Acoustic assessment and distribution of anchovy, sardine and chub mackerel in ICES Subdivision 9a South during the *ECOCADIZ-RECLUTAS 2021-10* Spanish survey (October 2020) with notes on the distribution of other pelagic species. Preliminary information.

By

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ABSTRACT

The present working document summarises a part of the main results obtained during the *ECOCADIZ-RECLUTAS 2021-10* Spanish (pelagic ecosystem-) acoustic survey. The survey was conducted by IEO between 21st October and 07th November 2021 in the Portuguese and Spanish shelf waters (20-200 m isobaths) off the Gulf of Cadiz (GoC) onboard the R/V *Ramón Margalef*. The survey suffered a ten-day delay in relation to the usual starting dates, resulting in ending dates very close to the starting ones of the WGACEGG meeting. Therefore, no acoustic estimates were available at the time of WG meeting. The survey's main objective is the acoustic assessment of anchovy and sardine juveniles (age 0 fish) in the recruitment areas of the GoC. The 21 foreseen acoustic transects were sampled. A total of 18 valid fishing hauls were carried out for echo-trace ground-truthing purposes. This working document only provides information on the results of these hauls in terms of species-specific occurrences, yields in numbers and weight, size ranges, mean size and mean weight in catches.

INTRODUCTION

The first attempt by the IEO of acoustically assessing the abundance of anchovy and sardine juveniles in their main recruitment areas off the Gulf of Cadiz dates back to 2009 (*ECOCADIZ-RECLUTAS 1009* survey). However, that survey was unsuccessful as to the achievement of their objectives because of the succession of a series of unforeseen problems which led to drastically reduce the foreseen sampling area to only the 6 easternmost transects. The continuation of this survey series was not guaranteed for next years and, in fact, no survey of these characteristics was carried out in 2010 and 2011. In 2012, the *ECOCADIZ-RECLUTAS 1112* survey was financed by the Spanish Fisheries Secretariat and planned and conducted by the IEO with the aim of obtaining an autumn estimate of Gulf of Cadiz anchovy biomass and abundance. The survey was conducted with the R/V *Emma Bardán*. Although the survey was restricted to the Spanish waters only it has been considered as the first survey within its series (Ramos *et al.*, 2013). *ECOCADIZ-RECLUTAS 2014-10* re-started the series and it was conducted with the R/V *Ramón Margalef*. The 2017 survey should be the fifth survey within its series. However, an unexpected a serious breakdown of the vessel's propulsion system led to an early termination of the survey, which restricted the surveyed area to the one comprised by the seven easternmost transects only.

The general objective of these surveys is the acoustic assessment by vertical echo-integration and mapping of the abundance and biomass of recruits of small pelagic species (especially anchovy and sardine), as well as the mapping of both the oceanographic and biological conditions featuring the recruitment areas of these species in the Division 9a. The long term objective of the surveys would be to be able to assess the strength of the incoming recruitment to the fishery of these species the next year.

The *ECOCADIZ-RECLUTAS 2021-10* survey (the seventh within its series) has been completed in very close dates to those ones of the starting of the WGACEGG meeting. Echogram scrutiny and subsequent computation of acoustic estimates are still pending. Therefore, the present Working Document only advances some preliminary results from this survey, which will only refer to the information provided by the fishing hauls.

MATERIAL AND METHODS

The *ECOCADIZ-RECLUTAS 2021-10* survey was conducted between 21st October and 07th November onboard the Spanish R/V *Ramón Margalef* covering a survey area which comprised the waters of the Gulf of Cadiz, both Spanish and Portuguese, between the 20 m and 200 m isobaths. The survey design consisted in a systematic parallel grid with tracks equally spaced by 8 nm, normal to the shoreline (**Figure 1**).

The survey suffered a ten-day delay in relation to the usual starting dates, resulting in ending dates very close to the starting ones of the WG meeting. Causes for such a delay were of logistic (a delay in R/V's dry-dock repair works) and unforeseen (monitoring of the *Cumbre Vieja* volcano eruption) nature. Furthermore, the ship-time available was shortened in two days, and one day more was lost because stormy weather and rough sea. Echogram scrutiny and subsequent computation of acoustic estimates are still pending. A delay in the survey dates has entailed that no acoustic estimates were available at the time of the preparation of the present survey report.

Echo-integration was carried out with a recently installed *Simrad™ EK80* echo-sounder working in the multi-frequency fashion (18, 38, 70, 120, 200, 333 kHz) and in CW mode. Average survey speed was about 10 knots and the acoustic signals were integrated over 1-nm intervals (ESDU). Raw acoustic data were stored for further post-processing using *Myriax Software Echoview™* software package. Acoustic equipment was calibrated between 23rd and 24th October in the Bay of Algeciras following the ICES standard procedures (Demer *et al.*, 2015; see also Foote *et al.*, 1987).

Survey execution and abundance estimation followed the methodologies firstly adopted by the ICES Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX (ICES, 1998) and the recommendations given later by the *Working Group on Acoustic and Egg Surveys for Small Pelagic Fish in NE Atlantic* (WGACEGG; ICES, 2006a,b; see also ICES TIMES 64 report, Doray *et al.*, 2021).

Fishing hauls for echo-trace ground-truthing were opportunistic, according to the echogram information, and they were carried out using a *Gloria HOD 352* pelagic trawl gear (ca. 10 m-mean vertical opening net) at an average speed of 4-4.5 knots. Gear performance and geometry during the effective fishing was monitored with *Simrad™ Mesotech FS20* trawl sonar, a *Marport™ Narrow Band Trawl Eye* and *Scanmar™* trawl door sensors for inter-doors distance and depth. Trawl sonar data from each haul were recorded and stored for further analyses.

Ground-truthing haul samples provided biological data on species and they were also used to identify fish species and to allocate the back-scattering values into fish species according to the proportions found at the fishing stations (Nakken and Dommasnes, 1975).

Length frequency distributions (LFD) by 0.5-cm class were obtained for all the fish species in trawl samples (either from the total catch or from a representative random sample of 100-200 fish). Only those LFDs based on a minimum of 30 individuals and showing a normal distribution were considered for the purpose of the acoustic assessment.

Individual biological sampling (length, weight, sex, maturity stage, stomach fullness, and mesenteric fat content) was performed in each haul for anchovy, sardine, mackerel (2 spp.) and horse-mackerel species (3 spp.), and bogue. Otoliths were extracted from anchovy, sardine and chub mackerel sampled specimens.

