Falmouth Fish Selling Co. Ltd	Western Channel, Falmouth Bay	Sardine	29
June'10	FSP field survey	Western Channel, Plymouth Bay	Sardine	100
09/07/10	Falmouth Fish Selling Co. Ltd	Western Channel, Wolf Rock	Sardine	111

Plankton and oceanography

Plankton and hydrographic data were recorded from the *Wiron 1* platform, which allowed the *Wiron 2* to continue to survey the acoustic transects without interruption. At one inshore and

one offshore station in grid 1 and at regularly spaced intervals along the cross-shelf transects (Figure 5), a ringnet of 1 m diameter and 200 µm mesh was deployed to a maximum of 75 deep (or the seabed) to collect eggs and larvae of anchovy and sardine. The depth was chosen to include the upper layer above the thermocline, which is where pelagic eggs and larvae would be anticipated. Plankton samples were stored in 4% buffered formaldehyde. Samples were sorted and sardine eggs and larvae were counted back in the laboratory. It was beyond the scope of this project to identify the other eggs and larvae to species level.

A CTD (SAIV) was attached to the plankton net to obtain vertical profiles of the temperature and salinity simultaneously with the sampling. These parameters were recorded to obtain information on the habitat of spawning sardine.



Figure 5. Overview of the survey (left) with detail of Plymouth Bay (right) showing the acoustic transects (black dotted lines), plankton/CTD stations (blue) and fishing stations (green).

Results

Fisheries acoustics

Fisheries acoustics are generally perceived to be the preferred tool to investigate and map the distribution and abundance of pelagic species. There is a need, however, for groundtruth data (trawls) to confirm species identity. As insufficient groundtruth data could be collected during the survey, it was impossible to attribute species identification confidently to the observed acoustic marks. The acoustic backscatter was instead ascribed to different “groups” of pelagic fish and was not converted to biomass per species. The results presented here therefore provide a preliminary insight into the distribution and densities of pelagic species in the British waters of the Celtic Sea shelf and will be further analysed when Cefas undertakes dedicated acoustic research surveys in the area in 2011.

The results of two of the pelagic acoustic categories are presented here. One consisted of small strong (red) marks which fitted the general acoustic characteristics of clupeid marks and were mainly above or in the thermocline (Figure 6). Given their position in the water column and school morphology, they were unlikely to be herring and sprat and were most likely small sardine schools (as also suggested by both skippers). It is, however, possible that some schools consisted of a mixture of species. The other category consisted of a combination of different

marks, including horse mackerel (*Trachurus trachurus*) and mackerel (*Scomber scombrus*), as well as possible whiting (*Merlangius merlangus*) and boarfish (*Capros asper*) marks (Figure 7).

