Cruise report CEND18-12

PELTIC12: small pelagic fish in the coastal waters of the western Channel and Celtic Sea

Prepared by:

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Abstract

A 18 day multidisciplinary pelagic survey was undertaken in the western Channel and the Celtic Sea (“Mackerel box”) between the 23rd of October and the 10th of November. The main aim was to investigate the distribution and abundance of the small pelagic fish community in the area and the environmental drivers of the pelagic ecosystem.

1. Outline of the survey

1.1 Staff

Part 1 (23-29th of October)	Part 2 (29th of Oct- 10th of Nov)
Jeroen van der Kooij (SIC, acoustics)	Jeroen van der Kooij
Steve Warnes (2IC, deckmaster)	Steve Warnes
Rob Bush (2IC, deckmaster)	Rob Bush
Elise Capuzzo (Oceanography)	Elise Capuzzo
Bill Meadows (Acoustics, technician)	Dave Brown
Marc Whybrow (Acoustics, technician)	Marc Whybrow
Mark Etherton (fishroom, otoliths)	Mark Etherton
Joana Silva (fishroom, pelagic expert)	Joana Silva
Antonio Plirú (zoo-and ichtyoplankton)	Antonio Plirú
Paul Bouch (zoo-and ichtyoplankton)	Paul Bouch
Lavinia Suberg (PhD, NOC)	Lavinia Suberg
Conall O’Malley (Irish Foreign Observer)	Conall O’Malley

1.2 Duration

23rd of October – 10th of November

1.3 Location

Western Channel and Celtic Sea coastal zone (embarking/disembarking in Lowestoft)

1.4 Objectives

1. To carry out a multidisciplinary pelagic survey of the Western Channel and Celtic Sea waters to estimate the biomass and gain insight into the population structure of the key small pelagic fish species (sprat, mackerel, sardine, anchovy, horse mackerel, herring).
   a. To carry out a 24 hour fisheries acoustic survey using three operating frequencies (38, 120, 200kHz), to investigate:
      - distribution of small pelagic species
      - abundance of small pelagic species
      - distribution of the pelagic species in relation to their environment
   b. To trawl for small pelagics species, using a Fotö trawl and an Engels 800 trawl in order to obtain information on:
      - Species- and size composition of acoustic marks
      - Age-composition and distribution, from all small pelagic species
      - Length weight and maturity information on pelagic species
2. To collect plankton samples using 2 ringnets (80 µm and 270µm mesh) at fixed stations along the acoustic transects at night and at a subset of trawl stations during the day. Samples will be processed onboard:
   a. Ichtyoplankton (eggs and larvae) of pelagic species will be identified, staged and counted and combined with information from maturity to identify spawning areas.
   b. Zooplankton will be stored for further analysis back in the lab.
3. Water column sampling. At fixed stations (same as plankton samples) along the acoustic transect, a Rosette and ESM2 will be used to obtain a vertical profile of the water column. Water column profile and water samples will provide information on chlorophyll, oxygen salinity temperature, nutrient samples and the relevant QAQC samples for calibration of the equipment. Water samples will be collected and fixed on board for analysis post-hoc.
4. To collect macro plankton samples to study invasive species using 2 ringnets, 1 mm and 200 µm mesh (MEMO project, PM Sophie Pitois).
5. To collect water samples for nutrient and TA/DIC analysis in support of a programme on ocean acidification (Naomi Greenwood) to continue autumn time-series in area.
6. Seabirds and Marine Mammals. Locations, species, numbers and activities observed will be recorded continuously during daylight hours by three Marinelife observers from bridge.
7. Ferrybox Continuous CTD/Thermosalinigraph. Continuously collect oceanographic data on the sea surface during steaming.
8. To collect 100 sprat otoliths from Bristol Channel for sprat exchange programme (HAWG)

1.5 Additional objectives

9. Marine litter (2): macro litter samples collected in the trawl will be recorded and photographed
10. Tag elasmobranchs, in support of studies on their movement patterns in western Channel and Celtic Sea
11. Collect rare species for Jim Ellis (Cefas)

1.6 Narrative

RV Cefas Endeavour left Lowestoft port at 16:30 during the afternoon high tide of the 23rd of October (after the necessary inductions that morning), despite some heavy fog. The marine mammal and bird observer had pulled out at the last moment. The vessel steamed overnight to deeper waters of the central English Channel to conduct a shake-down tow with the Fotö trawl to fine-tune her geometry and get a feel of the gear. During the morning of the 24th of October, the Fotö trawl was tested until about 10:00 when a shake-down tow was successfully made. Given the favourable weather conditions the RV Cefas Endeavour then steamed to eastern Lyme Bay (near Portland 50° 36.180 N, 002° 35.762 W) to calibrate the echosounders. Whilst anchored the frame holding four ringnets (zooplankton) was tested, combined with a CTD (which provided the necessary environmental variables for the calibration later), followed by a muster drill. At 18:00 with the sphere in position the calibration was commenced in earnest and by 19:30 both the 38 and 120kHz were calibrated successfully. Despite seeing the target at the 200kHz, no single targets were detected and after having experimented for awhile, the most recent calibration file was loaded for the 200kHz, pending another opportunity to attempt the calibration. During the calibration, the Rosette plus ESM2 logger were also deployed to test the equipment was working.

Between the 25th and the 29th of October a series of north-south running transects in the western Channel (subarea 1) were completed. Due to the presence of static gear near the coast the inshore parts of the transects were covered during daylight. On the morning of the 29th of October a planned staff change was conducted in Falmouth using the searider, with Bill Meadows coming off and Dave Brown coming on. One crew-member was forced off for medical reasons. Shortly after sailing, a tow was conducted during which the port bridle parted, losing the weight. In the absence of spare bridles the remaining 5 bridles were halved and 6 of the resulting 10 bridles were fitted overnight. The next morning on Tuesday the 30th of October we conducted another tow with the Fotö trawl during which contact was made with the seabed. Both bottom bridles had parted, loosing both wing-end weights and in addition several of the panels were damaged. Due to the size of the net (and mesh) and the limited space on deck, this could not be mended and the Fotö was replaced by the back-up trawl, the smaller Engels 800, which took all day to be rigged. Whilst the trawl was being rigged, the final transect of the subarea 1 was covered and at 16:00 the RV headed back to Penzance to collect the replacement AB. During Wednesday and Thursday (31st of October-1st of November) subarea 2 (the Scilly Isles) were completed under deteriorating weather conditions (force 8 and 9), leading eventually to a two hour period of downtime sheltering from the westerly gales. It was also decided to switch the 4-ringnet fame to a 2-net frame to enable continued collection of plankton samples. The ESM2 logger is also deployed without the rosette, the deployment of which was swell dependant. On Friday the 2nd the RV Cefas Endeavour entered the third subarea (Bristol Channel), which was completed in the early hours of Tuesday the 6th of November. Wind and swell conditions gradually improved during this period.

At first light on Tuesday 6th of November a one day experiment was commenced: a 100 nmi transect from inside the Bristol Channel to the Celtic Deep was run at constant speed (11.5 knots). The aim was to collect concurrent data on pelagic fish and top predators (birds and mammals), as well as plankton and oceanography (already collected the previous days) covering different oceanographic conditions to explore the multi-trophic interactions.

After sunset the Cefas Endeavour gradually started to make her way back to Lowestoft, leaving enough time to pick up some of the plankton and oceanographic stations that were missed previously as a consequence of the adverse weather conditions. On Thursday the 8th of November an attempt was made to drop off a member of the scientific staff but permission was refused by the port authorities. The RV Cefas Endeavour arrived off Lowestoft at around 21:00 and docked on the early morning tide of Saturday the 10th of November.

