Centre for Environment Fisheries & Aquaculture Science

Cefas

RESEARCH VESSEL SURVEY REPORT

RV CEFAS ENDEAVOUR
Survey: C END 16 - 2021.

STAFF:

Name	Role
Jeroen van der Kooij	SIC/Acoustics
Joana Silva*/Elisa Capuzzo**	2IC/Fish/Oceanography
Fabio Campanella	2IC/Acoustics
Eleanor Haigh	Oceanography
Richard Humphreys	Lead Fishroom
Sílvia Rodríguez Climent	Acoustic/Fish
Samantha Barnett**	Deckmaster/Fish
Allen (Spike) Searle	Fish
Matt Eade	Fish/Zooplankton
Nevena Almeida	Zooplankton
Amy Larter	Zooplankton
Izzy Lake	eDNA
Peter Howlett	ML Observer
Emma Neave-Webb	ML Observer

*** disembarking on 21/10/21**
****joining 21/10/21**

DURATION: **4th October – 7th November (35 days)**

LOCATION: Western Channel, Celtic Sea, Cardigan Bay (ICES Divisions 7.e-f and parts of 7.a,g)

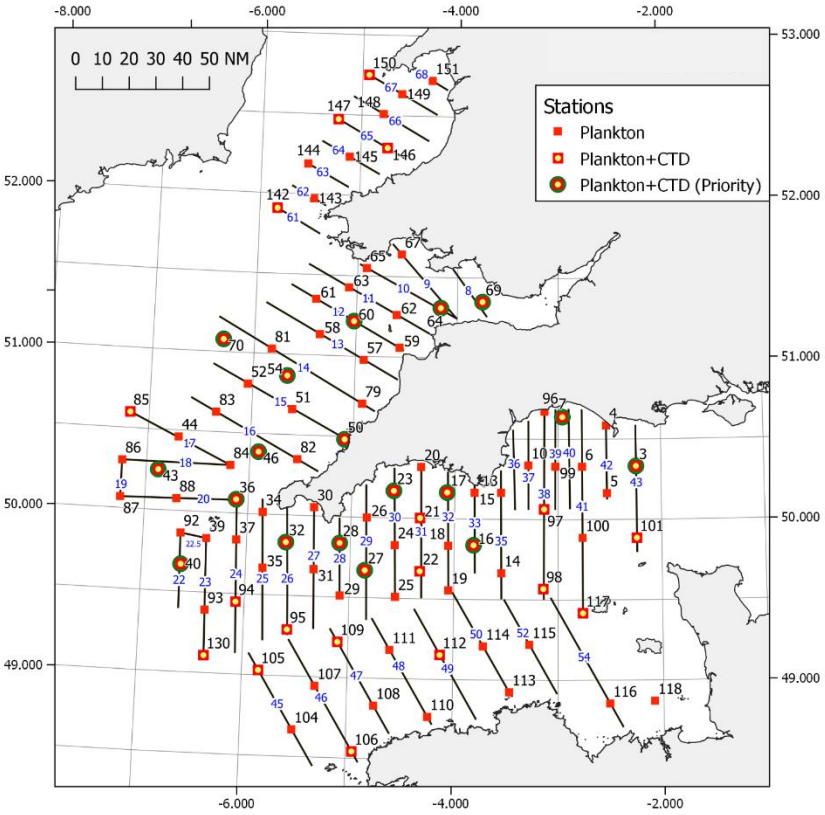

Figure 1. Overview of the planned survey area, with the acoustic transect (black lines, numbers in blue), plankton stations (red squares) and hydrographic stations (yellow circles). Priority stations indicated in green.

AIMS:

1. To carry out the tenth autumn PELTIC survey: pelagic ecosystem survey of the western Channel, Celtic Sea, including (for the second time) Cardigan Bay (for Welsh Government), to estimate the biomass of-, and gain insight into the populations of the small pelagic fish community including sprat *Sprattus sprattus*, sardine *Sardina pilchardus*, mackerel *Scomber scombrus* , anchovy *Engraulis encrasicolus*, horse mackerel *Trachurus trachurus*. The PELTIC derived sardine biomass in area 7 will feed into its stock assessment (WGHANSA) and sprat biomass data from the western English Channel will feed into the stock assessment of sprat in area 7de (HAWG).

    a. To carry out a fisheries acoustic survey during daylight hours only using four operating frequencies (38, 120, 200 and 333 kHz) to map and quantify the small pelagic species community.
    b. To trawl for small pelagic species using a 20x40m VDK herring (mid-water) trawl in order to obtain information on:
        - Species and size composition of acoustic marks
        - Age-composition and distribution, for small pelagic species
        - Length weight and maturity information of pelagic species
        - Stomach contents of selected species

2. To collect biological data (size, weight, age and maturity) on range of data-limited fish species, including European seabass *Dicentrarchus labrax*, black seabream *Spondyliosoma cantharus*, striped red mullet *Mullus surmuletus*, garfish *Belone belone* and saury pike *Scomberesox saurus*.

3. To collect plankton samples using two ring-nets with 80 µm, and 270 µm mesh sizes at fixed stations (red squares on map below). Carried out at night by vertical haul and samples will be processed onboard:
   a. Ichthyoplankton (eggs and larvae, 270 µm) of pelagic species will be identified, counted and (in case of clupeids) staged and measured onboard to identify spawning areas.
   b. Zooplankton (80 µm) will be stored for zooscan analysis back in the lab.

4. Water column profile and water sample (yellow stations on map below). At fixed stations along the acoustic transect, a CTD (ESM2 profiler or Seabird on Rosette sampler) will be deployed to obtain measurements of environmental properties within the water column: chlorophyll, dissolved oxygen, salinity, temperature, turbidity, dissolved inorganic nutrients as well as the relevant QA/QC samples for calibration of the equipment. Water samples will be collected and fixed on board for analysis post-survey. Samples for analysis of the phytoplankton and microzooplankton communities will also be collected at the subsurface at fixed sampling stations.

5. Seabirds and Marine Mammals. Locations, species, numbers and activities observed will be recorded continuously during daylight hours by two Marinelife observers located on the bridge.

6. Ferrybox Continuous CTD/Thermo-salinograph. Continuously collect oceanographic data at 4 m depth during steaming, including chlorophyll concentration (from calibrated fluorescence).

7. To collect water samples at 25 stations in the Bristol Channel and Cardigan Bay area to carry out an eDNA study on distribution and, where possible relative abundance of bluefin tuna (*Thunnus thynnus*) as well as biodiversity monitoring in Welsh waters.

8. To collect between 25-50 specimens per species (anchovy, boarfish, herring, horse mackerel, mackerel, sardine) and freeze for further analysis in the lab supporting a study on microplastics in fish stomachs (A. Bakir, Cefas - Lowestoft).

9. To collect a zooplankton sample using the 200 µm mesh ring-net at the West Gabbard2 SmartBuoy, for the Lifeform project (Defra) as part of the UK monitoring network of zooplankton.

10. To collect between 15-20 (similar sized) specimens per species (anchovy, boarfish, herring, horse mackerel, mackerel, sardine) and freeze (Stephen Smith, NMBAQC)

11. To collect 20 specimens each of anchovy and sardine at five different locations for a genetic study on both species (Naiara Rodriguez-Espeleta, AZTI, Spain)

12. To collect up to 24 specimens each of *Illex coindetii* and *Loligo forbesii* (V. Laptikhovsky, Cefas - Lowestoft)

13. Record macro-litter observations in the trawl (B. Silburn, Cefas - Lowestoft).

14. Collect ~25 sprat specimens from stations across the survey area for a genetic study on the stock structure of this species in the Celtic Sea ecoregion

15. Collect hourly samples of dissolved inorganic nutrients from the FerryBox flowthrough in the English Channel, for water quality assessment (winter nutrient concentratiom (N Greenwood, Cefas - Lowestoft)

NARRATIVE[1]:

On the evening of 1 October, two (remote) staff joined the vessel, Cefas staff Allen (Spike) Searle, and MARINElife observer Pete Howlett who conducted COVID PCR tests upon arrival and proceeded to isolate in their cabins. The remaining Cefas staff and second MARINElife observer arrived at the quay from 1500hr, 2 October, conducted a COVID PCR test after which they also joined the vessel one at the time, for cabin isolation. Negative test results for the two early arrivals and four of the remaining staff were received by 1300hr on 3 October, with eight further test results still pending. The remaining eight test results were still not received by the rescheduled pilot slot the morning of 4 October (which had already been moved from 0630hr to 1130hr) and in the afternoon it was decided to conduct a second PCR test for the individuals, in case the first batch of tests was lost. Second test results were returned around 0900hr 5 October, one of which was positive. After the positively tested staff member disembarked, the pilot joined and the RV sailed from Lowestoft at 1130hr, with 30 hours delay, heading towards Portland, central English Channel. Safety inductions for scientists were completed *en route* and gear was unpacked and prepared followed by a muster drill.

Upon arrival in Weymouth Bay at 1400hr, 6 October, fresh winds meant that the planned echosounder calibration was postponed until the next day and, instead, the first acoustic transect was run (Tr43). Overnight the first plankton and rosette stations were successfully completed following relevant toolbox talks. On the morning of 7 October, the echosounder calibrations were successfully completed at 1315hr and three frequencies (38, 120 and 200 kHz) were calibrated at two pulse durations. The rest of the daylight was used to complete the two first mid-water trawls.

From the morning of the 8 October, normal survey activities commenced, steaming along transects during the day, simultaneously recording fisheries acoustics and observing bird, mammal and tuna numbers and deploying the trawl to ground-truth acoustic data and collect biological data; at night plankton samples and CTD profiles (with either the rosette or ESM2) were collected at the prime stations. Exceptional weather conditions (winds <~10 knots) ensured very good progress for the next 10 days as the survey gradually proceeded west. From the 18 October, wind picked up although work could proceed. On the evening tide of the 20 October, the RV docked in Fowey, 12 hours before planned due to a storm coming through overnight, with the aim to drop a staff member off the following morning (0745hr). Two other staff joined on the evening of the 20 October, following self-isolation and negative PCR tests. At 0800hr on the 21 October the plot was picked up and the RV left Fowey and at 0900hr, the survey resumed with Transect 30 and 29, which were shortened slightly to fit in the day. At the end of the 23 October, the whole of the western English Channel, including the transects south of the Isles of Scilly were completed.

A small weather window provided the opportunity to survey Cardigan Bay. In transit from the Isle of Scilly to Cardigan Bay, the first eDNA samples was collected (NW of Transect 11). Routine survey work commenced in Cardigan Bay at first light on the 24 October. Where possible, acoustic transects in the bay were extended inshore (until a depth of 17m was reached or 1 nm from shore) to improve coverage of shallow water habitat. All seven transects were completed by last light on the 26 October; Reasonable night conditions enabled completion of all 10 plankton and CTD stations with further eDNA samples at each of the stations being collected, over two nights (24/25 October). In total the target number of 5 trawls were conducted providing useful ground-truth and biological data at the areas of highest fish densities.

After successful completion of Cardigan Bay, from the 27 October, work commenced in the Bristol Channel. Starting at the inner transects, reasonable shelter was found from strong southerlies

[1] All times up to 30~~th of~~ October in BST and in GMT for the rest of the survey

allowing work to continue. The RV progressively worked westwards, until on the 30 October, after completion of the offshore halves of transects 13 and 14 during a good weather day, and two plankton stations (81 and 54), at 2100hr, the vessel started the steam towards Bideford Bay to seek shelter from SW force 9 turning Westerly storm force 10 forecasted for the 31 October. On the morning of the 1 November at 0530hr, the anchor was lifted and the RV started to make its way to the inshore start of transect 13, to resume surveying. Despite variable weather of the following few days, the RV completed the remaining transects and by 1315hr, 5 November, she commenced the steam back to Lowestoft. The Gabbard plankton station was completed at the early hours of the 7 November before picking up the pilot off Lowestoft at 0900hr and docking at 1000hr.

