Centre for Environment Fisheries & Aquaculture Science

Cefas

RESEARCH VESSEL SURVEY REPORT

RV CEFAS ENDEAVOUR
Survey: C END 16 - 2020.

STAFF:

Name	Role
Jeroen van der Kooij	SIC/Acoustics
Joana Silva	2IC/Fish/Oceanography
Fabio Campanella	2IC/Acoustics
Eleanor Haigh	Oceanography
Richard Humphreys	Lead Fishroom
Louise Cox	Fish
Samantha Barnett	Deck Master
Allen (Spike) Searle	Fish
Hayden Close	Zooplankton
Nevena Almeida	Zooplankton
James Scott	PhD (PI)
Peter Howlett	ML Observer
Morgan Schofield	ML Observer

DURATION: **3rd October – 7th November (35 days)**

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

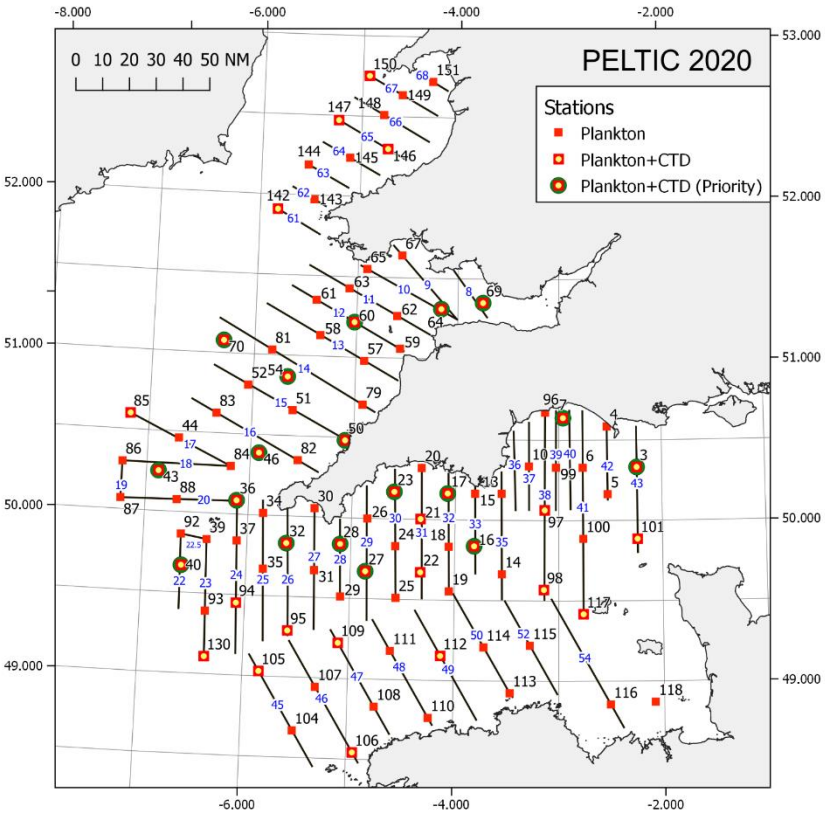

Figure 1. Overview of the planned survey area, with the acoustic transect (black lines, numbers in blue), plankton stations (red squares) and hydrographic stations (yellow circles). Priority stations indicated in green.

AIMS:

1. To carry out the nineth autumn PELTIC survey: pelagic ecosystem survey of the western English Channel, Celtic Sea, including (for the first 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 timeseries on sardine in area 7 will be assessed at an ICES (International Counsel for the Exploration of the Sea) benchmark meeting in February 2021 (WKWEST); sprat biomass data from the western English Channel will feed into the stock assessment of sprat in area 7de (HAWG, Herring Assessment Working Group).

    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 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*), saury pike (*Scomberesox saurus*) and John Dory (*Zeus faber*).

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 sampling (yellow stations on map below). At fixed stations along the acoustic transect, a CTD (either an ESM2 profiler or a Seabird mounted on a Rosette sampler) will be deployed to obtain measurements of environmental properties within the water column. Water column profile and water samples will provide information on chlorophyll concentration, dissolved oxygen, salinity, temperature, turbidity, and dissolved inorganic nutrients concentration 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 carry out hourly measurements of the phytoplankton functional groups using an online flow-cytometer, connected to the Ferrybox (V. Creach).

8. To further trial the continuous Plankton Imager (PI, James Scott, PhD).

9. 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).

10. To collect 25 whole sardine specimens at two locations in the western English Channel for a genetic study (J van der Kooij).

11. To collect 10 specimens per species (small sprat, herring, sardines, pearlsides and anchovy) for species ID training in Weymouth lab (S Davis).

12. 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.

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

NARRATIVE[1]:

On the evening of the 30th of September, three (remote) staff joined the vessel, Cefas staff Allen (Spike) Searle, and MarineLife observers Pete Howlett and Morgan Schofield. The remaining Cefas staff arrived at the quay for 08:00 on the 1st of October, joined the vessel one at the time and proceeded with COVID-19 testing and cabin isolation. Negative test results for all staff and crew were received by mid-day on the 2nd of October and scientists switched from isolation to following Cefas' safe ways of working protocol and government guidance. Safety inductions for scientists took place at 14:00 and, after all non-surveying staff had left the vessel at 18:00, staff started to unpack and prepare gear. Fishing gear checks were completed by SIC, First Mate and Bosun on the morning of the 3rd of October, followed by a 15 min scientific staff debrief and, at 15:00, a survey debrief with all scientists and crew. At 21:30 the vessel sailed from Lowestoft towards the central English Channel. In transit, on the 4th of October, at 11:00 a muster drill was completed and the echosounder calibration software was upgraded with support from the manufacturer, in preparation for the calibration off Portland Bill where we arrived on the morning of the 5th of October. Despite challenging conditions with both tide and wind building during the day, three frequencies (38, 120 and 200 kHz) were calibrated at two pulse durations by 15:30. At 16:30 the first acoustic transect (Tr 43) was surveyed until last light, when plankton nets and CTD were deployed for the first time starting at prime station 3.

From the morning of the 6th of 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 groundtruth 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. Gradually working our way west, by the 11th of October the transects in Lyme Bay were completed. On the morning of the 16th of October, the RV docked in Fowey to drop Jo Silva off (7:45) shortly after which the survey resumed with Transect 30. On the morning of the 20th of October, significant gear damage was sustained to the trawl (Stn 109) at the end of a tow on Tr46, probably due to an unchartered wreck. Although the catch was retained in the codend, the gear had to be swapped over. The second tow that day (on Tr26) was cut short due to a sudden loss of engine power. Although survey work continued for the next 36 hours, reduced vessel speed limited the number of plankton and CTD stations that could be completed overnight and during the day transect speed (Tr25) was reduced from 10 to 8-9 knots. No trawling was possible either although trawls on adjacent transects provided sufficient groundtruth information to continue work. On the morning of the 22nd of October the vessel went off survey to allow engine tests to be run in a sheltered location (off Newlyn). At 15:25 the northern end of Tr24 was surveyed following completion of all tests followed by a tow (Stn 150). On the 23rd of October, the whole of the western English Channel, including the transects south of the Isles of Scilly was completed.

On the 24th of October, Tr8 and 9 in the inner Bristol Channel were completed before a slight improvement in weather moved focus to Cardigan Bay, where surveying commenced at first light on the 25th of October. Where possible, acoustic transects in the bay were extended inshore (until a depth of 17m was reached or 1 nmi from shore) to improve coverage of shallow water habitat. Seven out of the eight transects were completed by last light on the 27th of October; Tr68 was not completed as most of the transect ran across waters shallower than 17m. Fair weather conditions overnight enabled completion of all 10 plankton and CTD stations over two nights. In total four trawls were conducted providing useful groundtruth and biological data, although it was one short of the target. Further trawl activities were however not possible due to the presence of static gear (inshore) or freshening weather conditions (offshore).

After successful completion of Cardigan Bay, from the 28th of October, work in the Bristol Channel was resumed. Deteriorating weather conditions restricted progress, because of the adverse

[1] All times prior to 25th of October in BST and in GMT for the rest of the survey

effect on vessel speed, limitations in steaming/surveying direction and lack of suitable conditions to conduct trawls. At 16:00 on Sunday the 1st of November, the RV went for anchor in Bideford Bay to shelter from storm Aiden. At 16:00 on Monday the 2nd of November, the anchor was lifted to start heading west. However, an issue with the deployment of the drop keel delayed departure by more than an hour. Good weather permitted all but one transect (Tr13) in the Bristol Channel to be completed before starting the steam back to Lowestoft at 18:00 on the 5th of November, where the vessel docked on the mid-day tide on the 7th of November.

RESULTS:

All aims were successfully completed. 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): 45 European seabass (*Dicentrarchus labrax*); 12 black seabream (*Spondyliosoma cantharus*); 1 striped red mullet (*Mullus surmuletus*); 2 garfish (*Belone belone*); 58 John Dory (*Zeus faber*). In total 16 samples of 25 whole specimens of small pelagic fish (6 species) were collected from 11 different stations for micro-litter analysis (objective 9). Genetic samples for sardine (objective 10) were collected at two stations: 47 and 98. Seven sets of 10 specimens of small pelagic fish were collected in the Bristol Channel for species ID purposes (objective 11). 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 4th of October, east of Portland Bill, and applied during PELTIC 2020. 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 (8.5)*	5.3 (8.5)*	5.3 (8.5)*	5.3 (8.5)*
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	26.67	26.12	27.58
Sa correction (dB)	-0.81	-0.39	-0.31	-0.64
3dB beam along (°)	6.98	6.71	6.83	7
3dB beam athwart (°)	6.96	6.72	6.79	0
Along offset (°)	0.11	-0.03	-0.04	7
Athwart offset (°)	0.07	0.08	0.07	0
RMS (Root Mean Square error)	0.18	0.06	0.08	-

*Drop-keel down

Pelagic Ichthyofauna

In total 47 acoustic transects, all but Transect 13 and parts of the transects north of the Isles of Scilly, were completed covering a total of 2019 nmi of acoustic sampling units. Survey time was lost as a results of weather downtime (37:48 hours) and technical issues (>25 hours). However, good coverage was achieved nonetheless and the relevant stocks were still captured in their entirety. A total of 37 trawl hauls (one less than in 2019) were made (Fig 2) to provide groundtruth information about the species and size composition and to collect biological information.

