

# DRAFT Survey report CEND22\_15

## PELTIC15: Small pelagic fish in the coastal waters of the western Channel and Celtic Sea

Jeroen van der Kooij, Elisa Capuzzo, Joana Silva, Mike Bailey



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### 1. Outline of the survey

STAFF:

Part 1 (3<sup>rd</sup> -13<sup>th</sup> of October)

1. Jeroen van der Kooij (SIC)
2. Elisa Capuzzo (2IC)
3. Joana Silva (2IC)
4. John Pinnegar
5. Dave Brown
6. Buster Rook Bishop
7. Richard Humphreys
8. Matt Eade
9. Paul Bouch
10. James Pettigrew
11. Samantha Barnett
12. Philip Lamb (PhD student)
13. Mike Bailey (observer)
14. Pete Akers (observer)
15. Jack Lucas (observer)

Part 2 (13– 21<sup>st</sup> of October)

- Jeroen van der Kooij (SIC)
- Elisa Capuzzo (2IC)
- Joana Silva (2IC)
- Dave Brown
- Ken May
- Richard Humphreys
- Matt Eade
- Paul Bouch
- James Pettigrew
- Phil Lamb (PhD student)
- Mike Bailey (observer)
- Pete Akers (observer)
- Jack Lucas (observer)

**1.2. Duration:** 3<sup>rd</sup> –21<sup>st</sup> 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 third in a series of five annual multidisciplinary pelagic survey of the Western Channel and Celtic Sea waters to map, 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 (stomach will be extracted frozen for future work)
2. To collect plankton samples using 2 different mesh ringnets (80 µm, and 270 µm mesh) at fixed stations along the acoustic transects at night and at a subset of trawl stations during the day. Samples will be processed aboard:
  - a. Ichthyoplankton (eggs and larvae, 270 µm) of pelagic species will be identified and counted onboard 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 along the acoustic transect, 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. To record the locations, species, numbers and activities of seabirds and marine mammals in the survey area during daylight hours.
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/pCO<sub>2</sub>. 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 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.
10. To map the acoustically derived zooplankton densities using the new 333 kHz frequency and compare it with data collected under 2 (and where possible 7) as part of Defra project HAZARD.
11. To collect genetic samples of gut contents and jellyfish for a UEA PhD studentship aiming to identify and quantify predation of jellyfish (Philip Lamb)
12. To collect and freeze samples of jellyfish for isotope work (Clive Trueman, NOC)
13. To quantify the size, biomass, distribution of the gelatinous species as part of a collaboration with the Nerc-Defra funded Marine Ecosystem Research Programme (MERP)

## 1.5 Narrative

Cefas staff joined the RV Cefas Endeavour in the afternoon of Friday the 2<sup>nd</sup> of October. The vessel left Portland the following morning at 6:00 AM of the 3<sup>rd</sup> of October and steamed straight to the calibration site off Portland Head (50° 36.180 N, 002° 35.762 W), to calibrate the echosounders. During the first

calibration attempt which commenced at 9:00, slack tide was just missed and currents rapidly became too strong (+0.8 knots) so the attempt was interrupted until next the next slack tide at ~14:30. Instead a toolbox talk, muster drill and safety walks with all scientific staff were conducted before lunch. The aim was to use the two hours between lunch and scheduled resumption of the calibration to conduct shakedown tows with the ESM2, and plankton nets. However as those gears were prepared for deployment, a distress call came in at 13:30 requiring the RV Cefas Endeavour to abandon all planned operations and leave the calibration site to aid a yacht which had engine issues and could not move due to lack of wind. Despite the fact that there was no threat to life and the engine was working again, the RV's searider had to act as safety vessel and escort the yacht back into port. At approximately 16:30 the searider was back onboard the RV. However by this time the slack tide window was missed again rendering the calibration futile; even a shakedown tow with the pelagic trawl was by this point not possible due to specialist fishing staff on deck (bowson) being out of their 12 hours. The next slack tide was due after sunset and as the calibration spheres had not been located and previous experience had demonstrated that doing that in darkness was pointless, it was decided to postpone the calibration until a suitable future window and start the first of the primary stations that evening continuing through the night.

On Saturday morning the 4<sup>th</sup> of October survey started proper commencing with the eastern most of the acoustic transects. Similar to last year's survey, fisheries acoustic transects, trawling and bird and mammal observations were conducted during daylight hours only, and CTD and plankton stations were covered during the night. The first trawl of the survey took a bit of time; firstly after the trawl was shot it appeared that the wrong trawl rigged. Secondly after the correct trawl was rigged on the netdrum 1½ hours later, the crew needed to get familiar with the gear. After only a few trawl operations this improved notably and before long the quickest recorded time to the survey series was achieved consistently to shoot and retrieve the trawl gear. 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 23 valid tows were made, the highest for the survey series.

On the morning of 13<sup>th</sup> October, after completing all but two transects in the western Channel and most of the Isles of Scilly sub-area, the Endeavour steamed to Falmouth for a planned staff changeover which commenced at 8:00. J. Pinnegar, S. Barnett and B. Rook Bishop left the vessel, whilst K. May joined.

After changeover, at 10:15 BST the Endeavour sailed to the start of the last two transects left in the Channel subarea which were completed that day. After completion of the necessary CTD and plankton stations the Endeavour steamed overnight to complete the last of the Isles of Scilly subarea on the 14<sup>th</sup> of October and set an eastwards course to begin the survey of the Bristol Channel sub-area. Between the 15<sup>th</sup> and the 18<sup>th</sup> of October all but four of the south-west to north east running transects were completed in the Bristol Channel sub-area and on the night of the 18<sup>th</sup> saw the last of the primary CTD and zooplankton stations completed. This year distinct "bands" of fish biomass were present parallel to the coast both halfway along the transects and at the end of the transects. Prior to completing the last four of the conventional Bristol Channel transects, the excellent forecast for the Monday lead to a decision to run the 100 nmi transect from the inner Bristol Channel to the Celtic Deep on the 19<sup>th</sup> of October. Two planned transects were completed on the 20<sup>th</sup> of October and deteriorating weather conditions meant that only one trawl could be performed in the morning.

Weather conditions throughout the survey were exceptionally favourable with the worst conditions on the 5<sup>th</sup> of October not exceeding much beyond 30 knots of wind. Unusually most of the wind was from an easterly direction.

