DRAFT Survey report CEND22_16

PELTIC16: Small pelagic fish in the coastal waters of the western Channel and Celtic Sea

Jeroen van der Kooij, Elisa Capuzzo, Joana Silva, Mike Bailey, Sophie Pitois and Paul Bouch

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1. Outline of the survey

STAFF:
1. Jeroen van der Kooij (SIC)
2. Elisa Capuzzo (2IC)
3. Joana Silva (2IC)
4. Marc Whybrow
5. Richard Humphreys
6. Matt Eade
7. Paul Bouch
8. James Pettigrew
9. Sophie Pitois
10. Tom Hull
11. Julian Tilbury (Plymouth University)
12. Mike Bailey (Observer)
13. Sean Minns (Observer)
14. Peter Howlett (Observer)

1.2. **Duration**: 3rd – 19st of October

1.3 Location

Western Channel and Celtic Sea coastal zone (embarking in Portland and disembarking in Swansea)

1.4 Objectives

1. To carry out the fifth and final of five annual multidisciplinary pelagic surveys of the Western Channel and Celtic Sea waters as part of project Poseidon, to estimate the biomass of-, and gain insight into the population of the small pelagic fish community (sprat, sardine, mackerel, anchovy, horse mackerel, herring).
   a. To carry out a fisheries acoustic survey during daylight only using four operating frequencies (38, 120, 200 and 333 kHz) 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 pelagic species using a 20x40m herring (mid-water) trawl (taking the Cosmos Fotø and Engels 800 as back up) 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
      - Stomach contents (see also 11)
2. To collect plankton samples using 2 different mesh ringnets (80 µm, and 270 µm mesh) at fixed stations along the acoustic transects (marked in red in below map) at night by vertical haul. Samples will be processed onboard:

   a. Ichtyoplankton (eggs and larvae, 270 μm) of pelagic species will be identified, counted and (in case of clupeids) measured onboard and combined with information from maturity to identify spawning areas.
   b. Zooplankton samples (from ringnet with 80 μm mesh) will be stored for further analysis back in the lab.
3. Water column sampling. At fixed stations along the acoustic transect, marked in yellow on below map, an ESM2 will be deployed to obtain a vertical profile of the water column. Water column profiles and water samples will provide information on chlorophyll concentration, dissolved oxygen concentration, salinity, temperature, inorganic nutrients concentration and the relevant QAQC samples for calibration of the equipment. Water samples will be collected and fixed on board for analysis post-hoc.
4. Seabirds and Marine Mammals. Locations, species, numbers and activities observed will be recorded continuously during daylight hours by three Marinelife observers from bridge.
5. Additional high resolution ESAS observations will be conducted on critically endangered Balearic shearwaters and other seabirds as part of a collaborative Defra funded project between MarineLife, Natural England and Cefas.
6. Ferrybox Continuous CTD/Thermo-salinigraph/pCO2. Continuously collect oceanographic data at the sea surface (4 m depth) during steaming.
7. To conduct further experiments with the online flow-cytometer to obtain continuous data on phytoplankton functional groups in collaboration with project JERICO NEXT.
8. To collect discrete samples of phytoplankton and micro-zooplankton at predetermined 18 primary stations for further analysis back to the lab (species composition, abundance, biomass and size distribution).
9. To test an automatic continuous zooplankton camera in collaboration with PML (Julian Tilbury).
10. To collect juvenile mackerel for AZTI (Paula Alvarez) in support of genetic study.
11. To collect jellyfish for PhD student Katie St John Glew in support of isotope study

1.5 Narrative

Staff from Cefas, MarineLife and Plymouth University joined the RV Cefas Endeavour in the afternoon of Sunday the 2nd of October from 16:00 BST. After initial gear-check and -set up in the afternoon and early evening, plus a safety induction for the relevant staff, the vessel left Portland at 06:00 on the 3rd of October, steaming straight to the calibration site off West Bay, west of Portland Bill. Whilst steaming staff were run through relevant dynamic risk assessments. A weighted parachute line was guided round the hull before the anchor was dropped. First the new rosette was deployed to ensure some recent alterations were successful and to train the oceanographic staff in its use. After successful deployment Tom Hull disembarked by searider and was dropped off on land (in West Bay) as planned. At the same time, at approximately 9:00 BST the plankton ringnets plus SAIV mini CTD were tested and the calibration of the echosounders commenced. Although the calibration spheres were briefly detected on the echosounder, the spring tides proved too strong to keep the targets in the beam. Despite further attempts during three slack tide periods, the spheres were not detected again and the calibration exercise was postponed, particularly as the weather conditions were picking up. During this period a toolbox talk was conducted. At ~19:00 BST we came off station and started sampling the primary stations (using Rosette and Plankton ringnets), which continued throughout the night.

On Monday morning the 4th of October the survey started proper, commencing first with the eastern most transects of the western English Channel. Similar to the previous two years' surveys, fisheries acoustic transects, trawling and bird and mammal observations were conducted during daylight hours, and CTD- and plankton stations were covered during the night. The exception was a number of inshore stations located in areas with static gear which were sampled during daylight, to maximise visibility. On a few occasions acoustic data acquisition continued after dusk to complete remainders of transects. During ~40 of the zooplankton stations the CALPS system (Cefas' Automatic Litter and Plankton Sampler) was switched on to collect surface zooplankton

It was decided to use the first targeted trawl as a shake-down tow, taking extra time for all involved to get used to gear. As it turned out, the whole process went very smoothly. For the duration of the survey, when appropriate, the pelagic trawl was deployed to ascertain the species- and length composition of acoustic targets, or ‘marks’. In total 15 successful trawls were conducted. On a few occasions no trawl could be conducted despite the presence of targets on the echogram. The main reasons were adverse weather and swell conditions (~ 3 days), presence of static gear and schools close to hard seabed substrate in areas of string relief.

During the 5th of October, acoustic data acquisition was stopped around mid-day as the data quality deteriorated due to the bad weather. Work was resumed on the 6th of October and continued throughout the rest of the survey. During a deployment of the trawl on the 8th of October the starboard G-link came off the pennant, delaying the deployment. During this trawl, several of the floats were removed around the Marport bag to improve its tilt angle for better communication with the dropkeel based transducer. This had the desired effect. On the morning of the 9th of October one of the three engines had to be switched off to enable repairs. The acoustic transect was able to be continued at 10 knots due to favourable swell and tide conditions, but no trawling operation could be conducted during this period. This was resolved in the afternoon and after completion of transects the RV sailed to some fish aggregations spotted earlier in the day to shoot the trawl. From the 16th late morning through to the 18th of October, survey conditions inside the Bristol Channel deteriorated due to gradual westward shift of winds which, in periods, compromised the acoustic data quality although it was not sufficiently bad to stop data acquisition.

The last of the night-time prime stations (Rosette and plankton) were completed on the 16th of October, which enabled the night shift to be moved back to day shifts to acclimatise before docking. Despite the fact that the survey programme had been adapted to accommodate for the reduced survey duration and as a result the acoustic transects around the Isles of Scilly were dropped, the primary stations of this area were successfully completed providing information on the physical oceanography and sardine eggs and larvae. The final acoustic transects of the regular survey design were completed on the 18th of October. On the morning of the 19th a final trawl was conducted on some fish aggregations observed the day before after which transect 39 was run from an approximate halfway point to the inner Bristol Channel. The vessel steamed to meet the pilot and docked in Swansea at approximately 19:45.

2. Material and Methods

2.1. Study area

The survey was conducted according to the PELTIC survey grid (Fig 1) established in 2012. Acoustic transects, plankton and water sampling were undertaken along the predefined transects, undertaken in a generally east to west direction for the first half of the survey, then a south-west to north east direction for the second half of the survey. Trawls were undertaken opportunistically, depending on the presence and type of acoustic marks observed. Acoustic data acquisition, trawling operation and marine mammal and bird observations were conducted during daylight hours, whereas the primary stations (plankton and water sampling) were conducted during the night. Due to the (planned) reduction in survey duration by two days it was decided to drop the acoustic transects around the Isles of Scilly. However, the primary stations were all completed, including those around the Isles of Scilly.