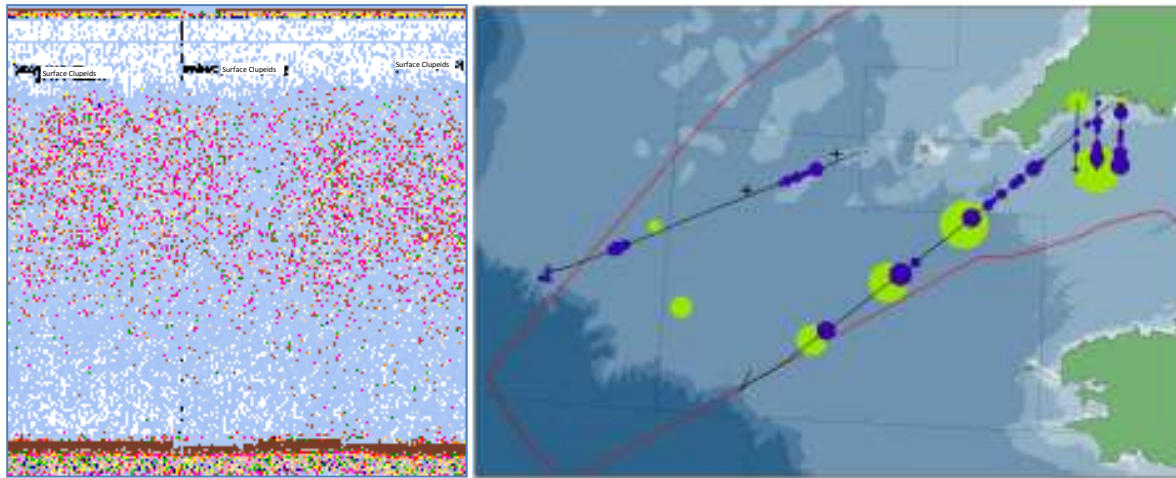


Figure 6. Echogram (left) showing a vertical profile of the water column with the transducer depth at the top (5 m below the surface) and the red/brown seabed below (~70 m deep). Small schools at the surface were categorised as surface clupeids. Note the scattering of small planktonic organisms forming a wavy band below the thermocline (~20 m). Overview of the survey area with surface clupeid schools integrated per 1 nautical mile (blue) along the survey tracks (black). Overlaid are the sardine egg densities from the plankton stations (green, see also below).

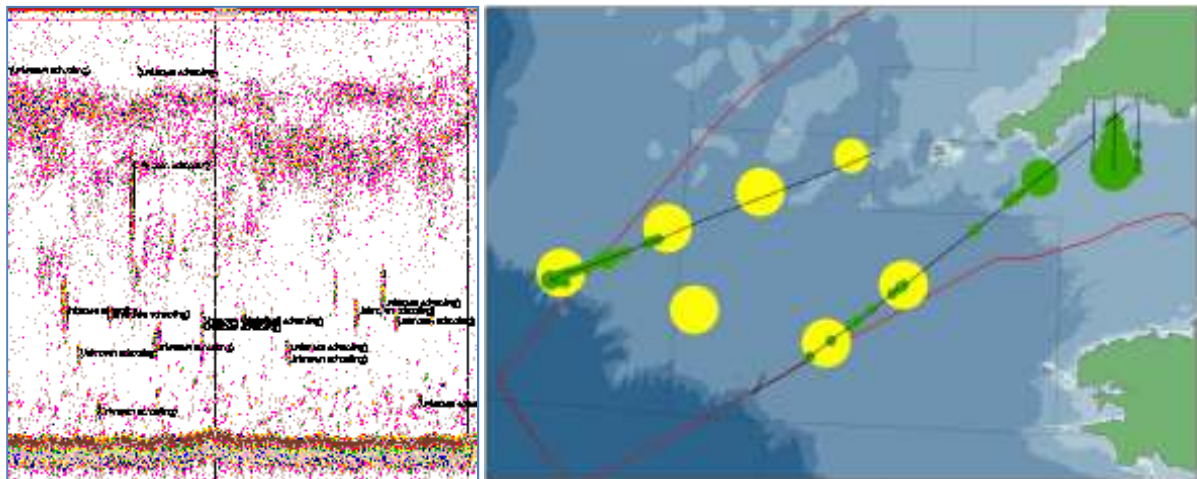


Figure 7. Echogram at 38kHz (left) of unknown pelagic species. This particular pattern continued for 5 h (50 nautical miles) along the northern cross-shelf transect B starting at the shelf edge (49°03.34N, 9°42.24W) at 170–200 m depth. Some of the schools were thought to consist of mackerel, given their frequency response, but other unknown species were mixed with it. (Right) Overview of the survey area with potential mackerel and horse mackerel schools including the unknown schooling species from the echogram, integrated per 1 nautical mile (green) along the survey tracks (black). Overlaid are the combined horse mackerel and mackerel egg densities from the plankton stations (yellow).

Biological sampling

Two trawls were made (stations 4 and 7; Figure 5) and both consisted mainly of horse mackerel (84 and 98% by weight, respectively), some whiting and sardine. At the first station herring and mackerel were also caught (Table 2).

Table 2. Catch composition in percentage weight by species for both trawls.