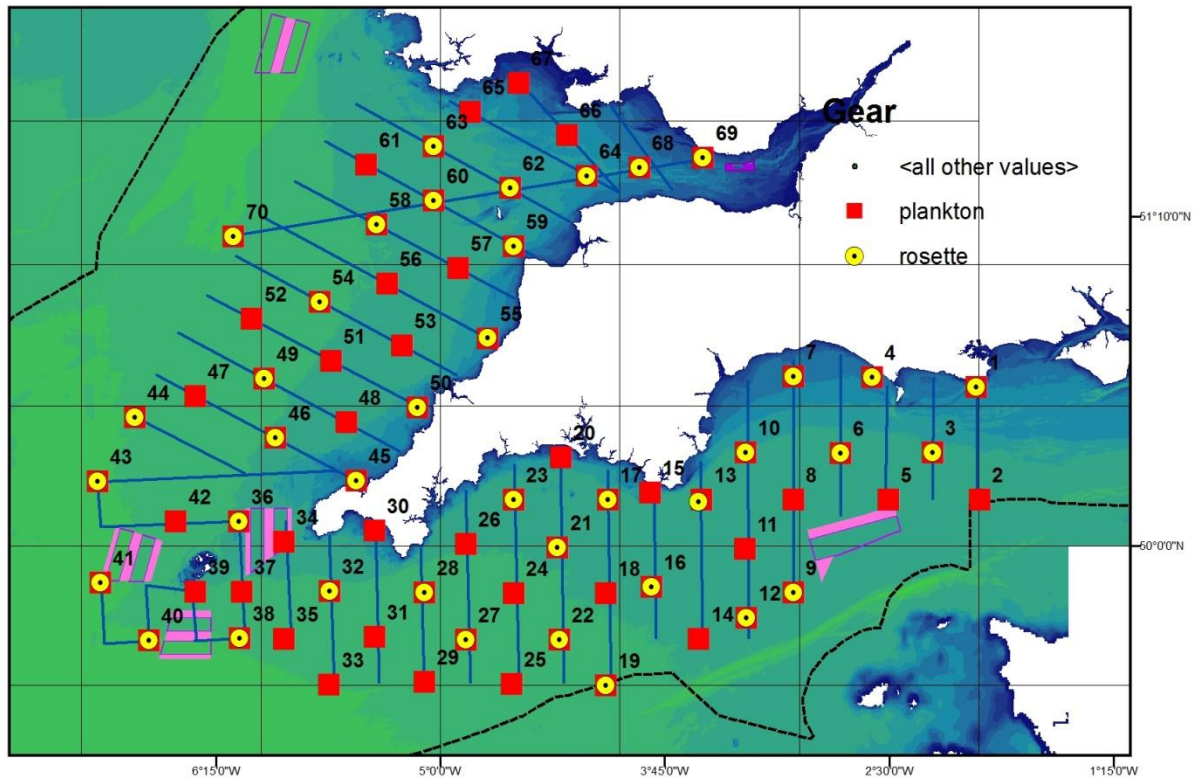
On the morning of the 21<sup>st</sup> the Endeavour completed the final two transect which ran from the north Devon coast into Swansea bay where the pilot was booked for 13:00. The RV Cefas Endeavour docked at 15:00 in Swansea port.

## **2. Material and Methods**

### **2.1. Study area**

The survey were conducted according to the PELTIC survey grid (Figure 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.



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

## 2.2 Fisheries acoustics

### 2.2.1. Acquisition

Due to the lack of a successful calibration at the start of the survey, the calibration settings from the previous survey were loaded. This excluded calibration settings for the 333 kHz which was not available for calibration at the time.

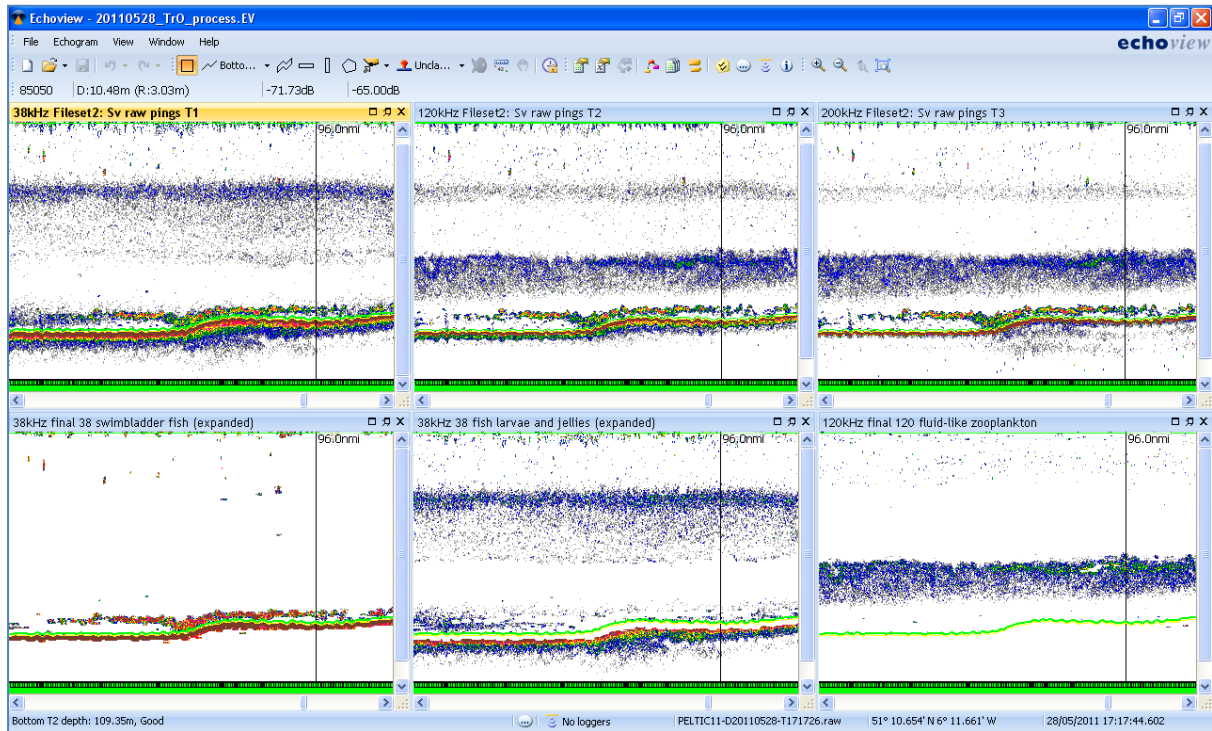
Fisheries acoustics were recorded along the pre-designed transects (Fig. 1) at the four operating frequencies (38, 120, 200 and 333 kHz). The transducers were mounted on a drop keel which was lowered to 3.0 m below the hull, 8.3 m below the sea surface. Pulse duration was set to 0.512 ms for the 38-200 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  $s^{-1}$ . Due to the exceptionally favourable weather conditions, acoustic data were of very high standard. Poor quality surface data due to aeration was only encountered on the 5<sup>th</sup> and 21<sup>st</sup> of October and at no time was it necessary to hold acoustic data collection altogether. 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.