2. Material and Methods

2.1 Fisheries acoustics

2.1.1. Acquisition

Fisheries acoustics were recorded along the pre-designed transects (Fig. 1) at three operating frequencies (38, 120 and 200 kHz). The transducers were mounted on a drop keel which was lowered to 3.5 m below the hull, 8.7 m below the sea surface, which reduced adverse effects of weather. Pulse duration was set to 0.516 µs for all three frequencies and the ping rate was set to 0.5 pings s^{-1}. Acoustic data were generally of very high standard despite fairly constant strong windy conditions and Atlantic swell, although occasional spells of very bad weather adversely affected some of the surface data due to aeration. At all times on-transect live acoustic data were monitored and when unidentified acoustic marks appeared the trawl was shot where possible to identify these marks.

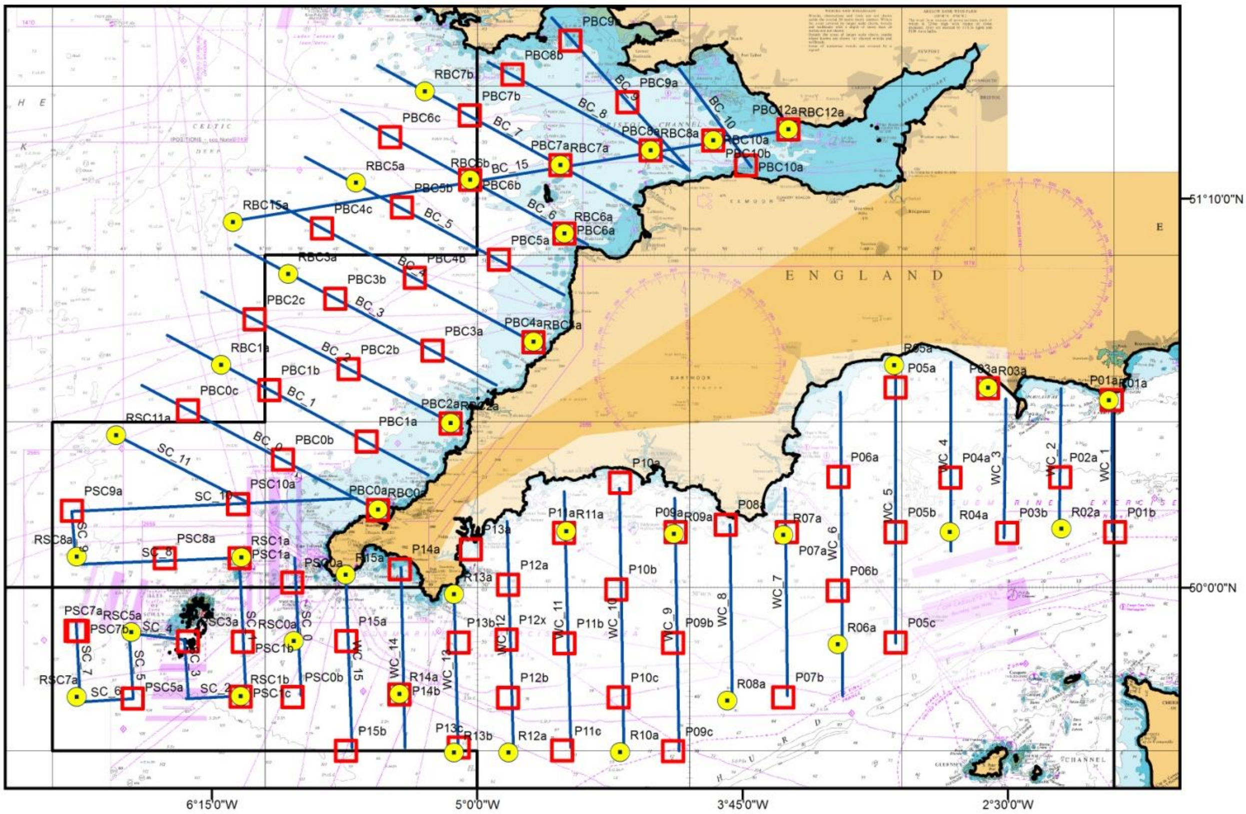


Figure 1. Overview of the survey area, with the acoustic transect (blue lines), plankton stations (red squares) and Hydrographic stations (Yellow circles).

2.1.2. Processing

Acoustic data were cleaned, which included removal of data collected during plankton and oceanographic stations, fishing operations and the steam between transect, retaining only the on-transect data. Surface aeration caused by bad weather was removed setting a surface exclusion line and acoustic data below 1 m above the seabed were also removed, to exclude the strong signals from the seabed. Large amounts of plankton were present throughout the survey, often represented in layers on all three acoustic frequencies (although at different strengths depending on the organisms). Fish schools and plankton were often mixed and a simple extraction of fish echoes was not possible. Therefore to distinguish between organisms with different acoustic properties (echotypes) a multi-frequency algorithm was developed (fig. 1), principally based on a threshold applied to the summed backscatter of the three frequencies (*sensu* Ballon et al., 2011), eventually resulting in separate echograms for each of the echotypes (fig. 1). The echogram with only the echoes from fish with swimbladders was then scrutinised and split into a number of categories:

1. Echoes in the bottom 10 m above the seabed consisting of loosely aggregated gadoids, and scattered mackerel and/or clupeids
2. Dense schools in mid-water consisting predominantly of either sprat or boarfish
3. Thin scattering near surface consisting of mackerel, sardine, horse mackerel and blue whiting
4. Diffuse Unidentified Scattering Targets in mid water, often containing fish. Particularly at night but also apparent during day.
5. Probable sardine schools: groundtruth trawl not successful or available, but acoustic features match those of sardine from adjacent areas and/or sardine eggs were recorded in nearby plankton stations
6. Residual plankton scatterings from very dense plankton layers that could not be removed by the filter

The acoustic density within each of these categories was then attributed to individual species based on the nearest relevant trawls, using imagery of sonar and netsonde collected during the trawling process to assess the sampling performance in relation to the acoustic marks.