RESULTS:

All aims were successfully completed, with the exception of the mackerel acoustic data due to noise on the 200 kHz. A summary of the echosounder calibration settings are provided in Table 1. Biological data (size, weight, age and maturity) on the following data-limited species were collected (objective 2): 11 European seabass; 8 black seabream; 15 garfish; 29 John Dory *Zeus faber*. eDNA samples (objective 7) were collected at 29 stations in Welsh waters. In total 18 samples of 25 whole specimens of small pelagic fish (6 species) were collected from 15 different stations for micro-litter analysis (objective 8, Annex 1). At four stations 15-20 (similar sized) specimens per species were collected for anchovy, boarfish, herring, horse mackerel, mackerel, sardine (objective 10, Annex 1). Genetic samples for sardine and anchovy were collected at five stations (objective 11, Annex 1). More details on the other aims are provided in the relevant sections below.

Table 1. Summary of echosounder (EK60 transceivers; EK80 operating software) calibration settings obtained on the 7th of October, in Weymouth Bay, and applied during PELTIC 2021. The 333 kHz was not calibrated and settings used are from the previous on-axis calibration performed in 2019.

Variable	38 kHz	120 kHz	200 kHz	333 kHz
Transducer type	ES38B	ES120-7C	ES200-7C	ES333-7C
Transducer depth (m)	5.3 (8.3)*	5.3 (8.3)*	5.3 (8.3)*	5.3 (8.3)*
Transducer power (W)	2000	250	120	50
Pulse length (milliseconds)	0.512	0.512	0.512	1.024
2-way beam angle (dB)	-20.7	-20.7	-20.7	-20.7
Transducer gain (dB)	22.67	26.45	25.82	27.58
Sa correction (dB)	-0.918	-0.397	-0.3415	-0.64
3dB beam along (°)	6.84	6.38	6.46	7
3dB beam athwart (°)	6.81	6.39	6.60	0
Along offset (°)	0.13	-0.03	0.00	7
Athwart offset (°)	0.06	-0.01	-0.25	0
RMS (Root Mean Square error)	0.068	0.097	0.11	-

*Drop-keel down

Pelagic Ichthyofauna

In total all 48 acoustic transects were completed covering a total of 2181 nm of acoustic sampling units. Survey time was lost due to a COVID related delay in sailing (30 hours) and weather downtime (~30 hours). However, good coverage was achieved nonetheless, and the relevant stocks were still captured in their entirety. A total of 41 trawl hauls were made (Fig 2) to provide ground-truth information about the species and size composition and to collect biological information.

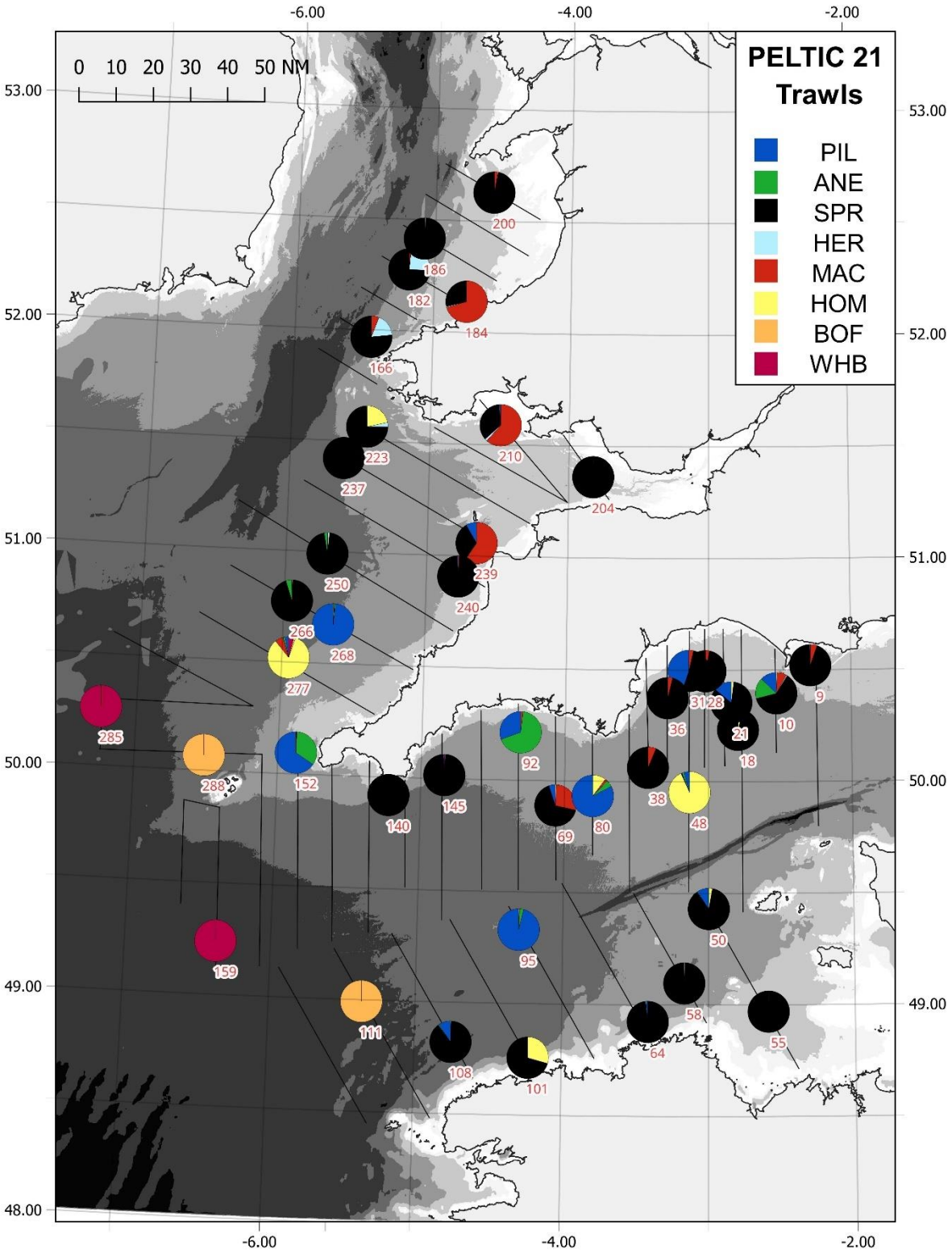

Figure 2. Overview map of the PELTIC21 survey area. Acoustic transects (black lines) and Trawl stations (pies) with relative catch composition by key species. Three letter codes: PIL=sardine, ANE=anchovy, SPR=sprat, HER=herring, MAC=mackerel , HOM= horse mackerel, BOF=Boarfish, WHB=Blue whiting

Many of the trawls in the western Channel were conducted at last light in areas where backscatter was highest, which, due to reduced effect of avoidance, provided a more unbiased insight into the species composition of the most important areas for pelagic fish. General patterns of fish distribution were similar to those observed for the time series although some species-specific differences were observed. Survey coverage included, for the fifth year running, the French waters of the western Channel. For the second time PELTIC surveyed the coastal waters of Cardigan Bay (Wales). A summary of the number of individuals sampled for length and biological parameters is provided for key species (Table 2).

Table 2. Summary of lengths measured and biological parameters (including weight, age, maturity) collected for small pelagic fish species.

Species	Scientific name	Measured	Biological samples
Sprat	*Sprattus sprattus*	6661	874
Sardine	*Sardina pilchardus*	4306	752
European anchovy	*Engraulis encrasicolus*	1804	494
Horse mackerel	*Trachurus trachurus*	1826	272
European mackerel	*Scomber scombrus*	2169	322
Boar fish	*Capros aper*	405	75
Herring	*Clupea harengus*	956	260
Blue Whiting	*Micromesistius poutassou*	429	46

Sprat *Sprattus sprattus* was more widespread and abundant (Fig. 3) than previously observed, driven by a strong recruitment pulse (0-group, Fig 4). Highest densities were found in the usual two areas of Lyme Bay and the Bristol Channel and it was the most abundant small pelagic fish in Cardigan Bay (Fig 5). Sprat biomass in the western Channel, the core area that is used in the assessment, increased more than 3-fold to 107,355 t (CV 0.26) which is the highest in the time series (Fig. 3). Compared to recent years, the highest sprat densities in Lyme Bay were further offshore (Fig 5) and there was a notable increase of sprat in French waters of the western Channel. Lyme Bay was the first area surveyed following requests by the industry. Weather conditions during surveying the area were exceptionally calm.

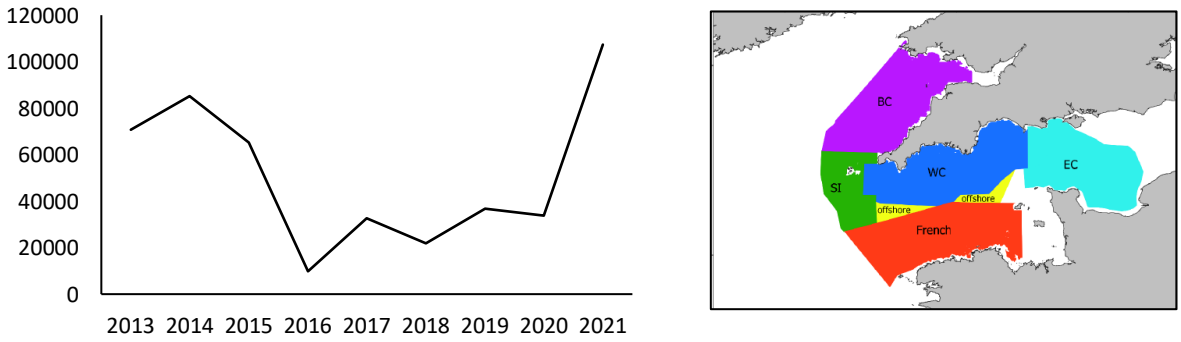

Figure 3. Sprat biomass trend (left) for the consistently sampled stratum in the western Channel: WC (blue) in map of strata (right).

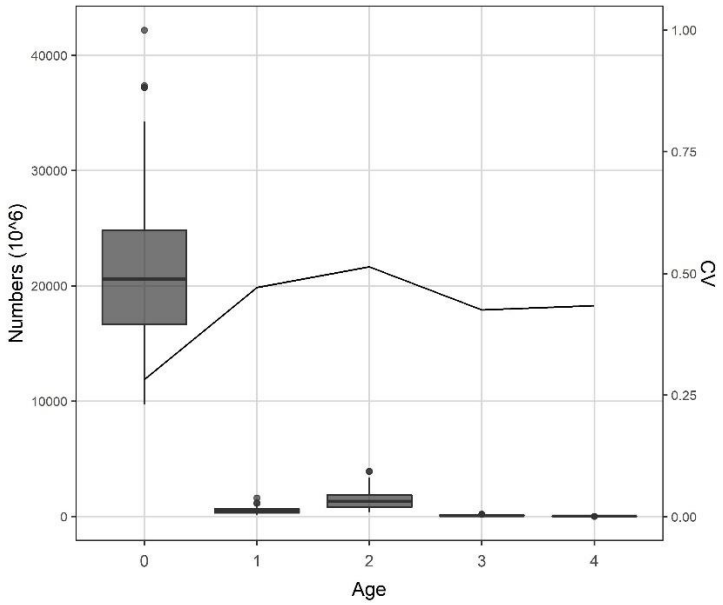

Figure 4. Sprat numbers at age (boxplots, primary y-axis) and CV (line, secondary y-axis) in the consistently sampled western Channel stratum (see Fig 3).

Sprat was more widespread in the northern part of the survey specifically in the inner waters of the Bristol Channel. This year sprat was found further west in the Bristol Channel and more inshore along the north Cornish coast. Due to dominance of 0-group sprat no discernible difference in size was observed between the different areas although small numbers of bigger specimens were found in Lyme Bay (>10 cm, Fig 5).