2.2 Fisheries acoustics

2.2.1. Acquisition

Fisheries acoustics were recorded along the pre-designed transects (Fig. 1) at the four operating frequencies (38, 120, 200 and 333 kHz). The transducers were mounted on a drop keel which was lowered to 3.0 m below the hull, 8.3 m below the sea surface. Pulse duration was set to 0.512 ms for the 38-200 kHz frequencies and to 1.024 for the 333 kHz frequency (as better results were obtained) and the ping rate was set to 0.5 pings s^{-1}. During the first 10 days, fairly persistent easterly winds caused occasional interference although the 38kHz echogram remained of good quality. During the last week, winds turned westerly and caused further periods of poor data quality largely due to surface 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.

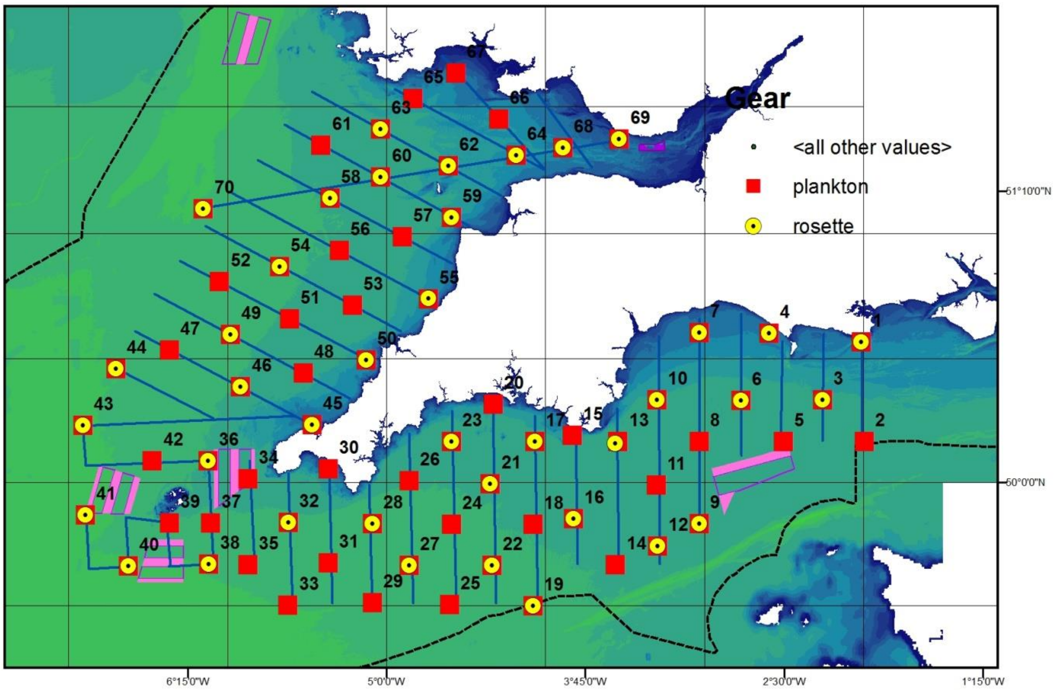


Figure 1. Overview of the survey area, with the acoustic transect (blue lines), plankton stations (red squares) and hydrographic stations (Yellow circles).

2.2.2. Processing

Acoustic data were cleaned, which included removal of data collected during fishing operations. Both the on-transect data and those collected during the steam between transects were retained. Only the former was used for further biomass estimates but the inter-transect data was retained and cleaned for future studies on spatial distribution of predators and prey. A surface exclusion line was set at 13 m 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 developed in 2012 was refined to separate echograms for each of the echotypes (Fig. 2). The echogram with only the echoes from fish with swimbladders was then scrutinised and attributed to individual species based on expertise and 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.

In the case of mackerel a separate algorithm was used (following Korneliussen 2010). An additional bad weather filter was developed which removed “empty” pings as a result of adverse weather conditions. This was applied only on files which were affected by bad weather.

2.3 Fishing and catch sampling

A heavy duty ‘herring’ trawl (20 x 40m v d K Herring trawl, KT nets) was used to sample the pelagic community for the purpose of validating acoustic marks and collecting biological samples. 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. Trawling operations went very well with no gear damage.

Fish were sorted to species and size categories before the total catch was weighed and measured using the Cefas Electronic Data Collection (EDC) system. In the case of very large catches, subsamples were taken before weighing and measuring. The sex and maturity of the pelagic species in each trawl was assessed (up to 5 per length class of mackerel, sprat, sardine, anchovy, horse mackerel, garfish, herring), and their otoliths and stomachs were dissected out and removed for later analysis. For the stomachs a total of up to 25 stomachs were taken across the various length categories per species per catch.

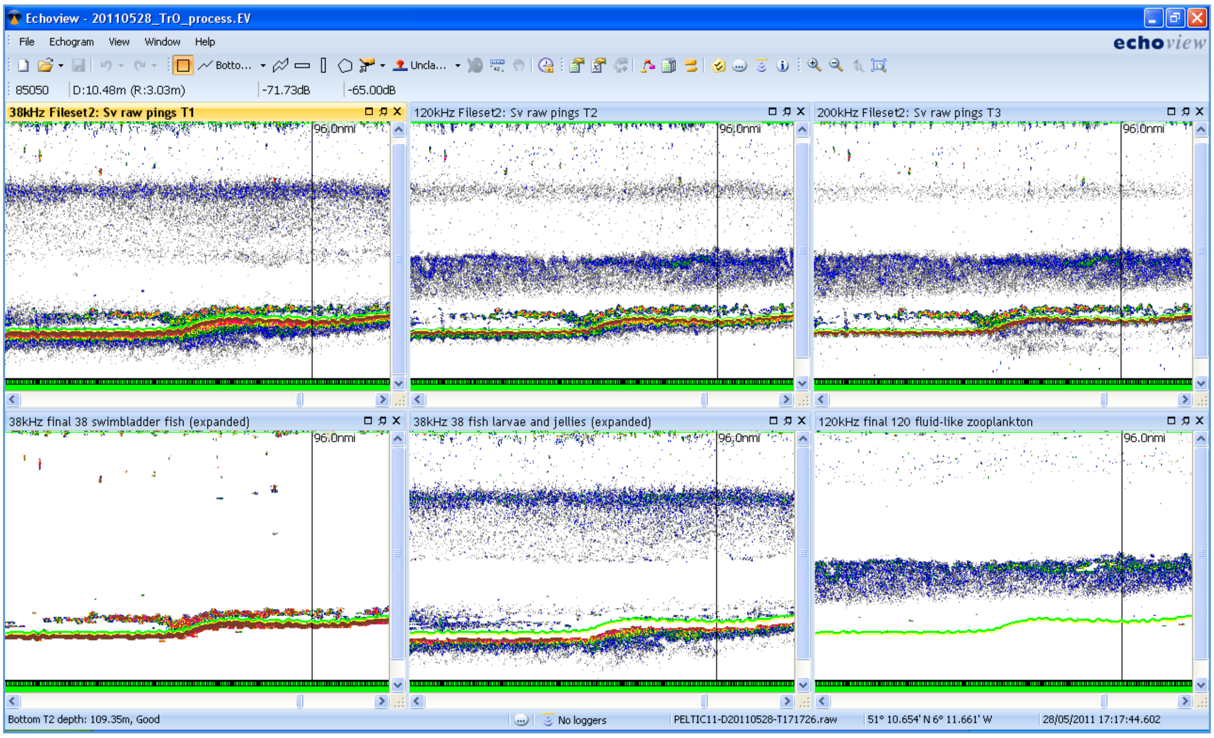


Figure 2. Dataflow of algorithm (top) used to divide the acoustic data by echotype. Screen-shot example (bottom) with raw echograms of 38, 120 and 200 kHz (top panels) and three examples of extracted echotypes (bottom panel from left to righ): fish with swimbladder (sardine schools at surface and myctophids layer near seabed), fish larvae/ jellyfish and zooplankton (dense krill layer).