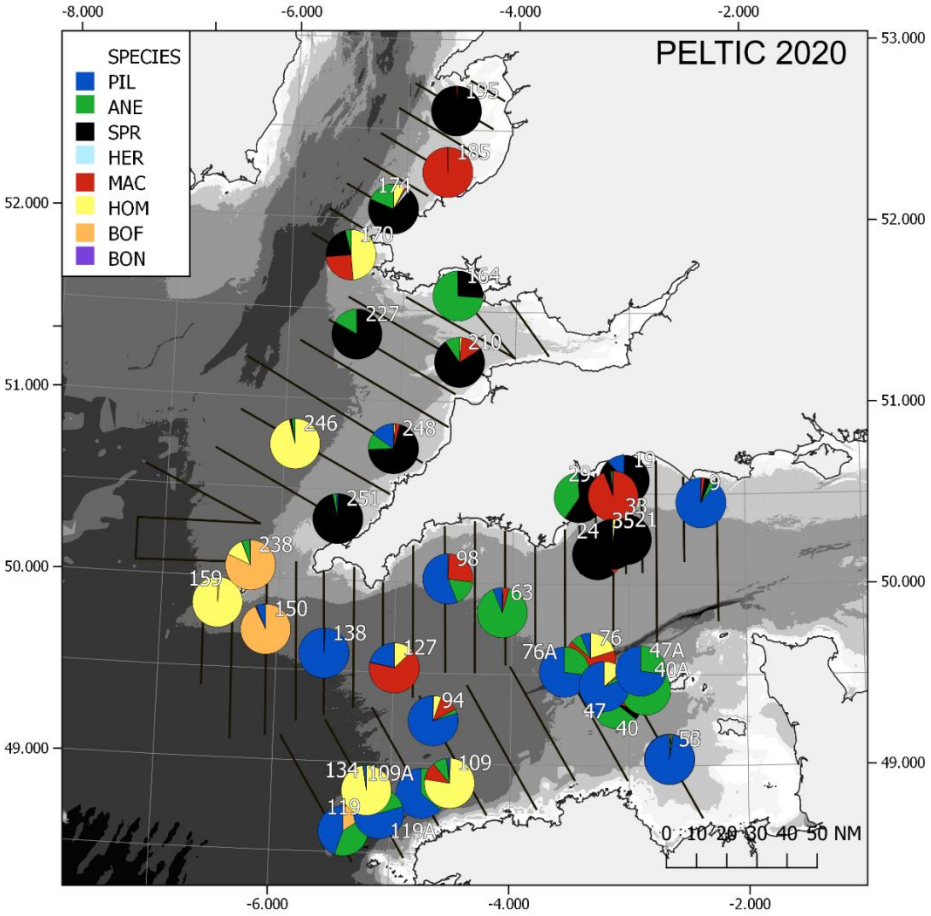

Figure 2. Overview map of the PELTIC20 survey area. Acoustic transects (black lines) and Trawl stations (pies) with relative catch composition by key species. Three letter codes: PIL=sardine, ANE=anchovy, SPR=sprat, HER=herring, MAC=mackerel , HOM= horse mackerel, BOF=Boarfish, BON=Atlantic bonito

This year, many of the trawls in the English Channel were conducted after sunset in the 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. The trawl was changed over approximately halfway during the survey, due to gear damage. 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 fourth year running, the French waters of the western English Channel. For the first 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*	3550	503
Sardine	*Sardina pilchardus*	3328	633
European anchovy	*Engraulis encrasicolus*	2563	657
Horse mackerel	*Trachurus trachurus*	1691	265
European mackerel	*Scomber scombrus*	1405	287
Boar fish	*Carpos aper*	632	94
Herring	*Clupea harengus*	49	42

Sprat (*Sprattus sprattus*) dominated in the usual two main areas of Lyme Bay and the Bristol Channel and was the most abundant small pelagic fish in Cardigan Bay. Sprat biomass in the western English Channel, the core area that has been consistently sampled from 2013, was 33,798 t (CV 0.25), similar to 2019 (Fig. 3). Low numbers of age-0 were found in Lyme Bay with the bulk of the population consisting of one-year old fish (Fig 3). Notably, the highest sprat densities were distributed inshore (although captured by the survey). Lyme Bay was the first area surveyed and therefore slightly earlier than previous three surveys following requests by the industry. Weather conditions during surveying were reasonable although some fresh conditions preceded coverage of Lyme Bay.

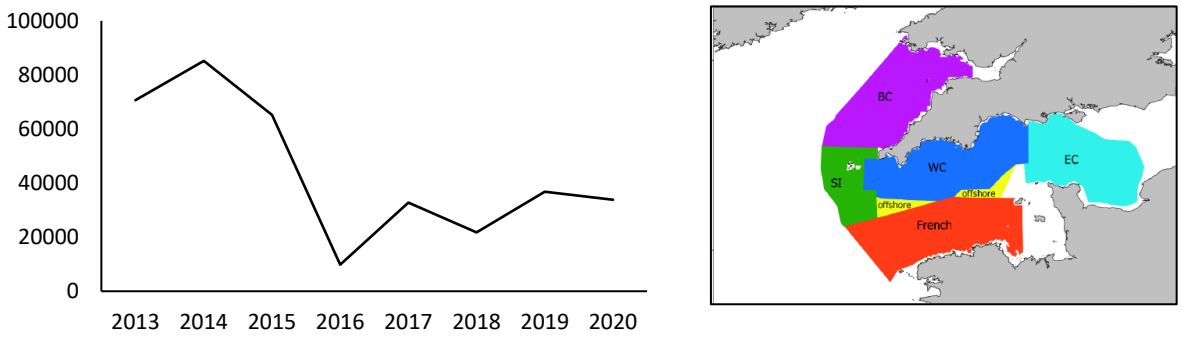

Figure 3. Sprat (*Sprattus sprattus*) biomass trend (left) for the consistently sampled stratum in the western English Channel: WC (blue) in map of strata (right).

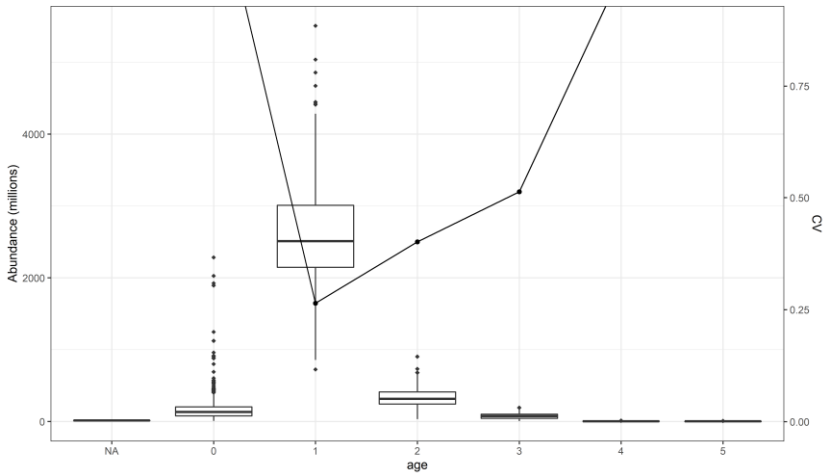

Figure 4. Sprat numbers at age (boxplots, primary y-axis) and CV (line, secondary y-axis) for sprat in the consistently sampled western Channel stratum (see Fig 3).

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. Like previous surveys, Bristol Channel Sprat were smaller (mean of 7.5-8 cm) than those in Lyme Bay (10.5-11cm, Fig 5).