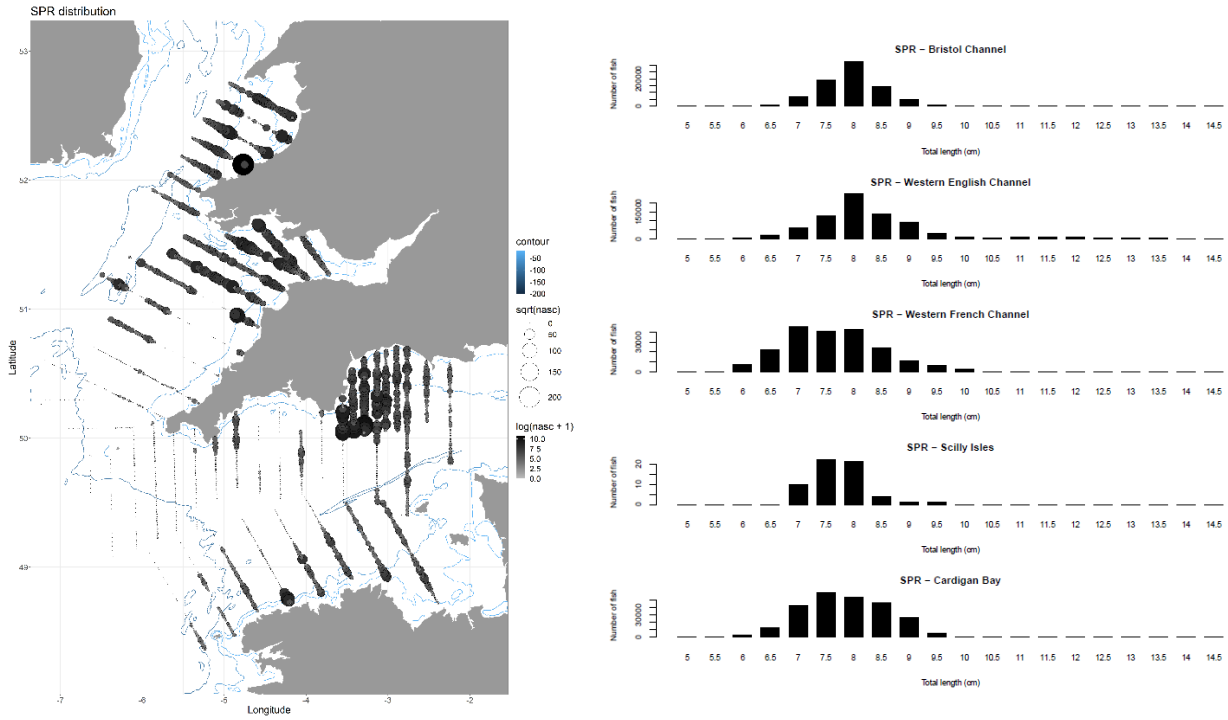

Figure 5. Relative acoustic sprat density distribution (Nautical Area Backscattering Coefficent - NASC, left) and trawl-based length frequency histogram for sprat in the subareas of the PELTIC survey (right).

Sprat was again the most dominant small pelagic species in Cardigan Bay, and, in contrast to 2020 when it was limited to very shallow inshore areas, was found to widespread throughout the Bay. Total biomass of sprat in Cardigan Bay was 102,762 tonnes (CV 0.25), a five-fold increase from 2020. The increase may be due to last year's inshore distribution, in water too shallow to survey. However, at least part of the increase is due to a strong recruitment given the dominance of 0-group size classes (Fig 5).

Sardine *Sardina pilchardus* was again the most abundant small pelagic fish species in the survey area with a total biomass (for the total area, consistently surveyed since 2017, Fig 6) of 227,117 t (CV 0.19), which was down from previous two years but still high.

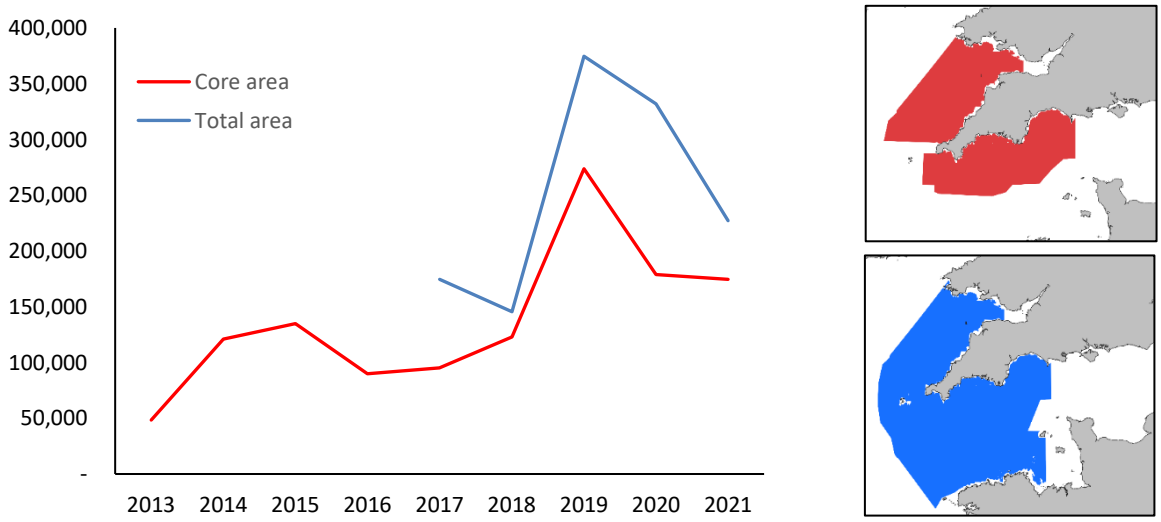

Figure 6. Sardine biomass (tonnes) trends (left) based on two available survey strata: the core area, consisting of the English waters of the western Channel and the Bristol Channel, surveyed consistently from 2013 (top right, red) and the total area, which also includes the Isles of Scilly and French waters of the western Channel, surveyed from 2017 (bottom right, blue).

Sardine was again widely distributed in the waters less than 100 m of the survey area, with highest densities from the Eddystone Bay to east of the Isles of Scilly (Fig 7). Sardine here comprised of fish from multiple cohorts, with the biggest fish further west. Good numbers of sardine were also found in western French waters, which included a broad range of sizes, including larger fish. (Fig 7). Sardine were again observed in the Bristol Channel comprising of both the largest and small size classes in the study area. Sardine was scarce in Cardigan Bay (305 t) and was dominated by fish with modal length of 14.5 cm.

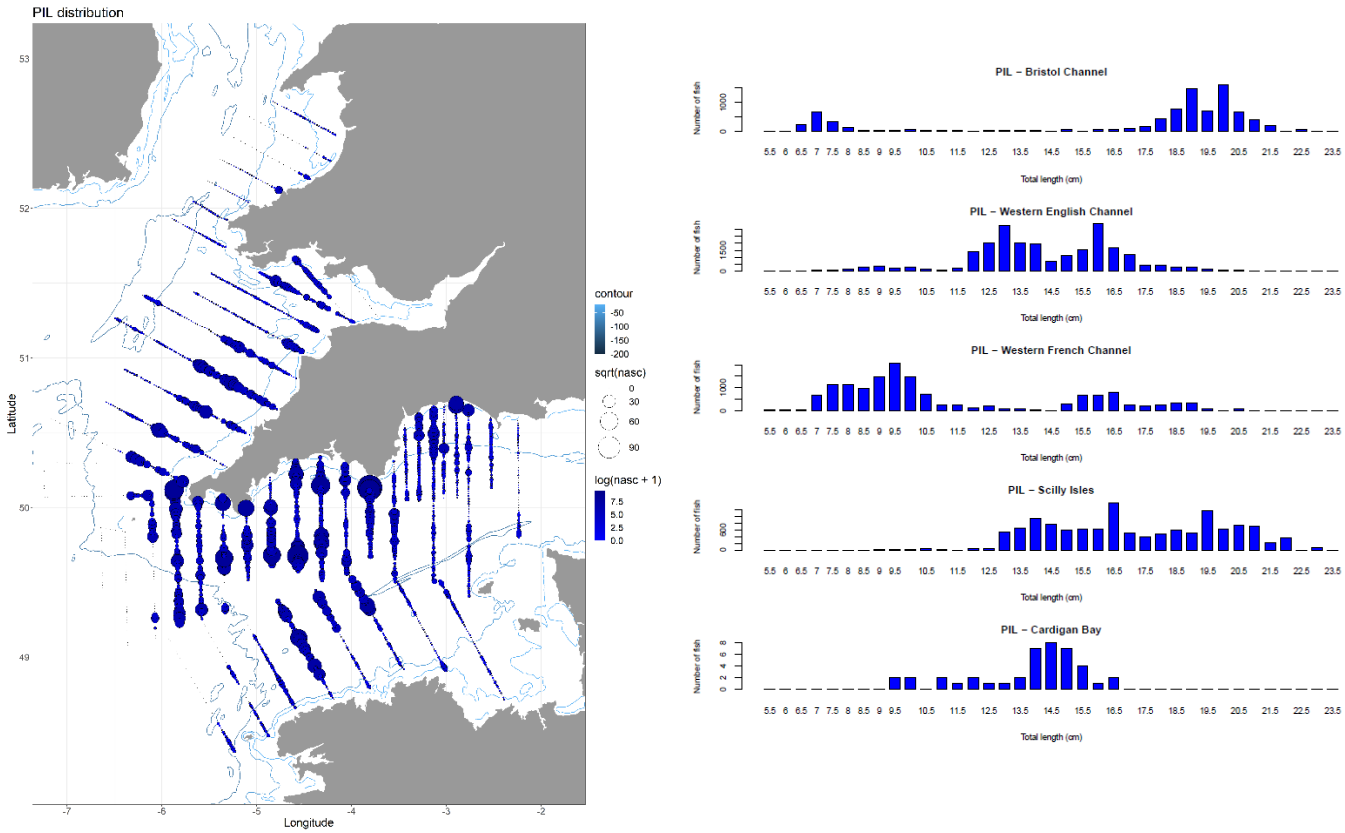

Figure 7. Relative acoustic sardine density distribution of sardine (Nautical Area Backscattering Coefficient - NASC, top left), and trawl-based length frequency histogram for sardine in the subareas of the PELTIC survey (top right).

Most sardine were between 0 and 2 years old with decreasing numbers at older ages (max 7 years old; Fig 8).

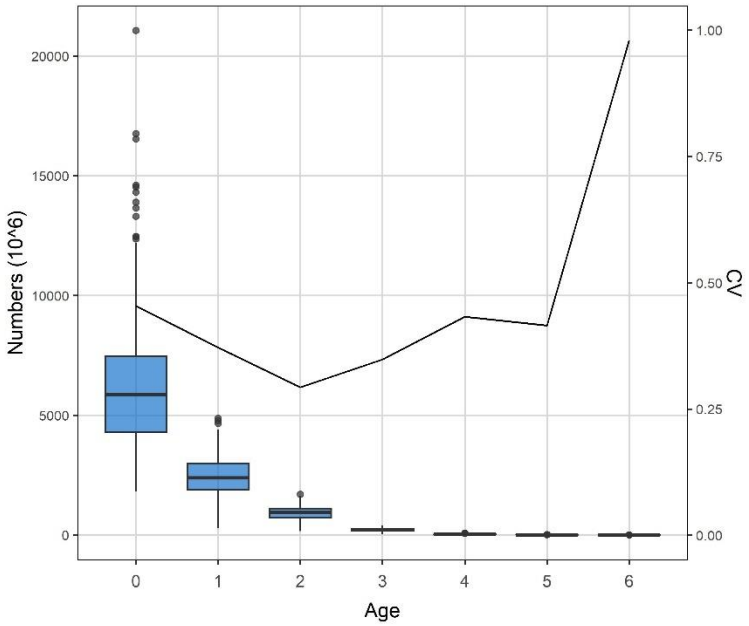

Figure 8. Sardine numbers at age (boxplots, primary y-axis) and CV (line, secondary y-axis) in the consistently sampled total area. Note that this graph excludes the 9,8 billion juvenile sardine recorded in French surface waters.