### 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.



**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 right): 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 (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. The trawl was tested and tuned during the morning of the 2<sup>nd</sup> of October 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, the trawl performed well and caught a broad range of species and size classes.

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 10 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.

## 2.4 Zooplankton

The various planktonic size components were sampled at 71 fixed plankton stations along the various transects using two ringnets of different mesh: 270  $\mu\text{m}$  (ichthyoplankton and macro-zooplankton) and 80  $\mu\text{m}$  (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  $\mu\text{m}$  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  $\mu\text{m}$  samples were counted and, in the case of clupeid larvae, measured and raised using flow meter derived sample volumes. Samples from the 80  $\mu\text{m}$  mesh were transferred into jars and preserved with 4% buffered formaldehyde for later analysis using a zooscan in the lab.

At a subset of 18 prime stations two water samples were taken and fixed on lugol, one for phytoplankton analysis back in the lab and one for micro-zooplankton analysis. In addition, this year at 40 stations surface samples of zooplankton were taken using the new CALPS (Cefas Autonomous Litter and Plankton Sampler). For an hour at each of these stations a sample was taken using an 80  $\mu\text{m}$  mesh net to be compared with the vertical casts.

## 2.5 Oceanography

Physical, chemical and biological properties of the water column were investigated using different platforms of observations (Ferrybox, CTD, remote sensing) and by collecting of discrete water samples at the subsurface.

The Ferrybox provided continuous measurements in real time at the subsurface of different variables including temperature, salinity, fluorescence and dissolved oxygen concentration. Daily and weekly maps of chlorophyll concentration (OC5 algorithm), sea surface temperature and frontal systems were downloaded from Neodaas ([www.neodaas.ac.uk](http://www.neodaas.ac.uk)). The Ferrybox, was connected to a flow cytometer, which performed hourly measurements of the size and abundance of pico- and nanoplankton populations. A pCO<sub>2</sub> analyser carried out continuous measurements of the dissolved carbon dioxide in water and air during the whole survey.

Vertical profiles of temperature, salinity, fluorescence, optical backscatter, dissolved oxygen and Photosynthetically Available Radiation (PAR) were collected at 39 sampling stations using an ESM2 profiler. At 18 of these stations, water samples were collected at the surface from the continuous water pump that supplies the Ferrybox, for analysis of salinity, dissolved inorganic nutrients (for this project), samples for flow cytometry and pigments analysis, as well as for analysis of phytoplankton and microzooplankton communities.

Surface samples for determination of Total Alkalinity (TA), dissolved inorganic nutrients and dissolved organic matter (for PML, Shelf Sea Biogeochemistry project), and samples for dissolved oxygen analysis were collected from a Niskin bottle connected to the hydrowire of the ESM2 logger.

Samples for analysis of dissolved oxygen concentration, salinity and chlorophyll will be used for calibrating the sensors on the ESM2 profiler and on the Ferrybox.

A summary of the samples collected and of the CTD casts carried out during the survey is given in Table 1.

**Table 1.** Samples collected during the survey and number of vertical casts carried out.

	Total
Salinity	21
Dissolved oxygen	24
TA/DIC	13
Dissolved inorganic nutrients (PML)	13
Dissolved organic nutrients (PML)	13
Dissolved inorganic nutrients (Cefas)	18
Chlorophyll/Pigments analysis	38
Flow Cytometry	38
Phytoplankton	18
Microzooplankton	18
CTD casts with ESM2	39

## 2.6 Top predators

Effort-related surveys were made for top predators daily during all daylight hours whenever the ship was moving on or between transects. This year, 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 employed an effort-based distance sampling straight-line transect survey following strict ESAS methodology, whilst on the other Bridge wing, a single volunteer MARINELife surveyor 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 continuously during daylight hours, including all transit cross-lines, and with the additional coverage provided by the MARINELife surveyor, a 180° scan area was surveyed almost continually throughout the entire survey. Furthermore, observations were conducted during the net-retrieval stage of each trawl to identify species of birds associated with the fishing activity of the survey vessel. 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. Fortunately, the weather conditions during the entire 2015 Peltic survey rarely reached sea state 5 or above, facilitating almost constant useable data gathering.

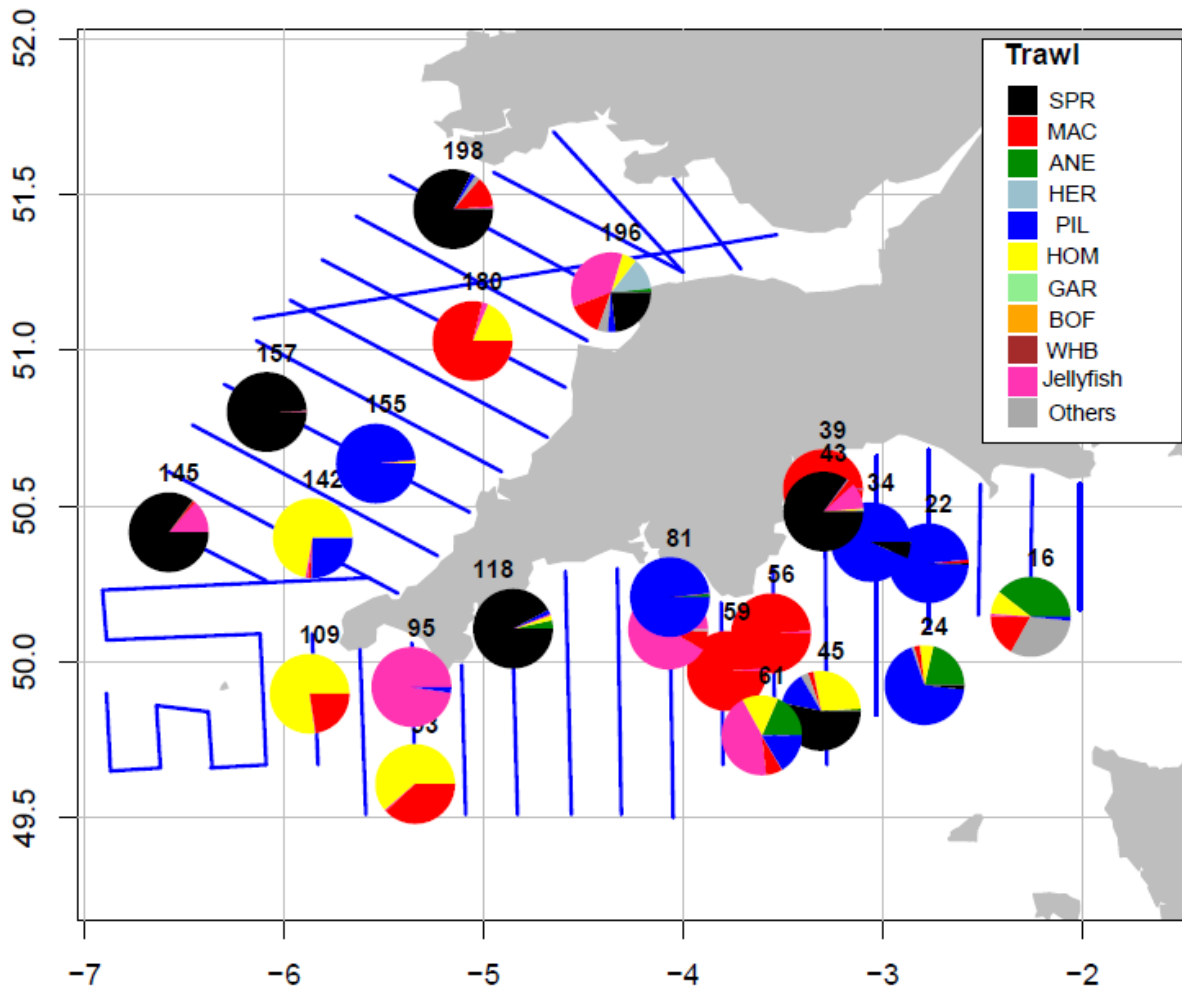
Special attention was given to gathering data on Balearic Shearwaters, as the waters off south west England are considered an increasingly important habitat for this globally critically endangered seabird.