The following TS/length relationship table was used for acoustic estimation of assessed species (recent IEO standards after ICES, 1998; and recommendations by ICES, 2006a,b):

Species	b_{20}
Sardine (*Sardina pilchardus*)	-72.6
Round sardinella (*Sardinella aurita*)	-72.6
Anchovy (*Engraulis encrasicolus*)	-72.6
Chub mackerel (*Scomber japonicus*)	-68.7
Mackerel (*S. scombrus*)	-84.9
Horse mackerel (*Trachurus trachurus*)	-68.7
Mediterranean horse-mackerel (*T. mediterraneus*)	-68.7
Blue jack mackerel (*T. picturatus*)	-68.7
Bogue (*Boops boops*)	-67.0
Transparent goby (*Aphia minuta*)	-67.5
Atlantic pomfret (*Brama brama*)	-67.5
Blue whiting (*Micromesistius poutassou*)	-67.5
Silvery lightfish/pearlside (*Maurolicus muelleri*)	-72.2
Longspine snipefish (*Macroramphosus scolopax*)	-80.0
Boarfish (*Capros aper*)	-66.2* (-72.6)

*Boarfish b_{20} estimate following to Fässler *et al*. (2013). Between parentheses the usual IEO value considered in previous surveys.

The *PESMA* software (J. Miquel, IEO, unpublished) has got implemented the needed procedures and routines for the acoustic assessment following the above approach and it has been the software package used for the acoustic estimation.

A *Sea-bird Electronics™ SBE 21 SEACAT* thermosalinograph and a *Turner™ 10 AU 005 CE Field* fluorometer were used during the acoustic tracking to continuously collect some hydrographical variables (sub-surface sea temperature, salinity, and in vivo fluorescence). Vertical profiles of hydrographical variables were also recorded by night from 168 $CTDO_2$ casts over 22 transects (from the 23-transect planned grid) using a *Sea-bird Electronics™ SBE 911+ SEACAT* (with coupled *Datasonics* altimeter, *SBE 43* oximeter, *WetLabs ECO-FL-NTU* fluorimeter and *WetLabs C-Star 25 cm* transmissometer sensors) profiler (**Figure 2**). *VMADCP RDI 150 kHz* records were also continuously recorded by night between CTD stations. Census of top predators was not recorded during the survey.

RESULTS

Acoustic sampling

The acoustic sampling was restricted to the period comprised between 25th October and 06th November. The complete grid (21 transects) was acoustically sampled (**Table 1**; **Figure 1**). The sampling scheme followed to accomplish this grid was conditioned by the conduction of Spanish Navy and Army exercises (*FLOTEX 21*) during the survey, which occupied all the Spanish shelf waters. The sampling experienced one "jump" looking for space-time opportunity windows for the acoustic surveying trying to avoid such military exercises. Thus, the order and/or direction of the realization of the acoustic transects RA01 to RA04 had to be modified on 25th and 26th October. The acoustic sampling was partially interrupted on 28th-29th October in order to satisfy the R/V's refueling and provisioning needs. All works at sea were totally interrupted on 30th October because a stormy weather and rough sea. In order to perform the acoustic sampling with daylight, the acoustic sampling started at 06:40-06:45 UTC until 31st October, and at 07:15-07:20 UTC later

on, although this time might vary depending on the duration of the works related with the hydrographic sampling the previous night.

Groundtruthing hauls

A total of eighteen (18) fishing operations for echo-trace ground-truthing (all of them were valid according to a correct gear performance and resulting catches), were carried out during the survey (**Table 2**, **Figure 3**). Because of many echo-traces usually occurred close to the bottom, all the pelagic hauls were carried out like a bottom-trawl haul, with the ground rope working over or very close to the bottom. Only one haul was performed over a determined isobath instead of being conducted over the acoustic transect. According to the above, the sampled depth range in the valid hauls oscillated between 25 and 202 m.

During the survey were captured 3 Chondrichthyan, 44 Osteichthyes, 8 Cephalopod, 3 Echinoderm, and several Cnidarian and Ascidian species. The percentage of occurrence of the fish species (sharks excluded) in the hauls is shown in the enclosed Text Table below (see also **Figure 4**). The pelagic ichthyofauna was both the most frequently captured species set and the one composing the bulk of the overall yields of the catches. Within this pelagic fish species set chub mackerel and anchovy (both with 78% presence index) and sardine (61%) were the most frequent species in the valid hauls, followed by horse mackerel and bogue (both 56%), mackerel (44%), Mediterranean horse mackerel (39%) and Blue jack mackerel (28%). Round sardinella (17%) and blue whiting (11%) showed very low occurrences. Boarfish, longspine snipefish and pearlside showed an incidental occurrence (6% each) in the hauls performed in the surveyed area.

For the purposes of the acoustic assessment, anchovy, sardine, mackerel species, horse & jack mackerel species, bogue, boarfish, snipefish and pearlside were initially considered as the survey target species. All the invertebrates, skates, rays and benthic fish species were excluded from the computation of the total catches in weight and in number from those fishing stations where they occurred. Catches of the remaining non-target fish species were included in an operational category termed as "Others".

According to the above premises, during the survey were captured a total of 10 889 kg and 182 thousand fish (**Table 3**). Forty nine per cent (49%) of this "total" fished biomass corresponded to sardine, 38% to chub mackerel, 5% to anchovy, 4% to Mediterranean horse mackerel, 1% to horse mackerel and contributions lower than 1% for the remaining species. The most abundant species in ground-truthing trawl hauls was sardine (50%), followed by anchovy (24%), chub mackerel (21%), and horse mackerel (3%), with each of the remaining species accounting for equal to or less than 1%.

The species composition of these fishing hauls (as expressed in terms of percentages in number) is shown in **Figure 4**.