2.4 Zooplankton

2.4.1. Ringnets

The various planktonic size components were sampled at 71 fixed plankton stations along the various transects using two ringnets of different mesh: 270 µm (ichtyoplankton and macro-zooplankton) and 80 µm (zooplankton). The two ringnets were fixed to a frame which enabled them to be deployed simultaneously. Both nets had flowmeters (General Oceanics mechanical flowmeters with standard rotor, model 2030R) mounted in the centre of the aperture of the net and a mini-CTD (SAIV) was attached to the bridle. Position, date, time, seabed depth, sampled depth (from CTD attached to net) and flowmeter reading were recorded. Nets were washed down on hauling and samples were transferred from the terminal mesh grid. When possible, samples from the 270 µm mesh were transferred into jars and immediately analysed under a binocular microscope before the full sample was preserved in 4% buffered formaldehyde. If immediate analysis was not possible, samples were transferred into 1 lb glass jars and preserved before analysis on a later day during the survey. Ichthyoplankton (eggs and larvae) and macrozooplankton from the 270 µm samples were counted, aged and, in the case of clupeid larvae, measured and raised using flow meter derived sample volumes. Samples from the 80 µm mesh were transferred into jars and preserved with 4% buffered formaldehyde for later analysis using a zooscan in the lab.

2.4.2. Microzooplankton

At a subset of 18 prime stations two water sample were taken and fixed on lugol, one for phytoplankton analysis back in the lab and one for micro-zooplankton analysis.

2.4.3. CALPS

At 40 ringnet stations additional surface samples of zooplankton were taken using the CALPS (Cefas Autonomous Litter and Plankton Sampler). For an hour at each of these stations a sample was taken using an 80 µm mesh net to be compared with the vertical casts, starting ~20 mins before arriving at the station, running during the station and continuing until ~20 mins after the station.

2.4.4. Plankton Image Analyser

A Plankton Image Analyser (PIA) system was trialled during the Peltic survey. PIA is a real-time high speed instrument developed by Phil Culverhouse (University of Plymouth) that continuously takes samples from a water inlet (the same one used by the CALPS) whilst underway. As the pumped water passes through a flow-cell, the PIA takes images of the passing particles. Those images will be sent to a recognition software which will classify them into categories corresponding to zooplankton taxonomic groups. The PIA was ran for the entire duration of the cruise, collecting over 10 million images of zooplankton throughout the sea trip.

2.5 Oceanography

A Ferrybox system provided continuous subsurface measurements in real time of various environmental variables (e.g. temperature, salinity, fluorescence and dissolved oxygen) during steaming. In addition, weekly maps of sea surface temperature, frontal systems, and chlorophyll concentration were obtained from Neodaas (www.neodaas.ac.uk). The Ferrybox was connected to a flow cytometer, which performed hourly measurements of the size and abundance of pico- and nano-phytoplankton populations in the water.

Vertical profiles of temperature, salinity, fluorescence, optical backscatter, dissolved oxygen and Photosynthetically Available Radiation (PAR) were collected at 38 sampling stations using a Rosette sampler equipped with a SeaBird CTD, in calm and moderate sea states. An ESM2 profiler was used instead in rough sea conditions.

At 18 of these 38 sampling stations, surface water samples for analysis and calibration of salinity, inorganic nutrients, dissolved oxygen, and phytoplankton pigments were collected using the Rosette sampler, or, when not in use (during periods of adverse weather), from the continuous water pump that supplies the Ferrybox. At the same 18 stations further surface samples for analysis of phytoplankton and microzooplankton communities were collected; at one of these stations, prime station 27, samples were also collected at depth, due to the presence of a Deep Chlorophyll Maximum.

Samples for analysis of dissolved oxygen concentration, salinity and phytoplankton pigments will be used for calibrating the sensors of the SeaBird CTD, of the ESM2 profiler and of the Ferrybox. A summary of the samples collected, and of the CTD profiles carried out during the survey, is given in Table 1.

Table 1. Samples collected during the survey and number of profiles carried out.

Salinity	19
Dissolved oxygen	8 (x3)
Chlorophyll/Pigments analysis	40
Inorganic nutrients	20
Phytoplankton	19
Microzooplankton	19
CTD profiles with Rosette SeaBird	28
CTD profiles with ESM2	10

2.6 Top predators

For the second year running, two different but complimentary approaches were taken to record birds and marine mammals. On the Bridge wing of one side of the vessel (selected as appropriate to minimise sun glare), two experienced JNCC-accredited European Seabirds At Sea (ESAS) surveyors (Mike Bailey and Sean Minns) employed an effort-based distance sampling straight-line transect survey following strict ESAS methodology, whilst on the other Bridge wing, a single experienced volunteer MARINElife surveyor (Peter Howlett) employed an adapted and slightly simplified version of this methodology. As a result, a 90° bow-to-beam scan area was surveyed by the ESAS team along transect lines during daylight hours, and with the additional coverage provided by the MARINElife surveyor, a 180° scan area was surveyed along every transect line. During transits between transects, both teams maintained incidental observations whenever possible, logging significant species only. Furthermore, observations were regularly conducted during the net-retrieval stage of many trawls to identify species of birds associated with the fishing activity of the survey vessel but only significant species were logged as incidental records. All species of birds (both seabirds and terrestrial migrants) were recorded, along with all sightings of marine mammals.

ESAS methodology aims to achieve an assessment of the numbers and distribution of animals in a designated quantifiable area by employing a sampling method so that numbers can be extrapolated into the entirety of the study zone. ESAS methodology is an internationally recognised sampling method conforming to internationally accepted standards enabling data to be compared with surveys elsewhere.

It is recommended that ESAS surveys only occur in sea state 4 or less, although the effects of environmental conditions on surveyability are very vessel dependent. Frustratingly, the weather conditions during this 2016 Peltic survey regularly exceeded sea state 4 (reaching sea state 8 on one day) meaning that some of the data will be unusable using the usual ESAS analysis methods.

The single MARINElife surveyor adopted a transect on the opposite side of the vessel to the side used by ESAS observers (and was therefore frequently affected by sunglare). Priority was given to detecting marine mammals, often at significant distance, so the use of binoculars was far more frequent, and this undoubtedly affects the detectability and reliability of recording each bird within transect. In addition to cetaceans, specific effort was made to detect Balearic Shearwater (Puffinus mauretanicus), and any other birds. Communication between the two teams was maintained throughout via two-way PMR446 radio to ensure that any unusual or significant sightings were corroborated, although in reality this was sometimes impossible to do when large aggregations were encountered and when the vessel's bulkhead prevented viewing across to the opposite transect. Otherwise, all data recorded by the two teams was kept separate to ensure independence when detecting animals.

During the deployment of the fishing net, both teams paused effort. However, during the net-retrieval phase, incidental records of significant species was logged (e.g. Balearic Shearwater, Sooty Shearwater, cetaceans) whenever time permitted. Observations were conducted from the rear of the Bridge to cover a 180° arc, aft of the vessel. Whilst this data was not part of the standard transect data it provided an opportunity to observe behaviour and associations with a fishing vessel and could provide useful comparisons with future surveys in these waters.

3. Preliminary results

3.1. Pelagic Ichthyofauna

After removing the off-transect data a total of ~1200 nautical miles of acoustic sampling units were collected for further analysis (Fig. 3). A total of 15 successful trawls were made (Fig. 3). The trawls were evenly spread across the survey area, providing a suitable source of species and length data to partition the acoustic data.