Trawl	Total weight (kg)	Horse mackerel (%)	Whiting (%)	Sardine (%)	Herring (%)	Mackerel (%)
Station 4	8,000	83.65	3.5	0.88	7.30	4.67
Station 7	24,000	98.19	1.08	0.72	0	0

The sardine caught during the survey ranged from 18.5 to 25.5 cm long, with bimodal peaks at 20 and ~23 cm (see Figure 8a). This is comparable with the general length frequency distribution of all available sardine from the western Channel (April, June and July, see Table 1) combined. These included the samples supplied by industry that were caught in a similar area and time. The similar length frequency distribution supported this assumption.

Equal proportions of male (121) and female (118) sardine were found when all Channel sardine were combined. The preliminary age readings suggest that the sardine population in the western Channel includes fish ranging from 1 to 11 years old, with a peak at 4 and 5 years (Figure 8b). More than half the sardine were ready to spawn (64%) or had recently spawned (23%), and just 13% were either immature or developing.

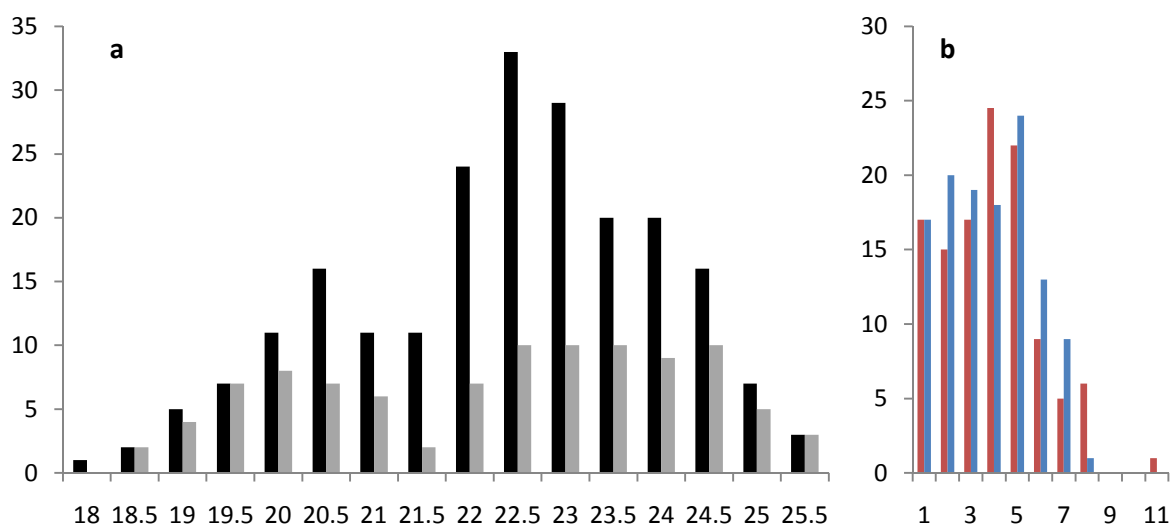


Figure 8. a. Length frequency distribution of all sardines analysed (black, see table 1 for source) and FSP survey sardines only (grey). b. sardine age distribution by sex, females (red) and males (blue).

No anchovy eggs, larvae or adults were found during the survey. Anecdotal evidence suggests that anchovy start to appear in the Channel in autumn with occasional observations throughout

the winter through to spring. The results presented here were based on anchovy we received from the fishing industry collected off south Cornwall in April, and from an additional ~200 anchovy that were collected in the Irish Sea, west of the Isle of Man during a Cefas research survey (Table 1).