Northern **Anchovy *Engraulis encrasicolus*** biomass in PELTIC was the highest of the timeseries at 45,616 t (CV 0.23) for the total area (same consistently sampled strata as for sardine).

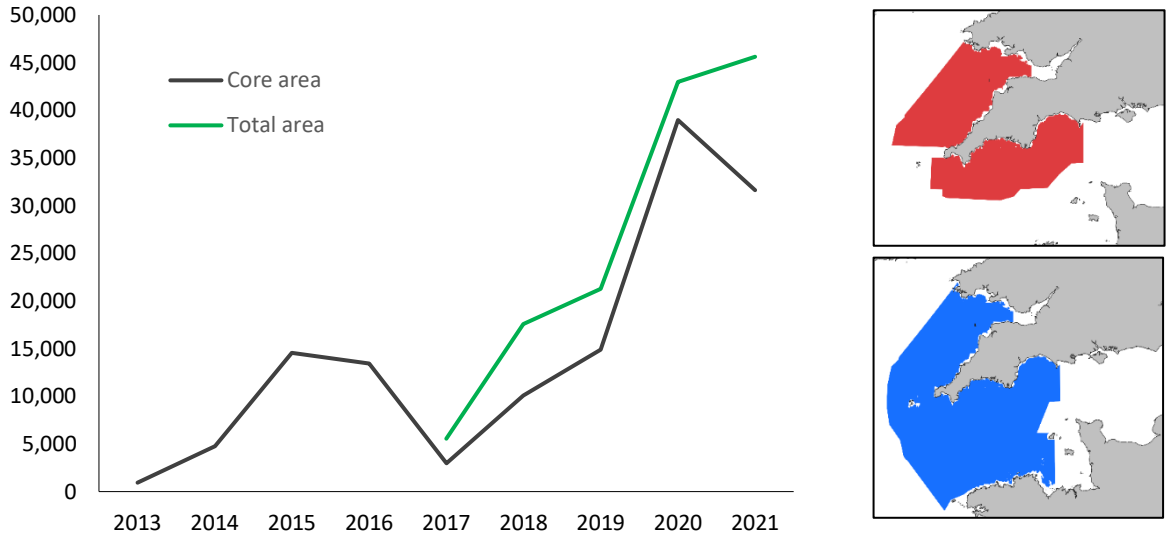

Figure 9. Anchovy biomass (tonnes) trends (left) based on two available survey strata: the core area, consisting of the English waters of the western Channel and the Bristol Channel, surveyed consistently from 2013 (top right, red) and the total area, which also includes the Isles of Scilly and French waters of the western Channel, surveyed from 2017 (bottom right, blue).

Anchovy was mainly distributed in the north-western waters of the western Channel, off the Eddystone Bay between Lands-End and the Isles of Scilly (Fig 10). Fish in these areas comprised of the larger specimens (Fig 11). Smaller numbers consisting exclusively of smaller specimens (8 cm modal length) were found in deeper waters of the Celtic Sea and the inner Bristol Channel (Fig 10). Small numbers of anchovy were also found in Cardigan Bay (159 t), with a peak at 11.5 cm modal length (Fig 10). Post-larval surface anchovy schools, found previously (2019 and 2020) in French waters, were not observed this year.

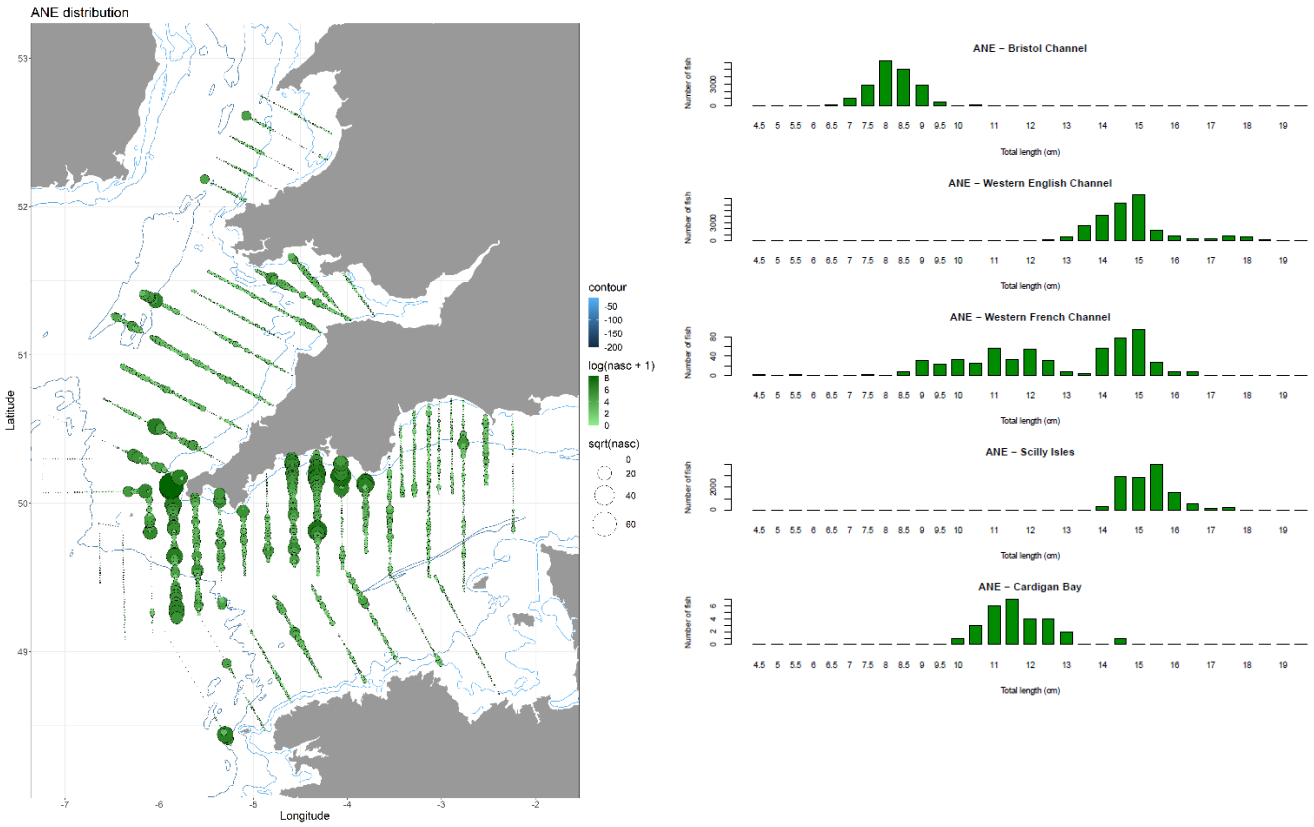

Figure 10. Relative acoustic anchovy density distribution for the northern population (NASC, top left), and trawl-based length frequency histogram for anchovy in the subareas of the PELTIC survey (top right).

Anchovy is the shortest lived small pelagic species in the study area and the oldest fish found during this survey were 2 year old (Fig 11). The dominant age were the 1 year olds.

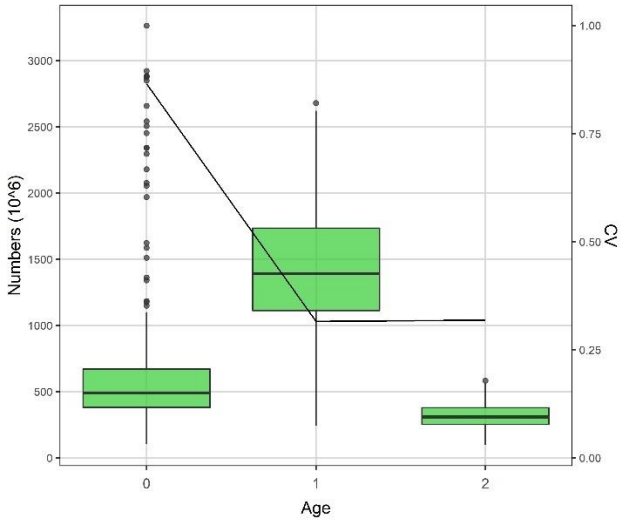

Figure 11. Anchovy numbers at age (boxplots, primary y-axis) and CV (line, secondary y-axis) in the consistently sampled total area. Note that this graph excludes the 13,5 billion post larval anchovy recorded in French surface waters.

Other pelagic fish species (no biomass estimates available at the time of reporting): **Horse mackerel *Trachurus trachurus*** was widespread, although typically in deeper waters of the survey area. As found in previous years, these were mainly made up of juvenile fish with modal length of 9 cm (age 0), with small numbers of larger fish (mode are 17 and 23 cm) also caught (Fig 12). **Herring *Clupea harengus*** numbers were higher than in previous two years and were found mainly in Lyme Bay, the inner Bristol Channel and Cardigan Bay, mixed in with sprat, all of which were juvenile with a mean modal length of 11 cm (Fig 12). **Mackerel *Scomber scombrus*** was widespread in the area. No biomass estimate could be calculated due to a continuation of the noise issue with the 200 kHz which is the reference frequency used to calculate the biomass. Length frequency of mackerel suggested two cohorts (at 19 and 28 cm modal length, Fig 12). **Boarfish *Capros aper*** were, as per usual, found in the deeper waters of the western Channel, particularly off the Isles of Scilly although also further south this year. This area appears to be at the eastern-most range of this species which is typically associated with deeper waters of the Northeastern Atlantic Ocean. This year, a larger range of sizes was found (Fig 12), from juveniles (modal length of 2 cm) to the larger specimens but with intermediate sizes as well. For the first time since 2012 **blue whiting *Micromesistius poutassou*** was caught in significant numbers at two stations in similar areas to boarfish. The modal length of 17 cm suggests that these are predominantly juveniles. For the third year in the survey series (also in 2018 and 2020) **Atlantic bonito *Sarda sarda*** was observed. One specimen was caught in Lyme Bay.

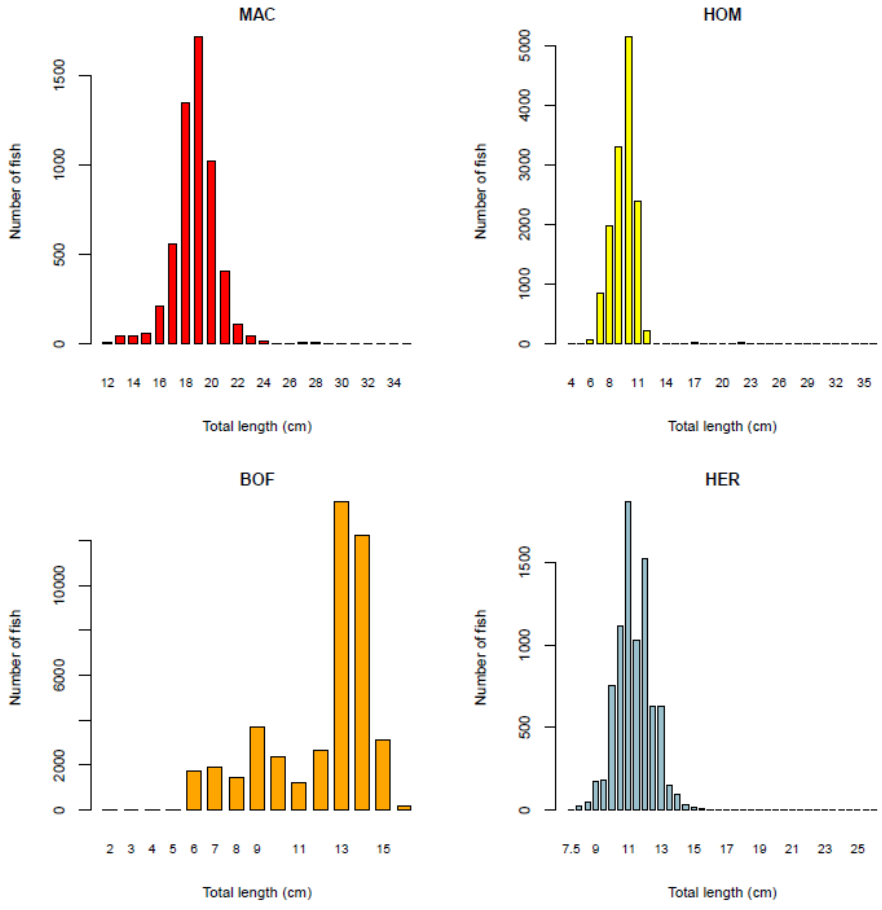

Figure 12. Length frequency histograms for mackerel (MAC), horse mackerel (HOM), boarfish (BOF) and herring (HER), derived from the PELTIC21 trawl catches. Note that these have not been raised by acoustic densities.