## 3. Preliminary results

### 3.1. Pelagic Ichthyofauna

After removing the off-transect data a total of ~1400 nautical miles of acoustic sampling units were collected for further analysis (Fig. 3). A total of 23 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.

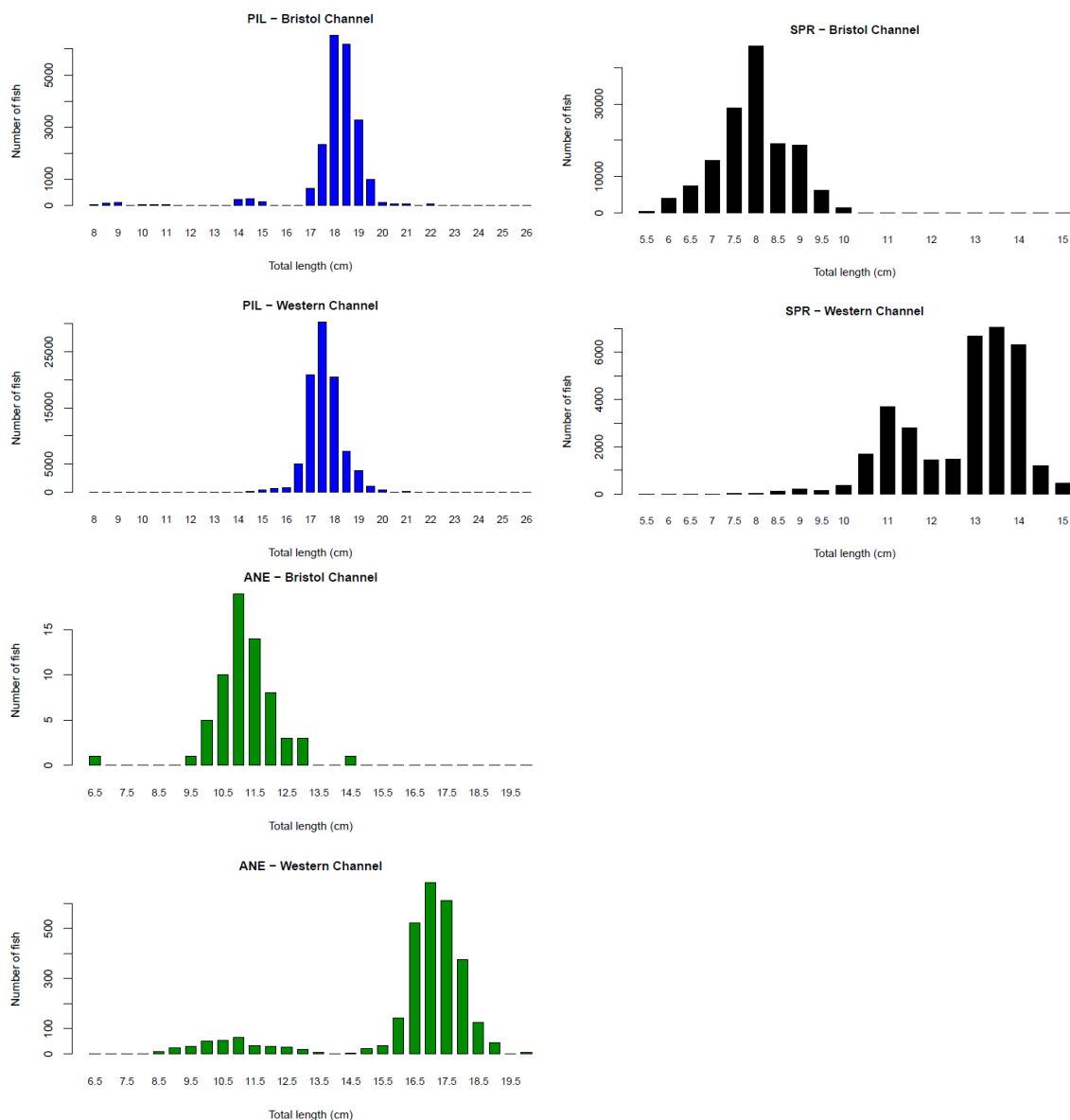




**Figure 3.** Overview map and detail of the survey area. Acoustic transects (blue lines) and trawl catches (pies) with relative catch composition by key species. Three letter codes: SPR=sprat, MAC=mackerel, ANE=anchovy, HER=herring, PIL=sardine, HOM= horse mackerel, GAR=garfish, BOF=Boarfish, WHB=Blue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

Several trawls included jellyfish of at least three species. Sprat (*Sprattus sprattus*) dominated the inshore waters of the English Channel. In the Bristol Channel distinct schooling aggregations were found offshore in the deeper waters and, as in previous years in inshore waters further east of the Bristol Channel. Sprat in the Bristol Channel consisted nearly entirely of small specimens, whereas those from the Lyme Bay area were more mature (fig. 4).

Sardines (*Sardina pilchardus*) were much more widespread than in previous years according to the trawl stations (fig. 3), with specimens found in most hauls (fig. 3). Despite the large numbers caught, very few specimens larger than 20 cm were caught (Fig 4).



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

Mackerel (*Scomber scombrus*) observations appeared to be in line with those in 2012 and 2014 when only small numbers of juvenile mackerel were found. None of the very large mackerel schools as seen in 2013 were observed in the western channel this year despite the large overlap in timing of the surveys. Horse mackerel (*Trachurus trachurus*) was found in most trawls suggested wide distribution, although apparently preferring the deeper waters. Both mackerel and horse mackerel displayed two distinct length classes (fig. 5).