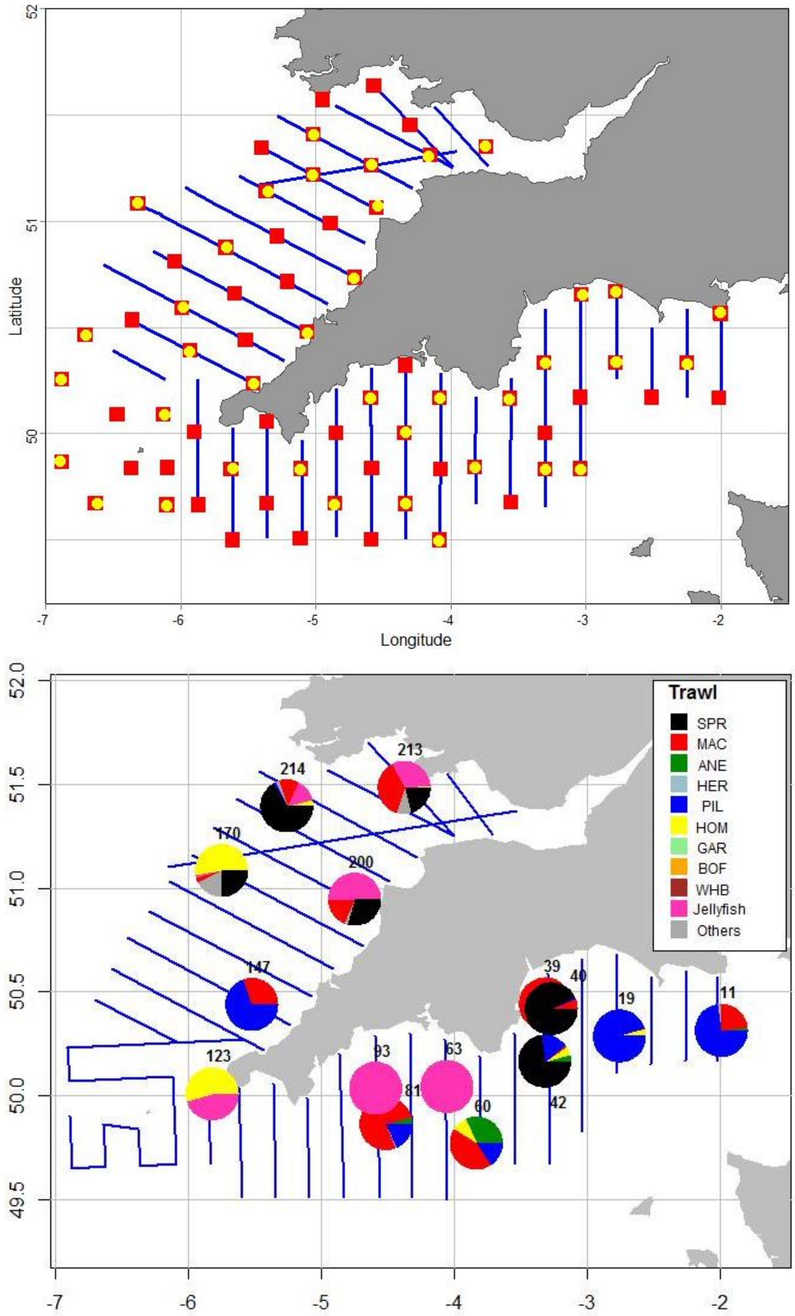


Figure 3. Overview map and detail of the survey area. Top: Acoustic transects (blue lines) and prime stations completed during PELTIC16. Bottom: Trawl catches (pies) with relative catch composition by key species. Three letter codes: SPR=sprat, MAC=mackerel, ANE=anchovy, HER=herring, PIL=sardine, HOM= horse mackerel, GAR=garfish, BOF=Boarfish, WHB=Blue whiting.

Species distribution in 2016 was comparable to those observed in previous years. Sprat dominated in western Lyme Bay and in the coastal waters of the Bristol Channel. As in previous years, sprat in the Bristol Channel consisted nearly entirely of juvenile specimens, whereas those from the Lyme Bay area were more mature although maximum size was relatively low at 14 cm (fig. 4) compared to previous years.

Sardines (*Sardina pilchardus*) were widespread as in 2015 and specimens were found in most hauls (fig. 3). As was the case in 2015, the size of specimens collected in the Bristol Channel included larger adults fish of around 19 cm although the dominant large numbers of fish of around 15cm were also found this year (Fig 4). Similar length frequency distribution was obtained from the English

Channel trawl stations. Maximum sardine size exceeded 22 cm (Fig 4) which is larger than 2015 (20) but smaller than 2014 (25 cm).

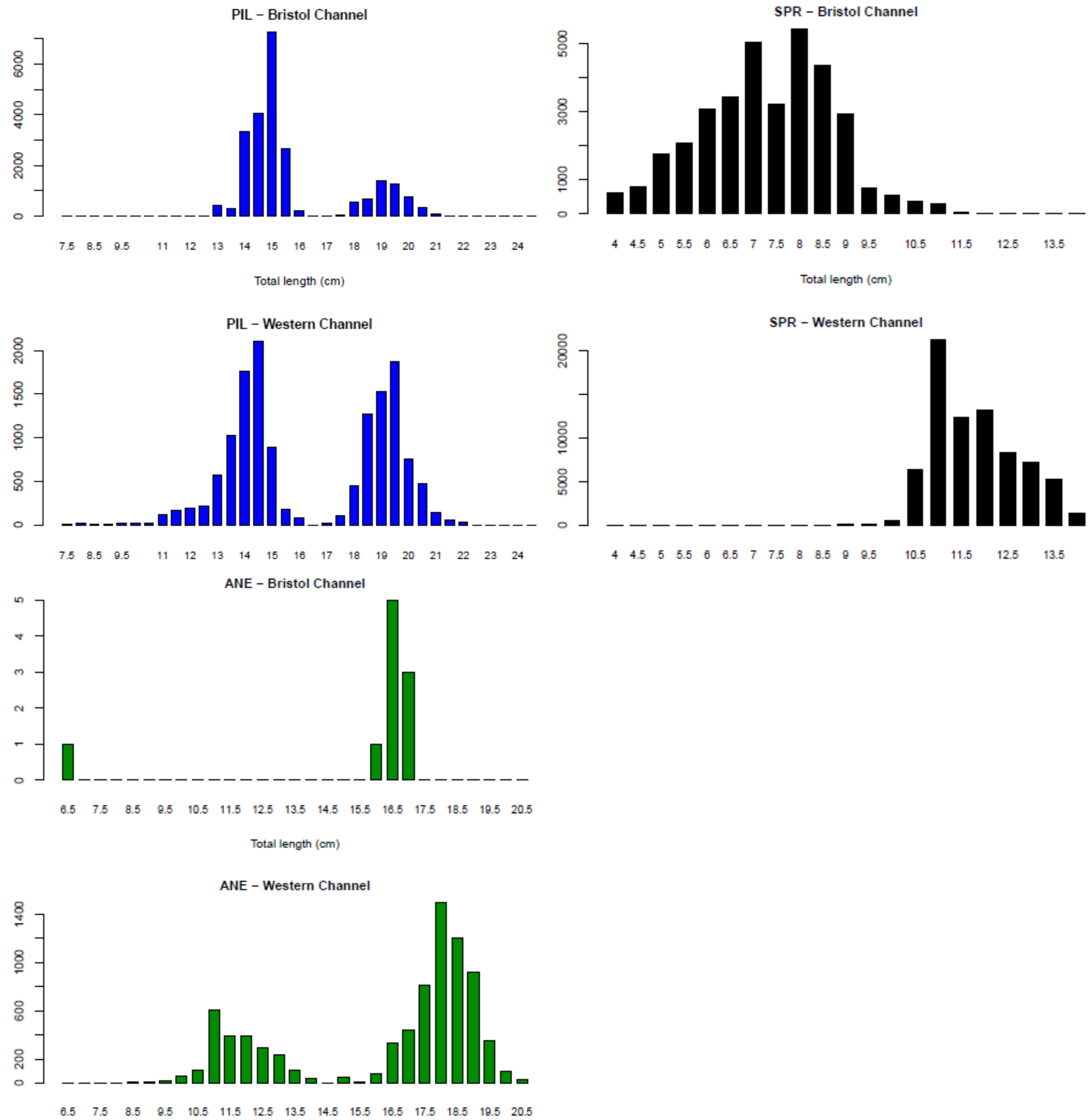


Figure 4. Trawl-caught numbers by length of sardine (*Sardina pilchardus*) (PIL, top left) sprat (*Sprattus sprattus*) (SPR, top right) and anchovy (*Engraulis encrasicolus*) by subarea. Please note that these numbers are not raised by the acoustic data.

Anchovy (*Engraulis encrasicolus*) was found in good numbers and more widespread in the Bristol Channel area. Mackerel (*Scomber scombrus*) and horse mackerel (*Trachurus trachurus*) were found widespread throughout the survey area dominated by juvenile specimens (Fig 5). Some large and relatively dense mackerel aggregations were apparent near the Celtic Deep.