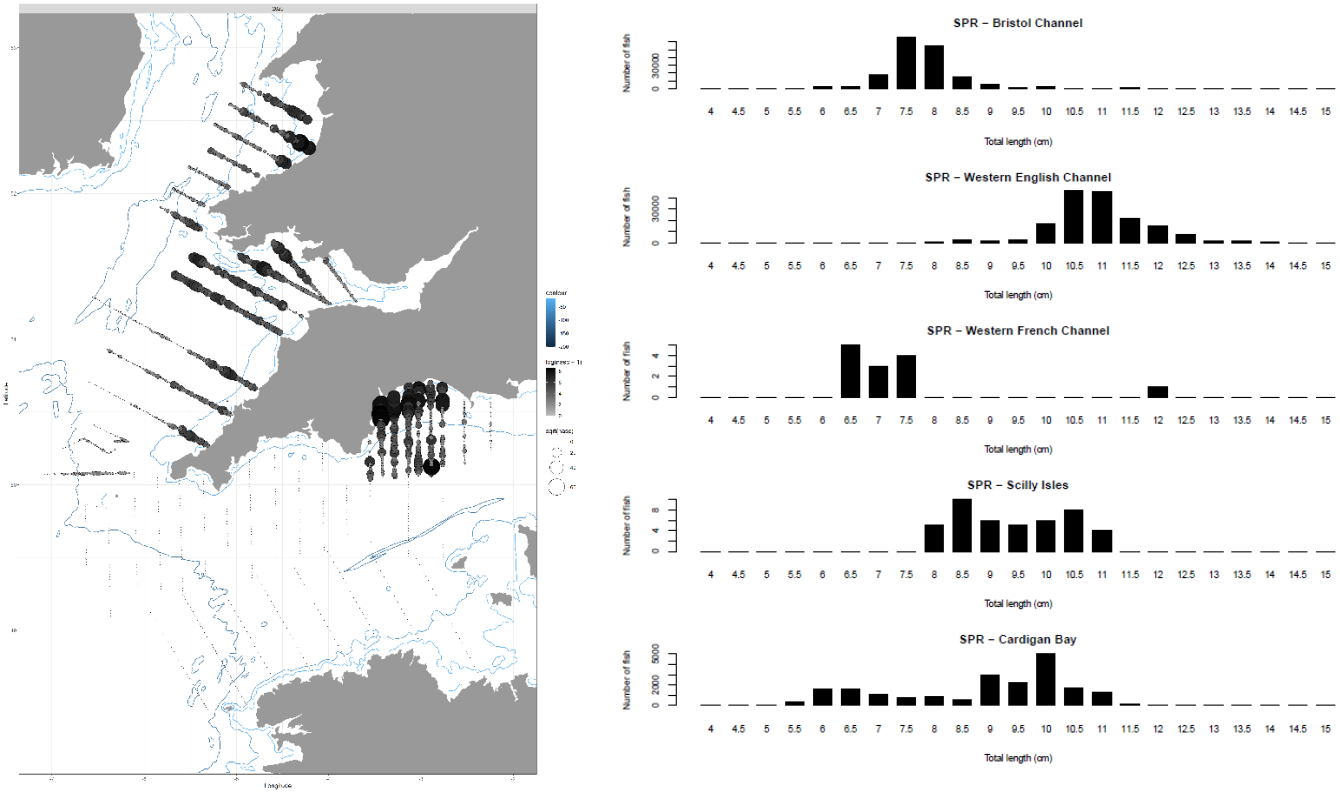

Figure 5. Relative acoustic sprat density distribution (Nautical Area Backscattering Coefficent - NASC, left) and trawl-based length frequency histogram for sprat in the subareas of the PELTIC survey (right).

Sprat was the dominant small pelagic species in Cardigan Bay, with highest densities in the very shallow (<20 m) eastern waters of the Bay. Total biomass of sprat in this area was 21,542 tonnes (CV 0.65) with at least two cohorts visible in the length frequency histogram (Fig 5). The inshore distribution may be due to the prevailing westerly weather conditions which, despite being workable, were strong (>20 knots for most of the survey days) and may have pushed fish toward the coast in more sheltered waters. However, as this was the first time Cardigan Bay was surveyed during PELTIC, it is difficult to establish whether this is typical for the area at this time of year.

Sardine (*Sardina pilchardus*) was again the most abundant small pelagic fish species in the PELTIC survey with a total biomass (for the total area, consistently surveyed since 2017, Fig 6) of 332,098 t (CV 0.21), slightly down from 2019 but the second highest in the time series.

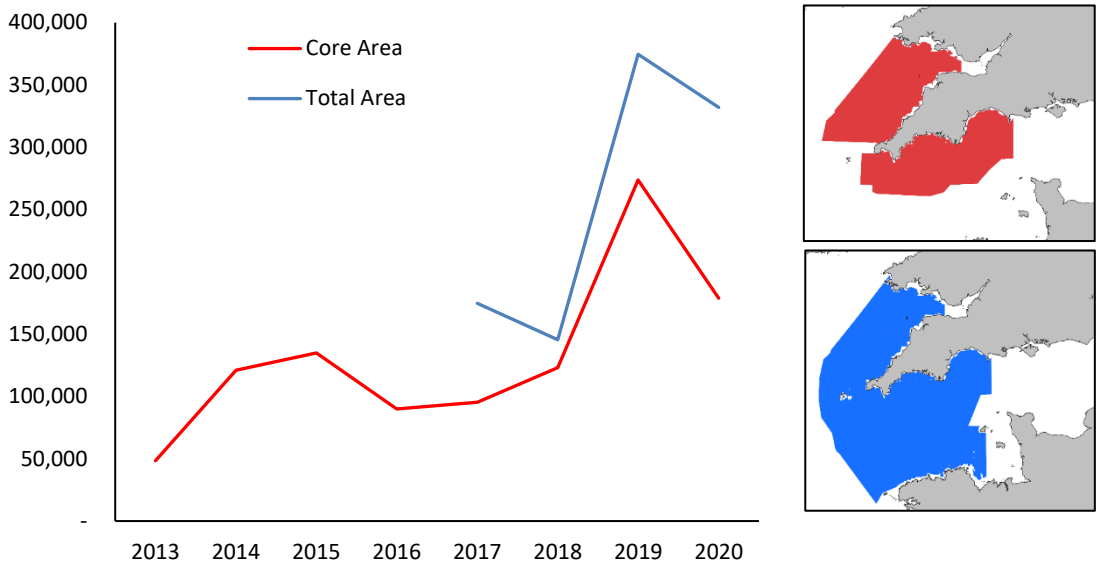

Figure 6. Sardine biomass (tonnes) trends (left) based on two available survey strata: the core area, consisting of the English waters of the western Channel and the Bristol Channel, surveyed consistently from 2013 (top right, red) and the total area, which also includes the Isles of Scilly and French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

Although widely distributed in the survey area, the core of the sardine distribution was located further west than in previous years with the highest densities found southwest of the Cornish Peninsula (Fig 7). Sardine here comprised of fish from across the length spectrum, from 8-8.5 cm modal length up to fish larger than 23 cm. High numbers of sardine were also found in French waters, which included a broad range of sizes, including, unlike in previous years, larger fish. Notably, this year large numbers of surface schools were observed along the French coast as far east as the Channel Islands, which, as well as post-larval anchovy, consisted of juvenile sardine of a modal size of 7-7.5 cm (Fig 7). Few sardine schools were observed in the Bristol Channel where biomass was lower than in recent years. Sardine was scarce in Cardigan Bay (636 t) and was dominated by fish with modal length of 17.5 cm.

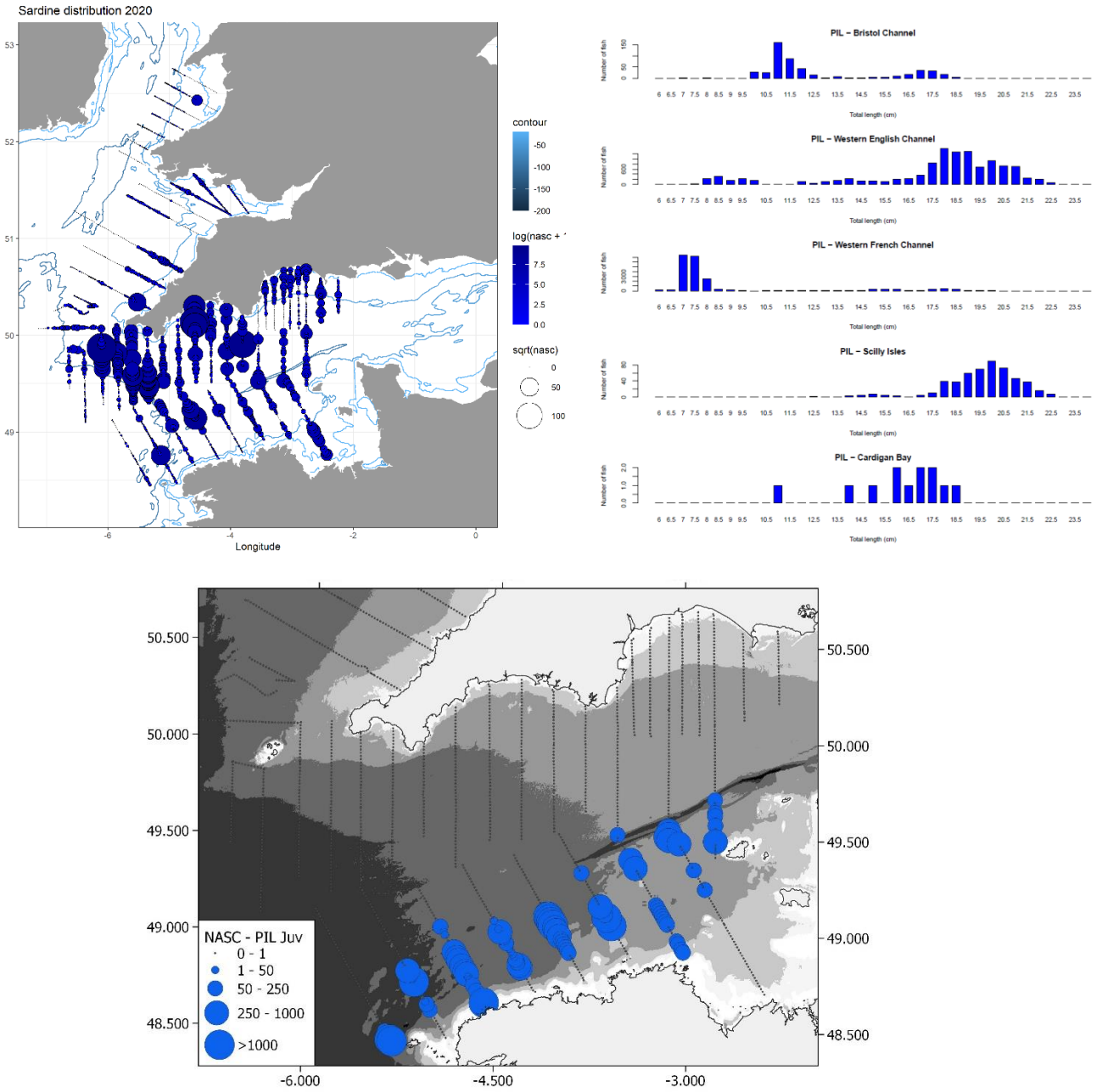

Figure 7. Relative acoustic sardine density distribution of sardine (Nautical Area Backscattering Coefficient - NASC, top left), juvenile sardine in surface schools (bottom) and trawl-based length frequency histogram for sardine in the subareas of the PELTIC survey (top right).