Plankton and Oceanography

Mesozoo- and ichthyoplankton samples were collected at 95 stations with ring nets with mesh size of 80 µm and 270 µm, respectively (Table 3). One stations could not be completed (primary station 65), and another station (prime 15) was sampled twice. Mesozooplankton samples were stored on 4% buffered formaldehyde for zooscan processing post-survey. All results will be stored on the ZooTaxa database. Ichthyoplankton was processed aboard with all eggs and larvae staged and measured respectively. Sardine eggs and larvae dominated the ichthyofauna and numbers were among the highest in the time series, although not quite reaching the 2020 numbers. The location of highest densities of sardine eggs corresponded well with the distribution of the main acoustic sardine backscatter suggesting main spawning grounds in the Eddystone Bay and west off Lands-End (Fig 13). Eggs were also found north of the Cornish Peninsula corresponding spatially with the presence of sardine schools in this area (Fig. 13). A small number of eggs were also found at one isolated station in Cardigan Bay (same stations as in 2020). As expected, sardine larvae were more widespread in the survey area although they were absent from the offshore stations. Finally, zooplankton samples were also collected at the West Gabbard smartbuoy location during the return transit back to Lowestoft (objective 9).

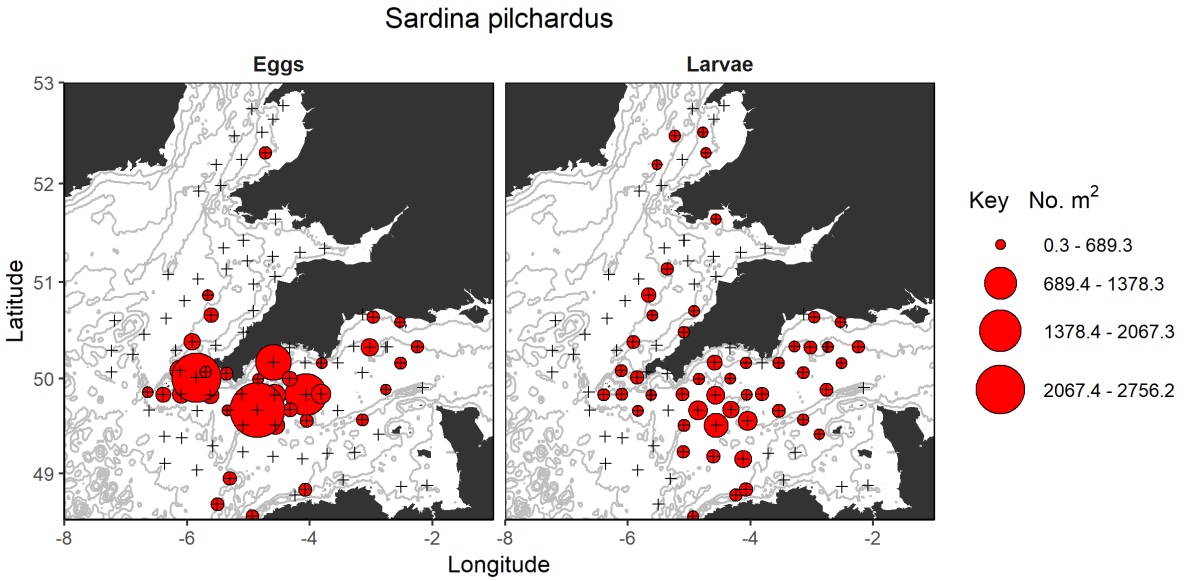

Figure 13 . Distribution of sardine eggs (left) and larvae (right) at the sampling stations derived from samples collected with the 270 µm ring net and analysed on board.

Oceanography

Vertical profiles of temperature and salinity of the water column were carried out at 95 plankton stations using a SAIV mini CTD, although no profiles are available at prime stations 61 and 97 due to failure of the mini CTD in recording environmental data. Furthermore, mini CTD profiles were carried out twice at each of prime stations 15, 32 and 63 (hence bringing the total of profiles carried out to 96; Table 3). At a subset of 36 of the sampling stations, additional data were collected (Table 3): a Rosette with SeaBird CTD and 10 Niskin bottles was deployed at 20 stations to collect information using temperature, salinity, PAR

(Photosynthetic Active Radiation), dissolved oxygen, turbidity and fluorescence sensors and collect water samples for future analysis of phytoplankton (microscope) and microzooplankton (Flowcam) communities, dissolved oxygen, salinity, phytoplankton pigments (including chlorophyll-a) and dissolved inorganic nutrients (nitrate, nitrite, ammonium, phosphate, silicate). At 16 stations adverse weather conditions and damage to the lifting bar of the Rosette prevented the use of the Rosette. Instead, an ESM2 logger was deployed, and surface and bottom water samples were collected from the flow-through of the FerryBox and a single Niskin respectively (Table 3).

Subsurface (4 m) conditions were continuously monitored by the FerryBox, which recorded temperature, salinity, fluorescence, turbidity, and oxygen (Figure 14). No flow cytometer or Plankton Analyser, connected to the FerryBox, were available this year due to uses with these instruments and associated softwares.

At the end of the survey, during the journey back to Lowestoft, dissolved inorganic nutrients were collected hourly from the FerryBox flowthrough between 8 am – 8 pm, in the western Channel, for water quality assessment (winter nutrient concentration; Objective 15).

Table 3. Number of samples collected and number of profiles carried out during PELTIC 21.

	Total
Salinity	39
Dissolved oxygen (triplicates)	22
Chlorophyll/Pigments analysis (HPLC - duplicates)	36
Inorganic nutrients (36 x 2 methods)	72
Phytoplankton	36
Microzooplankton	36
Mesozooplankton (80 µm)	96
Mesozooplankton (270 µm)	96
eDNA samples	29
CTD profiles with Rosette	20
CTD profiles with ESM2	16
CTD profiles with SAIV MiniCTD	96

Dissolved oxygen samples from water near the bottom were analysed on board by the Winkler method using an auto-titrator; while salinity and inorganic nutrient samples were stored for analyses in the Laboratory. Duplicate inorganic nutrient samples were collected at all stations, to allow comparison between two different sample preservation methods (freezing vs. mercuric chloride). Chlorophyll and pigments samples were stored at -80 °C for subsequent HPLC (High Performance Liquid Chromatography) analysis at DHI (Denmark). Phytoplankton samples were fixed with Lugol for processing in the Lowestoft Laboratories using an inverted microscope, while microzooplankton samples (also fixed with Lugol) will be analysed with the FlowCam by Plymouth Marine Laboratory. Samples for dissolved oxygen, salinity and chlorophyll-a were collected to calibrate sensors on the FerryBox and on the SeaBird profiler.

Sea surface temperature was highest in the western Channel (the most easterly part sampled) and in the offshore stations in the Celtic Sea (Figure 14). Maximum temperature recorded by the FerryBox at the subsurface was 17.6 °C, higher than temperature recorded in 2020 (16.46 °C) and in 2019 (17.2 °C). Lowest surface temperatures were recorded offshore between the Celtic Sea and French side of the Channel and north of the Isles of Scilly (Figure 14). The lowest surface temperature recorded this year was 13.3 °C, warmer than the lowest surface temperature recorded in 2020 (12.7 °C) and 2018 (12.8 °C). Western offshore stations in the Bristol Channel, the Western approaches, Lizard Point and Eddystone Bay, were seasonally thermally stratified (Delta_T > 0.5 °C; Figure 14). The difference between surface and bottom temperatures was highest at offshore stations in the Celtic Sea, up to 4.5 °C (Table 4). The strength of stratification observed this year was comparable to that of previous years (typically between 4 and 5 °C).

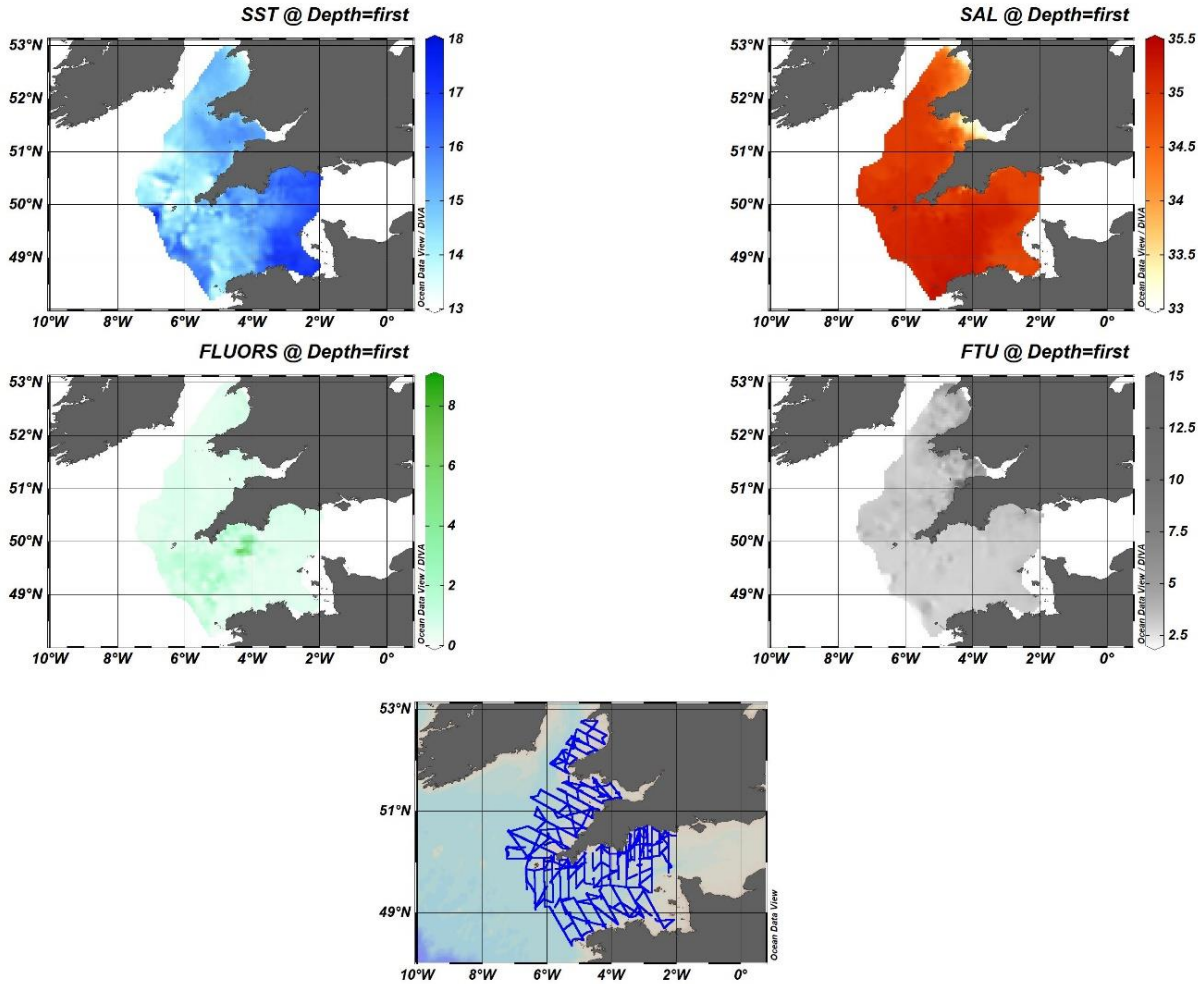

Figure 14. Sea surface temperature (SST), salinity (SAL), chlorophyll fluorescence (FLUORS), and turbidity (FTU) measurements (at 4 m depth) from the FerryBox underway system (track shown bottom), between 6/10 and 05/11/2021.