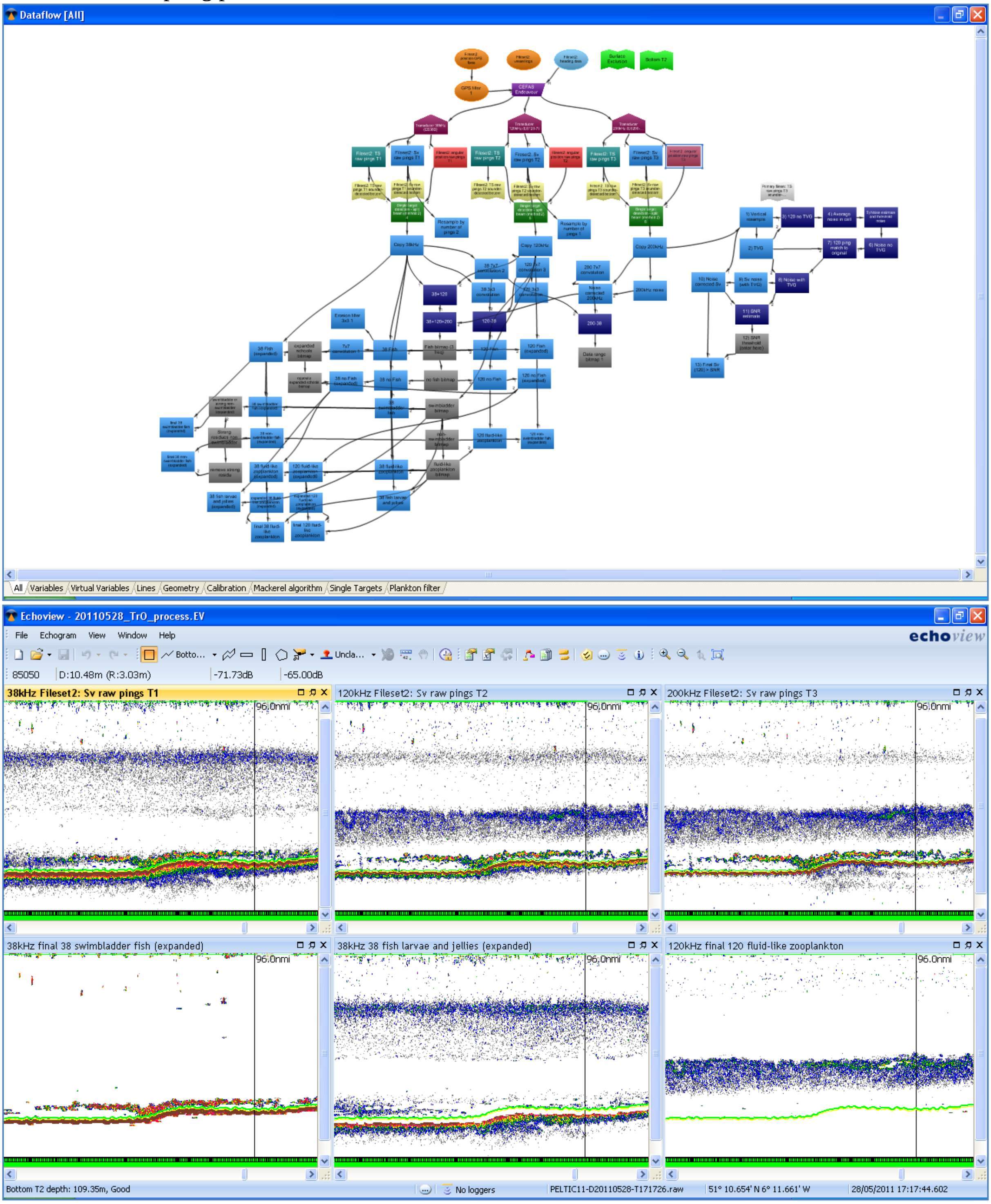


Figure 1. Dataflow of algorithm (top) used to divide the acoustic data by echotype. Screen-shot example (bottom) with raw echograms of 38, 120 and 200 kHz (top panels) and three examples of extracted echotypes (bottom panel from left to righ): fish with swimbladder (sardine schools at surface and myctophids layer near seabed), fish larvae/ jellyfish and zooplankton (dense krill layer).

In the case of mackerel a separate algorithm was used (*sensu* Korneliussen 2010). An additional bad weather filter was developed which removed “empty” pings as a result of adverse weather conditions.

2.1.3. Fishing

A Cosmos Fotö trawl (15m vertical and 50m spread) and Engels 800 mid water trawl (10m vertical and 20m spread) were used to sample the pelagic community for the purpose of validating acoustic marks and collect biological samples. The first survey day was dedicated to fine tune the trawl by experimenting with different weights, speeds and warp. A wireless 50 kHz Marport net-sonde was mounted on the head-rope of the trawl at the mouth of the net, which allowed for live monitoring of the trawling performance. In general both trawls performed well: particularly the Fotö trawl was successful at catching a broad range o f species and size classes. The Engels was found to be more flexible in its deployment, ideal for targeting fish at various vertically stratified depth intervals.

2.2. Plankton

The various planktonic size components were sampled at fixed plankton stations along the various transects using four ringnets of different mesh: 1mm (ctinophores and medusae), 270 µm (ichtyoplankton), 200 µm (macrozooplankton) and 80 µm (zooplankton). The four ringnets were fixed to a frame which enabled them to be deployed simultaneously. All four nets had flowmeters (General Oceanics mechanical flowmeters with standard rotor, model 2030R) mounted in the centre of the "mouth" and a min CTD (SAIV) was attached to the bridle. At each zooplankton station a water sample was taken for phytoplankton analysis. Position, date, time, seabed depth, angle of the net, sampled depth (from CTD attached to net) and flowmeter reading were recorded. Samples were transferred from the "bag ends" into 1 lb glass jars and preserved with 4% buffered formaldehyde. Ichtyoplankton (eggs and larvae) from the 270 µm samples were counted and, in the case of clupeid larvae, measured and raised to numbers per m^{-2} using the flow meter records. Other

2.3. Oceanography

Vertical profiles of the oceanographic conditions in the study area were made at regular stations along the acoustic transects, using a Rosette fitted with a Falmouth Scientific Inc. Integrated (FSI) CTD. Temperature, Pressure, Conductivity, Photosynthetically Active Radiation, Turbidity and Fluorescence were measured. Additional temperature profiles had been obtained from the CTD attached to a plankton net. PAR profiles will be analysed to calculate the vertical light attenuation coefficient (K_d) and the depth of the photic zone. Information on the light penetration through the water column was also derived from the measurement of the Secchi disk depth.

Water samples were collected at 4 meters depth (using Niskin bottles and/or the Ferrybox) and just above the seabed (using Niskin bottles) to determine dissolved oxygen concentration (for calibration of the oxygen sensor in the ESM2 profiler), Total Alkalinity (TA), Dissolved Inorganic Carbon (DIC), dissolved inorganic nutrients concentration, chlorophyll concentration, as well as phytoplankton size and composition for analysis via flow cytometry. The remaining water was filtered through a 200µm mesh; 4ml of this was mixed with 100µl of glutaraldehyde 8% and stored at -68°C for flow cytometry. A 1000ml of water from each depth was filtered a second time through a GF/F filter. The filter was stored at -68°C for Chlorophyll analysis and 60ml of the twice filtered water was mixed with 100µl of mercuric chloride and stored at 3°C for nutrient analysis.

A synoptic view of the studied area was provided by satellite images of sea surface temperature, chlorophyll concentration and frontal systems, derived using Neodaas (www.neodaas.ac.uk) and My Ocean (www.myocean.eu.org).

During the survey, continuous measurements of different environmental parameters (e.g. temperature, salinity, fluorescence, oxygen saturation, pH, pCO2) were carried out by a Ferrybox and a pCO2 analyser.

Calibration of the FSI temperature sensor was performed pre-cruise in the laboratory and values were found to be accurate to ± 0.07°C. The CTD attached to the plankton net was also calibrated pre -cruise and found to be accurate to ± 0.1°C. Temperature values from the Rosette's thermometer were compared against temperature readings from two reversing thermometers which took a reading at the thermocline or deepest point of a profile and against the Ferry box measurement which sampled water from an inlet at 5 m depth. The Rosette and reversing thermometers showed a high degree of agreement, on average to 2 decimal places (d.p.). However the Ferry box was on average 0.3 °C higher and the spread of the differences was very small (the standard deviation of the differences was 0.07 (2 d.p.)), suggesting the Ferry box temperatures were 0.3 °C higher than the actual sea temperature at 5 m, probably due to the water being heated as it travelled through the ship. On average the Ferry box salinity was 0.05 (2 d.p.) higher than the Rosette again with a very small spread around this average (standard deviation 0.03 (2.d.p.)).

2.4. Top predators

During the Bristol Channel-Celtic Sea transect a marine mega-vertebrate and sea bird surveys was conducted. Effort data were recorded every 15 minutes. Data recorded included ship's location, course, speed, sea state, visibility, cloud cover, swell height, wind- speed/direction and precipitation type/intensity. For all cetacean and sea bird sightings time, species, number, age and behaviour of individuals were recorded.