Species	OCCURRENCE (Number of valid hauls)	OCCURRENCE (% over Total valid hauls)	Total weight (Kg)	Total number
Scomber colias	14	78 %	4167,685	37825
Engraulis encrasicolus	14	78 %	559,681	44176
Sardina pilchardus	11	61 %	5357,42	90324
Trachurus trachurus	10	56 %	141,529	1361
Boops boops	10	56 %	15,798	108
Merluccius merluccius	10	56 %	4,072	34
Scomber scombrus	8	44 %	18,903	133
Trachurus mediterraneus	7	39 %	388,923	2007
Spondyliosoma cantharus	7	39 %	13,401	105
Pagellus erythrinus	7	39 %	7,605	44
Trachurus picturatus	5	28 %	66,589	1462
Lepidopus caudatus	5	28 %	0,107	12
Diplodus vulgaris	4	22 %	7,720	41
Spicara flexuosa	4	22 %	3,402	99
Pagellus bellottii bellottii	4	22 %	2,540	29
Pagellus acarne	4	22 %	2,038	15
Sardinella aurita	3	17 %	3,712	15
Pomatomus saltatrix	3	17 %	3,450	10
Diplodus annularis	3	17 %	0,221	5
Brama brama	2	11 %	6,605	15
Diplodus bellottii	2	11 %	4,785	107
Pomadasys incisus	2	11 %	3,875	44
Caranx rhonchus	2	11 %	2,580	8
Stromateus fiatola	2	11 %	1,955	3
Liza ramada	2	11 %	1,620	6
Zeus faber	2	11 %	0,905	2
Sparus aurata	2	11 %	0,862	2
Micromesistius poutassou	2	11 %	0,209	7
Mola mola	1	6 %	49,850	2
Macroramphosus scolopax	1	6 %	18,705	1849
Dentex gibbosus	1	6 %	10,770	2
Sarda sarda	1	6 %	5,455	3
Zenopsis conchifer	1	6 %	1,79	1
Maurolicus muelleri	1	6 %	1,62	1684
Spicara maena	1	6 %	1,55	40
Capros aper	1	6 %	0,962	129
Alosa fallax	1	6 %	0,625	4
Parapristipoma octolineatum	1	6 %	0,262	1
Trachinotus ovatus	1	6 %	0,19	1
Umbrina canariensis	1	6 %	0,131	1
Mullus barbatus	1	6 %	0,128	1
Trachinus draco	1	6 %	0,054	1
Chelidonichthys obscurus	1	6 %	0,038	1

Back-scattering energy attributed to the "pelagic assemblage" and individual species

No NASC data are still available from this survey since echogram scrutiny and estimation of species-specific abundances and biomasses are still pending.

Spatial distribution and abundance/biomass estimates

For the time being, information only referred to the results from the pelagic hauls.

Anchovy

Parameters of the survey's length-weight relationship for anchovy are given in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 5**.

The whole size class range for the pooled catches varied between the 2.0 and 18.5 cm size classes (mean size: 12.05 cm; 12.67 g), with 3 modal classes, the main mode at 10.0 cm, a secondary mode at 14.5 cm and a third mode, composed by tiny juveniles (2.0-4.5 cm) at 3.0 cm. Regional mean size and weights in the pooled catches were estimated at 15.36 cm and 24.51 g in Portuguese waters and 11.14 cm and 9.43 g in Spanish ones. The size composition of anchovy catches throughout the surveyed area confirms the usual pattern exhibited by the species during the survey season, with the largest (and oldest) fish being distributed in the westernmost waters and the smallest (and youngest) ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters.

Sardine

Parameters of the survey's size-weight relationship for sardine are shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 6**.

The whole size class range for the pooled catches varied between the 10.0 and 21.5 cm size classes (mean size: 18.41 cm; 59.31 g), with 2 modal classes, the main mode at 19.0 cm and a secondary mode at 12.5 cm. Regional mean size and weights in the pooled catches were estimated at 18.66 cm and 61.27 g in Portuguese waters and 13.20 cm and 18.47 g in Spanish ones. The size composition of sardine catches throughout the surveyed area confirms the usual pattern exhibited by the species during the survey season, with the largest (and oldest) fish being distributed in the Portuguese waters and the smallest (and youngest) ones concentrated in the coastal waters between Chipiona and El Rompido.

Mackerel

Parameters of the survey's length-weight relationship are shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 7**.

The whole size class range for the pooled catches varied between the 24.0 and 35.5 cm size classes (mean size: 26.52 cm; 142.13 g), with 2 modal classes, the main mode at 25.5 cm and a secondary mode at 27.0 cm. Regional mean size and weights in the pooled catches were estimated at 26.42 cm and 140.55 g in Portuguese waters and 27.75 cm and 161.50 g in Spanish ones. No clear spatial pattern in mean size was observed; perhaps the smallest fish were more common in Portuguese waters.

Chub mackerel

Parameters of the survey's length-weight relationship are shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 8**.

The whole size class range for the pooled catches varied between the 17.0 and 37.5 cm size classes (mean size: 23.29 cm; 110.18 g), with 1 modal class at 22.5 cm. Regional mean size and weights in the pooled catches were estimated at 23.09 cm and 105.61 g in Portuguese waters and 29.61 cm and 251.34 g in Spanish ones. The largest fish were commonly captured in Spanish waters, with smaller fish occurring in Portuguese waters and the smallest ones in the middle-outer shelf waters between Albufeira and Alfanzinha.

Horse mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 9**.

The size class range for the pooled catches varied between the 6.5 and 30.5 cm size classes (mean size: 22.70 cm; 103.99 g), with 2 modal classes, the main mode at 23.0 cm and a secondary one at 18.0 cm. Regional mean size and weights in the pooled catches were estimated at 22.79 cm and 105.03 g in Portuguese waters and 18.56 cm and 56.34 g in Spanish ones. No clear spatial pattern in mean size was observed, although the largest fish occurred in Portuguese waters.

Mediterranean horse-mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 10**.

The size class range for the pooled catches varied between the 20.0 and 39.0 cm size classes (mean size: 28.23 cm; 193.78 g), with 1 modal class at 27.0 cm. Regional mean size and weights in the pooled catches were estimated at 27.83 cm and 180.38 g in Portuguese waters and 28.24 cm and 198.00 g in Spanish ones. No clear spatial pattern in mean size was observed, although the largest fish occurred in the easternmost Spanish waters.

Blue jack mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 11**.

The size class range for the pooled catches varied between the 15.5 and 23.0 cm size classes (mean size: 17.95 cm; 45.55 g), with 1 modal class at 27.0 cm. All the catches occurred in Portuguese waters. No clear spatial pattern in mean size was observed.

Bogue

The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 12**.

The size class range for the pooled catches varied between the 10.5 and 34.5 cm size classes (mean size: 23.80 cm; 146.28 g), with 1 modal class at 23.0 cm. Regional mean size and weights in the pooled catches were estimated at 22.41 cm and 107.49 g in Portuguese waters and 27.42 cm and 247.13 g in Spanish ones. No clear spatial pattern in mean size was observed, although the largest fish occurred in the easternmost Spanish waters.

Boarfish

   The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 13**.

The size class range for the pooled catches varied between the 05.0 and 09.0 cm size classes (mean size: 07.09 cm; 07.46 g), with 1 modal class at 06.5 cm. All the catches occurred in Portuguese waters. No spatial pattern in mean size was observed.

Longspine snipefish

   The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 14**.

The size class range for the pooled catches varied between the 09.0 and 14.5 cm size classes (mean size: 11.66 cm; 10.12 g), with 2 modal classes, the main mode at 12.0 cm and a secondary mode at 09.0 cm. All the catches occurred in the westernmost Portuguese waters. No spatial pattern in mean size was observed.