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

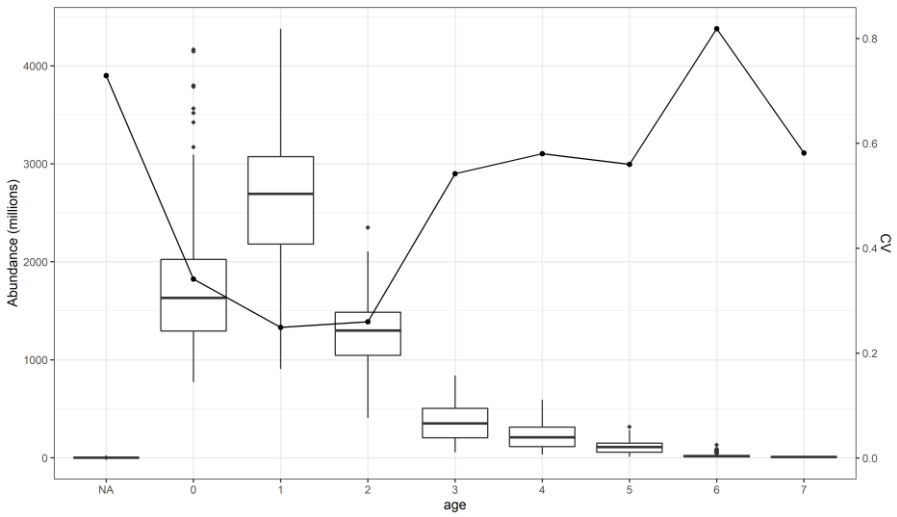

Figure 8. Sardine numbers at age (boxplots, primary y-axis) and CV (line, secondary y-axis) in the consistently sampled total area. Note that this graph excludes the 9,8 billion juvenile sardine recorded in French surface waters.

Northern **Anchovy (*Engraulis encrasicolus*)** biomass in PELTIC doubled from last year to 42,998 t (CV 0.43) for the total area (same consistently sampled strata as for sardine).

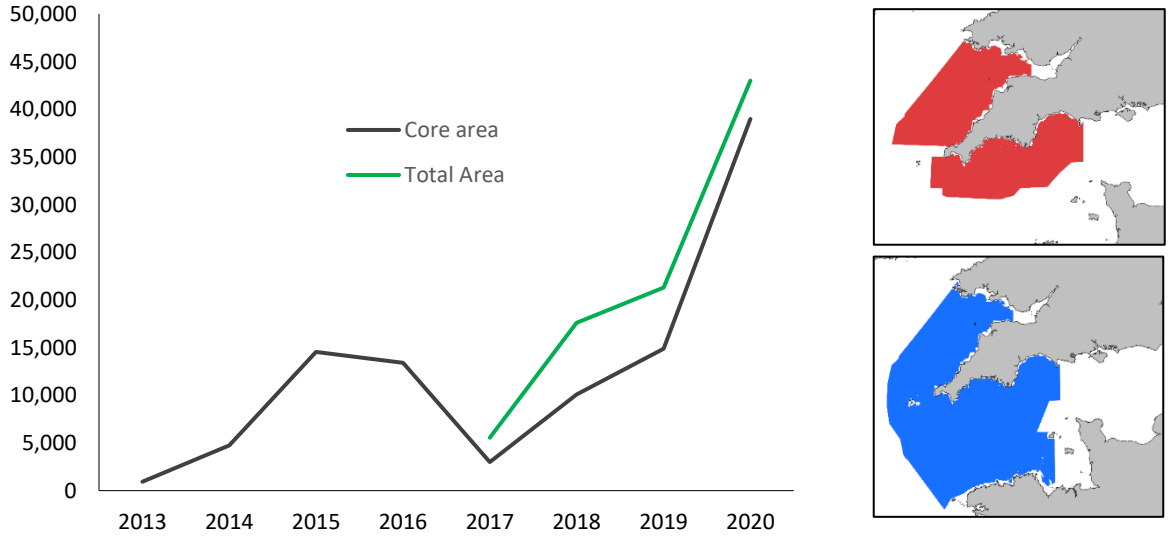

Figure 9. Anchovy biomass (tonnes) trends (left) based on two available survey strata: the core area, consisting of the English waters of the western Channel and the Bristol Channel, surveyed consistently from 2013 (top right, red) and the total area, which also includes the Isles of Scilly and French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

Although widespread, anchovy hotspots were in Lyme Bay, off the Eddystone Bay and in the Bristol Channel (Fig 10). Small numbers of anchovy were also found in Cardigan Bay (569 t), with a peak at 10 cm modal length and smaller numbers of larger fish at 15.5 cm (Fig 10). These 1 year old fish with modal length of 15 cm were found to be most widespread in the survey area, from Cardigan Bay in the north, higher numbers near the Isles of Scilly and the western English Channel and again small numbers in French waters. The largest anchovy specimens were found off the southwest coast of Cornwall. An additional 26,163 t of post-larval anchovy were found in French waters (Fig 10). Like in 2019, when they were first

observed, these anchovy formed a near continuous series of schools at the surface (see echogram in Fig 10) which is different behaviour from the anchovy commonly observed during PELTIC. While restricted to a small area off the north coast of France in 2019, this year the distributional range had increased significantly and expanded across all southern transects on the French side. The northern limit of these surface schools was the Hurd Deep in the central English Channel (Fig 10). These post-larval surface schools were quantified separately because preliminary results of genetic samples obtained in 2019 suggest that these anchovy are from a separate stock (Bay of Biscay). More work is required to establish the extent and impact of this observation on the current and possible future management of the two populations.

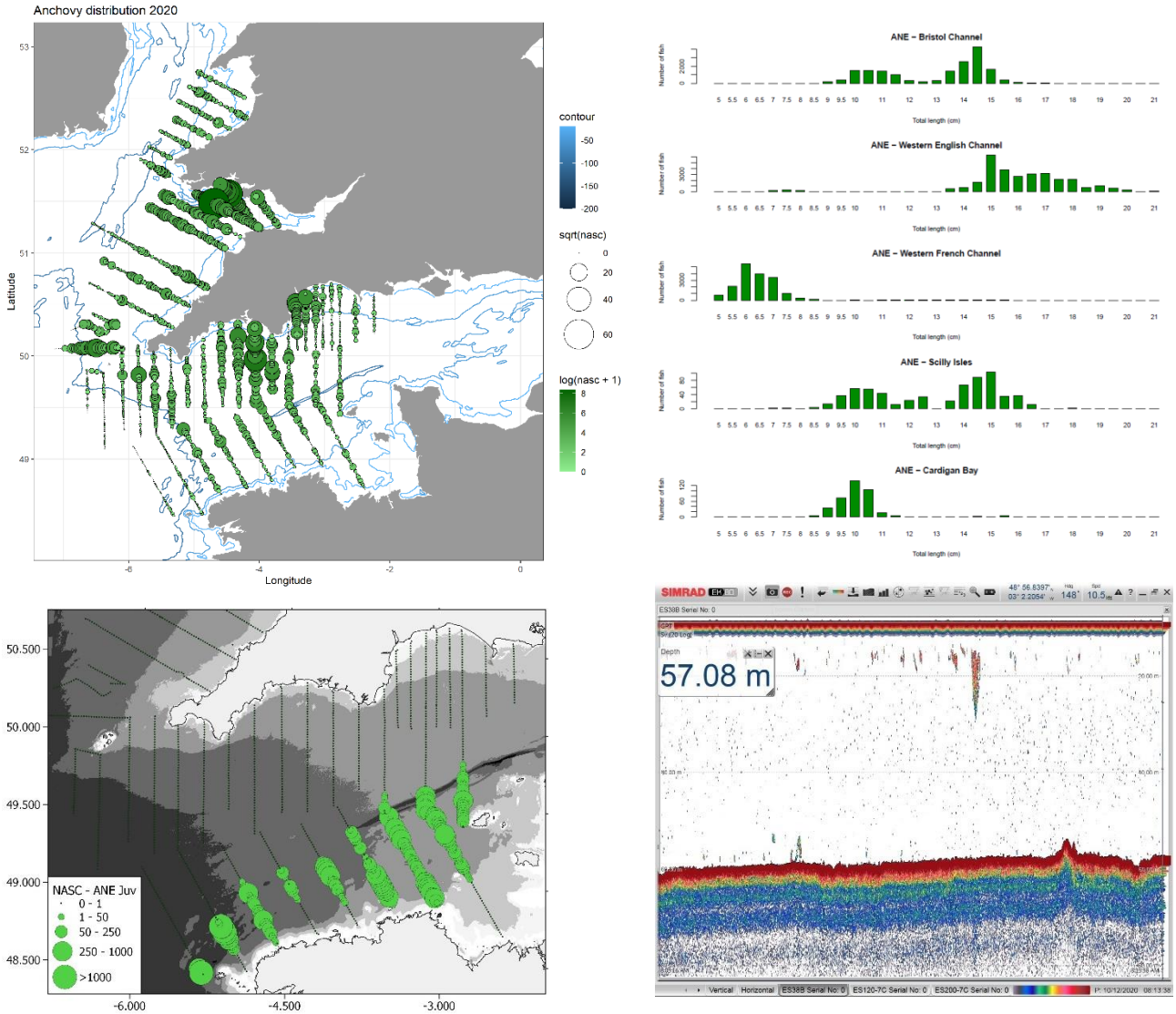

Figure 10. Relative acoustic anchovy density distribution for the northern population (NASC, top left), for the post-larval surface schools (from Bay of Biscay) in French waters (bottom left) and trawl-based length frequency histogram for anchovy in the subareas of the PELTIC survey (top right). Example 38kHz echogram of surface anchovy schools (Threshold of -70 dB; bottom right).

Anchovy is the shortest lived small pelagic species in the study area and the oldest fish found during this survey were 3 year old (Fig 11).