3. Results

3.1. Small Pelagic Ichtyofauna

After removing the off-transect data a total of 1495 nautical miles of acoustic sampling units were collected for further analysis (fig. 2). A total of 22 successful trawls were made (fig. 2). Geographically they were evenly spread, providing a suitable source of species and length data to adequately partition the acoustic data. However it fell below the originally planned number of trawls for a number of reasons: 1. absence of sufficient densities of marks: to increase the chance of catching a decent sample of fish trawling was only undertaken when target schools persisted over 2 nmi of transect; 2. Inaccessibility: at times trawling was not possible due to busy traffic, traffic separation zones, gear repairs and presence of static gear.

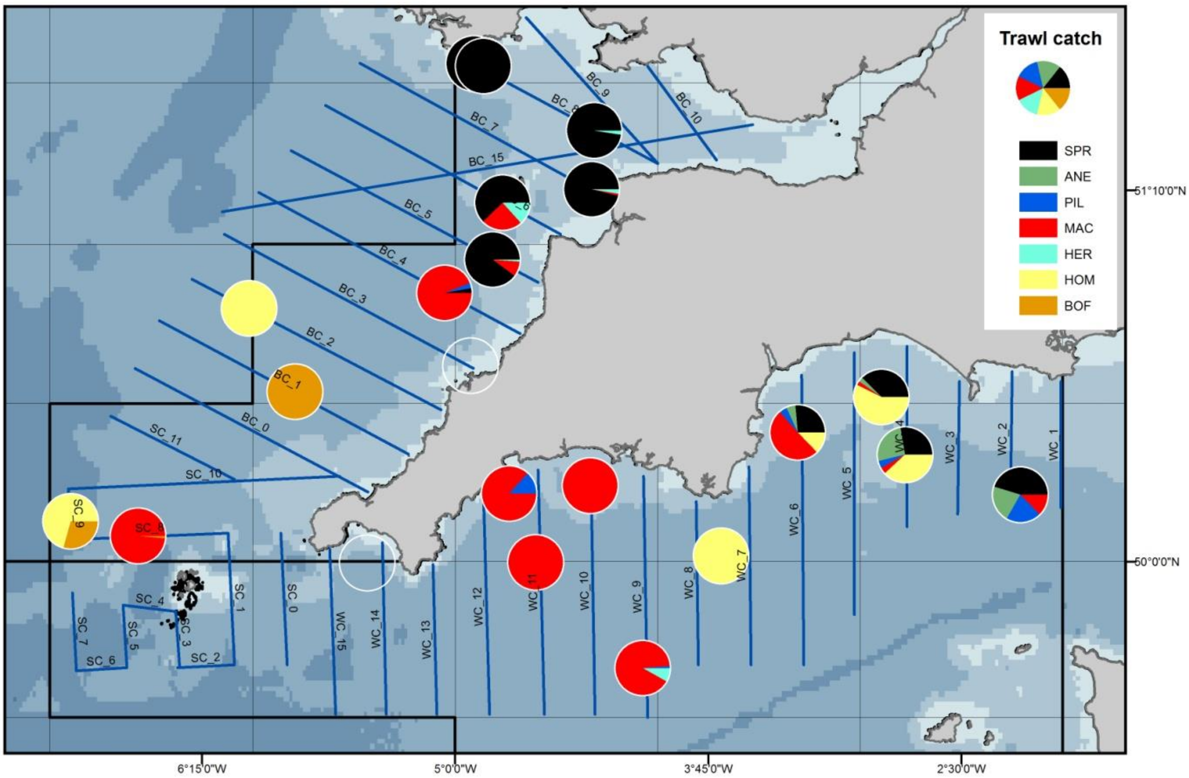


Figure 2. Overview map (inset) and detail of the survey area. Acoustic transects (red lines) and trawl catches (pies) with relative catch composition by key species. Three letter codes:, SPR=sprat, ANE=anchovy, PIL=sardine, MAC=mackerel, HER=herring, HOM= horse mackerel, BOF=boarfish.

A total of 36 species were caught consisting predominantly by fish and some cephalopods. Several trawls included jellyfish of at least three species. The ichtyofauna consisted of a diverse group of species with distinct communities distributed across the area, generally divided into an inshore, shallow water group and an offshore, deep water group.

Sprat (*Sprattus sprattus*) dominated the inshore waters of England, both in the English Channel and particularly in the Bristol Channel. However sprat in the Bristol Channel consisted nearly entirely of small specimens of age 1, whereas those from the Lyme Bay area were more mature.

Only few sardines (*Sardina pilchardus*) were caught and acoustic data suggest that sardine is mainly distributed south of the Cornish Peninsula (in the western Channel) and to a lesser extend in the northeastern parts of the Celtic Sea (fig. 3). Boarfish (*Capros aper*) was the most numerous pelagic species in the deeper waters of the survey area, occurring in dense schools throughout the water column in waters from ~75 m depth, predominantly around the Scilly Isles and the western offshore transects of the north Cornish Penninsula . Horse mackerel (*Trachurus trachurus*) and herring (*Clupea harengus*) were found in the study area (fig. 3) although generally not in dense schools, but mixed in with other small pelagic species. Herring typically displayed a more coastal distribution whereas horse mackerel were found pretty much across the entire study area notably also in surface waters off the shelf edge. Mackerel (*Scomber scombrus*) was also found throughout the study area. Several small schools were observed in the acoustic data throughout the study area, and in addition mackerel was also scattered in layers mixed with other species. Most catches included small juvenile specimens.

Table xx Numbers measured and mean length at age for the key pelagic species.

Figure 3. From left to right, top to bottom: sardine (pilchard), sprat, boarfish, blue whiting, horse mackerel and herring density distributions, as derived from the acoustic data.

3.2. Plankton data

In total zooplankton was collected with the four ringnets at 70 stations. At the same 70 stations and an additional 10 stations watersamples were taken for phytoplankton samples. Onboard ichthyoplankton processing revealed that sardine eggs and particularly larvae were prevalent in a large number of stations. Back in the laboratory a detailed analysis will be undertaken into the zooplankton species and size composition at the various stations.