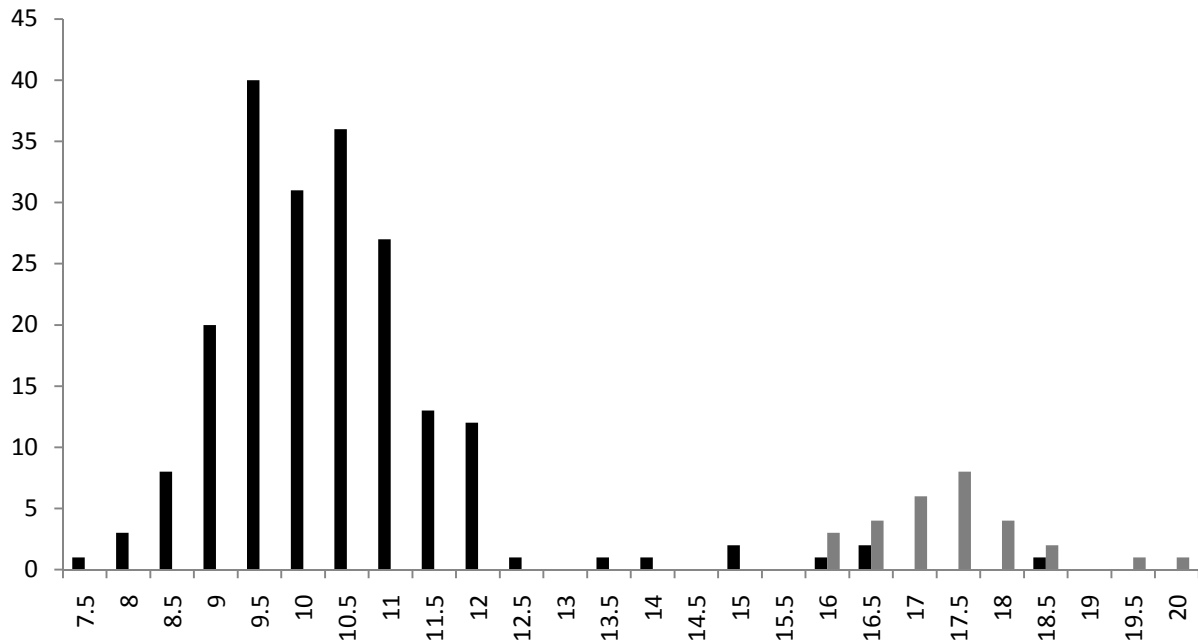


Figure 9. length frequency distribution of anchovy collected in the Irish Sea in February 2010 (black) and samples provided by Falmouth Fish Selling Co. Ltd originating from the Channel in April 2010 (grey).

The Irish Sea anchovy lengths (Figure 9) ranged from 7.5 to 18.5 cm, with most <12 cm (peaking at ~10 cm). Preliminary age readings suggest that all fish up to 12 cm had hatched the previous summer, assuming that Irish Sea spawning time is between May and July. The fish from the Channel were much larger, but it is likely that the gear used was more selective of larger fish, so the information on length composition has to be viewed with caution. The size range exceeded that of the Irish Sea fish and the proportion of larger fish was much lower in the Irish Sea.