Offshore salinity showed little variation (Figure 14). Highest salinity (35.33) was recorded in the south-west corner of the Celtic Sea, and lowest (33.06) in the Bristol Channel and Cardigan Bay. Salinity stratification (Delta_S) was highest at the most westerly stations in the Celtic Sea, where the stratified water column presented a warmer and less salty, surface mixed layer separated by a thermocline from a saltier and cooler bottom mixed layer (Figure 15).

Table 4. Summary statistics (minimum, maximum, mean, standard deviation, and number of observations) of temperature measurements, recorded by the SAIV MiniCTD at the sampling stations.

	Temperature	Salinity	Fluorescence	Turbidity
Mean	13.33	33.06	0.31	2.86
Min	17.59	35.33	8.92	14.52
Max	15.19	34.94	0.74	3.49
Std Deviation	0.87	0.31	0.46	1.28
Number	41078	41078	41058	41098

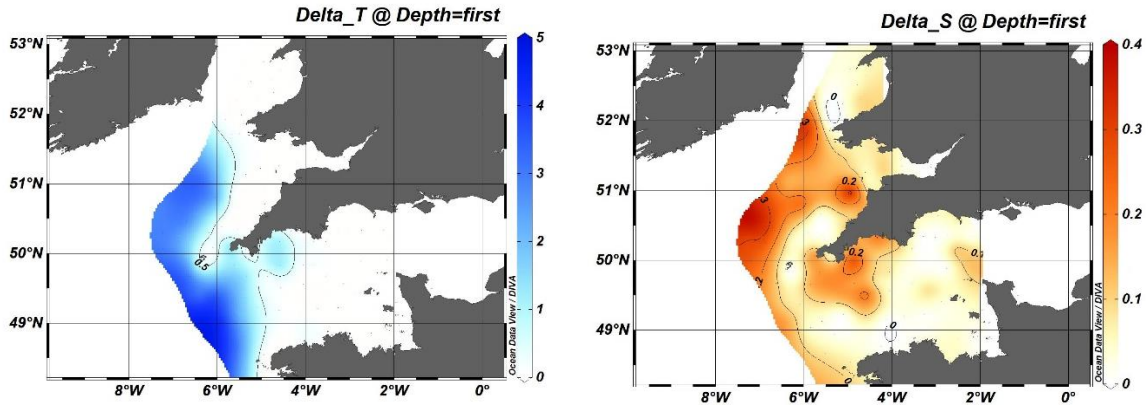

Figure 15**.** Delta_T (°C), difference in temperature between surface and bottom (left) and Delta_S, difference in salinity between surface and bottom (right) as recorded by the SAIV MiniCTD at the 96 sampling stations. The isotherm of Delta_T = 0.5 °C is highlighted to distinguish between mixed (Delta_T < 0.5 °C) and stratified waters (Delta_T > 0.5 °C).

Surface distribution of chlorophyll was estimated by fluorometer on the FerryBox. Fluorescence values (proxy for chlorophyll-a) were highest in the area south of Plymouth (Figure 14). This coincided with the easterly edge of the 0.5 °C isotherm, perhaps indicative of enhanced productivity in the frontal area between mixed and stratified waters. Images of surface chlorophyll distribution from satellite remote sensing (Figure 16) confirmed the presence of a bloom in the offshore area south of Plymouth, extending south along the Ushant Front. Although remote sensed images identified high chlorophyll concentration in the Bristol Channel, the fluorescence measurements from the FerryBox in this area were low. The inner Bristol Channel is an optically complex area with high levels of suspended sediments and coloured dissolved organic materials (CDOM) from the River Severn; therefore, it is possible that the algorithm used to estimate the chlorophyll map (OC4) is less suited for these optically complex areas. In fact, highest turbidity values were measured in the Bristol channel, causing some adaptations to be made to sample filtration, and zooplankton analysis (Figure 14).

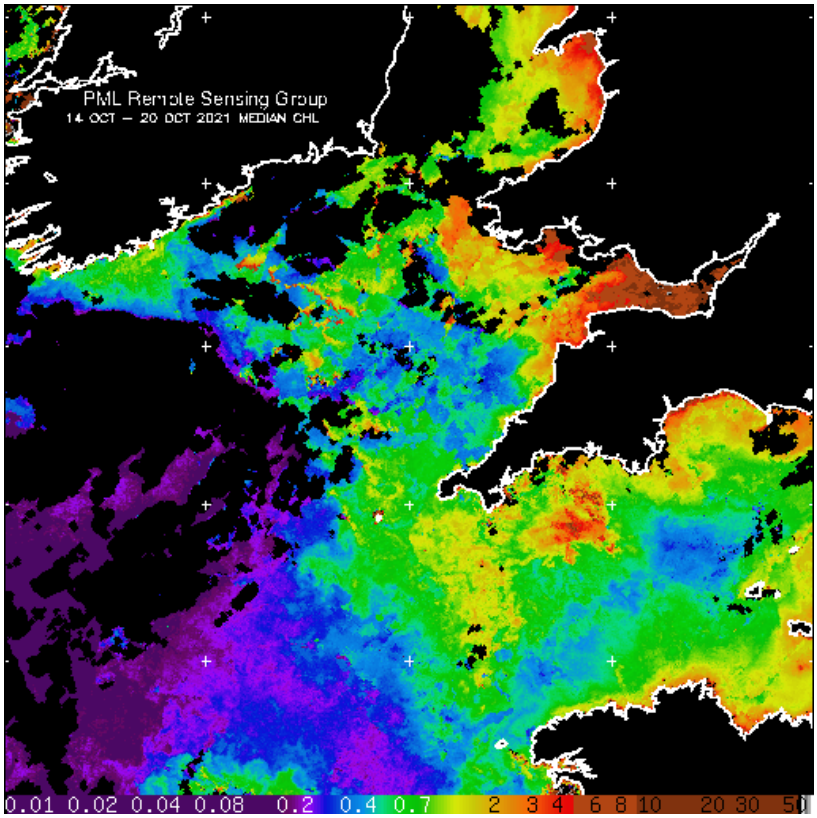

Figure 16 Surface chlorophyll distribution (OC4ME algorithm) between 14-20 October 2021, from https://data.neodaas.ac.uk/).

Observer data: apex predators

For the ninth year running, two volunteer MARINElife surveyors were stationed on the bridge in a central position, and employed an effort-based 300m box methodology for recording birds (an adapted version of ESAS methodology) with an additional 180° area scanned to survey each transect line. During transits between transects, the team recorded incidental observations when possible, logging significant species only. Furthermore, casual observations were recorded during the net-retrieval stage of trawls to identify species of birds associated with the fishing activity of the survey vessel but only where there was a significant gathering of birds. During survey transects, all species of birds (both seabirds and terrestrial migrants) were recorded, along with all sightings of marine mammals and pelagic fish such as tuna. The effort-based 300m box methodology employed was developed by the Cetacean Group of the Mammal Society for use from platforms of opportunity such as commercial ferries. The aim of this method is for the observer to record and identify as many seabirds and cetaceans as possible that pass through the 300m box and also record birds and marine mammals outside the box out to a distance of 1km. In 2021 both surveyors recorded cetaceans and seabirds.

Survey effort was made on 29 days from 6 October to 5 November, sampling approximately 4,039 km of transect line (the longest distance of any PELTIC surveys). The 2021 survey was very definitely a survey of two (almost equal) halves (Table 5). The period 6-17 October was characterised by light winds with a mean wind speed of force 2.2 and the sea state two or three for 73% of survey effort and only reaching five for just 4% of survey effort. The wind had an easterly component for 44%, westerly for 27%, due north or south

for 20% and calm for 9% of survey effort. In stark contrast the period 18 October-5 November was characterised by strong westerly winds, with a mean wind speed of force 4.9 and with the wind between NW-SSW for 62% of survey effort and due north or south for the rest. Sea state was five or above for 70% of survey effort and a sea state two or less seen for just 3% of survey effort.

Table 5: Survey effort and sea state conditions from 2013-2021 by MARINElife team on the PELTIC Survey. *Only parts 1&2 of the 2017 survey during which both survey teams were present are included in this table.

	2013	**2014**	**2015**	**2016**	**2017***	**2018**	**2019**	**2020**	**2021**
Transect length (km)	2092 (+278*)	3058	2447	2990	2644	3706	3025	3741	4039
No. survey days	16 (+2*)	20	18	16	24	32	26	30	29
Mean sea state	5.01	3.78	3.08	5.34	4.32	3.86	3.24	4.83	3.92
Modal sea state (% of total)	4	3	4	3	3	5	3	5	5
% Effort sea state 4 or less	37	67	92	45	53	63	81	39	56
Modal wind direction (% of effort)	SW (33)	SW (30)	NE (30)	ENE(24)	SW (40)	NE (28)	TBC	SW (15)	W (17)

*Southern North Sea

A total of 35 **bird** species were recorded on effort during the survey this year, slightly down on the 41 recorded in 2020. A total of 8,543 sightings of 24,107 birds were recorded throughout the survey (Table 6), exceeding the record set last year for the longer surveys undertaken since 2017. The additional transects in Cardigan Bay accounted for an additional 3,421 birds. Even if the Cardigan Bay transects are excluded from the total, the resulting 20,686 birds recorded is still higher than any 2017-2020 total. The Cardigan Bay transects accounted for about 14% of the total, comparable to the 12% last year.

As in all previous surveys, Gannet was the most commonly recorded species, although, once again, fewer were recorded than in 2017 & 2018. There seemed to be a lack of birds in the central English Channel, with no substantial numbers drawn to the vessel's trawling activity (despite the trawls being successful with decent amounts of fish) and few trawlers were encountered with large feeding flocks, unlike in previous years. This lack of trawler encounters may also be the reason Great Black-backed Gull and Great Skua numbers were low, although the latter has reportedly had successive poor breeding seasons.

The observed high abundance of small fish (0-group sprat, above) during the survey was a possible reason eight species – Balearic Shearwater, Black-headed-, Mediterranean- and Herring Gull, Kittiwake, Puffin, Guillemot, and Razorbill – were observed in record numbers. These species target prey fish in the 5-10cm range, which matches the size of year 0 Sprat. For the first time (since at least 2016) Razorbill numbers were close to those for Guillemot (normally half or less than Guillemot). The daily counts for Razorbill show good numbers on several days throughout the survey, with a peak day count of 337 on 24 October in Cardigan Bay, which suggests there were generally more birds present this year. Kittiwake

are one of the easier birds to age during a survey and it was interesting to note that of the total of 1,690 birds observed, almost half (808) were juveniles, suggesting a decent breeding season in some parts of their range. The 229 Wigeon were all observed towards the north end of a transect in the western edge of Lyme Bay and they were likely there due to disturbance on the saltmarshes around Dawlish Warren and the Exe estuary.