Pearlside

   The survey's length-weight relationship for this species is shown in **Table 4**. Size composition and mean size in the fishing hauls are represented in the spatial context in **Figure 15**.

The size class range for the pooled catches varied between the 03.5 and 05.5 cm size classes (mean size: 04.91 cm; 0.96 g), with 1 modal class at 04.5 cm. The only positive catch occurred in the Cape Santa Maria area in Portuguese waters.

   The time series of anchovy, sardine and chub mackerel estimates from this survey series are described in **Tables 5**, **6** and **7** and **Figure 16**.

ACKNOWLEDGEMENTS

REFERENCES

Demer, D.A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., *et al*. 2015. Calibration of acoustic instruments. *ICES Coop. Res. Rep,* 326, 133 pp.

Doray, M., Boyra, G., and van der Kooij, J. (Eds.). 2021. ICES Survey Protocols – Manual for acoustic surveys coordinated under the ICES Working Group on Acoustic and Egg Surveys for Small Pelagic Fish (WGACEGG). 1st Edition. *ICES Techniques in Marine Environmental Sciences* Vol. 64. 100 pp. https://doi.org/10.17895/ices.pub.7462

Fässler, S. M.M., C. O'Donnell, J.M. Jech, 2013. Boarfish (*Capros aper*) target strength modelled from magnetic resonance imaging (MRI) scans of its swimbladder. *ICES Journal of Marine Science*, 70: 1451–1459.

Foote, K.G., H.P. Knudsen, G. Vestnes, D.N. MacLennan, E.J. Simmonds, 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. *ICES Coop. Res. Rep.*, 144, 57 pp.

ICES, 1998. Report of the Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX. A Coruña, 30-31 January 1998. *ICES CM 1998/G:2*.

ICES, 2006a. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas VIII and IX (WGACEGG), 24-28 October 2005, Vigo, Spain. *ICES, C.M. 2006/LRC: 01*. 126 pp.

ICES, 2006b. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 27 November-1 December 2006, Lisbon, Portugal. *ICES C.M. 2006/LRC:18*. 169 pp.

Nakken, O., A. Dommasnes, 1975. The application for an echo integration system in investigations on the stock strength of the Barents Sea capelin (*Mallotus villosus*, Müller) 1971-74. *ICES CM 1975/B:25*.

Ramos, F., M. Iglesias, J. Miquel, D. Oñate, J. Tornero, A. Ventero, N. Díaz, 2013. Acoustic assessment and distribution of the main pelagic fish species in the ICES Subdivision IXa South during the *ECOCÁDIZ-RECLUTAS 1112* Spanish survey (November 2012). Working document presented in the ICES Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA), Bilbao (Basque Country), Spain, 21-26 June 2013 and in the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG). Lisbon, Portugal, 25-29 November 2013.

Table 1. *ECOCADIZ-RECLUTAS 2021-10* survey. Descriptive characteristics of the acoustic tracks.

Acoustic Track	Location	Date	Start				End			
			Latitude	Longitude	UTC time	Mean depth (m)	Latitude	Longitude	UTC time	Mean depth (m)
R01	Trafalgar	26/10/21	36º 02.01' N	06º 29.12' W	13:30	240	36º 13.03' N	06º 08.84' W	15:35	23
R02	Sancti-Petri	26/10/21	36º 19.31' N	06º 14.93' W	6:50	26	36º 08.79' N	06º 34.30' W	10:35	204
R03	Cádiz	25/10/21	36º 17.40º N	06º 36.24' W	11:23	181	36º 29.79' N	06º 18.93' W	15:09	23
R04	Rota	25/10/21					36º 24.53' N	06º 40.80' W	10:34	199
R05	Chipiona	27/10/21	36º 40.36' N	06º 29.41' W	6:46	21	36º 31.25' N	06º 46.24' W	10:15	193
R06	Doñana	27/10/21	36º 38.00' N	06º 51.65' W	11:10	200	36º 46.60' N	06º 35.70' W	14:46	19
R07	Matalascañas	29/10/21	36º 54.45' N	06º 38.95' W	12:20	16	36º 43.90' N	06º 58.32' W	16:15	220
R08	Mazagón	31/10/21	36º 49.39' N	07º 06.06' W	7:25	198	36º 01.08' N	06º 44.78' W	11:37	20
R09	Punta Umbría	31/10/21	37º 04.30' N	06º 56.08' W	13:53	23	36º 49.68' N	07º 06.55' W	15:34	198
R10	El Rompido	01/11/21	36º 50.03' N	07º 07.21' N	7:22	191	37º 07.93' N	07º 07.21' W	11:18	18
R11	Isla Cristina	01/11/21	37º 06.84' N	07º 17.06' W	13:57	22	36º 53.47' W	07º 17.14' W	15:16	200
R12	V.R. do Sto. Antonio	02/11/21	37º 06.35' N	7º 17.26' W	7:16	18	36º 56.26' N	07º 27.11'W	10:18	202
R13	Tavira	02/11/21	36º 57.10' N	07º 37.12' W	11:05	189	37º 05.19' N	07º 37.17' W	11:55	16
R14	Fuzeta	02/11/21	36º 59.27' N	07º 46.96' W	14:33	42	36º 55.48' W	07º 47.02' W	14:55	193
R15	Cabo Sta. María	03/11/21	36º 56.13' N	07º 56.99' W	7:21	51	36º 52.15' N	07º 56.91' W	7:46	187
R16	Cuarteira	03/11/21	37º 01.77' N	08º 07.05' W	10:19	19	36º 49.82' N	08º 06.85' W	11:41	162
R17	Albufeira	04/11/21	36º 49.39' N	08º 16.83' W	7:22	196	36º 01.8' N	08º 17.01' W	8:36	21
R18	Alfanzinha	04/11/21	37º 04.30' N	08º 26.99' W	11:34	24	36º 50.23' W	08º 26.69' W	14:57	209
R19	Portimao	05/11/21	37º 06.02' N	08º 37.07' W	7:36	21	36º 51.88' W	08º 36.62' W	9:01	148
R20	Burgau	05/11/21	36º 51.17' N	08º 46.68' W	9:52	217	37º 02.47' N	08º 46.96' W	13:31	45
R21	Punta de Sagres	06/11/21	36º 59.13' N	08º 56º.79' W	7:07	24	36º 50.56' N	8º 56.58' W	8:01	206

Table 2. *ECOCADIZ-RECLUTAS 2021-10* survey. Descriptive characteristics of the fishing hauls.