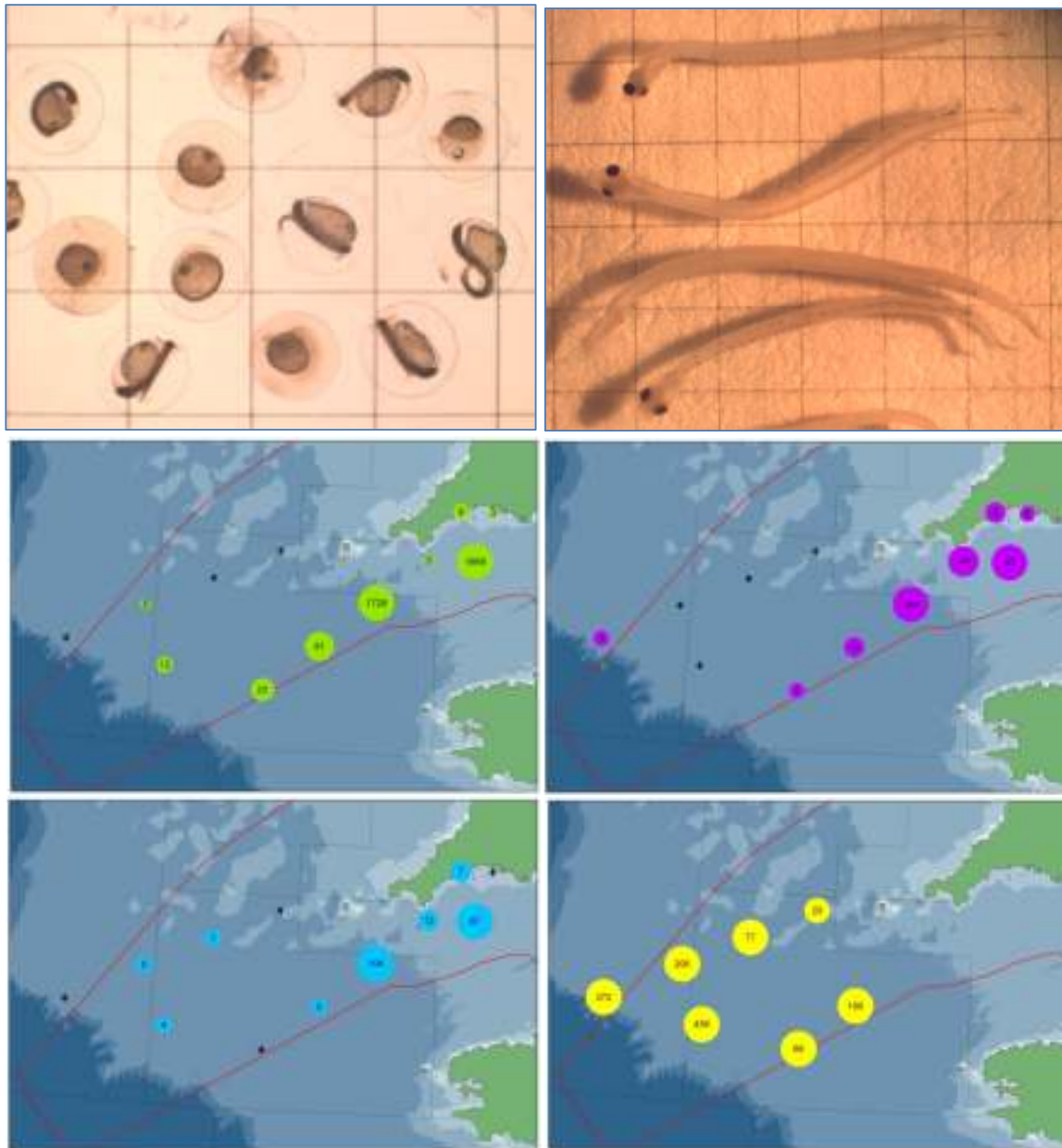


Figure 10. Different stages of sardine eggs (a) and larvae (b) from the plankton samples (photos by J. Pettigrew). Numbers of sardine eggs (c), sardine larvae (d), clupeid larvae (e) and combined mackerel/horse mackerel eggs (f).

Plankton

In all, 13 plankton samples were taken (Figure 5). The sample at one station (19) was not preserved adequately and could not be analysed. No anchovy eggs and larvae were found in the plankton samples. Nine of the remaining 12 stations contained sardine eggs (Figure 10a, c) and eight contained confirmed sardine larvae (Figure 10b, d). A component of the clupeid larvae was damaged and could therefore not be identified to species level (Figure 10e): to distinguish between the larvae of sprat and sardine one has to count the number of muscle blocks (myotomes). However, because most of the identified clupeid larvae and eggs were sardine, and sprat larvae were only found inshore (stations 9 and 11), these unidentified clupeid larvae were likely to consist mainly of sardine. The distribution of sardine eggs and larvae (Figure 10c, d)

overlapped, with largest numbers for both found offshore in Plymouth bay (Figure 5 station 6) and south of the Scilly Isles (Figure 5 station 13) on the southern cross-shelf transect, gradually decreasing in numbers towards the shelf edge. Only very few sardine eggs and larvae were found on the northern cross-shelf transect, and only in the deeper parts towards the shelf edge in the west. Horse mackerel and mackerel eggs (not identified to species level) were also found in large numbers, mainly in the western, deeper areas near the shelf edge (Figure 10f).