Table 6: List of all bird species recorded on effort during Peltic survey 2021

Species	Scientific Name	No of sightings	No of birds
Dark-bellied Brent Goose	*Branta bernicla*	1	7
Wigeon	*Anas penelope*	4	229
Common Scoter	*Melanitta nigra*	9	36
Great Northern Diver	*Gavia immer*	3	5
Fulmar	*Fulmarus glacialis*	90	243
Manx Shearwater	*Puffinus puffinus*	42	54
Balearic Shearwater	*Puffinus mauretanicus*	73	346
Sooty Shearwater	*Puffinus griseus*	27	30
Shearwater sp.	*Puffinus sp.*	6	6
European Storm Petrel	*Hydrobates pelagicus*	50	159
Petrel sp.		4	6
Gannet	*Morus bassanus*	2990	7697
Cormorant	*Phalacrocorax carbo*	2	3
Shag	*Phalacrocorax aristotelis*	10	11
Little Egret	*Egretta garzetta*	1	1
Common Snipe	*Gallinago gallinago*	1	1
Great Skua	*Stercorarius skua*	122	135
Pomarine Skua	*Stercorarius pomarinus*	1	1
Arctic Skua	*Stercorarius parasiticus*	13	13
Skua sp.	*Stercorarius sp.*	4	4
Black-headed Gull	*Chroicocephalus ridibundus*	19	92
Common Gull	*Larus canus*	37	44
Mediterranean Gull	*Larus melanocephalus*	85	252
Herring Gull	*Larus argentatus*	169	512
Lesser Black-backed Gull	*Larus fuscus*	103	244
Yellow-legged Gull	*Larus michahelis*	1	1
Great Black-backed Gull	*Larus marinus*	193	380
Larus sp.	*Larus sp.*	68	601
Kittiwake	*Rissa tridactyla*	1195	4472
Little Gull	*Hydrocoloeus minutus*	8	31
Puffin	*Fratercula arctica*	262	512
Guillemot	*Uria aalge*	1437	2885
Razorbill	*Alca torda*	633	2101
Auk sp.		844	2858
Barn Swallow	*Hirundo rustica*	2	3
Meadow Pipit	*Anthus pratensis*	23	113
Pied Wagtail	*Motacilla alba yarrellii*	8	11
Starling	*Sturnus vulgaris*	1	5
Robin	*Erithacus rubecula*	1	1
Song Thrush	*Turdus philomelos*	1	2
Total		**8543**	**24107**

Table 7: List of bird species recorded off-effort either at sea or onboard CEFAS Endeavour

Species	Scientific name	No of birds
Balearic Shearwater	*Puffinus mauretanicus*	45
Yellow-legged Gull	*Larus michahellis*	2
Chiffchaff	*Phylloscopus collybita*	8
Dusky Warbler	*Phylloscopus fuscatus*	1
Blackcap	*Sylvia atricapilla*	4
Song Thrush	*Turdus philomelos*	4
Robin	*Erithacus rubecula*	6
Grey Wagtail	*Motacilla cinerea*	3
Chaffinch	*Fringilla coelebs*	2
Snow Bunting	*Plectrophenax nivalis*	2

As Europe's only critically endangered seabird, **Balearic Shearwater** has been a target species of the PELTIC survey and additional data were recorded, including, where possible, 30 minutes effort after any off-transect sightings. This year a total of 387 birds were recorded, the highest total for the species in any of the Peltic surveys by some margin. In total 346 specimens were recorded on transects (Table 6) and a further 41 while off-transect (in transit, during trawling, Table 7). In contrast to the early years of PELTIC no aggregations to the south-west of Lundy in the Bristol Channel were seen (Fig 16). This year nearly all the large numbers of birds were seen either shortly after dawn or near sunset and close to the French coast, the exception being the area to the southwest of Guernsey, an area known to be home to large numbers of Balearic Shearwater through July and August.

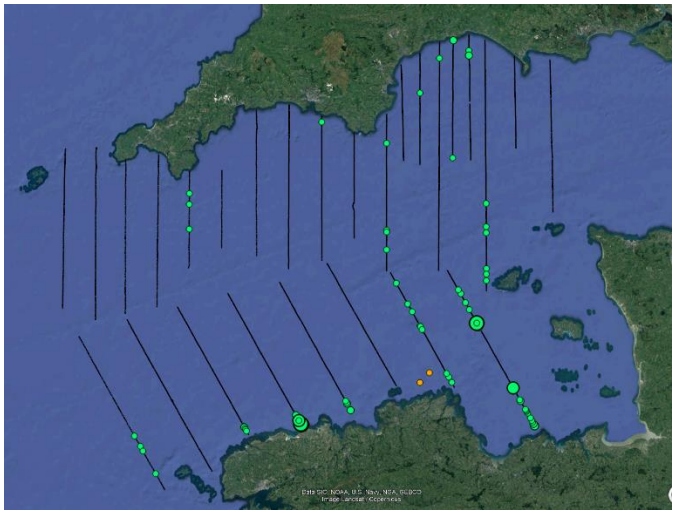

Figure 16: Distribution of all Balearic Shearwater sightings in 2021, scaled to abundance. Abundance categories (small to large circles): 1-5, 6-10, 11-20, 20+. Green dots were birds recorded on transect, orange dots off transect, black lines mark survey effort.

Cetaceans

A total of 293 cetacean encounters were made, totalling approximately 4,081 animals of eight species (Table 8). The total number of animals recorded is more than double that recorded in 2020 and is the best year for cetaceans so far. However, Harbour Porpoise observations totalled 32, which is low given the good surveying conditions while in their main habitat of the western Channel and particularly Lyme Bay.

Table 8. Cetacean species recorded by MARINElife surveyors on effort during Peltic survey 2021

Species	Scientific Name	No. sightings	No. animals
Fin Whale	*Balaenoptera physalus*	2	2
Fin Whale (probable)	*Balaenoptera physalus*	1	1
Minke Whale	*Balaenoptera acutorostrata*	3	3
Long-finned Pilot Whale	*Globicephala melas*	1	8
Risso's Dolphin	*Grampus griseus*	4	33
Common Bottlenose Dolphin	*Tursiops truncatus*	4	21
Common Dolphin	*Delphinus delphis*	246	3899
White-beaked Dolphin	*Lagenorhynchus albirostris*	1	3
Harbour Porpoise	*Phocoena phocoena*	17	32
Dolphin sp.		14	79
	Total:	293	4081

Common Dolphin was again by far the most frequently recorded species, with 246 sightings of 3,899 animals, the best year yet for the species on the PELTIC surveys (Table 8). The species is widely distributed throughout the survey area (Fig 16) with notable hotspots in Lyme Bay, mid-western Channel, around the Isles of Scilly and the Celtic Deep. Day totals exceeded 100 on 14 days with a maximum of 401 (30th October) and another four days with over 300 seen. The maximum count for a single pod was an estimated 300, followed by 200 and a further four in excess of 100.

A total of 10 Fin Whales were recorded plus a further five large rorquals – most likely Fin as well – of which only two (plus one probable) were seen on effort (Fig 16). In contrast to previous years, only one sighting was recorded near the Celtic Deep – the traditional area for fin whale sightings. Of note were three animals in the western Channel, especially the one about 30km south of Start Point, which may well be the animal seen feeding in Falmouth Bay a few days earlier.

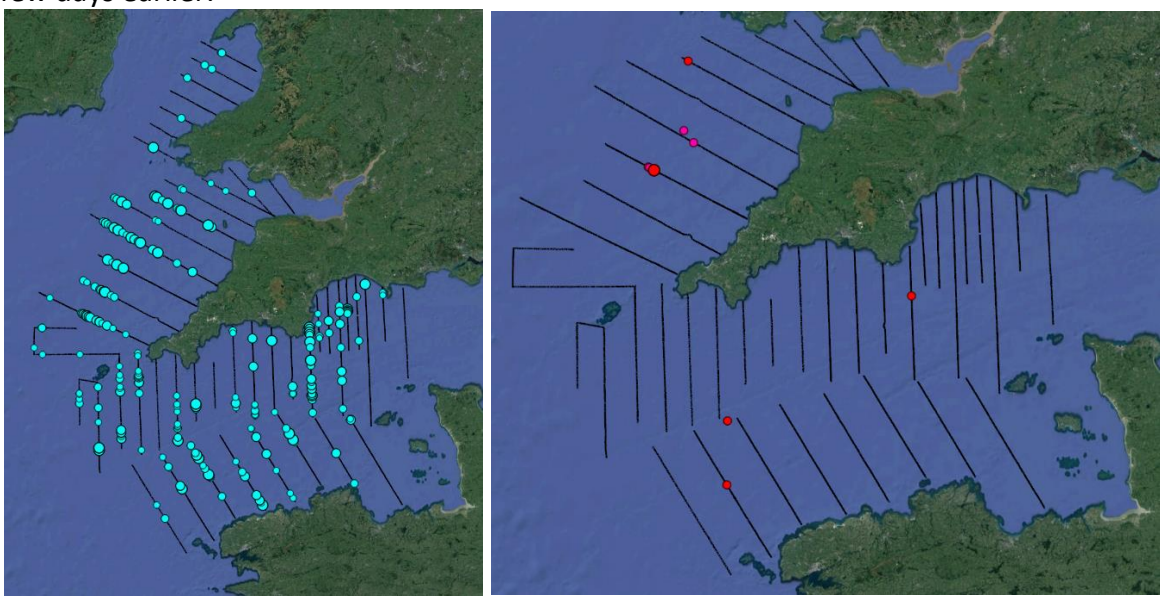

Figure 17: Distribution of Common Dolphin sightings (left, light blue circles), scaled to abundance. (small to large circles: 1-5, 6-10, 11-20, 20+) and Fin Whale/probable Fin Whale sightings (right) in 2021 (confirmed Fin red dot, probable pink dot), black lines mark survey effort.

Despite some calm conditions, Harbour Porpoise numbers were low with only 32 recorded, all bar one of which were in Lyme Bay (Fig 18). None were seen in typical habitats, such as Falmouth Bay, Mounts Bay and around the Isles of Scilly. Given that good numbers were

recorded in Lyme Bay in the summer (Tom Brereton pers. comm.), it is possible that there was an autumnal distribution shift westwards where sea state was unfavourable for detection of Harbour Porpoise. A group of eight Long-finned Pilot Whale was observed just south of Eddystone light. It is a scarce species for the PELTIC surveys and has been recorded only a handful of times. One of the bulls had a hooked dorsal fin, similar to a Short-finned Pilot Whale, though it is extremely unlikely it was this species. A solitary group of three (probable) White-beaked Dolphin were once again seen in Lyme Bay. One appeared smaller so they may well have been the group, which included a calf, present in the Berry Head area for a week or two prior to the survey. Four groups of Risso's Dolphin, totalling 33 animals, and four small groups of Bottlenose Dolphin were recorded on widely scattered transects (Fig 18). Only three Minke Whales were recorded.

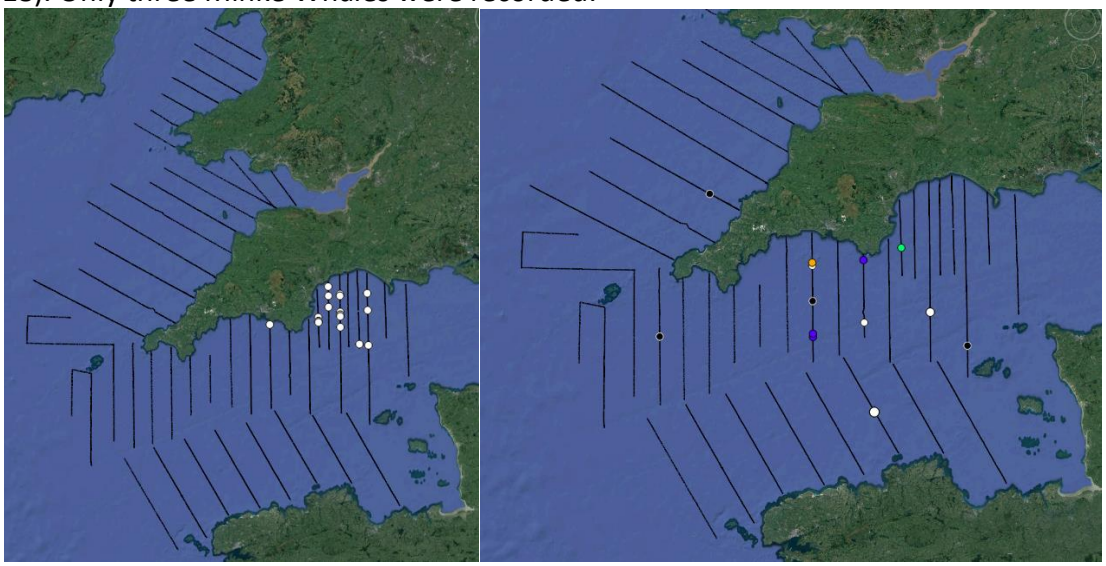

Figure 18: Distribution of Harbour Porpoise (left, white dots) and scarce cetacean species sightings (right). Black = Bottlenose Dolphin, green = White-beaked Dolphin, white = Risso's Dolphin, orange = Pilot Whale, purple = Minke Whale. Black lines mark survey effort.