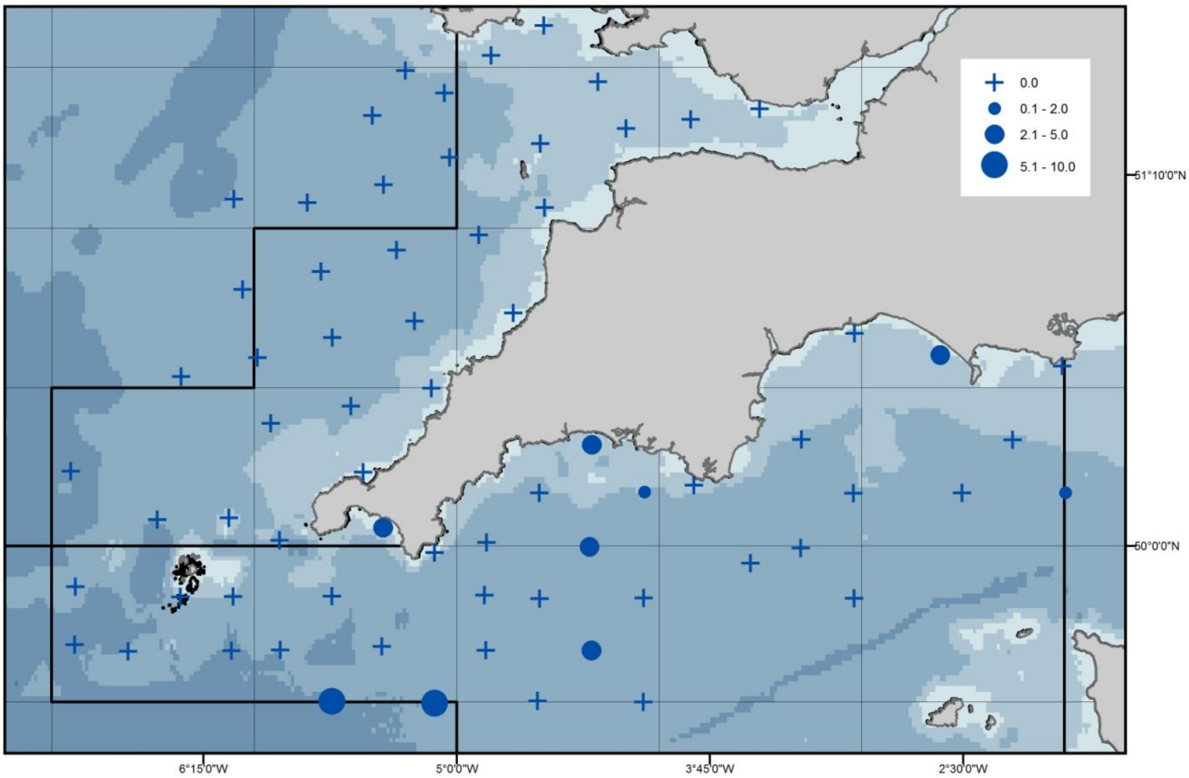


Figure 4. Ichtyo-plankton stations with sardine eggs. Bubble size relative to numbers caught.

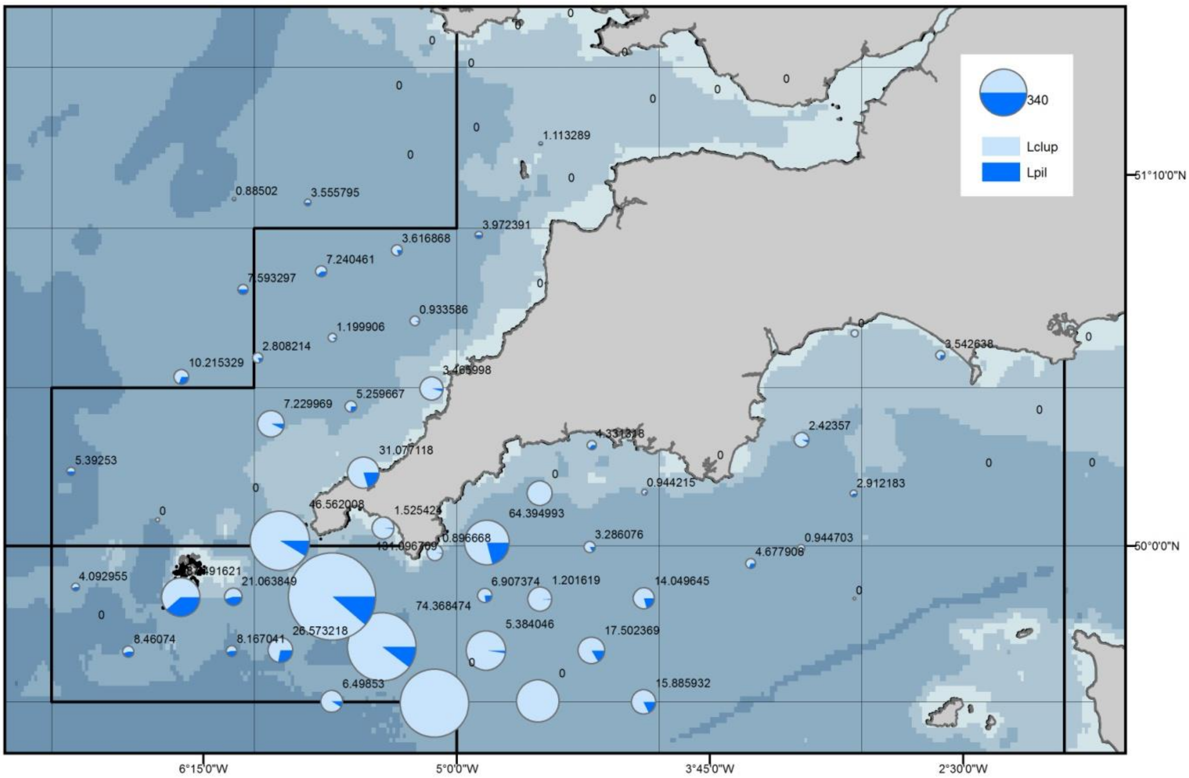


Figure 5. Ichtyo-plankton stations with clupeid (light blue) and sardine (dark blue) larva. Pie size relative to total larvae numbers caught; numbers of sardine larvae m^{-2} indicated in centre.

Few sardine eggs were found and generally in relatively isolated areas, both inshore and offshore although all in the western Channel. Sardine larvae where much more abundant and widespread with highest densities south of the southwestern Cornish tip and between the SW tip of Cornwall and the Scilly Isles. Not all clupeid larvae could be identified to species level, but with only very few sprat larvae present, the only other likely clupeid larvae candidate, the majority of unidentified clupeid larvae were thought to consist of sardine. The eastern parts of both Bristol and English Channel yielded lowest densities, gradually increasing west, then showing strong decline in numbers at the western-most stations.

3.3. Oceanographic data

The total number of samples collected and CTD profiles carried out during the cruise are given in Table 1. The majority of the samples were collected at the subsurface due to rough sea conditions which did not allow the deployment of the Rosette. However, as the water column was vertically mixed at almost all stations, it was assumed that the subsurface sample was representative of the whole water column.

	Total	**Surface**		**Bottom**	**Mid water**
		Niskin	Ferrybox	Niskin	Niskin
Dissolved oxygen samples for calibration ESM2 (x3)	8	4		4	
TA/DIC	53	15	22	15	1
Salinity	57	17	24	15	1
Dissolve nutrients	52	15	22	14	1
Chlorophyll/Pigments analysis	106	16	75	14	1
Flow Cytometry	38	15	22		1
Secchi depth	11				
CTD casts with ESM2	35				
CTD casts with FSI/Rosette	18				

Table 1. Summary of samples collected and number of CTD casts derived during Poseidon cruise Cend 18_12. Depth and collection method of the samples are also specified.

Samples for dissolved oxygen, chlorophyll and nutrients concentrations, as well as samples for TA/DIC and salinity, will be processed in the lab. CTD casts derived with the ESM2 profiler will be downloaded in the lab and processed for deriving temperature, salinity, fluorescence, dissolved oxygen and downward irradiance profiles.

The Secchi disk depth ranged between a minimum of 3 m, recorded in the inner Bristol Channel (station PBC09b) and a maximum of 18 m, measured south of Land's End (station P14b). Estimates of the light attenuation coefficient (K_d) were derived from Secchi disk depth using a relationship by Devlin et al. (2008), and ranged between 0.096 m^{-1} (P14b) and 0.384 m^{-1} (PBC9b). The lowest estimate of K_d was comparable to estimates of K_d derived for off-shore Case-1 waters[1], while the highest value was comparable to estimates of K_d derived for coastal Case-2 waters[2]. The depth of the photic zone (calculated as the depth at which the irradiance is 1% of the surface irradiance) varied between 12 m (PBC09b) and 47.8 m (P14b). In other words, at station P14b phytoplankton organisms received enough light for photosynthesize up to almost 50 m depth, while in the Inner Bristol Channel only up to 12 m. More accurate estimates of K_d will be derived from the PAR profiles collected with ESM2 profiler.