This year, anchovy appeared more widespread than in previous years although main densities were in Lyme Bay trawl stations (Fig 3). For the first time small anchovy was found also in the inner Bristol Channel. Herring (*Clupea harengus*) were found in the study area in small numbers (fig. 3). It appeared to be mixed in with juveniles of the other small pelagic species and mainly in the inner Bristol Channel.

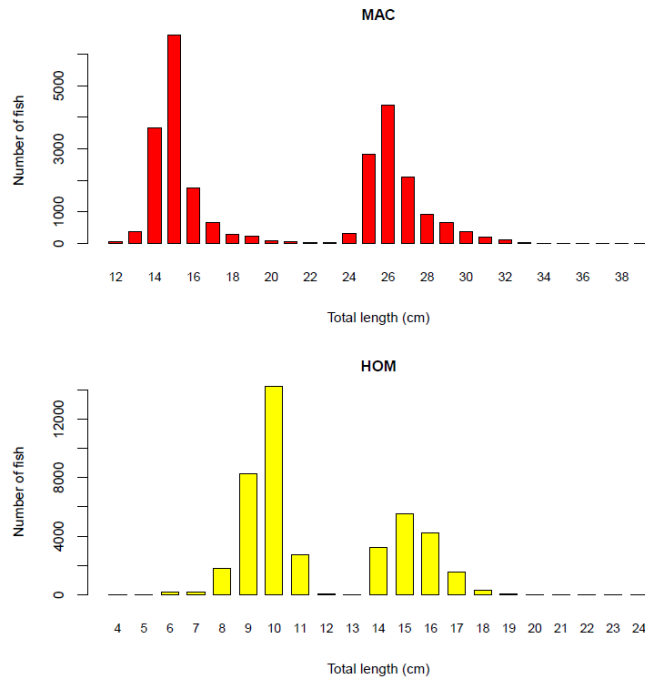


Figure 5. Trawl caught numbers by length of mackerel and horse mackerel for survey.

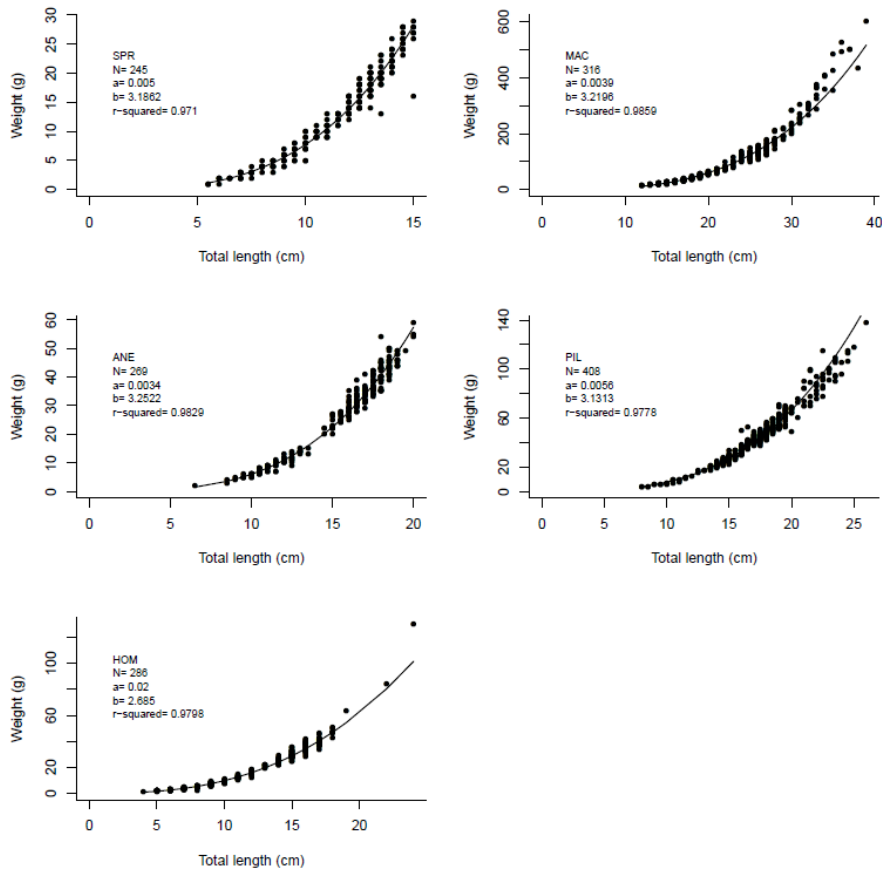


Figure 6. Length weight relationships of dominant pelagic species across the survey area.

### 3.2. Plankton data

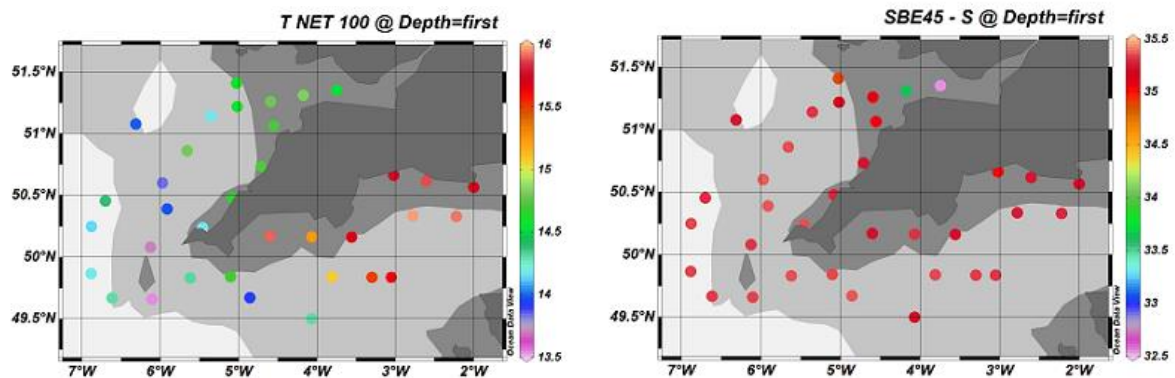
Zooplankton samples were collected at 70 stations with the two ringnets. Whilst water samples were taken from 39 stations, only a subset of 18 “key” stations will be further analysed to extract microzooplankton. Onboard ichthyoplankton processing revealed that the bulk of eggs were sardine, with

small numbers of sprat, lemon sole and sandsol making up the remaining categories. Most abundant were sardine eggs and larvae and “unidentified clupeid” larvae the vast majority of which were thought to comprise of sardine as few other clupeid species are spawning at this time of year. Sardine eggs were patchily distributed predominantly in the western part of the English Channel with smaller numbers in the Isles of Scilly. This year for the first time small numbers of eggs were found in the Bristol Channel. A detailed size based (zooscan) and taxonomic analysis of the zooplankton will be undertaken on return to the laboratory.