Oceanography

The upcast from the CTD provided vertical profiles of temperature and salinity at each plankton station (Table 3). Surface temperatures ranged between 12.97°C and 15.46°C and temperatures at depth (bottom or ~75 m) between 9.82°C and a maximum of 13.42°C on the inshore station 2. All stations apart from station 2 (which was very shallow and well mixed) showed stratification, which was strongest (difference between surface and bottom temperature of ~5°C) at stations deeper than 40 m, and the thermocline depth increased from ~20 to ~40 m with increasing depth offshore (Figure 11). The southern cross-shelf transect was on average slightly warmer than the northern transect. Small differences between surface salinity and salinity at depth were observed. As expected, the inshore station (2) had the lowest salinity but all values were relatively high.

Table 3. Summary table with the temperature and salinity readings for each of the plankton/CTD stations. Max depth represents the maximum sampling depth and only represents the seabed depth in station 2, 6 and 9.

		Station	Max depth	Surf Temp	Temp depth	Surf Sal	Sal depth
grid 1	inshore	2	10.9	13.44	13.42	34.98	34.95
grid 1	offshore	6	70.2	15.15	10.53	35.44	35.15
Transect South	inshore	9	36.6	12.97	11.55	35.23	35.10
Transect South	↓	11	71.0	15.16	10.24	35.54	34.78
Transect South	↓	13	71.9	15.11	10.61	35.52	35.17
Transect South	↓	15	67.1	15.46	10.29	36.41	35.46
Transect South	↓	17	54.9	15.22	10.56	35.72	35.38
Transect South	offshore	19	73.1	14.70	11.92	35.76	35.54
Inter Transect		21	77.9	14.93	10.86	35.76	35.37
Transect North	offshore	23	39.0	14.94	14.87	37.19	35.77
Transect North	↓	25	73.2	14.97	9.99	35.63	35.32
Transect North	↓	27	72.3	14.71	9.82	35.65	35.17
Transect North	inshore	29	68.5	14.72	9.88	35.56	34.90

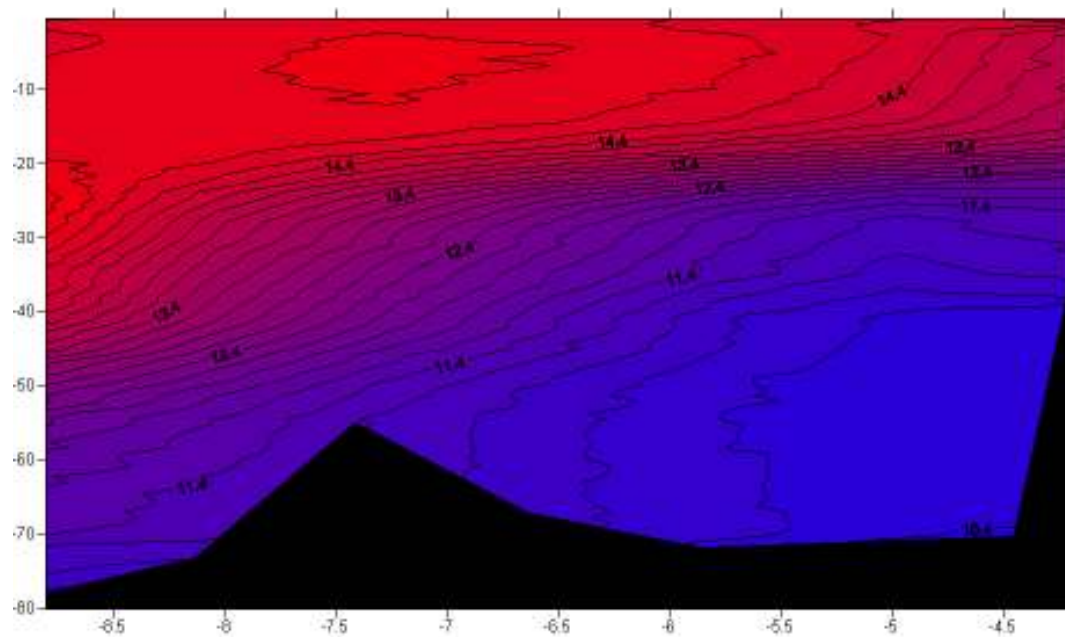


Figure 11. East (right) to west section of the southern cross-shelf transect A showing temperatures (temperature readings in the Figure) of the upper ~75 m of the watercolumn. Interpolation of the vertical CTD profiles 9, 11, 13, 15, 17 and 19, from right to left.