Estimates of temperature and salinity at the subsurface (approximately 4 m depth) and at the bottom were recorded at each sampling station from Ferrybox and CTD (FSI). Based on these estimates, temperature ranged between 11.15 °C in the inner Bristol Channel (RBC15a) and 15.16 °C

[1] Where phytoplankton is the major component of the water column affecting the underwater light climate.

[2] Where suspended solids and Coloured Dissolved Organic Materials are the major components of the water column affecting the underwater light climate.

in the Western Channel (R02a). Station RBC15a was also characterized by the lowest salinity (29.63), suggesting that this station was influenced by freshwater from the River Severn. The highest salinity was recorded at station P15b (approximately 30 nautical miles south of Land's End). In general, stations in the Western Channel were characterized by slightly higher temperature (between 13.6 and 14.8 °C) than stations in the Scilly Isles transects (12.0 – 13.4 °C) and Bristol Channel transects (11.3 – 13.6 °C), based on Ferrybox measurements.

Vertical profiles of temperature and salinity derived from the FSI CTD showed that the water column was vertically mixed at all stations except for the most westerly stations of the transects in the Bristol Channel and Scilly Isles (stations on the Whale-transect, RBC15a, RBC1a, RSC11a and RSC8a). In the latest stations it was possible to observe the presence of a bottom layer ('pillow') of cooler (ΔT ≈ 1 °C) and saltier (ΔS ≈ 0.1) Atlantic water (see Figure 1).

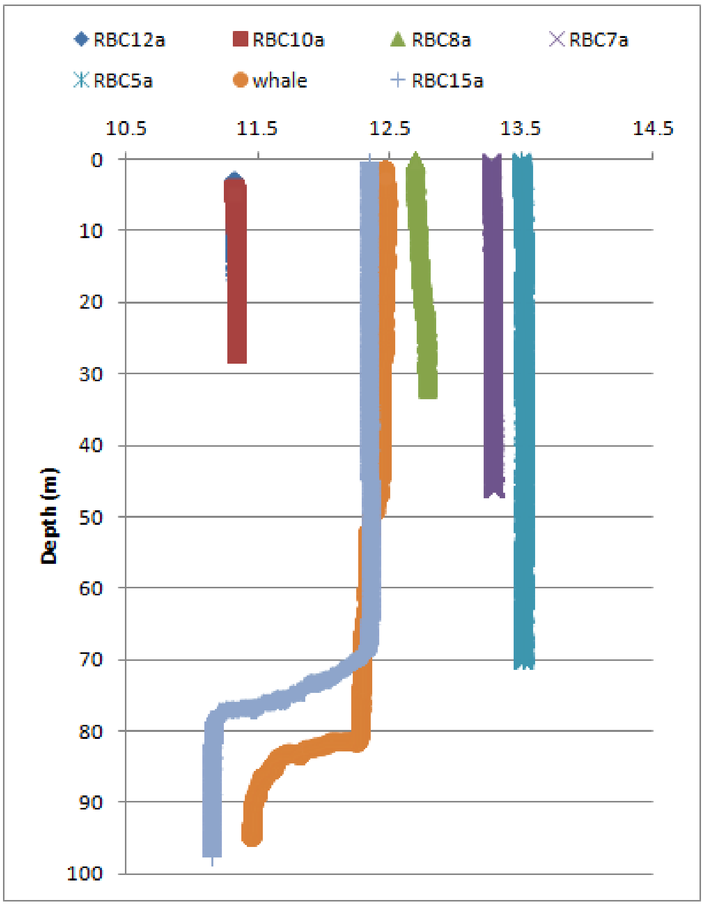
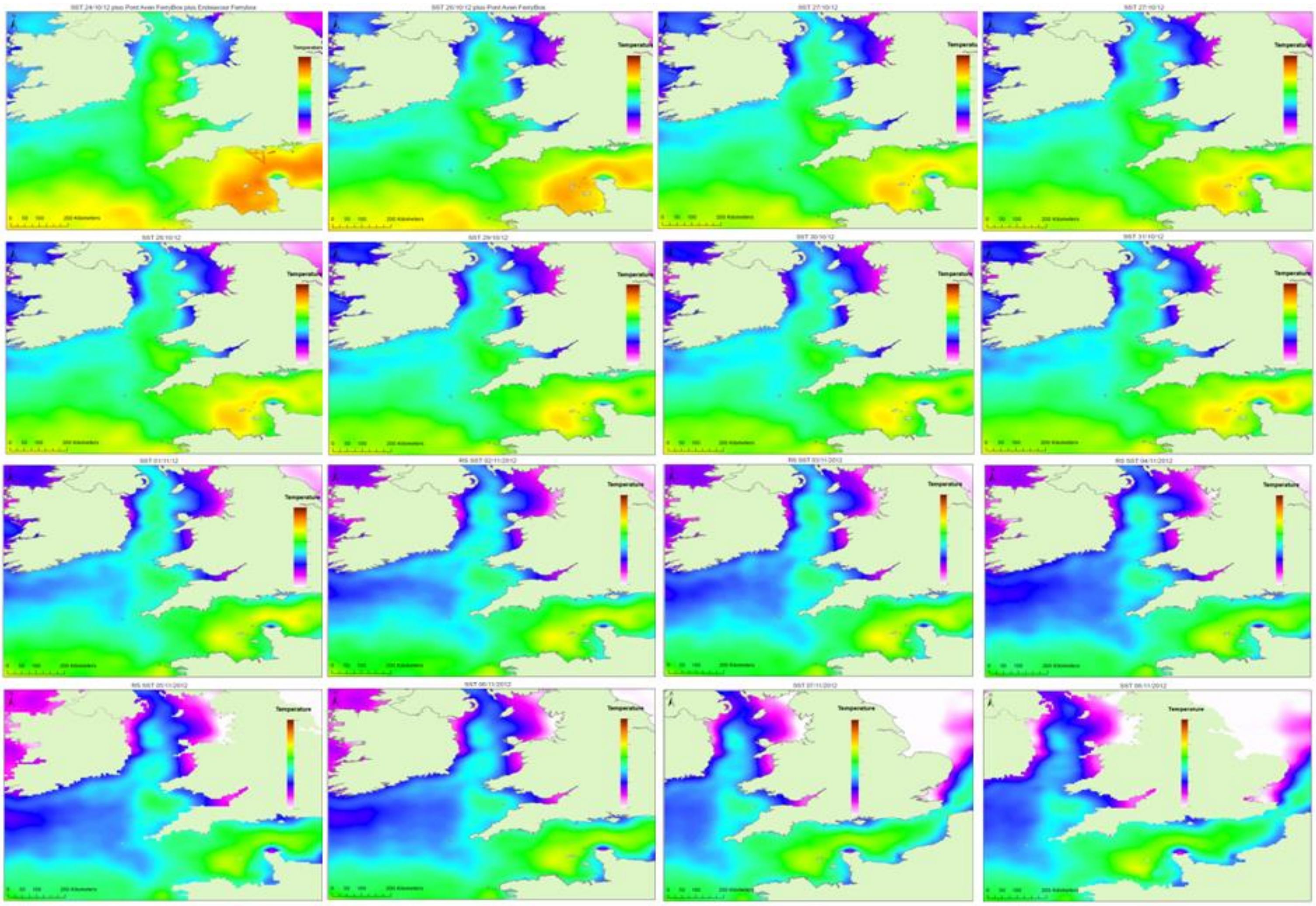


Figure xx. Temperature (°C) vertical profiles from FSI CTD, for stations along Transect 15 in the Bristol Channel.

Remote-sensed surface maps of sea temperature, chlorophyll concentration and frontal systems were acquired on a daily basis. Due to the frequent overcast conditions, full satellite coverage of the area was limited. However, daily maps of sea surface temperature were generated daily by Kate Collingridge in Cefas using a cloud-free product from My Ocean (Figure 2).