### 3.3. Oceanographic data

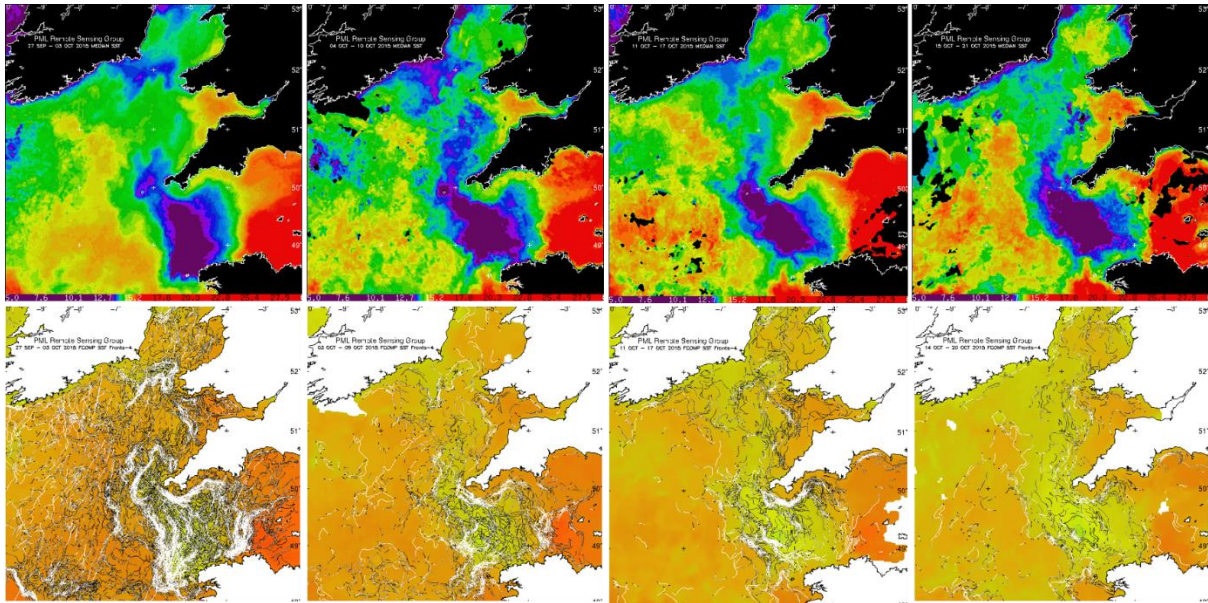
#### 3.3.1. Temperature and salinity

With temperatures up to 16°C, surface waters of the Western English Channel were warmer than surrounding waters of the Celtic and Irish Seas (Figures 7 and 8). The average, minimum and maximum temperatures recorded at the 39 sampling stations during this survey (Table 2) were comparable with temperatures recorded during the survey in 2013 (Cend20\_13); however, they were lower than temperatures measured in 2014 (Cend20\_14). Particularly, the maximum temperature recorded in 2015 (15.95°C) was approximately 2°C lower than the maximum temperature measured in 2014 (18.14°C). Salinity of surface water at the different sampling stations was similar except for the inner stations in the Bristol Channel, which had a lower salinity as result of increased freshwater influence from the river Severn. The salinity range was comparable with the other three surveys (Table 2).



**Figure 7.** Temperature (T Net 100, °C) and salinity (SBE45) at 4 m depth measured by the Ferrybox at the 39 oceanographical sampling stations between 3rd October and 19th October.

Remote sensing images (Figure 7) showed that a patch of slightly cooler water (approximately 14°C (Figures 7 and 8) was located south of Eddystone Bay and the Isles of Scilly south to the France coast. During the course of the survey the location of this patch of cooler water did not change, likely as result of the calm weather conditions and sea state. A similar patch of cooler water was also clearly visible in the remote sensing images from the 2014 survey, although in 2014 it extended westward during the course of the survey.



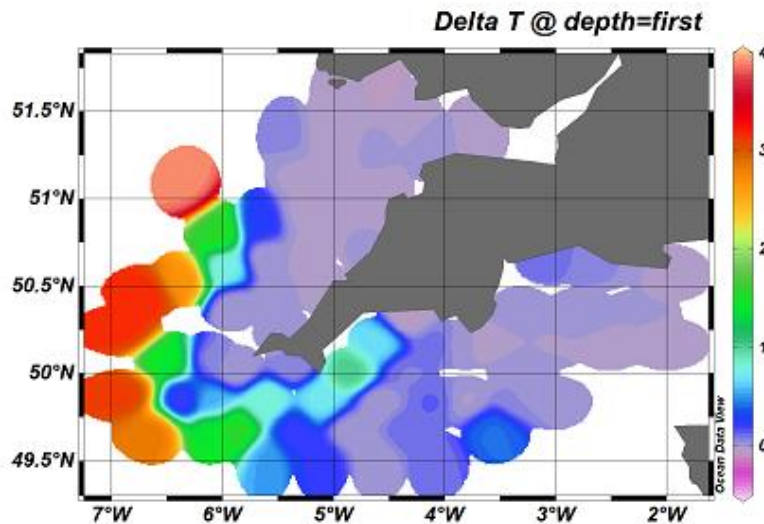
**Figure 8.** Composite surface maps for the periods 27 September - 3 October, 4 – 10 October, 11 – 17 October and 14-20 October 2015 of temperature (upper row of images) and thermal frontal systems (lower row) from Neodaas.co.uk.

The northern, eastern and western boundaries between the cool water patch and the warmer waters of the English Channel and the Celtic Sea was marked by a series of frontal systems (Figure 7), clearly visible particularly in the composite image for the week 27 September – 3 October. The frontal systems were present throughout the survey although they became weaker over time (Figure 7).

**Table 2.** Average, minimum and maximum values at 4 m depth of temperature, salinity and fluorescence, measured by the Ferrybox at the 39 oceanographical sampling stations, during surveys in 2015 (Cend22\_15), 2014 (Cend20\_14) and 2013 (Cend20\_13).