Bluefin tuna

A total of 721 tuna were recorded in 88 encounters on the survey transects. Three categories of sighting are distinguished:

- possible – a single erratic splash is seen, nature of splash rules out a cetacean but not another large pelagic fish species
- probable – multiple erratic splashes with glimpses of animal but not enough to confirm identity as bluefin tuna
- definite – enough of the animal is seen to identify it as a bluefin tuna species

In contrast to last year all the sightings were in the eastern half of the survey area (Fig 19), although this is at least partly due to change in weather during the second half of the survey. Of particular note were the large numbers of tuna seen west of Guernsey on the French side of the Channel, this has traditionally been a poor area for sightings (cetacean, seabird and tuna and other fish) but the presence of sprat this year, likely accounted for the increased activity. This year saw more encounters with sizable feeding frenzies than 2020 but still fewer than were seen in 2017 and 2018.

In addition, there were two sightings of Atlantic Grey Seal *Halichoerus grypus* and three Basking Shark *Cetorhinus maximus*, the latter all seen in a 20-minute period on 13 October in Sea State 0 conditions in the middle of the Channel south off Plymouth.

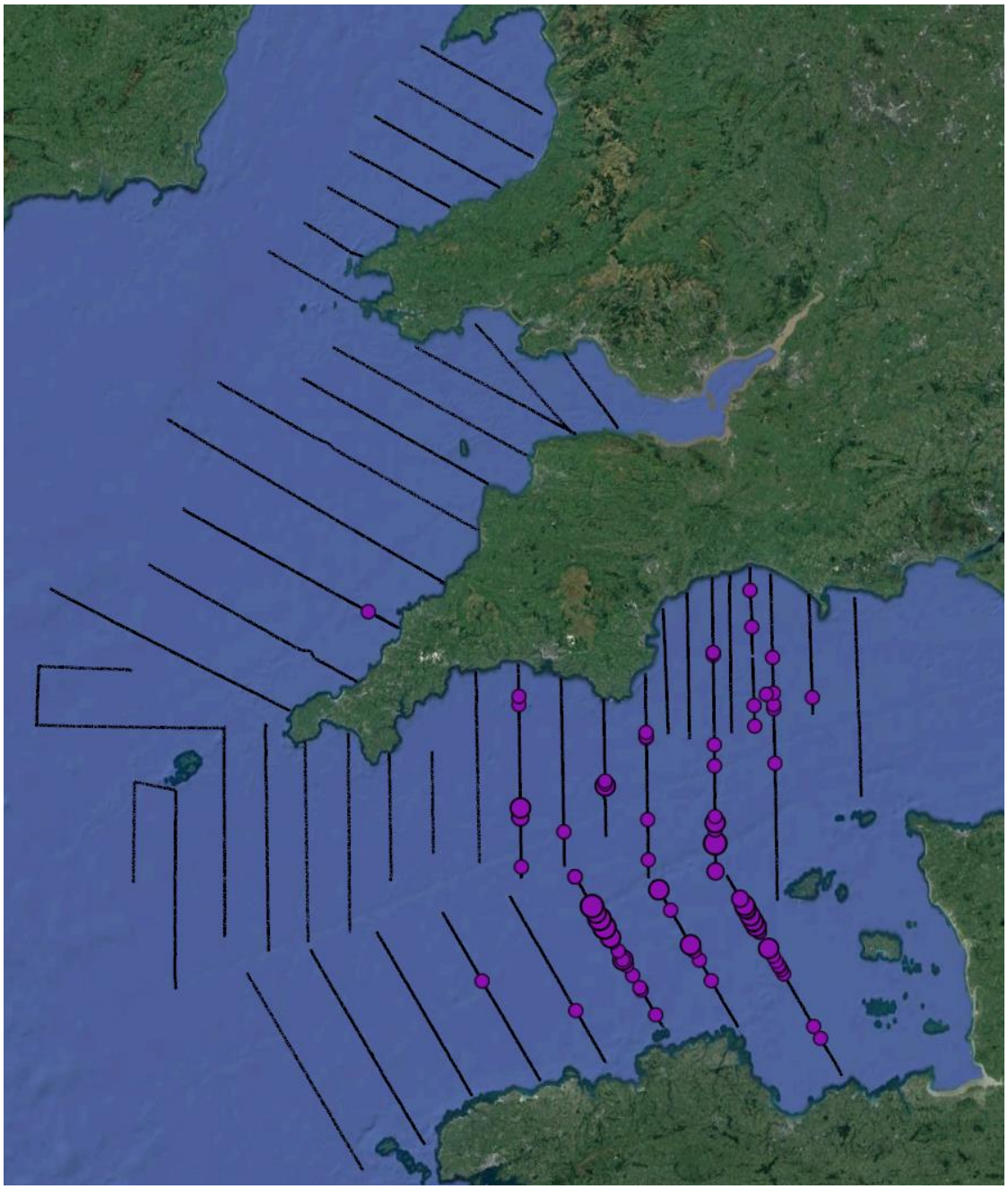

Figure 19: Distribution of all tuna sightings in 2021, scaled to abundance. Abundance categories (small to large purple dots): 1-5, 6-10, 10+. Black lines mark survey effort.

Summary

The 2021 PELTIC survey was successfully completed despite delays due to COVID and inclement weather. The biomass estimates for key pelagic species was deemed of good quality: sprat in ICES area 7de and sardine in area 7ef for stock assessment. Sprat biomass in the core survey area used for the assessment was 107,355 t which was more than three times the 2020 estimate and the highest since the start of the PELTIC timeseries in 2013. This was comprised of 0-group fish, confirming a very strong recruitment. As in previous years, the highest quantities were found in Lyme Bay, showing a more offshore distribution than in 2020, although sprat was also found in the Eddystone Bay. Larger than usual numbers of sprat were also found along the northern French coast, although this areas is not considered in the assessment. Outside the western Channel, sprat was again also found north of the Cornish Peninsula: offshore in the deeper waters of the Celtic Sea, in the Inner Bristol Channel and, in very high numbers, in Cardigan Bay.

Sardine biomass for the survey areas included in the new assessment was 227,117 t. This represents a reduction by one third from peak values in 2020 (and 2019), although still higher than 2017 and 2018 and a close second most abundant small pelagic fish species after sprat. Anchovy biomass increase slightly from 2020 last year to 45,616t with again one year old fish dominating the population. There was sign of significant presence of post-larval Bay of Biscay anchovy, observed during PELTIC 2020 across all southern English Channel transects. Atlantic bluefin tuna were regularly observed particularly around the Channel Islands.

For the second time, PELTIC extended into Cardigan Bay to study its pelagic ichthyofauna and ecosystem. As was the case for the wider survey area, sprat was the most important small pelagic species with significant biomass observed (102,762 t). Horse mackerel, sardine, anchovy and herring were also found although in much lower numbers. A small number of sardine eggs were again found at one station (the same station as in 2020) confirming local spawning activity of this species, the northern-most location in the survey area to date.

Jeroen van der Kooij
Scientist in Charge
15/12/2021

Acknowledgement: This report was compiled by JvdK with contributions from FC, JS, EC, NA and PH. We would like to thank all scientists, the officers and crew of the RV Cefas Endeavour for their help, support, advice, skill and cooperation, which were critical to the successful completion of the survey, particularly with the challenges of COVID-19.

DISTRIBUTION:
Survey participants
I Holmes (PI)
P Falconer (PL)
D Pettengell (PM)
S Kirby (PL)
S Close (PM)
L Slater (PM)
Cefas Fisheries Survey SICs/2ICs
G Burt (CDP)
C O'Brien
R Nash
D Evans (AW)
B Salter (AW)
G. Nieuwenhuijze (AW)
Master and skipper (*RV* Cefas Endeavour)
T Brereton (MarineLife)
C O'Donnell (Marine Institute)
G Boyra (AZTI)
I Glasgow (Defra)
M Hackett
B Badger
B Cioffi (WG)
M Sayer (WG)
P Wensley (WG)
R Caslake (Seafish)
Marine Management Organisation (MMO)
Southern, Devon & Severn, Cornwall, Isle of Scilly IFCAs
D. Wilkinson (States of Guernsey)
P. Chambers (Government of Jersey)
FCO (France)

Annex 1: Metadata objectives 8, 10, 11, 14

Objective 8: To collect between 25-50 specimens per species (anchovy, boarfish, herring, horse mackerel, mackerel, sardine) and freeze for further analysis in the lab supporting a study on microplastics in fish stomachs (A. Bakir).

Trawl station	Survey stratum	Species code	Common name
18	western Channel	HER/SPR	Herring and Sprat
28	western Channel	MAC	Mackerel
38	western Channel	ANE	Anchovy
48	western Channel	HOM	Horse mackerel
55	western Channel	SPR	Sprat
80	western Channel	ANE	Anchovy
101	western Channel	HOM	Horse mackerel
108	western Channel	ANE	Anchovy
111	western Channel	BOF	Boarfish
152	Scilly Isles	MAC	Mackerel
152	Scilly Isles	PIL	Sardine
152	Scilly Isles	ANE	Anchovy
166	Cardigan Bay	SPR	Sprat
166	Cardigan Bay	HER	Herring
184	Cardigan Bay	MAC	Mackerel
204	Bristol Channel	SPR	Sprat
210	Bristol Channel	MAC	Mackerel
250	Bristol Channel	ANE	Anchovy

Objective 10: To collect between 15-20 (similar sized) specimens per species (anchovy, boarfish, herring, horse mackerel, mackerel, sardine) and freeze (Stephen Smith, NMBAQC)

Trawl station	Survey stratum (label in bag)	Species code	Common name	ICES Rectangle	ICES Division
9	WEC (western English Channel)	MAC	Mackerel	30E7	7.e
48	WEC (western English Channel)	PIL	Sardine	28E6	7.e
		ANE	Anchovy		
		HOM	Horse mackerel		
101	WFC (western French Channel)	HOM	Horse mackerel	26E5	7.e
111	WFC (western French Channel)	BOF	Boarfish	26E4	7.h

Objective 11. To collect 20 specimens each of anchovy and sardine at five different locations for a genetic study on both species (Naiara Rodriguez-Espeleta, AZTI, Spain)

Trawl station	Survey stratum	Species code	Common name
28	western Channel	PIL	Sardine
48	western Channel	ANE	Anchovy
108	western Channel	ANE	Anchovy
152	Scilly Isles	ANE	Anchovy
152	Scilly Isles	PIL	Sardine
250	Bristol Channel	ANE	Anchovy

Objective 14. Collect ~25 sprat specimens from stations across the survey area for a genetic study on the stock structure of this species in the Celtic Sea ecoregion

Trawl station	Survey stratum	Species code	Common name
9	western Channel	SPR	Sprat
28	western Channel	SPR	Sprat
55	western Channel	SPR	Sprat
166	Cardigan Bay	SPR	Sprat
204	Bristol Channel	SPR	Sprat