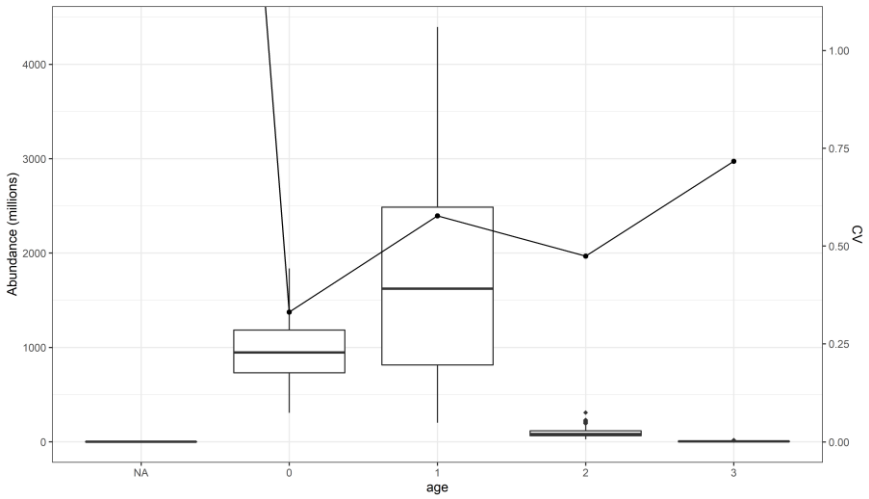

Figure 11. Anchovy numbers at age (boxplots, primary y-axis) and CV (line, secondary y-axis) in the consistently sampled total area. Note that this graph excludes the 13,5 billion post larval anchovy recorded in French surface waters.

Other pelagic fish species: **Horse mackerel (*Trachurus trachurus*)** was widespread, although typically in deeper waters of the survey area. The total biomass of 24,978 t was mainly made up of juvenile fish with modal length of 8-9 cm (age 0). Larger fish with mean modal length of 24 cm were caught (Fig 12) in the Bristol Channel and had an age range of 2 to 5 years old. Juvenile horse mackerel were a distant second most abundant species in Cardigan Bay (951 t) after sprat. Small numbers of **herring (*Clupea harengus*)** were found and mainly in Lyme Bay and the inner Bristol Channel, all of which were juvenile with a mean modal length of 13.5 cm (Fig 12). A few larger herring were caught in Cardigan Bay although herring biomass in this area was low (30 t). **Mackerel (*Scomber scumbrus*)** was widespread in the area. This year no biomass estimate could be calculated due to a noise issue with the 200 kHz which is the reference frequency used to calculate the biomass. Length frequency of mackerel suggested two cohorts (at 16 and 20 cm modal length, Fig 12). **Boarfish (*Capros aper*)** were found off the Isles of Scilly. 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. Boarfish quantities observed during PELTIC fluctuate annually; this year, the species was more abundant (biomass of 54,144 t) than the survey average and included larger specimens (17 cm, Fig 12). As was the case in the last few years, juvenile boarfish (modal length of 3 cm) were also regularly observed in the trawl catches offshore in the English Channel. For the second year in the survey series (first in 2018) **Atlantic bonito (*Sarda sarda*)** were observed. Two specimens were caught in Lyme Bay.

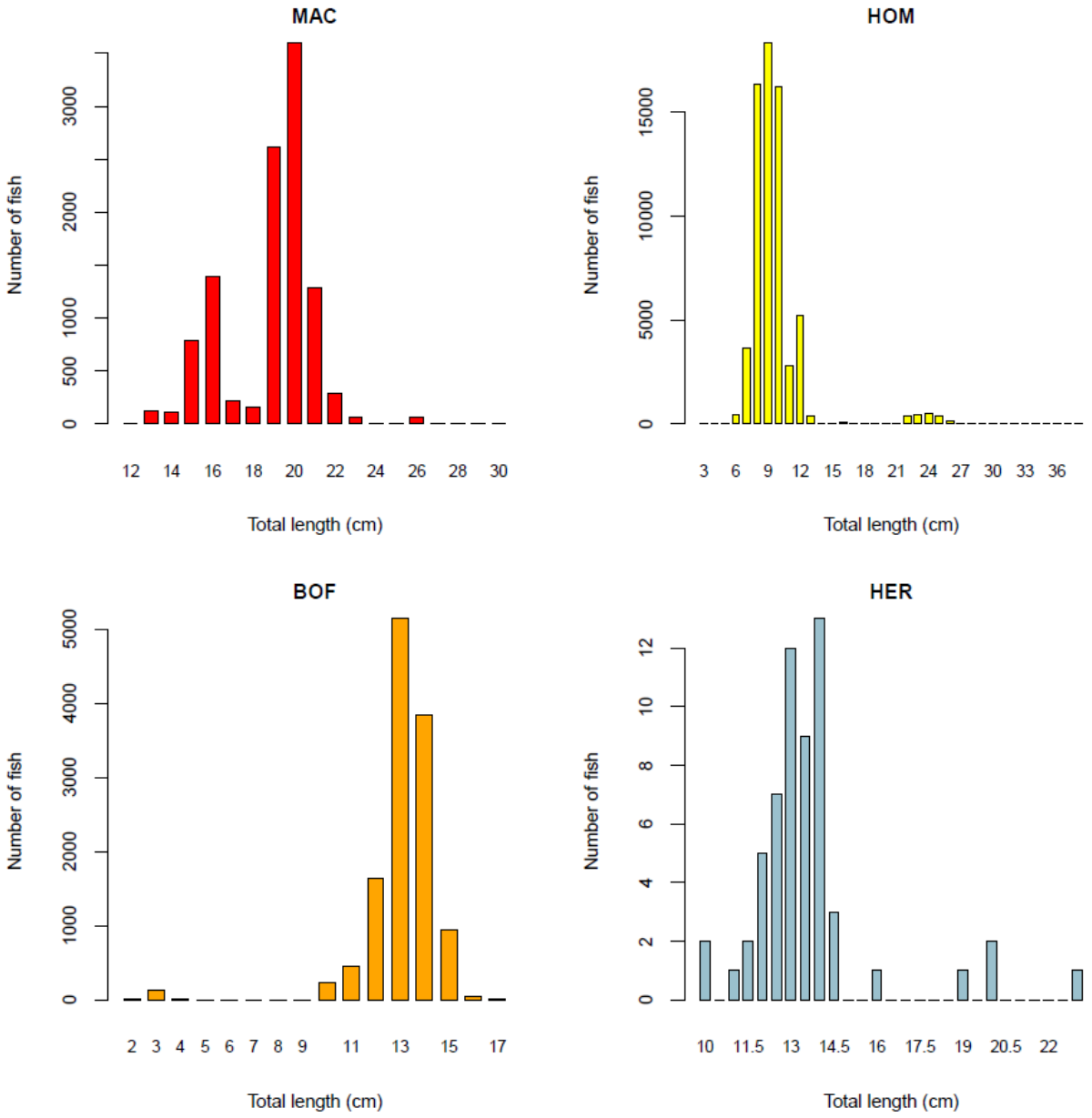

Figure 12. Length frequency histograms for mackerel (MAC), horse mackerel (HOM), boarfish (BOF) and herring (HER), derived from the PELTIC20 trawl catches. Note that these have not been raised by acoustic densities.

Plankton and Oceanography

Mesozoo- and ichthyoplankton samples were collected at 94 stations with ring nets with mesh size of 80 µm and 270 µm, respectively (Table 3). Two stations could not be completed (primary station 86 and 101). 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 the maximum egg numbers exceeded those reported in previous surveys (approximately double the highest values in previous surveys), suggesting significant spawning activity. The location of highest densities of sardine eggs corresponded well with the distribution of the main acoustic sardine backscatter and suggested more westerly position of main spawning grounds

(Fig 13). Compared to recent years, few eggs were found north of the Cornish Peninsula which also corresponds to a reduced number of sardine schools in this area (Fig. 13). A small number of eggs were also found at one isolated station in Cardigan Bay. As expected, sardine larvae were more widespread in the survey area. Finally, zooplankton samples were also collected at the West Gabbard smartbuoy location during the return transit back to Lowestoft (objective 13).

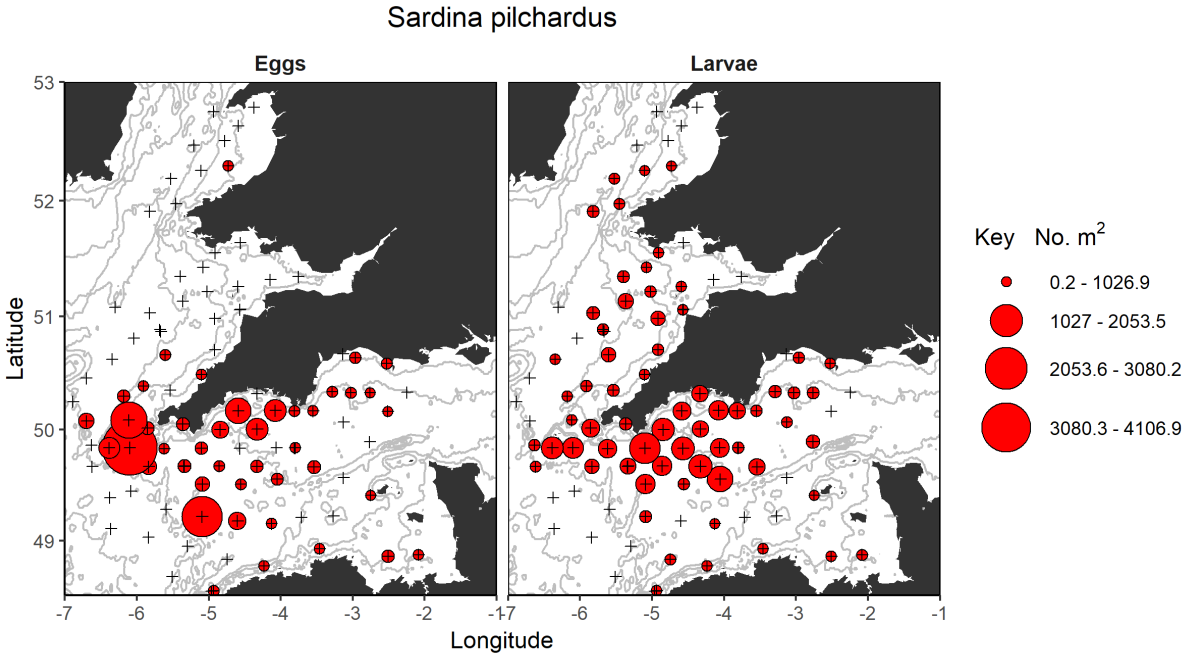

Figure 13 . Distribution of sardine eggs (left) and larvae (right) at the sampling stations derived from samples collected with the 270 µm ring net and analysed on board.