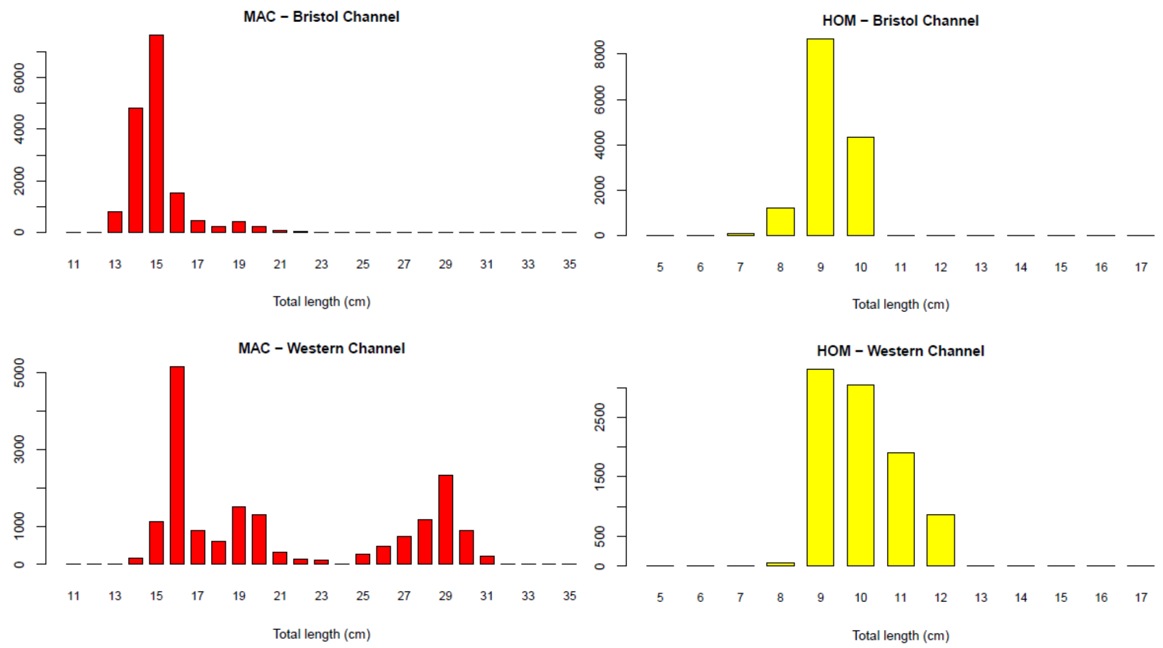


Figure 5. Trawl caught numbers by length of mackerel (MAC, left) and horse mackerel (HOM, right) in the Bristol Channel (top) and English Channel (bottom).

3.2. Plankton

3.2.1. Ichthyoplankton

Good numbers of sardine egg were found, with the highest densities in the Eddystone Bay, western Channel. As in previous years, sardine larvae were slightly more widely distributed although the highest densities were also found in Eddystone Bay. Prior to 2015, no sardine eggs had been found north of the Cornish Peninsula. In 2015 two stations contained small numbers of eggs. This year however, eggs were found at five station in the Bristol Channel and at one station in larger numbers. Sardine larvae, normally found in low numbers in the Bristol Channel, were particularly abundant on one of the offshore Bristol Channel stations (Fig 6).

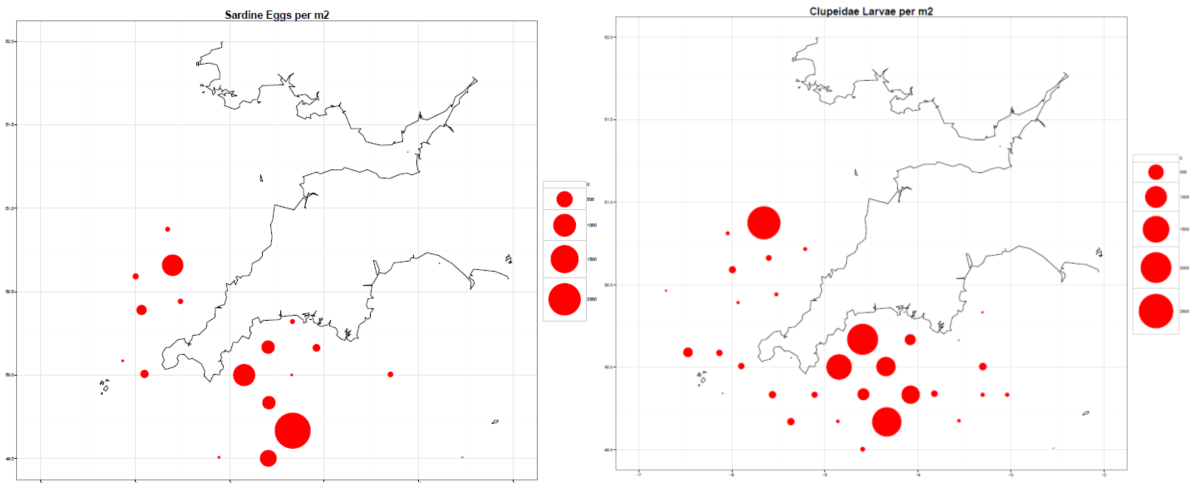


Figure 6. Sardine egg densities in m2 (left) and larvae (right) as sampled during the 2016 Peltic survey.

3.2.2. Plankton Image Analyser

PIA was successfully deployed throughout the survey, collecting over 10 million images of zooplankton throughout the sea trip. Despite the significant swell and wind conditions the system operated consistently and reliably, collecting good quality images (Fig 7 for some examples). These will be further processed and categorised back in the lab and compared with the zooscan results from the 70 Ringnet samples and from 40 CALPS stations.

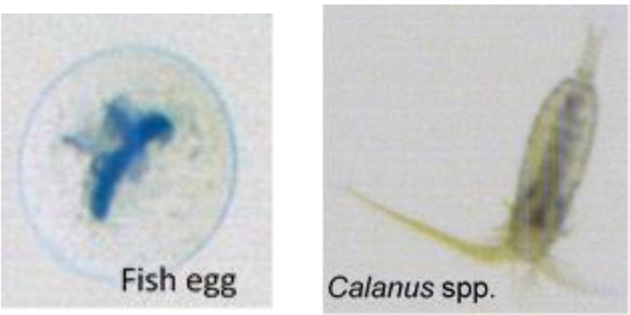


Figure 7. Examples of two images recorded during the PELTIC16 survey using the Plankton Image Analyser system.

3.3. Oceanographic data

3.3.1. Temperature and salinity

Surface waters of the Western English Channel were warmer than waters of the Celtic and Irish Seas with temperatures up to 17.13°C (from the SAIV MiniCTD; Figs 8 and 9). The maximum temperature recorded during the survey in 2016 was higher than maximum temperatures during surveys in 2013 and 2015 (approximately 16°C), but it was 1°C lower than maximum temperature recorded in 2014. Temperatures near the bottom were highest at stations in the Western English Channel and lowest at offshore stations in the Celtic Sea (down to 10.15°C; Figure 8).

Salinity was similar between the sampling stations, except at the inner stations in the Bristol Channel, which had lower salinity (33.48), as result of freshwater inputs from the River Severn. The salinity range (33.48-35.13) was comparable with ranges measured during surveys in the previous years.