Fishing haul	Date	Start Latitude	Start Longitude	End Latitude	End Longitude	UTC Time Start	UTC Time End	Depth (m) Start	Depth (m) End	Effective Trawling	Total Manoeuvre	Trawled Distance (nm)	Acoustic Transect	Zone (landmark)
1	25-10-2021	36º 27.8394 N	6º 34.7840 W	36º 28.9480 N	6º 32.7166 W	08:47	09:14	83,46	68,48	00:27	01:13	2,002	R04	Rota
2	25-10-2021	36º 23.6390 N	6º 24.7175 W	36º 21.5517 N	6º 28.5754 W	12:53	13:44	51,45	69,28	00:50	01:24	3,748	R03	Cádiz
3	26-10-2021	36º 15.6718 N	6º 21.7453 W	36º 16.7514 N	6º 19.0876 W	08:09	08:41	47,41	40,79	00:32	01:11	2,404	R02	Sancti-Petri
4	26-10-2021	36º 09.3423 N	6º 33.4767 W	36º 10.5130 N	6º 31.3233 W	11:17	11:46	156,46	116,12	00:28	01:27	2,099	R02	Sancti-Petri
5	27-10-2021	36º 36.3974 N	6º 36.7585 W	36º 38.0278 N	6º 33.7723 W	07:54	08:34	57,78	38,16	00:39	01:17	2,903	R05	Chipiona
6	27-10-2021	36º 40.5672 N	6º 46.9273 W	36º 38.8771 N	6º 49.7937 W	12:05	12:46	94,71	120,81	00:40	01:28	2,858	R06	Doñana
7	29-10-2021	36º 50.6064 N	6º 46.4508 W	36º 52.1859 N	6º 43.6623 W	13:35	14:12	41,17	24,89	00:37	01:13	2,738	R07	Matalascañas
8	31-10-2021	36º 53.9092 N	6º 56.8250 W	36º 52.3850 N	7º 00.6593 W	08:42	09:20	79,98	101,41	00:38	01:26	3,432	R08	Mazagón
9	30-10-2021	36º 59.6417 N	6º 47.3898 W	36º 57.9788 N	6º 50.3552 W	12:06	12:46	26,91	36,97	00:40	01:10	2,899	R08	Mazagón
10	01-11-2021	36º 52.3377 N	7º 07.1216 W	36º 49.9269 N	7º 07.0607 W	08:10	08:42	123,59	201,96	00:32	01:26	2,408	R10	El Rompido
11	01-11-2021	37º 05.5373 N	7º 07.0416 W	37º 03.0531 N	7º 06.5738 W	12:02	12:36	26,3	42,23	00:33	01:04	2,509	R10	El Rompido
12	02-11-2021	37º 03.4301 N	7º 27.0741 W	37º 05.4515 N	7º 27.0567 W	08:03	08:29	59,9	29,39	00:26	01:24	2,019	R12	Vila Real do Santo Antonio
13	02-11-2021	37º 00.4410 N	7º 36.9744 W	36º 58.6553 N	7º 36.9066 W	12:33	12:57	94,78	108,48	00:24	01:18	1,784	R13	Tavira
14	03-11-2021	36º 52.6355 N	7º 56.9689 W	36º 55.2322 N	7º 57.3097 W	08:13	08:51	102,88	66,44	00:37	01:22	2,608	R15	Cabo de Santa María
15	03-11-2021	36º 53.9360 N	8º 06.0203 W	36º 53.9802 N	8º 07.0103 W	12:48	12:58	87,49	84,58	00:10	00:55	0,795	R16	Cuarteira
16	04-11-2021	36º 59.1968 N	8º 16.8204 W	36º 56.3192 N	8º 16.8261 W	09:09	09:49	45,5	72,19	00:40	01:22	2,874	R17	Albufeira
17	04-11-2021	36º 54.3264 N	8º 26.7825 W	36º 57.0316 N	8º 26.7953 W	13:01	13:39	115,8	89,08	00:37	01:23	2,702	R18	Alfanzina
18	05-11-2021	36º 54.5772 N	8º 46.6952 W	36º 57.6744 N	8º 46.7128 W	11:59	12:41	110,12	92,32	00:42	01:23	3,093	R20	Burgau

Table 3. *ECOCADIZ-RECLUTAS 2021-10* survey. Catches by species in number (upper panel) and weight (in kg, lower panel) from valid fishing stations.

Fishing haul	CATCH IN NUMBER														
	Anchovy	Sardine	Round sardin.	Chub mack.	Mackerel	Blue Jack mack.	Horse-mack.	Medit. Horse-mack.	Atlantic pomfret	Bogue	Boarfish	Snipefish	Pearlside	Other spp.	TOTAL
01	1629	1	0	0	0	0	0	0	0	0	0	0	0	1	1631
02	0	0	12	244	0	0	0	229	0	19	0	0	0	1	505
03	0	0	0	1	0	0	8	81	0	0	0	0	0	155	245
04	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
05	820	2024	0	3	0	0	0	168	0	4	0	0	0	22	3041
06	17535	238	0	0	4	0	0	0	0	0	0	0	0	7	17784
07	0	780	2	44	0	0	14	997	0	1	0	0	0	141	1979
08	3181	20	0	2	4	0	0	0	0	0	0	0	0	3	3210
09	2776	362	1	879	0	0	3	464	0	5	0	0	0	115	4605
10	8505	0	0	0	2	0	0	0	14	0	0	0	0	2	8523
11	250	712	0	15	0	0	4	36	0	1	0	0	0	14	1032
12	170	74413	0	130	0	0	10	32	0	22	0	0	0	85	74862
13	94	4860	0	35853	0	509	55	0	0	12	0	0	0	9	41392
14	988	0	0	27	6	25	30	0	0	2	0	0	1684	18	2780
15	902	0	0	1	17	0	0	0	1	0	0	0	0	4	925
16	66	5979	0	554	9	925	1010	0	0	39	0	0	0	30	8612
17	7247	0	0	56	81	1	224	0	0	3	0	0	0	21	7633
18	13	935	0	16	10	2	3	0	0	0	129	1849	0	8	2965
TOTAL	44176	90324	15	37825	133	1462	1361	2007	15	108	129	1849	1684	638	181726

Table 3. *ECOCADIZ-RECLUTAS 2021-10* survey. Cont'd.