Survey	Average	Minimum	Maximum
Cend22_15 – Temperature (°C)	14.72	13.53	15.95
Cend22_15 – Salinity	35.14	32.53	35.14
Cend22_15 – Fluorescence	1.17	0.46	2.32
Cend20_14 – Temperature (°C)	15.98	14.62	18.14
Cend20_14 – Salinity	35.09	33.33	35.37
Cend20_14 – Fluorescence	0.19	0.08	0.44
Cend20_13 – Temperature (°C)	14.91	13.65	16.15
Cend20_13 – Salinity	35.28	33.36	35.61

Vertical profiles of temperature and salinity (carried out with a SAIV Mini CTD mounted on the zooplankton sampling nets) were plotted using the software Ocean Data View (ODV). Surface maps from CTD measurements (Figure 7) showed a temperature distribution similar to the one observed from the satellite-derived maps. The surface maps of the Western English Channel (Figure 10) show the presence of a gradient from cooler and saltier waters towards the Scilly Isle to warmer and less salty waters in Lyme Bay. Stations in the Bristol Channel showed a similar gradient (warm and less salty waters in the inner Bristol Channel, cooler and saltier waters in the outer Channel; Figure 10), although waters in the Bristol Channel were not as warm as in Lyme Bay (16.33 and 18.08 °C respectively; Table 2).



**Figure 9.** Values of  $\Delta T$  (surface temperature – bottom temperature; °C) at the 69 sampling stations, as measured by the SAIV MiniCTD. The water column is considered stratified when  $\Delta T > 0.5$  (°C).

### 3.3.2. Chlorophyll and fluorescence

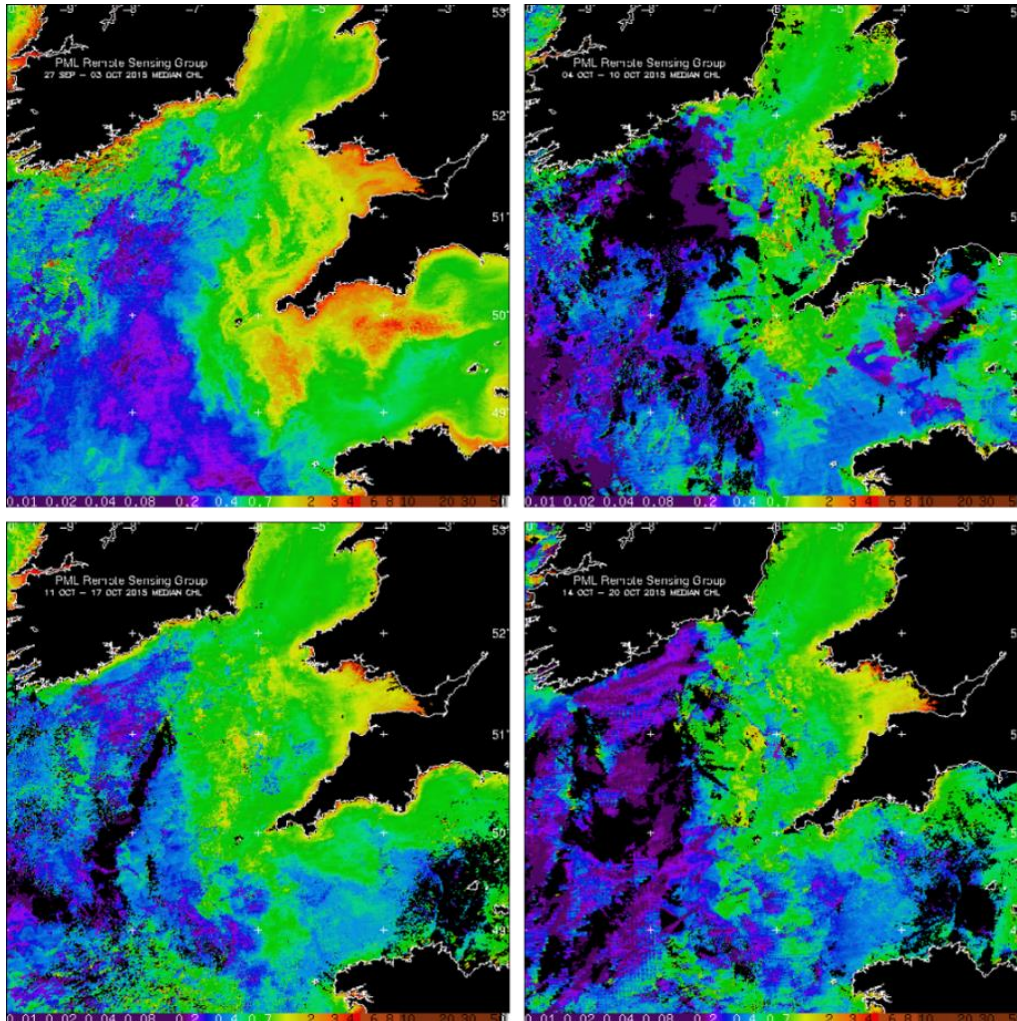
Higher levels of chlorophyll concentration were observed offshore, south of Eddystone Bay and around the Scilly Isles (Figure 10), corresponding with the frontal systems around the cool patch of water in the Western English Channel. In these frontal systems, nutrient-rich waters are mixed with nutrient-depleted surface waters leading to an observed increase in phytoplankton biomass.

Chlorophyll concentration was higher south of Lyme Bay and off the Scilly Isles, as shown by the Ferrybox raw fluorescence (Figure 11). Remote sensing images also indicated high level of chlorophyll concentration in Bristol Channel. However, this observation was not supported by the Ferrybox fluorescence measurements which were generally low (compare Figure 4 and 5). This was likely due to the higher level of suspended solids in the inner Bristol Channel affecting the reliability of the remote sensing algorithm for calculating chlorophyll concentration.

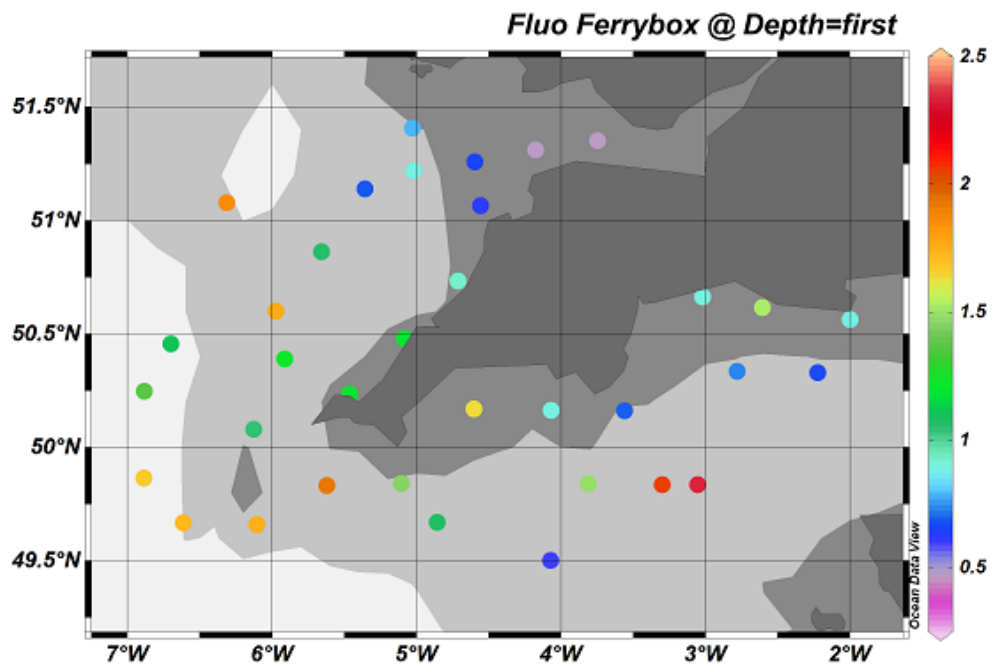
Remote sensed images (Figure 10) shows that the autumn bloom was well developed during the week before the survey (27 September - 3 October); however high level of fluorescence were recorded throughout the survey in different areas. On average, fluorescence measurements at the different sampling stations, recorded by the Ferrybox during this survey, were 6 time higher than average fluorescence measured during the previous year survey (Cend20\_14).