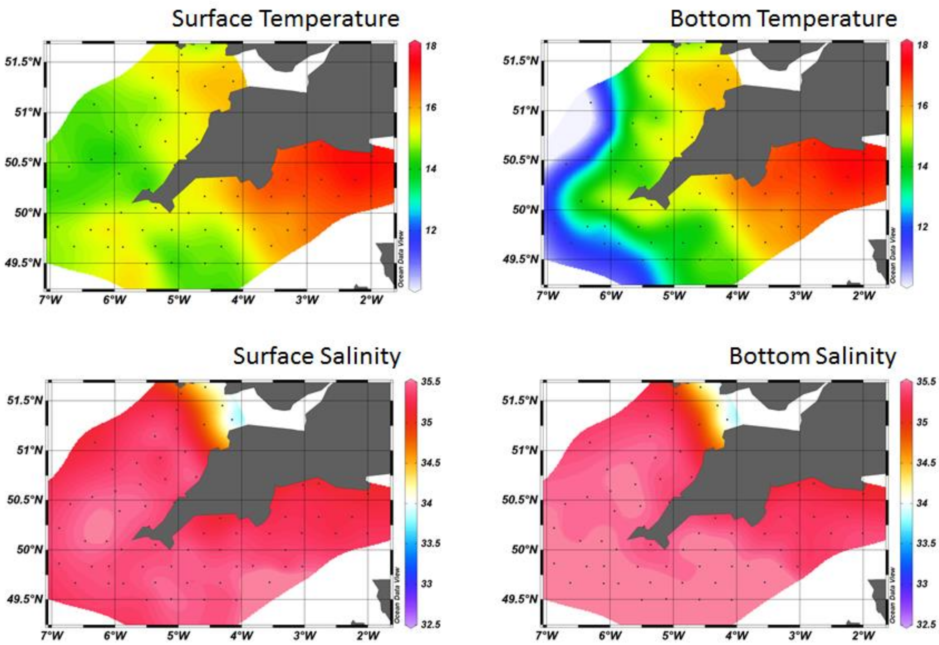
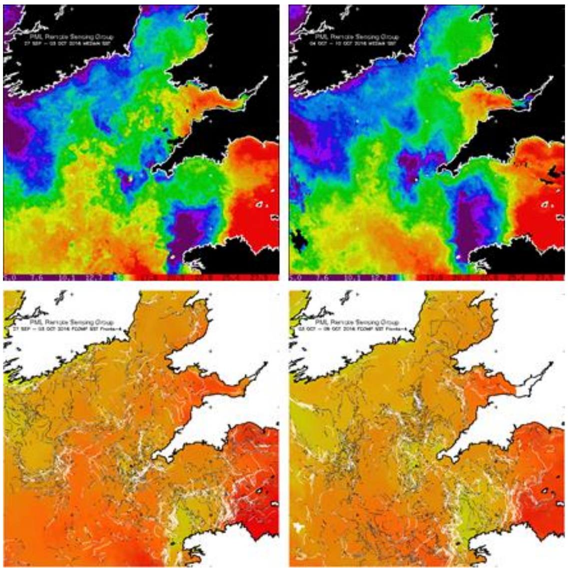


Figure 8. Temperature (°C) and salinity at the subsurface (1-2 m depth) and above the bottom measured by the SAIV MiniCTD at the 69 sampling stations between 3rd October and 19th October 2016. Maps prepared with Ocean Data View (ODW).

The patch of slightly cooler water, located south of Eddystone Bay, was clearly visible in satellite remote sensing images (Fig 9a). In comparison with images from previous years, the patch was smaller and located further south, near the France coast (compare Fig 9a and 9b). During the course of the survey the patch extended northwards, towards the Cornish coast.

The boundary layer where the patch cooler waters meet the warmer waters of the English Channel and the Celtic Sea was marked by a series of frontal systems (Fig 9a); in 2016, the fronts were located further south and appeared to be weaker than the previous year (compared Fig 9a and 9b).

a) 

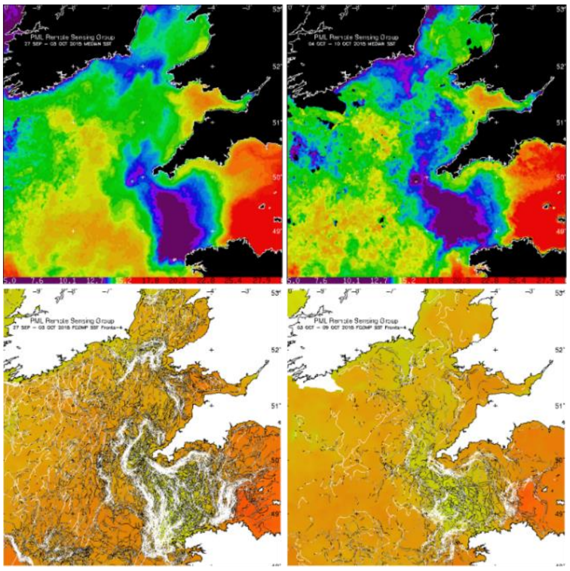
b) 

Figure 9. Composite surface maps for the periods 27 September - 3 October, 4 – 10 October 2016 (a) and 2015 (b) of temperature (upper row of images) and thermal frontal systems (lower row) from Neodaas.co.uk (PML).

The majority of stations near the Isles of Scilly, the most westerly stations of the Western English Channel and the offshore stations of the Bristol Channel area, were thermally stratified ($\Delta T > 0.5°C$), with difference in temperature between surface and bottom of up to 4.35°C (Fig 10). Distribution of the mixed/stratified areas in 2016 was similar to distribution in 2013 and 2015 (Fig 10).

Differences in surface and bottom salinity were small, suggesting that the vertical stratification of the water column was mainly driven by changes in temperature rather than salinity.

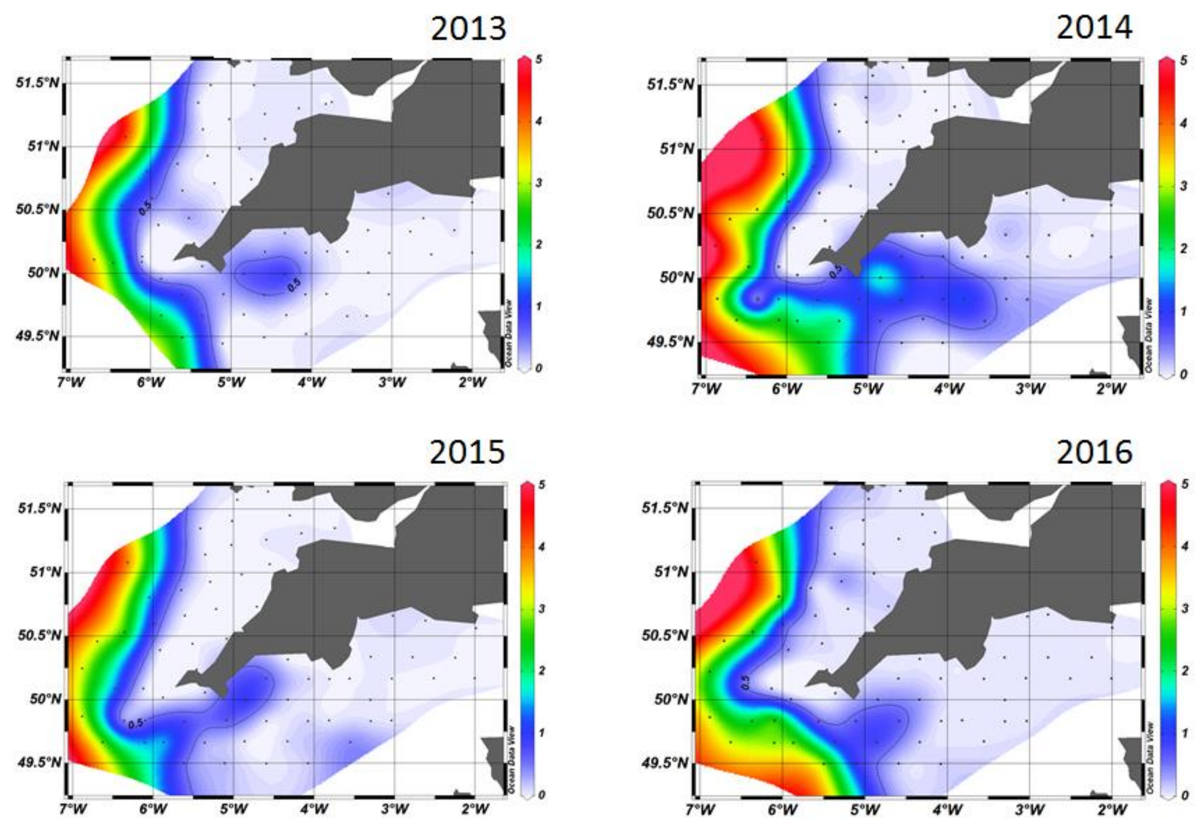


Figure 10. Values of ΔT (surface temperature – bottom temperature; °C) at the 69 sampling stations, as measured by the SAIV MiniCTD, in 2013, 2014, 2015 and 2016. The water column is considered stratified when ΔT > 0.5 (°C); ΔT = 0.5 °C is marked by the continuous black line. Maps prepared with Ocean Data View (ODW).