The daily maps of sea surface temperature showed the progressive advancing of cooler Atlantic water (~12 °C) from the west into the Celtic Sea, south of Ireland. Areas of warmer water (~14-15 °C) in the Western Channel and Irish Sea became progressively weaker and smaller during the cruise period (Figure XX). In particular, the warmer area in the Irish Sea disappeared completely except for a small pool of water in the outer part of the Bristol Channel. Transect 15 in the Bristol Channel ran across this area and demonstrated a difference in temperatures between the sampling stations (Figure 1). In particular, the temperature increased progressively moving along the transect from east to west, from station RBC15 to station RBC5a, and then decreased at the final two stations ('Whale' and RBC15a). The Scilly Isles were characterised by cooler water, compared to the Western Channel and Bristol Channel transects, for the duration of the survey.

Figure 2. Daily sea surface temperature maps from My Ocean from 24[th] October to 8[th] November 2012. The scale varies from 10 to 17 °C.



Sea surface temperature composite maps from Neodaas for the week before the survey (18-24 October) and for the periods 25-31 October and 1-7 November 2012 are given in Figure 3. As already observed in the temperature maps from My Ocean, the composite sea surface temperature maps showed the presence of warmer water in the Western Channel, south of the Scilly Isle and in the outer Bristol Channel. The presence of these water masses with different temperature resulted in the formation of frontal systems highlighted in the composite maps of Figure 4. Frontal systems were mainly located around the Scilly Isles and in the Bristol Channel, and they seemed to weaken in the second part of the cruise. However it is important to remember that this could be simply the result of lack of satellite coverage due to cloudy conditions.

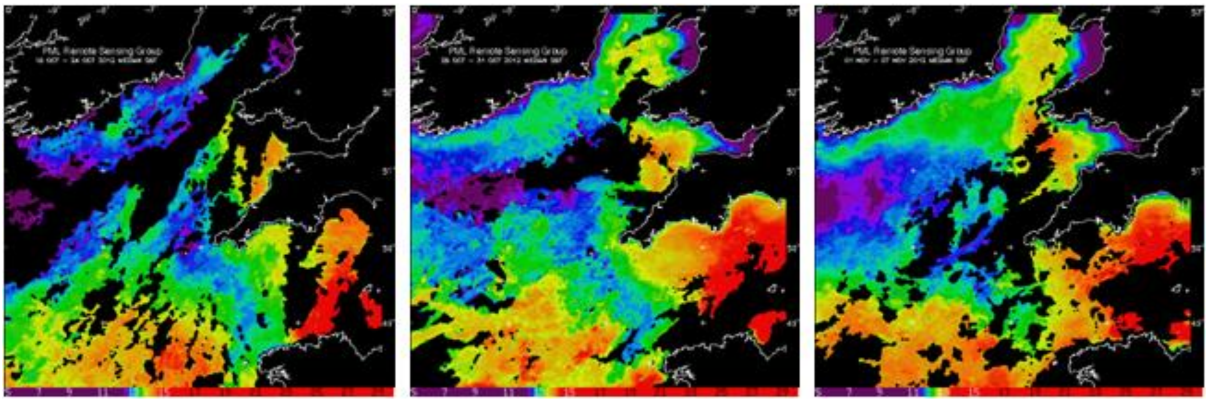


Figure 3. Composite maps of sea surface temperature from Neodaas for the periods 18-24 October, 25-31 October and 1-7 November 2012, respectively.

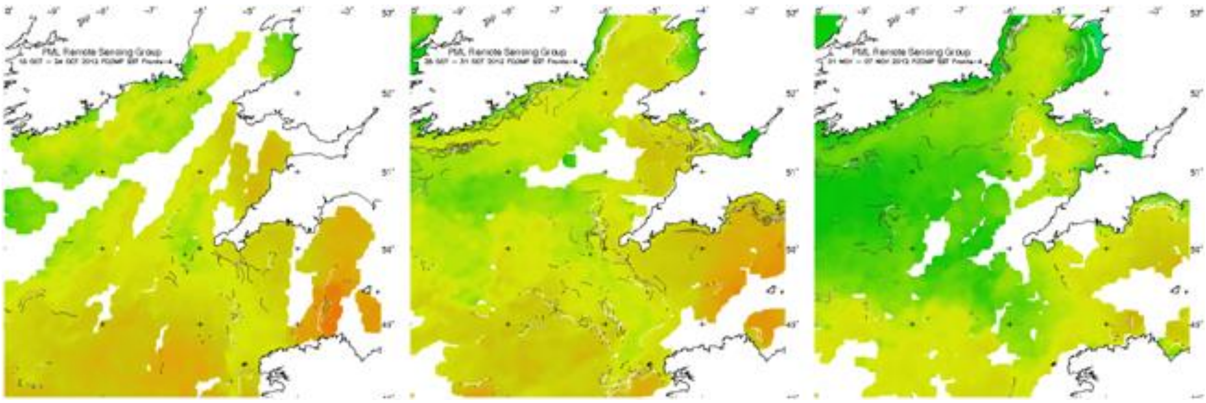


Figure 4. Composite maps of frontal systems from Neodaas for the periods 18-24 October, 25-31 October and 1-7 November 2012, respectively.

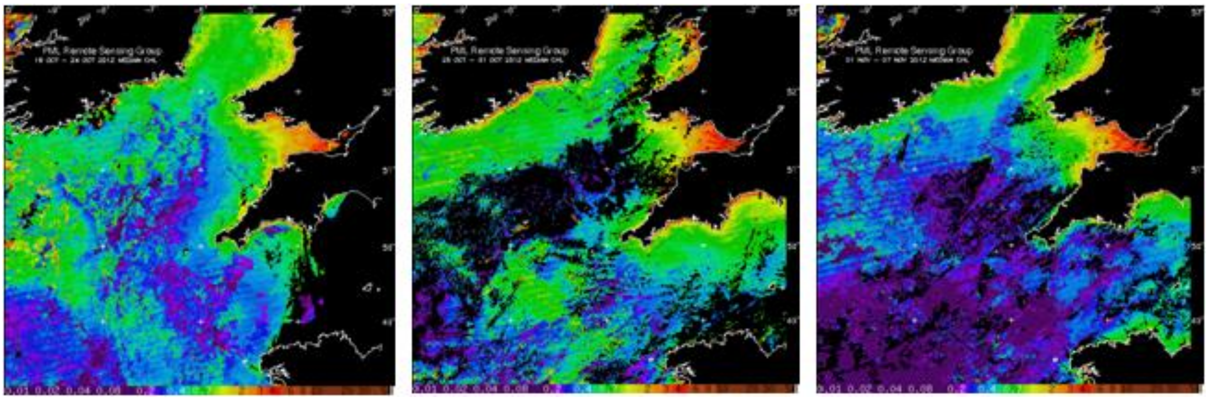


Figure 5. Composite maps of surface chlorophyll concentration from Neodaas for the periods 18-24 October, 25-31 October and 1-7 November 2012, respectively.

Ocean colour composite maps for the same periods showed that chlorophyll concentration was generally low (< 1 mg L-1; Figure 4) in the Celtic Sea and Western Channel except for the coastal area and the inner Bristol Channel. Environmental data from the Ferrybox will be downloaded and analysed at the end of the survey.

3.4. Marine Mammals and birds

Due to a last minute withdrawel of marine mammal and bird observers, no continuous observations could be made during the main part of the survey. Twenty-two opportunistic sightings of common dolphins (*Delphinus delphis*) were recorded on the bridge and will be sent to the seawatch foundation.