The **Plankton Imager (PI)**, a high-speed colour line scan-based imaging instrument, which continuously pumps water and takes images of the passing particles, was run continuously through the survey. The instrument was switched off for the inner most part of Bristol Channel to avoid imaging silt. The first five days of the survey were used to test both hardware and software developments since the PI's last deployment. Implementation of changes in the field proved unsuccessful but did reveal important, resolvable bugs in the software. A new LED also brought challenges with issues to be resolved before the next deployment. The final complication was caused by high turbidity, resulting from rough weather in the latter half of the survey. Lesson learned from the previous PELTIC survey suggested implementation of a new minimum threshold particle size (180 µm) which meant that more of the mesozooplankton community can be captured. In total 1.9 tb of data were collected approximating to 12 million images. In total 31 stations were analysed and validated by an expert. These data will form part of the PI time series available on the Cefas Datahub. Areas for improvements are not reported due to the creation of a new system (PI-10) for the next survey.

Oceanography

Vertical profiles of temperature and salinity of the water column were collected at the 94 plankton stations using a min SAIV CTD (although at station 31, 95 and 99 recording failed)

and, at a subset of 35 of these, additional data were collected (Table 3): a Rosette with SeaBird CTD and 10 Niskin bottles was deployed at 26 stations to collect information using PAR, 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 9 stations adverse weather conditions prevented the use of the Rosette. Here, 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. Furthermore, a flow cytometer, connected to the FerryBox, carried out measurements of abundance and size of the phytoplankton community every hour.

Table 3. Number of samples collected and number of profiles carried out during PELTIC 20.

	Total
Salinity	38
Dissolved oxygen (triplicates)	32
Chlorophyll/Pigments analysis (HPLC - duplicates)	34
Inorganic nutrients	69
Phytoplankton	35
Microzooplankton	35
Mesozooplankton (80 μm)	94
Ichthyo-and Macrozooplankton (270 μm)	94
CTD profiles with Rosette	26
CTD profiles with ESM2	9
CTD profiles with SAIV Mini CTD	91

Dissolved oxygen samples 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 but the first station, to allow comparison between two different sample preservation methods. Chlorophyll and pigments samples were stored at -80 °C for subsequent HPLC (High Performance Liquid Chromatography) at DHI (Denmark). Phytoplankton samples were fixed with Lugol for processing in the Lowestoft Laboratories using an inverted microscope. 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 English Channel, at approximately 3°W and, as in previous years, in the Bristol Channel (Fig 14). Maximum temperature was 16.46°C, which was in keeping with previous surveys in 2018 and 2017, but cooler than 2019 maximum temperatures (17.2°C). Lowest surface temperatures were recorded offshore between the Celtic Sea and French side of the Channel (Fig 14). The lowest surface temperature recorded this year was 10.3°C, in the westernmost stations of the survey. This is significantly cooler than the lowest temperature of 12.8°C recorded in 2018, but comparable to the 10.6°C recorded in 2019.

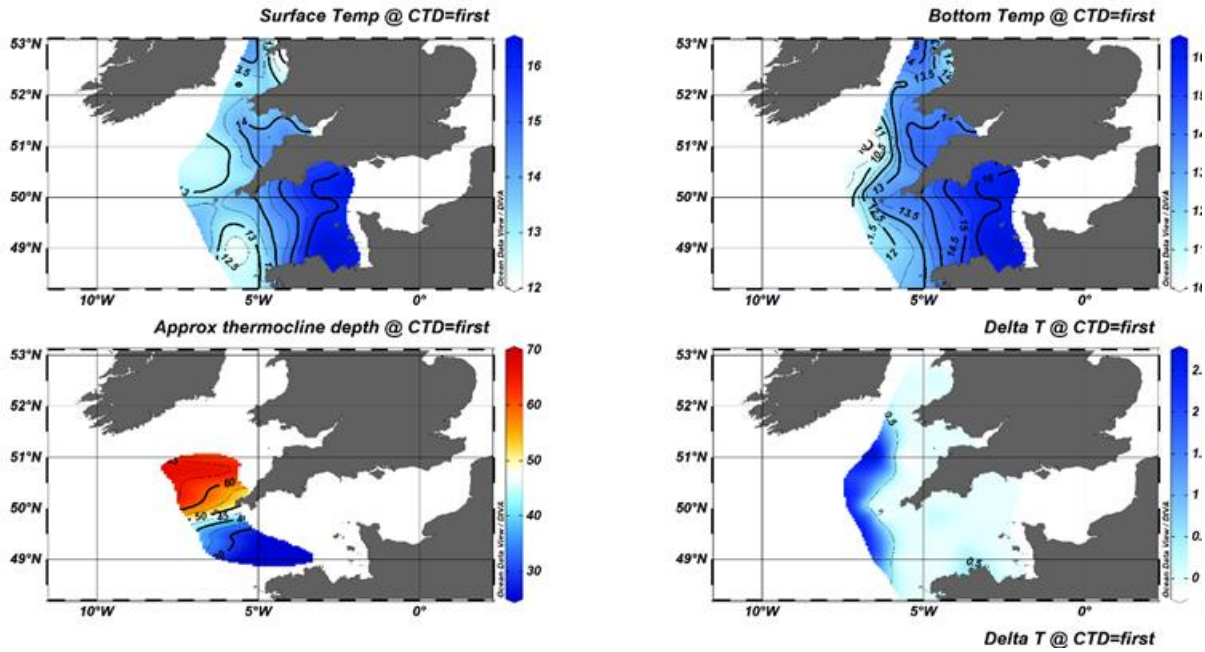

Figure 14. Temperature (T, °C) distribution at the surface and bottom as recorded by the SAIV MiniCTD at the 95 sampling stations. The difference in temperature (Delta_T) between surface and bottom (bottom right), and depth of the thermocline in stratified waters (Delta_T > 0.5 °C, bottom left).

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.

	Surface Temp	Bottom Temp	Thermocline depth	Delta T
Mean	14.10	13.86	52.23	0.23
Min	12.07	10.35	28	-0.15
Max	16.45	16.46	66	2.62
Std Deviation	1.15	1.45	13.70	0.58
Number	95	95	13	95

Western offshore stations in the Bristol Channel, the Western approaches, west of Lizard Point and moving up into the Irish sea, were seasonally thermally stratified (Delta_T > 0.5 °C; Fig 14). Coastal stations on the English and French side of the Channel, were vertically mixed (Fig 14). The difference between surface and bottom temperatures was highest at offshore stations in the Celtic Sea, up to 2.67°C (Table 4). Thermoclines with the deepest initial start of stratification, >50m, were found at offshore stations (off the Bristol Channel). Those with shallower stratification were South of Lizard point. The strength of stratification observed this year was lower than that of previous years, (typically between 4 and 5°C). This may be due to changes in timing, with the survey falling slightly later in the season this year, particularly the Bristol Channel which was surveyed at the end of the survey.

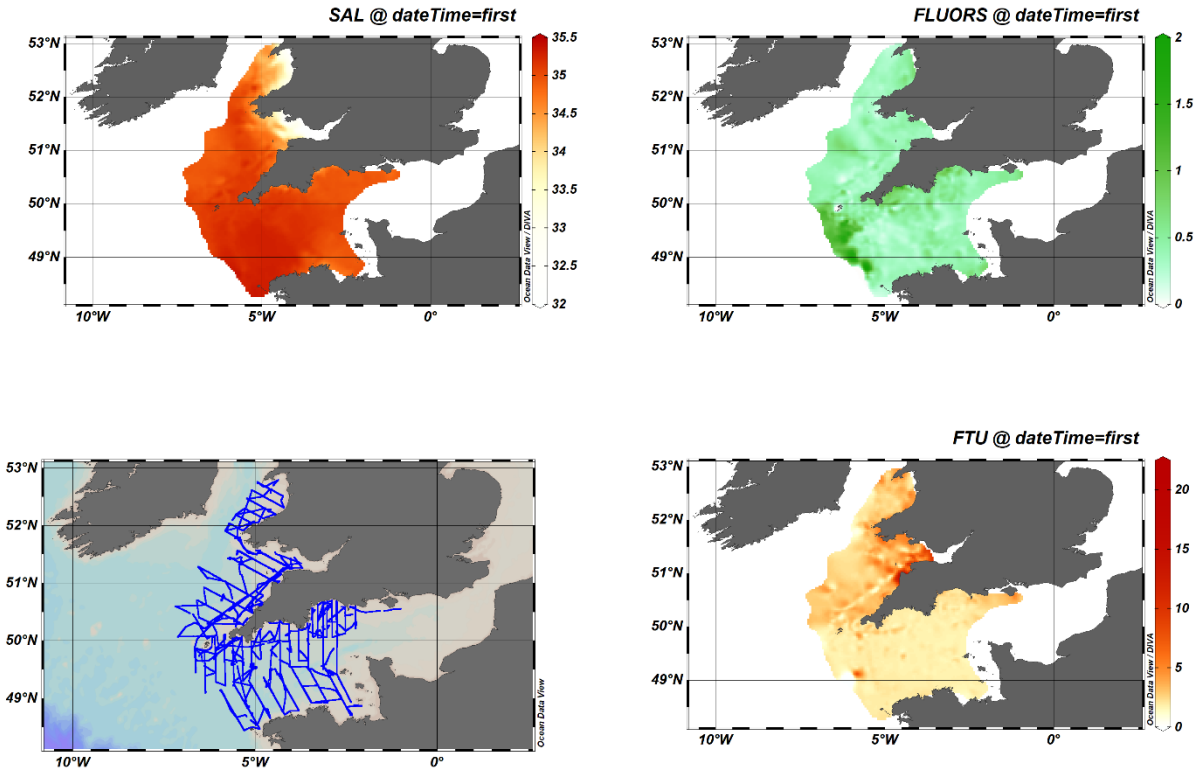

Figure 15. Sub surface (4m depth) salinity (SAL), fluorescence (FLUORS), and turbidity (FTU) measurements from the FerryBox underway system (track shown bottom left).