Fishing haul	CATCH IN WEIGHT (kg)														
	Anchovy	*Sardine*	*Round sardin.*	*Chub mack.*	*Mackerel*	*Blue Jack mack.*	*Horse-mack.*	*Medit. Horse-mack.*	*Atlantic pomfret*	*Bogue*	*Boarfish*	*Snipefish*	*Pearlside*	*Other spp.*	**TOTAL**
01	15,780	0,022	0	0	0	0	0	0	0	0	0	0	0	0,089	**15,891**
02	0	0	3,220	89,325	0	0	0	49,020	0	5,700	0	0	0	0,090	**147,355**
03	0	0	0	0,422	0	0	0,432	17,636	0	0	0	0	0	27,855	**46,345**
04	0	0	0	0	0	0	0	0	0	0	0	0	0	49,850	**49,850**
05	2,790	37,940	0	0,277	0	0	0	38,880	0	0,800	0	0	0	6,935	**87,622**
06	118,21	5,740	0	0	0,615	0	0	0	0	0	0	0	0	5,435	**130,000**
07	0	14,600	0,380	9,386	0	0	0,902	182,860	0	0,109	0	0	0	14,186	**222,423**
08	21,860	0,352	0	0,235	0,730	0	0	0	0	0	0	0	0	0,338	**23,515**
09	10,340	6,080	0,112	194,720	0	0	0,070	87,990	0	0,735	0	0	0	14,484	**314,531**
10	156,310	0	0	0	0,270	0	0	0	6,205	0	0	0	0	0,018	**162,803**
11	2,0150	11,690	0	4,230	0	0	0,230	6,765	0	0,070	0	0	0	2,532	**27,532**
12	2,048	4527,074	0	13,880	0	0	0,261	5,772	0	2,113	0	0	0	3,719	**4554,867**
13	1,678	324,842	0	3806,339	0	24,425	2,349	0	0	1,431	0	0	0	1,101	**4162,165**
14	17,130	0	0	2,830	1,115	1,330	4,950	0	0	0,405	0	0	1,620	2,743	**32,123**
15	17,600	0	0	0,083	2,530	0	0	0	0,400	0	0	0	0	0,066	**20,679**
16	1,230	359,620	0	37,650	1,470	40,600	105,910	0	0	4,045	0	0	0	6,283	**556,808**
17	192,260	0	0	6,675	10,945	0,059	26,020	0	0	0,390	0	0	0	1,391	**237,740**
18	0,430	69,460	0	1,633	1,228	0,175	0,405	0	0	0	0,962	18,705	0	3,305	**96,303**
TOTAL	**559,681**	**5357,420**	**3,712**	**4167,685**	**18,903**	**66,589**	**141,529**	**388,923**	**6,605**	**15,798**	**0,962**	**18,705**	**1,620**	**140,42**	**10888,552**

Table 4. *ECOCADIZ-RECLUTAS 2021-10* survey. Parameters of the size-weight relationships for the survey's target species susceptible of being assessed. FAO codes for the species: ANE: *Engraulis encrasicolus*; PIL: *Sardina pilchardus*; VAM: *Scomber colias*; MAC: S. *scombrus*; JAA: *Trachurus picturatus*; HOM: *T. trachurus*; HMM: *T. mediterraneus*; BOG: *Boops boops*; POA: *Brama brama*; BOC: *Capros aper*; SNS: *Macroramphosus scolopax*; MAV: *Maurolicus muelleri*.

Parameter	ANE	PIL	SAA	VAM	MAC	JAA	HOM	HMM	POA	BOG	BOC	SNS	MAV
Size range (mm)	27 - 193	104 - 216	260 - 344	182 - 374	240 - 357	162 - 232	69 - 308	200 - 415	342 - 400	181 - 345	91 - 141	54 - 90	35 - 55
n	685	464	13	406	101	128	180	301	14	85	150	129	151
a	0.003213570	0.002008436	0.002717708	0.001264585	0.002786321	0.005100145	0.008084745	0.066215667	0.017383890	0.006246972	0.005225102	0.027534889	0.037865257
b	3.250660	3.503799	3.311204	3.577470	3.296999	3.133309	3.011662	2.386548	2.803991	3.144430	3.014743	2.856752	2.086193
r^2	0.9947721	0.9607988	0.8205893	0.9885517	0.9343625	0.9502970	0.9817678	0.9156734	0.8094138	0.9726588	0.8784573	0.9309560	0.7588735

Table 5. *ECOCADIZ-RECLUTAS* surveys series. Anchovy (*E. encrasicolus*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cadiz anchovy population and for the juvenile fraction (*i.e.* age 0 fish, between parentheses). Note that the 2012 survey only surveyed the Spanish waters. The 2017 estimates correspond to an incomplete coverage (only the seven easternmost transects) of the standard surveyed area due to a research vessels' breakdown. Estimates from the 2021 survey are not yet available.

Estimate/Year	Total Population (Recruits at age 0)							
	2012	2014	2015	2016	2017	2018	2019	2020
Biomass (t)	13680 (13354)	8113 (5131)	30827 (29219)	19861 (15969)	7642 (7290)	10493 (3834)	48357 (36405)	36070 (21060)
Abundance (millions)	2469 (2619)	986 (814)	5227 (5117)	3667 (3445)	1492 (1433)	953 (543)	5505 (4845)	3197 (2385)

Table 6. *ECOCADIZ-RECLUTAS* surveys series. Sardine (*Sardina pilchardus*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cadiz anchovy population and for the juvenile fraction (*i.e.* age 0 fish, between parentheses). Age-0 estimates for 2020 not yet available. Note that the 2012 survey only surveyed the Spanish waters. The 2017 estimates correspond to an incomplete coverage (only the seven easternmost transects) of the standard surveyed area due to a research vessels' breakdown. Estimates from the 2021 survey are not yet available.

Estimate/Year	Total Population (Recruits at age 0)							
	2012	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Biomass (t)	22119 (9182)	36571 (705)	30992 (8645)	35173 (21899)	12119 (8778)	20679 (15224)	36465 (7858)	208400 (49259)
Abundance (millions)	603 (359)	507 (26)	861 (509)	2379 (1940)	591 (483)	1134 (1036)	937 (384)	5451 (2454)

Table 7. *ECOCADIZ-RECLUTAS* surveys series. Chub mackerel (*Scomber colias*). Acoustic estimates of biomass (t) and abundance (million fish) for the whole Gulf of Cadiz anchovy population and for the juvenile fraction (*i.e.* age 0 fish, between parentheses). Note that the 2012 survey only surveyed the Spanish waters. The 2017 estimates correspond to an incomplete coverage (only the seven easternmost transects) of the standard surveyed area due to a research vessels' breakdown. Estimates from the 2021 survey are not yet available.