Differences in vertical structure of the water column between the three main areas of the Western English Channel (WEC), Isles of Scilly (SI) and Bristol Channel (BC) were observed (Fig 11, based on measurements by the Rosette SeaBird CTD). WEC and BC had the highest temperatures and were fully mixed; BC had the lowest salinity and the highest turbidity (Fig 11). Offshore stations showed thermal stratification, with cooler water near the bottom, except at station prime 27 (indicated with a '*' in Fig 11) where the cooler water reached the mid-water column. Interestingly, this latter station also presented a Deep Chlorophyll Maximum (Fig 11 – Fluorescence Seapoint).

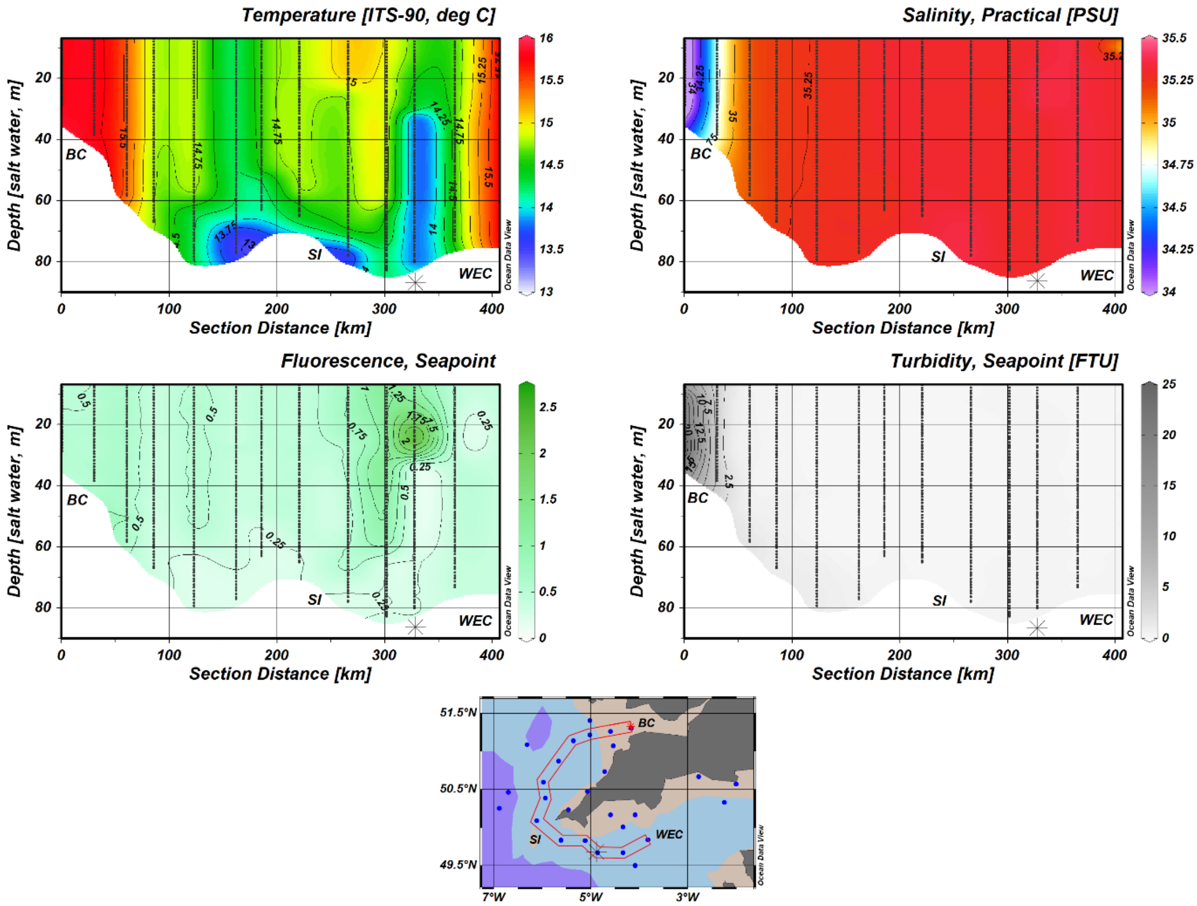


Figure 11. Section from Western English Channel (WEC), to the Bristol Channel (BC), passing through the Scilly Isles (SI), prepared combining temperature, salinity, fluorescence and turbidity profiles collected with the SeaBird on the Rosette sampler. Prime station 27, characterised by a Deep Chlorophyll Maximum (DCM) is indicated with a star '*'. Maps prepared with Ocean Data View (ODW).

3.3.2. Fluorescence and chlorophyll concentration

Remote sensing techniques showed that surface chlorophyll concentration at the end of September were highest south of the Cornish coast (in the middle of the Western English Channel) and offshore near the Isles Scilly (Fig 12). In situ measurements of surface fluorescence showed that higher levels of chlorophyll were observed south of Lizard Point (Fig 13, from Ferrybox measurements).

Furthermore, the satellite images of surface chlorophyll (Fig 12) also suggested high level of chlorophyll concentration in the Bristol Channel; this observation was not supported by the Ferrybox and SeaBird CTD fluorescence measurements which were generally low in the Bristol Channel area (Fig 11 and 13). This could be explained by the higher level of suspended solids in the inner Bristol Channel (see Fig 11 – Turbidity Seapoint [FTU] transect) affecting the reliability of the remote sensing algorithm for calculating chlorophyll concentration.

Chlorophyll concentration (expressed as fluorescence) at the 18 sampling stations was generally constant throughout the surface mixed layer, with exception of prime station 27 (in yellow in Fig 14), which showed the presence of a Deep Chlorophyll Maximum (DCM) at around 20 m depth. DCM are normally observed in seasonally stratified water column during summer. In the summer months the surface mixed layer is nutrient depleted while nutrients are 'locked' below the thermocline in the bottom layer. As the light level is low below the thermocline, phytoplankton is not able to utilize the available nutrients. However, just above the thermocline the light level is sufficient for phytoplankton to utilize the dissolved nutrients, resulting in a maximum of chlorophyll at depth. During the autumn, with the breaking of the vertical stratification, the inorganic nutrients are released throughout the water column, potentially leading to an autumn bloom.

Analysis in the laboratory of phytoplankton samples will provide details of the pico-, nano- and micro-phytoplankton community as well as their abundance and pigment composition.

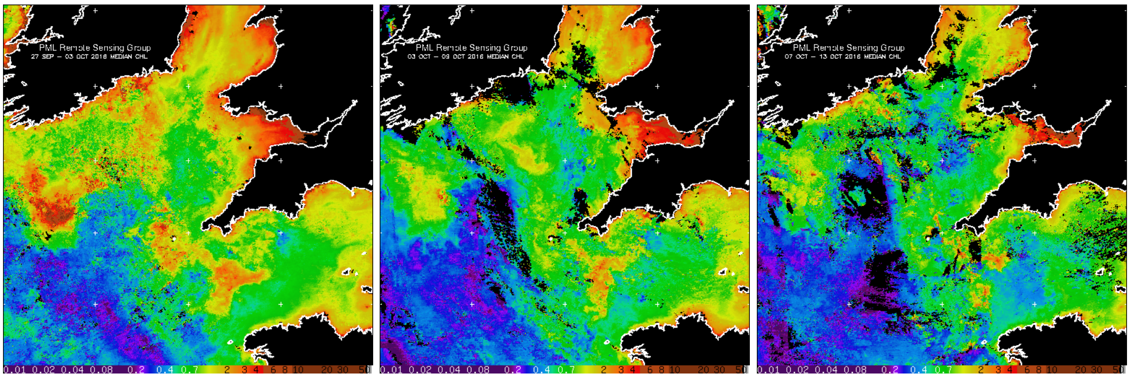


Figure 12. Composite surface maps of chlorophyll, OC3 algorithm, for periods 27 September - 3 October, 4 – 10 October, 7 – 13 October (left to right), from Neodaas.co.uk (PML).