Surface distribution of chlorophyll was estimated by fluorometers on the FerryBox and on the SeaBird profiler mounted on the Rosette sampler. Fluorescence values (proxy for chlorophyll-a) were highest between 49N and 50N at the most westerly stations in the Celtic sea (Fig 15). This coincided with the region of lowest temperature observations (Fig 14), perhaps indicative of enhanced productivity in thermal fronts.

Offshore salinity values showed little variation (Fig 15). Highest salinity values were recorded in the south west corners of the Celtic Sea, and lowest values in coastal regions and the Bristol Channel. As expected, highest turbidity values were measured in the Bristol channel, causing some adaptations to be made to sample filtration, and zooplankton analysis (Fig 15).

Observer data: apex predators

For the eighth 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 2020 both surveyors recorded cetaceans and seabirds.

Survey effort was made on 30 days from 5th October to 5th November, sampling approximately 3,425km of transect line. The weather was significantly worse during the 2020 survey when compared with 2019 with only 39% of effort conducted in sea state 4 or less (81% in 2019). Modal sea sate was 5 and mean sea state 4.83. The modal sea state is equal worst with 2018 and the mean sea state is only 'beaten' by the 5.01 in 2013 and 5.34 in 2016, ranking 2020 as one of the worst years for surveying conditions (Table 5).

Table 5: Survey effort and sea state conditions from 2013-2020 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
Transect length (km)	2092 (+278*)	3058	2447	2990	2644	3,706	3025	3,425
No. survey days	16 (+2*)	20	18	16	24	32	26	30
Mean sea state	5.01	3.78	3.08	5.34	4.32	3.86	3.24	4.83
Modal sea state (% of total)	4	3	4	3	3	5	3	5
% effort sea state 4 or less	37	67	92	45	53	63	81	39
Modal wind direction (% of effort)	SW (33)	SW (30)	NE (30)	ENE(24)	SW (40)	NE (28)	TBC	SW (15)

*Southern North Sea

A total of 41 **bird** species were recorded on effort during the survey this year which is more than in 2019 and on a par with 2017 & 2018. A total of 6,638 sightings of 19,291 birds were recorded throughout the survey (Table 6), the highest total since the PELTIC extension began in 2017. The additional transects in Cardigan Bay accounted for an additional 2,406 birds, although if removed from the total, the resulting number of birds recorded (16,894) is still higher than any 2017-2019 total.

As in all previous surveys, Gannet was the highest recorded species, although fewer were recorded than in 2017 & 2018. However, the numbers recorded for seven other species – Fulmar, Great Black-backed, Lesser and Herring Gull, Kittiwake, Guillemot and Razorbill are worthy of further comment. All are between three and five times higher than recorded in the previous three years and account for almost 93% of all sightings (80-88% for 2017-19). The predominant westerly winds may have helped keep birds in the area but the large number of auks suggests food availability may also have played a part. The westerly winds were also likely responsible for the small numbers of landbird migrants recorded this year (Table 7).

Table 6: List of all bird species recorded on effort during Peltic survey 2020

Species	Scientific Name	No of sightings	No of birds
Dark-bellied Brent Goose	*Branta bernicla*	2	12
Shoveler	*Anas clypeata*	1	3
Common Scoter	*Melanitta nigra*	10	49
Long-tailed Duck	*Clangula hyemalis*	1	1
Great Northern Diver	*Gavia immer*	2	2
Fulmar	*Fulmarus glacialis*	177	329
Manx Shearwater	*Puffinus puffinus*	17	222
Balearic Shearwater	*Puffinus mauretanicus*	22	57
Sooty Shearwater	*Puffinus griseus*	27	196
Great Shearwater	*Puffinus gravis*	2	99
European Storm Petrel	*Hydrobates pelagicus*	80	184
Petrel sp.		4	6
Gannet	*Morus bassanus*	2302	7327
Cormorant	*Phalacrocorax carbo*	2	2
Shag	*Phalacrocorax aristotelis*	4	4
Grey Heron	*Ardea cinerea*	1	2
Peregrine	*Falco peregrinus*	1	1
Purple Sandpiper	*Calidris maritima*	1	1
Great Skua	*Stercorarius skua*	165	181
Arctic Skua	*Stercorarius parasiticus*	7	6
Skua sp.	*Stercorarius sp.*	2	2
Black-headed Gull	*Chroicocephalus ridibundus*	1	3
Common Gull	*Larus canus*	29	36
Mediterranean Gull	*Larus melanocephalus*	29	66
Herring Gull	*Larus argentatus*	104	304
Lesser Black-backed Gull	*Larus fuscus*	106	481
Yellow-legged Gull	*Larus michahelis*	2	2
Great Black-backed Gull	*Larus marinus*	194	715
Larus sp.	*Larus sp.*	24	79
Kittiwake	*Rissa tridactyla*	1215	3670
Little Gull	*Hydrocoloeus minutus*	13	82
Sandwich Tern	*Stern sandvicensis*	4	3
Puffin	*Fratercula arctica*	36	48
Guillemot	*Uria aalge*	1276	2638
Razorbill	*Alca torda*	395	1294
Auk sp.		354	1080
Barn Swallow	*Hirundo rustica*	1	2
House Martin	*Delichon urbicum*	2	1
Meadow Pipit	*Anthus pratensis*	12	28
Pied Wagtail	*Motacilla alba yarrellii*	3	5
Starling	*Sturnus vulgaris*	2	45
Robin	*Erithacus rubecula*	2	2
Song Thrush	*Turdus philomelos*	4	8
Fieldfare	*Turdus pilaris*	1	2
Chaffinch	*Fringilla coelebs*	1	14
Total		**6638**	**19291**

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

Species	Scientific name	No of birds
Whooper Swan	*Cygnus cygnus*	3
Balearic Shearwater	*Puffinus mauretanicus*	123
Yellow-legged Gull	*Larus michahellis*	1
Long-eared Owl	*Asio flammea*	1
Goldcrest	*Regulus regulus*	1
Chiffchaff	*Phylloscopus collybita*	4
Blackcap	*Sylvia atricapilla*	1
Red-breasted Flycatcher	*Ficedula parva*	1
Song Thrush	*Turdus philomelos*	6
Redwing	*Turdus iliacus*	1
Robin	*Erithacus rubecula*	2
Black Redstart	*Phoenicurus ochruros*	2
Grey Wagtail	*Motacilla cinerea*	2
Chaffinch	*Fringilla coelebs*	1
Snow Bunting	*Plectrophenax nivalis*	1

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 180 birds were recorded, one of the highest numbers since the timeseries began in 2013. In total 57 specimens were recorded on transects (Table 6) and a further 123 while off-transect (in transit, during trawling). In contrast to previous years no aggregations to the south-west of Lundy in the Bristol Channel were seen (Fig 16). This year over 48% of all sightings, were made approximately 3.5km off the north coast of Ile D'Ouessant at the end off Brittany, starting at the last 5 km of the transect and continuing for approximately 15km transiting in NE direction (Fig 16). The area was characterised by a very strong tidal flow running to the SW along the north coast of the island. The area coincided with large numbers of surface schools of anchovy and sardine.

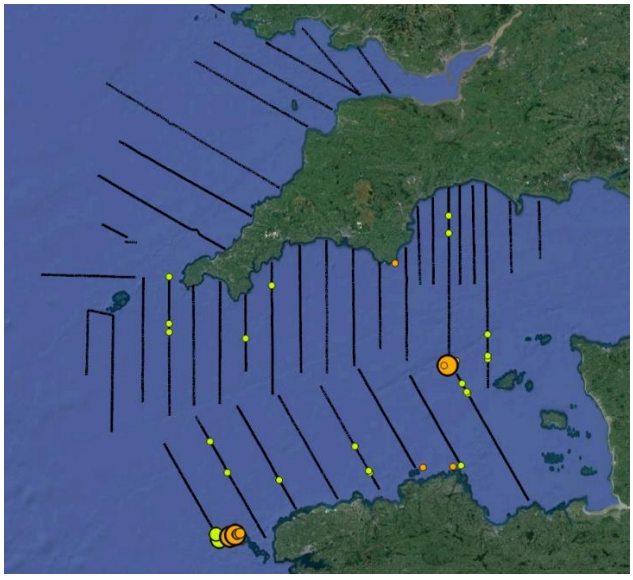

Figure 16: Distribution of all Balearic Shearwater sightings in 2020, scaled to abundance. Abundance categories (small to large circles): 1-5, 6-10, 11-20, 20+. Green dots were birds recorded on transect, orange dots off transect, black lines show survey effort.

Cetaceans

A total of 214 cetacean encounters were made, totalling approximately 1,840 animals of 7 species (Table 8). The total number of animals recorded shows a modest increase on 2019 but is only just over half the totals seen in 2017 & 2018.