Estimate/Year	Total Population (Recruits at age 0)							
	2012	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Biomass (t)	11155 (n.a.)	17471 (n.a.)	5683 (n.a.)	13689 (n.a.)	11726 (n.a.)	6950 (n.a.)	26212 (5265)	22918 (2759)
Abundance (millions)	157 (n.a.)	148 (n.a.)	65 (n.a.)	297 (n.a.)	86 (n.a.)	108 (n.a.)	367 (88)	295 (51)
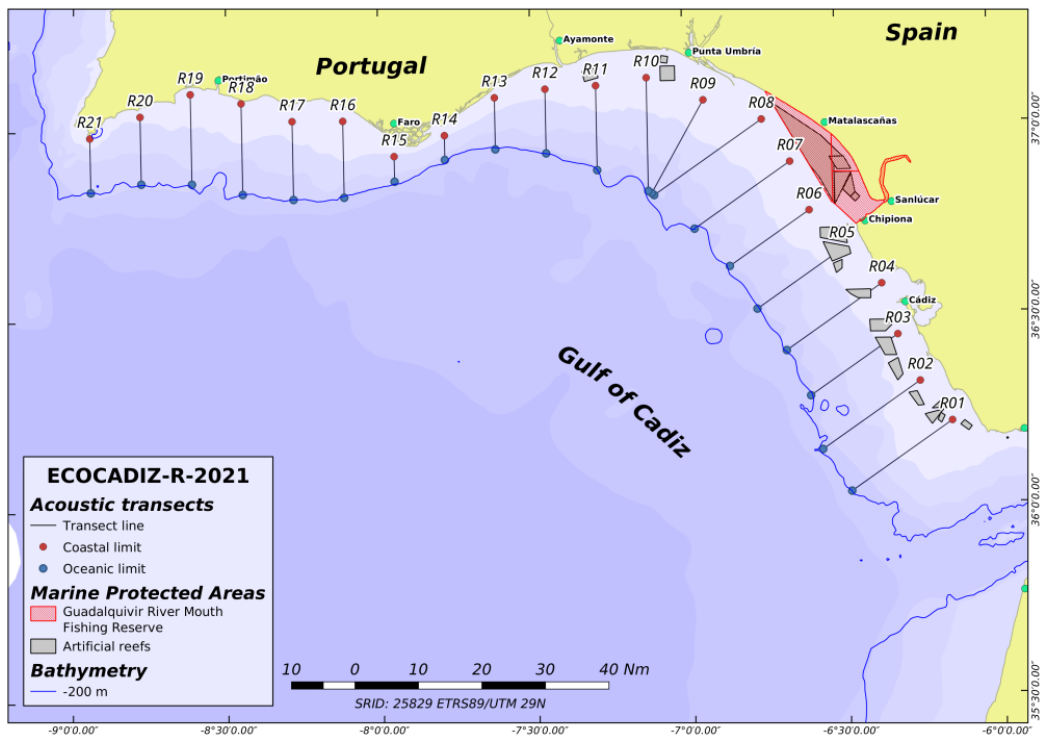
Figure 1. *ECOCADIZ-RECLUTAS 2021-10* survey. Location of the acoustic transects sampled during the survey. The different protected areas inside the