During the Bristol Channel-Celtic Sea transect, one of the scientific staff, aided by support staff, monitored birds and marine mammals during daylight. The main bird species recorded included gannets (Sulidae), gulls (Laridae), auks (Alcidae) and skuas (Stercorariidae). Towards the end of the transect near the Celtic Deep several common dolphins and at least three fin-whales (*Balaenoptera physalus*) were recorded feeding at the surface.

4. Discussion

Sardine and anchovy

The main aim of the current survey was to establish the (relative) abundance and distribution of sardine and anchovy and to map the spawning areas of both species. Peak spawning of both sardine and anchovy were thought to take place in May and June based on anecdotal information and peer reviewed literature (Cushing, 1957; Demir & Southward, 1974; Southward, 1974; Boddeke & Vingerhoed, 1996; Coombs *et al.*, 2005) which were used to determine the timing of the survey.

The location and quantities of sardine eggs found in this programme, confirm that sardine spawning is well established in the area; spatially and quantitatively it corresponds to spawning recorded during the late 1960s (Wallace & Pleasants, 1972) and are consistent with recent findings (van der Kooij et al., 2010). However some of the highest sardine egg concentrations were found northwest of the Cornish Peninsula, an area where previously little spawning appears to have occurred. This suggests a more northern distribution of the sardine spawning area compared to four decades ago. Generally the order of magnitude compares to medium-high egg densities in the Bay of Biscay and given the large spatial spawning area covered in the Celtic Sea, this suggests that the ”northern” spawning area is of significance. The acoustic densities of sardine suggest a predominantly coastal, widespread distribution. It is likely that these results are under-representing the actual abundance: only few sardines were caught in the trawl and as predominantly the catch composition from the trawl was used to partition the acoustic backscatter by species, this will have affected the results. At least in part the low sardine catches were due to their strong gear avoidance behaviour (Jacques Massé, pers comm.), but another factor is likely to be their availability (or lack of it) to the echosounders: there was some evidence that sardines occupied an area in the watercolumn just below the surface, in the acoustic deadzone (above the transducer). Certainly some of the schools that were strongly believed to be sardine were found high up in the watercolumn. It is possible that sardine, after spawning near the surface at night, stay near the surface during the day, rather than vertically migrating down in the watercolumn.

Results from small-scale inshore ichtyplankton surveys obtained shortly before the survey suggested that anchovy in the northern part of its distribution spawns at least partially in inshore areas, particularly estuaries, out of reach from the larger research vessel. However as no dedicated pelagic or ichtyoplankton survey has recently been conducted during May/June in the Celtic Sea it was impossible to exclude the possibility that spawning also took place in more offshore waters, as is the case in the Bay of Biscay. The results of this field work appeared to confirm our expectations that no anchovy spawning takes place in the open waters of the Celtic Sea and western Channel. Only one egg was found in the 66 ichtyplankton stations, and that one was at the southern edge of the survey area, towards the Bay of Biscay. It is possible that these findings were unusual due to adverse oceanographic conditions. However, communications during the survey with French colleagues who were surveying in the Bay of Biscay revealed that anchovy abundance in the Bay of Biscay was very high and, unusually, spatially extended beyond the shelf edge. This perhaps suggests that conditions were particularly favourable for anchovy this year and would have resulted in evidence of anchovy on the Celtic Sea. It is therefore most likely that the absence of anchovy was due to the fact that they were spawning in inshore waters at the time of the survey.

Other species

A range of other pelagic species was found in the area, including herring, horse mackerel, several species of sandeel and blue whiting. Most abundant however were sprat and boarfish. Sprat dominated the inshore waters, whereas boarfish were predominantly found in waters deeper than ~80m. Only three decades ago boarfish was known as a predominantly subtropical species with only small numbers found in the waters of the Celtic Sea and Channel (MAFF, 1965). However in recent years numbers of boarfish in the area have been increasing based on results from bottom trawl surveys (Warnes & Jones, 1991; Tidd & Warnes, 2006). During the current survey boarfish was found to be present throughout the watercolumn, from above the seabed, in mid-water to in the thermocline, nearer the surface. Although the deeper shelf waters of the Celtic Sea were not consistently surveyed compared to the inshore areas, the persistent presence of dense boarfish schools suggests a significant biomass, which may exceed that of other pelagic species. The apparent overlap in zooplankton diet with clupeid species could suggest competition but more information has to be gathered on this relatively unstudied organism (). In recent years a boarfish fishery has developed and in the last two years the fishery is controlled by a quota system. A dedicated boarfish survey was conducted by Ireland in July 2011 the results of which will hopefully shed more light on the species abundance, biology and ecological role in the Celtic Sea system.

References

[1] http://www.metoffice.gov.uk/climate/uk/2011/may/averages.html [accessed 21/06/2011 10:24]

[2] http://www.environment-agency.gov.uk/static/documents/Business /Drought_management_briefing_26_May_2011.pdf [accessed 17/06/2011 15:33]
http://www.metoffice.gov.uk/climate/uk/2011/may.html [accessed 21/06/2011 10:20]
http://www.sat.dundee.ac.uk/auth.html [accessed 22/06/2011 08:45]

Berx, B. and Hughes, S.L., 2009. Climatology of surface and near-bed temperature and salinity on the north-west European continental shelf for 1971-2000. Continental Shelf Research 29, 2286-2292.

Brown, J., Carrillo, L., Fernand, L., Horsburgh, K.J., Hill, A.E., Young, E.F. and Medler, K.J., 2003. Observations of the physical structure and seasonal jet-like circulation of the Celtic Sea and St. George's Channel of the Irish Sea. Continental Shelf Research 23, 533-561.

Boddeke, R., Vingerhoed, B., 1996. The anchovy returns to the Wadden Sea. ICES Journal Marine Science, 53, 1003–1007.

Coombs, S. H., Halliday, N. C., Southward, A. J. and Hawkins, S.J., 2005. Distribution and abundance of sardine (*Sardina pilchardus*) eggs in the English Channel from Continuous Plankton Recorder sampling, 1958–1980. Journal of the Marine Biological Association of the United Kingdom, 85, 1243–1247.

Coombs, S.H., Halliday, N.C., Conway, D.V.P., and Smyth, T.J., 2010. Sardine (*Sardina pilchardus*) egg abundance at station L4, Western English Channel, 1988–2008 Journal of Plankton Research.32: 693-697.

Korneliussen, R. 2010.

MAFF 1965. The Cornish Pilchard and its fishery. Ministry of Agriculture, Fisheries and Food, Laboratory leaflet [new series] No 9, 17 pp

Tidd, A. and Warnes, S. 2006. Species distributions from English Celtic Sea groundfish surveys, 1992–2003. Science Series Technical Report, Cefas Lowestoft, 137: 51pp

UNESCO, 1983. Algorithms for computation of fundamental properties of seawater. UNESCO Technical papers in marine science 44, 6-9.

van der Kooij, J., Mulligan, B., Delaunay, D., Roel, B.A. 2010. Sardine and Anchovy off Southwest England. FSP programme 40: 18pp. Available at: http://www.cefas.co.uk/media/457783/mf040_report2010_vfinal..pdf

van der Kooij, J., D. Brown, and B. Roel

Wallace, P.D. and Pleasants, C.A.. 1972. The distribution of eggs and larvae of some pelagic fish species in the English Channel and adjacent waters in 1967 and 1968. ICES CM/J:8.

Warnes, S. and Jones, B.W. 1995. Species distributions from English Celtic Sea groundfish surveys, 1984 to 1991. Fisheries Research Technical Report, MAFF Directorate of Fisheries Research, Lowestoft, 98: 42pp