Table 8. Cetacean species recorded by MARINElife surveyors on effort during Peltic survey 2018:

Species	Scientific Name	No. sightings	No. animals
Fin Whale	*Balaenoptera physalus*	1	1
Fin Whale (probable)	*Balaenoptera physalus*	3	3
Minke Whale	*Balaenoptera acutorostrata*	2	3
Risso's Dolphin	*Grampus griseus*	1	8
Common Bottlenose Dolphin	*Tursiops truncates*	3	15
Short-beaked Common Dolphin	*Delphinus delphis*	186	1767
White-beaked Dolphin	*Lagenorhynchus albirostris*	1	6
Harbour Porpoise	*Phocoena phocoena*	13	30
Dolphin sp.		4	7
	Total:	214	1840

Short-beaked Common Dolphin was again by far the most frequently recorded species, with 186 sightings of 1,767 animals (Table 8), whilst an increase on 2019 this is still only 59% of the number recorded in 2018 and 54% in 2017. The species is widely distributed throughout the survey area (Fig 16) but with notable hotspots in Lyme Bay, mid-English Channel, around the Isles of Scilly and the Celtic Deep. The lack of sightings in Cardigan Bay and the area around Lundy is almost certainly down to the poor weather conditions encountered whilst in those areas rather than a real lack of animals. There was only one encounter with a very large pod of Common Dolphin this year, an estimated 300 were seen feeding between the Isles of Scilly and Land's End, the next largest group was 90 in the Celtic Deep (Fig 17). Otherwise the majority of encounters were groups of 10 or less. A single group of White-beaked Dolphins were once again seen in Lyme Bay along with a single group of Risso's Dolphins and three small groups of Bottlenose Dolphin on widely scattered transects (Fig 17). Despite good viewing conditions during the Celtic Deep transect no Fin Whale were seen. Instead a single, positively identified, Fin Whale was seen 64km NW of Land's End and a further three large rorqual blows (almost certainly Fin Whale) were seen (Fig 17). Two of these in the same as area as the definite Fin Whale, the third in the English Channel, a very different distribution to other years. Harbour Porpoise sightings were quite reasonable given the viewing conditions during the survey.

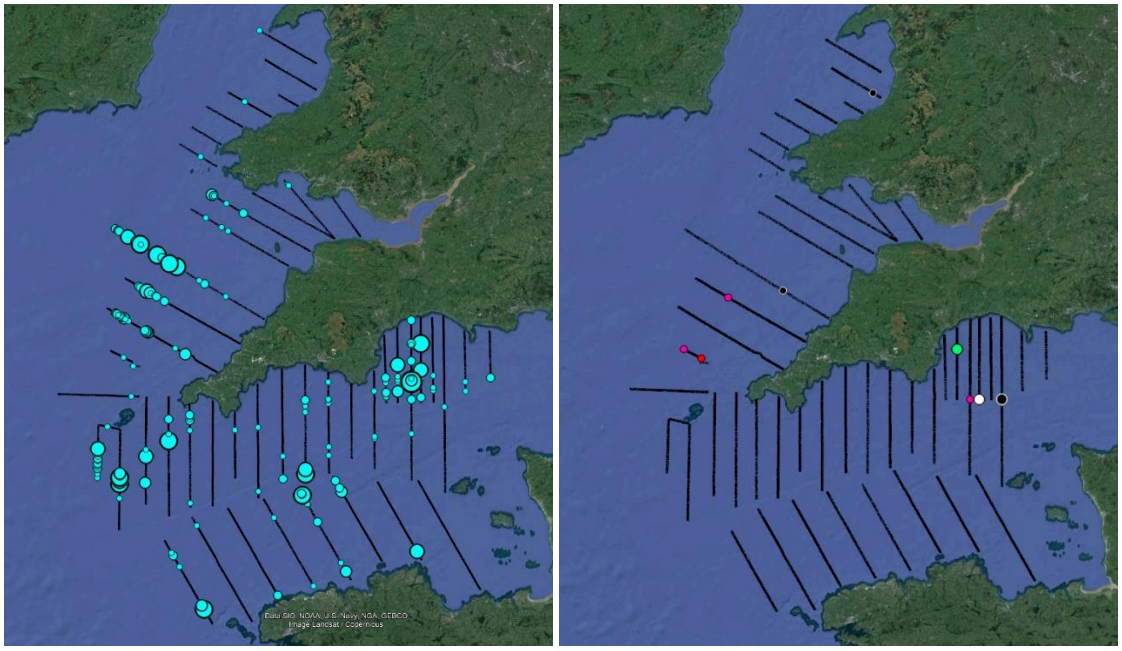

Figure 17: Distribution of Common Dolphin sightings (left, light blue circles), scaled to abundance. (small to large circles: 1-5, 6-10, 11-20, 20+) and distribution of other cetacean species sightings (right) in 2020. Black dot = Bottlenose Dolphin, green dot = White-beaked Dolphin, white dot = Risso's Dolphin, red dot = Fin Whale and pink dot probable Fin whale. Black lines show survey effort.

Bluefin tuna

A total of 118 bluefin tuna were recorded in 43 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

Bluefin tuna were widespread around the Isles of Scilly and the northern side of the English Channel (Fig 18). Although there were more sightings than 2019, the numbers were still well below those in 2017 and 2018. This year many of the encounters also appeared to be single animals and there were only one or two encounters with sizable feeding frenzies.

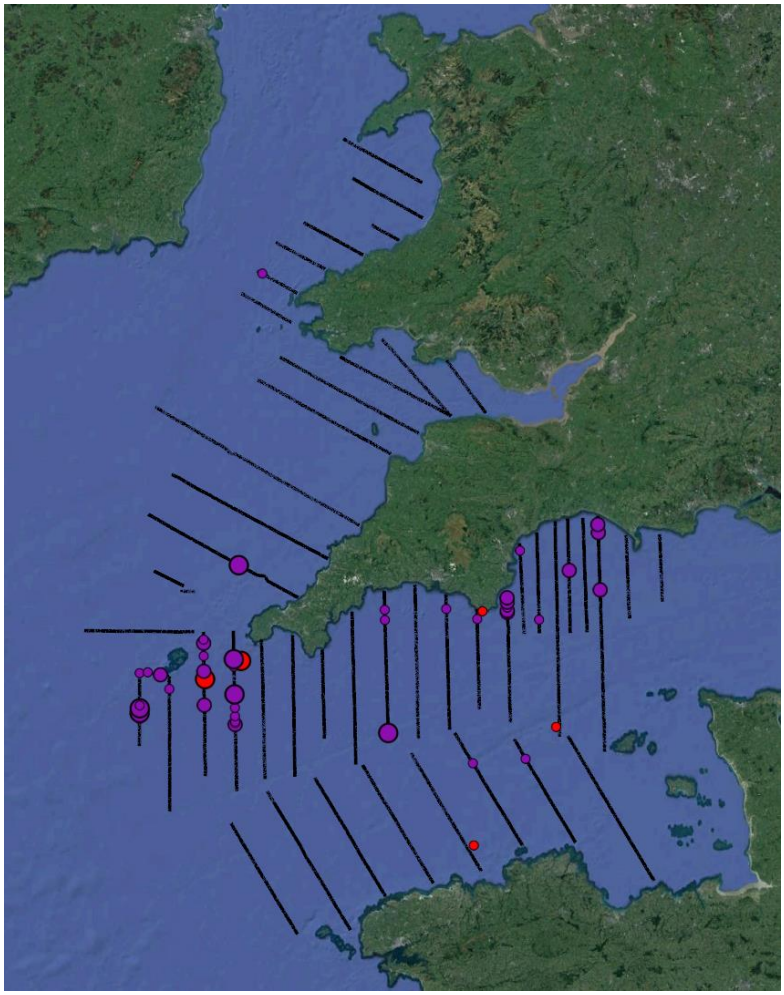

Figure 18: Distribution of all tuna sightings in 2020, scaled to abundance. Abundance categories (small to large circles): 1, 2-4, 5-10, purple dots are on transect, red off transect. Black lines show survey effort.

Summary

The 2020 PELTIC survey was successfully completed although persistent fresh weather conditions and some technical issues meant that one transect in the Bristol Channel was not surveyed and coverage of three short transects north of the Isles of Scilly was compromised. However, this has not adversely affected the quality of the biomass estimates for key pelagic species used (sprat in ICES area 7de) and considered (sardine in area 7ef) for stock assessment. Sprat biomass in the core survey area used for the assessment was 33,798 t which was similar but slightly lower than the 2019 estimate. Compared to previous years, the modal size was slightly smaller and spatially they were confined to Lyme Bay only, with highest densities inshore. The species was again also found north of the Cornish Peninsula, although in lower quantities and more inshore compared to previous years. Sardine biomass was high at 332,098 t, although slightly lower than in 2019, with notably fewer fish found north of the Cornish Peninsula. Sardine biomass had been growing in this area with increasing spawning activity suggesting a northward expansion. This year's observations have likely been affected by several strong westerly weather fronts coming through particularly in the latter half of the survey when this area was covered. Storms mix and cool the shelf seas, as evidenced also by the oceanographic results (low surface temperatures and deeper than usual thermoclines) and may have caused sardine to move away from the

area. This means that sardine biomass may have been underestimated. In the English Channel the highest densities of sardine and sardine eggs were found further west than normal which may have been driven by the oceanographic conditions, as demonstrated by the more westerly distribution of the front. Anchovy biomass doubled from last year with one year old fish dominating the population. A significant quantity of post-larval anchovy, distinguished from usual anchovy observations during PELTIC by distinct surface schooling behaviour, was found across all southern English Channel transects and suggested a northwards expansion by Bay of Biscay anchovy. Further studies are needed to confirm this as it could have significant implications for the Bay of Biscay anchovy assessment and management. Atlantic bluefin tuna were regularly observed although sightings were lower than in recent years, in part likely due to the generally poor sea state. The highest number of tuna observations overlapped with the most important area for sardine (spawning).

For the first time, PELTIC extended into Cardigan Bay to study its pelagic ichthyofauna and ecosystem. Sprat was the most important small pelagic species with significant biomass observed in the shallow, fresh-water influenced eastern and northern areas of the bay. The size composition of sprat differed from that in the adjacent Bristol Channel area which may suggest these are different populations. As these results are only a single snapshot of the area, it is difficult to draw further conclusions. Horse mackerel, sardine, anchovy and herring were also found although biomass for those species was more than an order of magnitude lower. A small number of sardine eggs confirm local spawning activity of this species, the northern-most location in the survey area to date.

Jeroen van der Kooij
Scientist in Charge
18/12/2020

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