Analysis of phytoplankton samples at the inverted microscope, and of samples for HPLC and flow cytometry in the laboratory will provide details of the pico-, nano- and phytoplankton community as well as their abundance and pigment composition.





**Figure 10.** Composite surface maps for the periods 27 September - 3 October, 4 – 10 October, 11 – 17 October and 14-20 October 2015 of surface chlorophyll from Neodaas.co.uk.



**Figure 11.** Fluorescence values at 4 m depth, at 18 sampling stations, as recorded by the Ferrybox.

### 3.4. Marine Mammals and birds

This year, as in 2014, all transects were run in daylight, and with more sea time in the survey area and better weather, almost complete coverage was achieved in all sections of the survey. Visibility during effort surveys was generally good to excellent, and rain was infrequent and fog absent.

In total, there were 170 sightings (96 in 2014) of seven cetacean species (same as in 2014), with significantly more individual animals counted (1790 compared to 1520 in 2014).

The most abundant cetacean species encountered throughout was Common Dolphin *Delphinus delphis* with 129 (76 in 2014) sightings of 1,650 animals (1520 in 2014), chiefly but not exclusively in deeper waters (>50m) in the west and northwest of the survey area. The White-beaked Dolphin *Lagenorhynchus albirostris* were encountered in the western section of Lyme Bay as in previous years; Long-finned Pilot Whales *Globicephala melas* were found south of Plymouth and all nine Fin Whale *Balaenoptera physalus* sightings (22 confirmed individuals) were located to the north west of the Cornwall and Devon coasts. Rorqual whale encounters where the animals were too distant to see their dorsal fins were logged as Unidentified rorqual sp., although they were all presumed to be Fin Whale. A single sighting of two animals at approximately 3 km distance from the vessel whose distinctly different blows were seen well and photographed, were thought to be humpback whales. However as no diagnostic views were obtained these were logged as unidentified baleen whales.

Detailed results of the bird observations were not available at the time of writing and only a brief summary is provided here. A total of 50 species of birds were recorded during the survey. A notable observation included a flock of at least 115 Storm Petrels *Hydrobates pelagicus*, feeding in the RV Endeavour's wake during net retrieval operations, south of Portland Bill, Dorset.

Some evidence of visible migration was noted, particularly along the Dorset coast, with a steady stream of Meadow Pipits *Anthus pratensis* overhead. A Richard's Pipit *Anthus richardi* and an Alpine Swift *Apus melba* seen off south Devon and south Dorset respectively were both vagrant individuals presumably blown off course by the easterly airflow which dominated the weather for most of the survey period.

Unexpectedly high numbers of Balearic Shearwaters, *Puffinus mauretanicus*, chiefly in the Bristol Channel in 2013 (79) and 2014 (205) provided an important focus again for 2015. This species is the UK's only critically endangered seabird, having declined by ~95% since 1970s. UK waters are at the edge of their non-breeding range however, distinct northward shifts in range have been noted in recent years so it is likely that the UK will become increasingly important. This year a minimum of 90 specimens were counted (subject to analysis of the two datasets recorded), the majority of which in the same general area to the west of Lundy Island in the Bristol Channel, as was the case in the previous two years. Behaviours noted include shallow plunge diving, surface pecking and active searching, particularly around feeding groups of Common Dolphin and occasionally investigating the RV Endeavour's wake during net retrievals. These data will be further analysed as part of a Defra funded project to establish the importance of the Bristol Channel as an important feeding area, and will be used to inform future conservation measures.

## 4. Summary

The fourth in the series of Pelagic Ecosystem Surveys in the western English Channel and Eastern Celtic Sea took place between the 3rd and 21st of October 2015. The oceanographic conditions were similar to those observed in 2013 and represented a typical autumn bloom scenario, in contrast to the much warmer 2014 survey and the winter conditions encountered in 2012. Primary production was high, 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 had increased in both abundance and distribution. Western English Channel sprat was distributed further west than the traditional Lyme Bay region and was found also in good numbers in coastal waters off Plymouth. In the Bristol Channel, the usual small but dense surface schools stretched for many miles

along the coast in the inner parts. In addition, this year very large schools were also prevalent in the deeper (>80 m) offshore waters of the western and central parts of the Bristol Channel which appeared to be associated with several aggregations of feeding fin whales. In contrast to the sprat in the western Channel which consisted of predominantly adult specimens (age 1-3), in- and offshore sprat in the Bristol Channel were predominantly age 0 (with a unimodal length distribution around 8 cm). Given the consistent occurrence of these very large juvenile sprat aggregations in this area it is clearly an important nursery area.

As in 2014, anchovy was found in large numbers in the western English Channel, this time extending further west than observed in previous years. Noticeably in this area were the larger number of 2 year old (and older) specimens than in previous years. This year for the first time, anchovy was also observed in the inner Bristol Channel, where the predominantly smaller specimens were mixed with several other small clupeids in what is clearly an important nursery area.

Sardine numbers also appeared to have increased, as has their distribution. 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 contrast to 2014, very few large specimens (> 20cm) were present in the trawls. 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 both in terms of magnitude and distribution although in 2015 for the first time (small numbers of) eggs were also observed in the Bristol Channel.

Although mackerel were observed throughout the survey area, both in and offshore, highest densities were found in the western parts of the English Channel and Bristol Channel and particularly around the Isles of Scilly. Young of the year made up more than half of the mackerel population in the area. Horse mackerel were prevalent in the survey area although they dominated the offshore areas of the western Channel and around the Isles of Scilly. Two distinct modes were observed in the length data, one at around 10cm and one at 15cm, generally associated with 0 and 1 year old fish.