Discussion

As mentioned above, the survey was cut short to three sampling days (plus one day for calibration) instead of the planned nine days. We were therefore not able to meet all the objectives. However, many of the data collected were novel and provided a preliminary insight into some of the unknowns of sardine and anchovy biology.

Of the two target species we only found sardine during the survey. There was clear evidence of sardine spawning activity throughout the area surveyed. Sardine eggs were present in most plankton station samples and very high concentrations of eggs were found offshore from Plymouth and south of the Scilly Isles, which corresponds with the previously reported distribution from plankton surveys (Wallace and Pleasants, 1972) and continuous plankton recorder (CPR) data (Coombs *et al.*, 2005). Numbers decreased towards the shelf edge and only a few sardine eggs and larvae were found on the plankton stations of the northern cross-shelf transect. This suggests that sardine spawning, albeit widespread, is largely concentrated in the southern part of the surveyed area.

The surface clupeid schools identified in the acoustic data were likely to be largely sardine. Apart from the acoustic signature and skipper's expertise, there was overlap between areas of higher acoustic densities of these schools and the presence of sardine eggs in the plankton samples. As sardine eggs tend to develop into larvae within a few days, this spatial overlap supports the acoustic identification. In addition, of the clupeid species found in the survey, either adults or eggs, sardine were the most likely candidate in terms of their behaviour. Herring were found in one of the trawls, but they are demersal spawners, laying their eggs in

clusters on coarse sand and gravel. Also, outside the spawning season, herring tend to be found on or just above the seabed by day. Some sprat eggs were identified in the samples, but only nearshore. Several acoustically distinct sprat schools were observed in the eastern Channel while steaming to the survey area (not presented here), but no clear evidence of sprat schools in the acoustic data was observed during the survey. Finally, of the three clupeid species, sardine is most associated with warmer temperature, particularly during the spawning season. Eggs are reported to require temperatures between 14 and 17°C to develop (Cushing, 1957) which fits the observed surface values in our survey. The acoustic data suggest that the distribution of sardine in the area is widespread across the shelf at this time of year. It was not possible to estimate the abundance of sardine, and hence to estimate the fraction of the stock being removed by fishing. However, one of the main fisheries targeting this species is the Cornish sardine fishery, which operates largely within 6 nautical miles of the coast from small vessels, so is likely to remove just a small fraction of the population. However our understanding of, for example, the movements of sardine is still limited and will need to be addressed in future. The age range was large with specimens as old as 11 years and equal numbers of 1–5 year old fish. This suggests a healthy population with fishing pressure at a sustainable level. However, our sample size was relatively small and further collection of age/length data from the larger Celtic Sea shelf, different seasons and consecutive years would shed more light on this. Genetic work could help in further identifying the origin of these Channel (and Celtic Sea) sardine.

Although anchovy are known to live in the English Channel, no anchovy eggs, larvae or adults were caught during the survey. At the nearest known anchovy spawning locations in the Bay of Biscay and southern North Sea (Dutch estuaries), anchovy spawn from April (in the south) and May (in the North) to August, with a peak in June. Our results strongly suggest that there is no spawning population of anchovy in the British waters of the western Channel (or out towards the shelf edge) during that time. If such fish do occur there, it would be at a very small scale. The adult anchovy caught in the Channel from autumn through to early spring are likely to be moving there from one of the surrounding spawning populations. At this point it is unclear from which spawning population they originate, and this would need to be investigated given the implications for management of the species. Apart from the spawning sites mentioned above, the size range of the anchovy sampled in the Irish Sea suggests that spawning may be taking place in the area. This will be one of the key questions we hope to be able to answer by analysing the anchovy genetic samples taken from the various spawning sites in the region, as part of a related project.

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