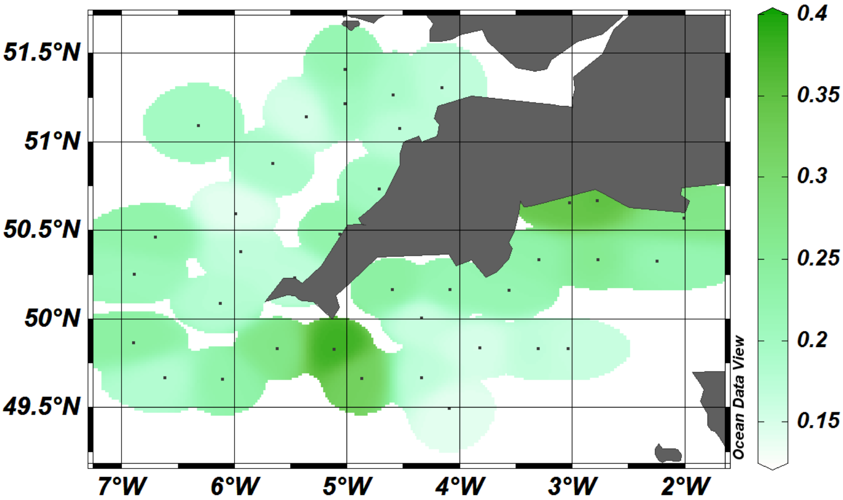


Figure 13. Fluorescence values at 4 m depth, at 18 sampling stations, as recorded by the Ferrybox. Maps prepared with Ocean Data View (ODW).

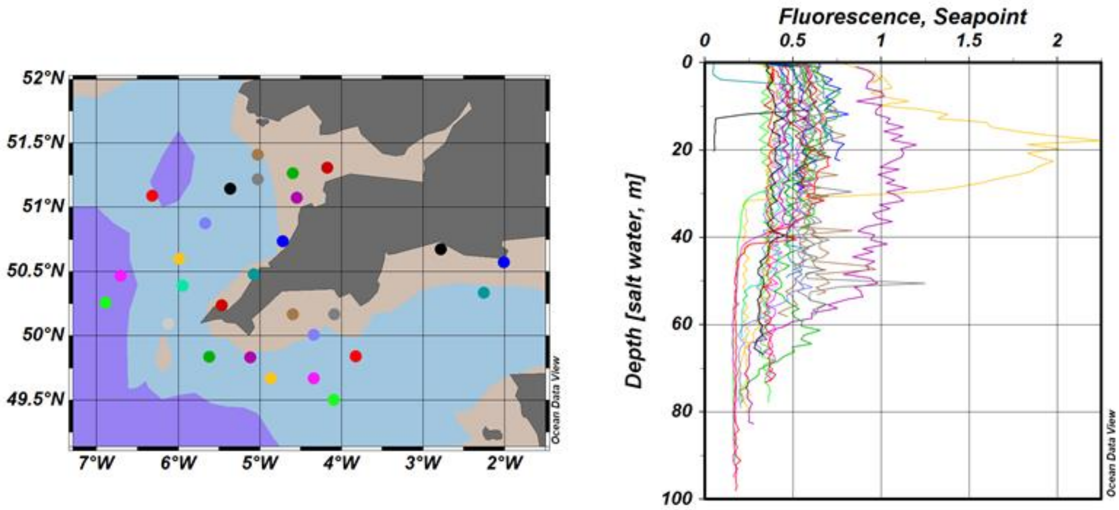


Figure 14. Fluorescence profiles at 18 sampling stations, as recorded by the SeaBird CTD mounted on the Rosette sampler. Maps prepared with Ocean Data View (ODW).

3.4. Marine Mammals and birds

Whilst a full analysis of the data has not yet been conducted, a superficial summary of species recorded by the two teams follows. Please note that due to the different methodologies used and the different times during which incidental records were logged, these totals from the two teams are not comparable. Some of the birds included in these totals may have been recorded by both teams simultaneously whilst others may not.

Bird species recorded (58 species in total):
Of significant note, the total number of Balearic Shearwater *Puffinus mauretanicus* seen was a minimum of 99 (subject to analysis of the two data sets recorded), with notable concentrations to the west of Lundy island, Devon. Behaviours noted include shallow plunge diving, surface pecking and active searching, particularly around the RV Endeavour's wake during one notable net retrieval. Numbers of Fulmar *Fulmarus galcialis* were very low this year.

Some evidence of visible migration was noted, particularly along the Dorset coast, with a steady stream of Meadow Pipits *Anthus pratensis* and Barn Swallow *Hirundo rustica* overhead. Additionally, a small variety of species were observed on board or attempting to land on board the survey vessel. Perhaps surprisingly, considering the challenging weather conditions, none of these required rehabilitation this year and all left the vessel of their own accord. The Long-tailed Skua *Stercorarius longicaudus* was arguably the highlight, but a migrating ring-tailed Hen Harrier *Circus cyaneus* and Hawfinch *Coccothraustes coccothraustes* also stand out as most unexpected species recorded. No rare vagrants were seen this year most likely due to the position of the weather systems.

Cetacean species recorded:
Animals were only recorded in transect by each team if they entered the respective transect. Any animals seen outside of this were recorded as out of transect. There were fewer sightings this year compared to last, arguably due to the poor sea state and weather. Most noticeably this affected the number of Harbour Porpoise *Phocoena phocoena* detected with only 6 animals seen. The Long-finned Pilot Whale *Globicephala melas* were found south of Plymouth and the Fin Whale *Balaenoptera physalus* were located to the north west of the Cornwall and Devon coasts, although they were a little further into the Celtic Deep than last year. No White-beaked Dolphin *Lagenorhynchus albirostris* were seen this year.

Fish species recorded:
Atlantic Bluefin Tuna *Thunnus thynnus* were seen by the ESAS observers at 6 different locations, scattered around the Dorset, Devon and Cornwall waters. Frustratingly however the fish never remained active after first detection so no photographs were taken. A further 7th separate observation was made by the MarineLife observer.

The most unusual species recorded was a Gem moth *Nycterosea obstipata* found in the garage area of the vessel by one of the fish scientists, having landed onboard overnight on 10 October. This is a rare migrant moth but several were found by lepidopterists along the south coast during this week so it is far from unprecedented.

4. Summary

The fifth in the series of Pelagic Ecosystem Surveys in the western English Channel and Eastern Celtic Sea took place between the 3rd and 19th of October 2016. The oceanographic conditions were similar to those observed in 2014 and represented a relatively warm autumn bloom scenario, in contrast to the more typical 2013 and 2015 condition and the winter conditions encountered in 2012. Primary production was relatively low, and was observed near the strong frontal systems particularly those around a cool water pool off the southwest of Cornwall.

Preliminary results on the small pelagic fish community suggested that most species were doing well apart from sprat. Few sprat schools were observed in Lyme Bay and also the offshore schools in deep waters of the Bristol Channel in 2015 were no present in the survey area. As has been observed in previous years, sprat in the western Channel consisted of predominantly adult specimens (age 1-3), compared to in-and offshore sprat in the Bristol Channel which were predominantly age 0 (with a unimodal length distribution around 8 cm).

Anchovy was found in large numbers in the western English Channel, extending further west as was the case in 2015. Noticeably in this area were the larger number of older specimens than in previous years. Anchovy was also observed in the Bristol Channel, including some larger specimens.

Good sardine numbers were found and their distribution was widespread. They were present in most trawl hauls conducted in the western channel. Distribution here was only limited, it seems, by the cold water pool that was situated south off the western tip of the Cornish Peninsula. In the Bristol Channel sardine appeared to be concentrated to the middle of the transects, between the deeper and very shallowest parts, apparently associated with prevailing frontal systems. Sardine spawning (based on egg distribution) was similar to in 2014 and 2015 both in terms of magnitude and distribution although for the second consecutive year eggs were observed in the Bristol Channel and in good numbers.

Mackerel were observed throughout the survey area, both in and offshore, although particular areas contained higher densities, most noticeably around the Celtic Deep. Young of the year made up the majority although older specimens were also found. Horse mackerel were prevalent in the survey area although they dominated the offshore areas of the western Channel and around the Isles of Scilly. Unlike previously the length data showed unimodal distribution around 9 cm which was generally associated with 0-year old fish.

One of the most notable observations were the seven separate feeding aggregations of blue fin tuna along the coast; the only other time one this species was observed during the 5 year time series was in the other hot year (2014).