Guadalquivir river mouth Fishing Reserve and artificial reef polygons are also shown.
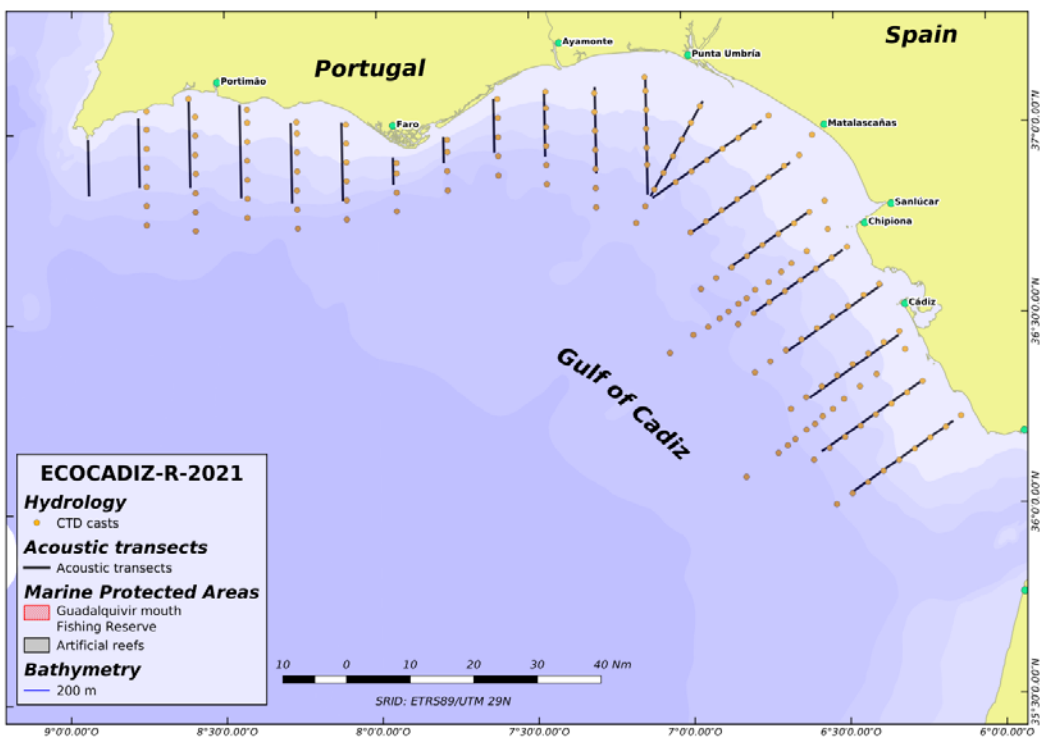
Figure 2. *ECOCADIZ-RECLUTAS 2021-10* survey. Location of CTD stations.
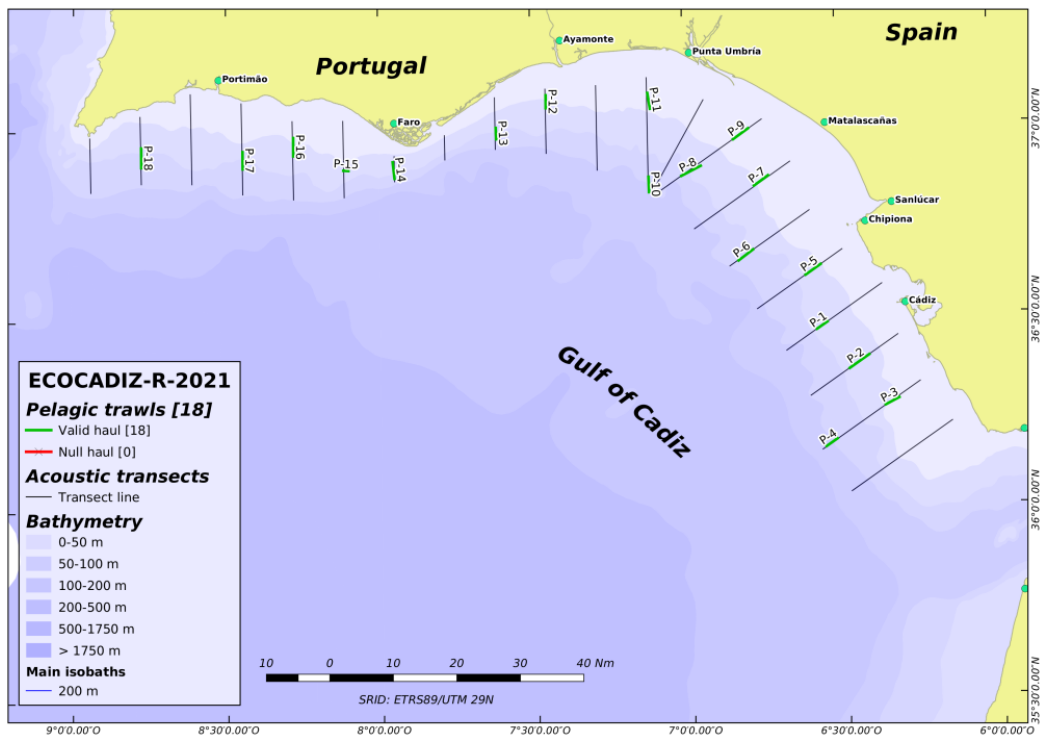
Figure 3. *ECOCADIZ-RECLUTAS 2021-10* survey. Location of ground-truthing fishing hauls.
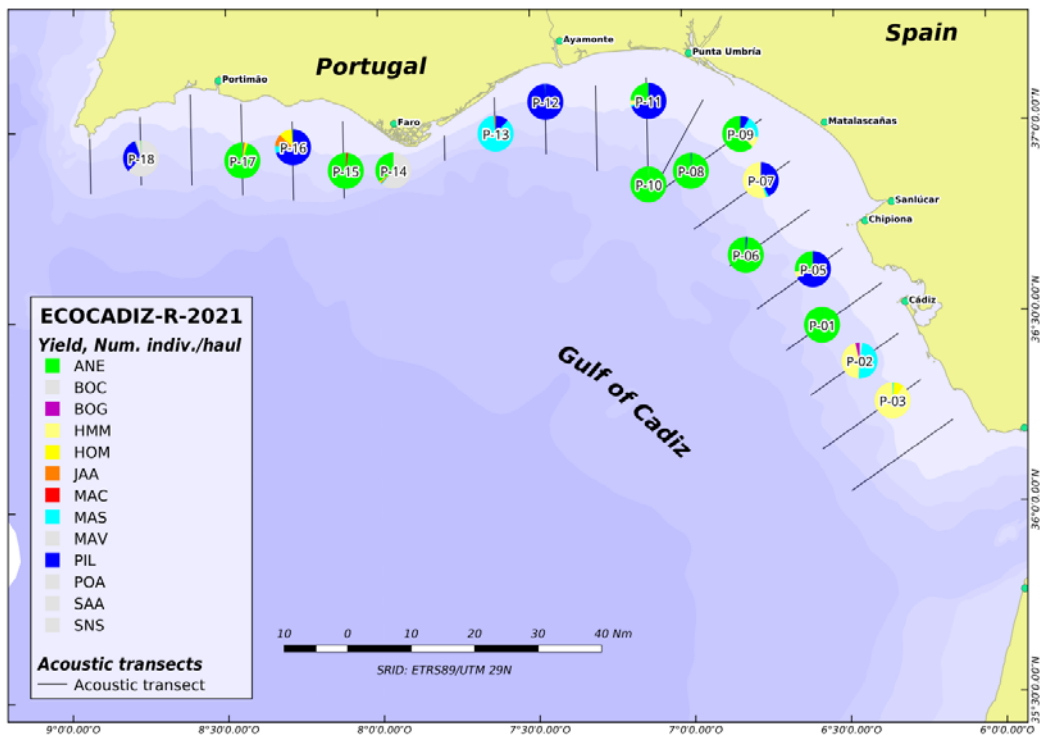
Figure 4. *ECOCADIZ-RECLUTAS 2021-10* survey. Species composition (percentages in number) in valid fishing hauls.
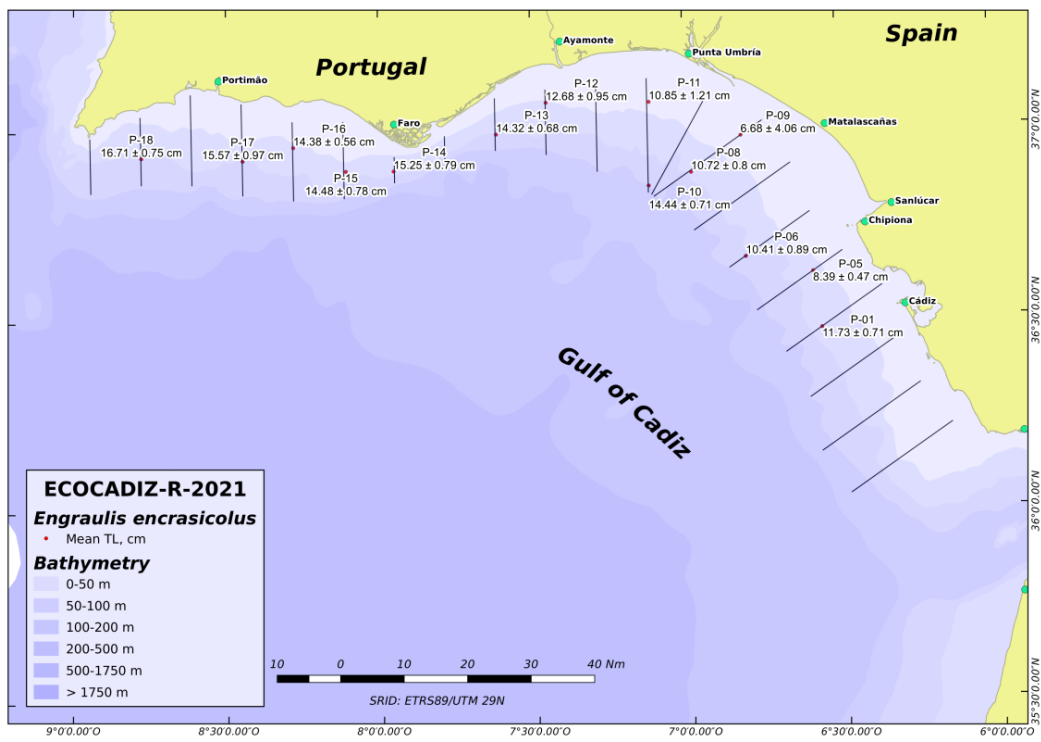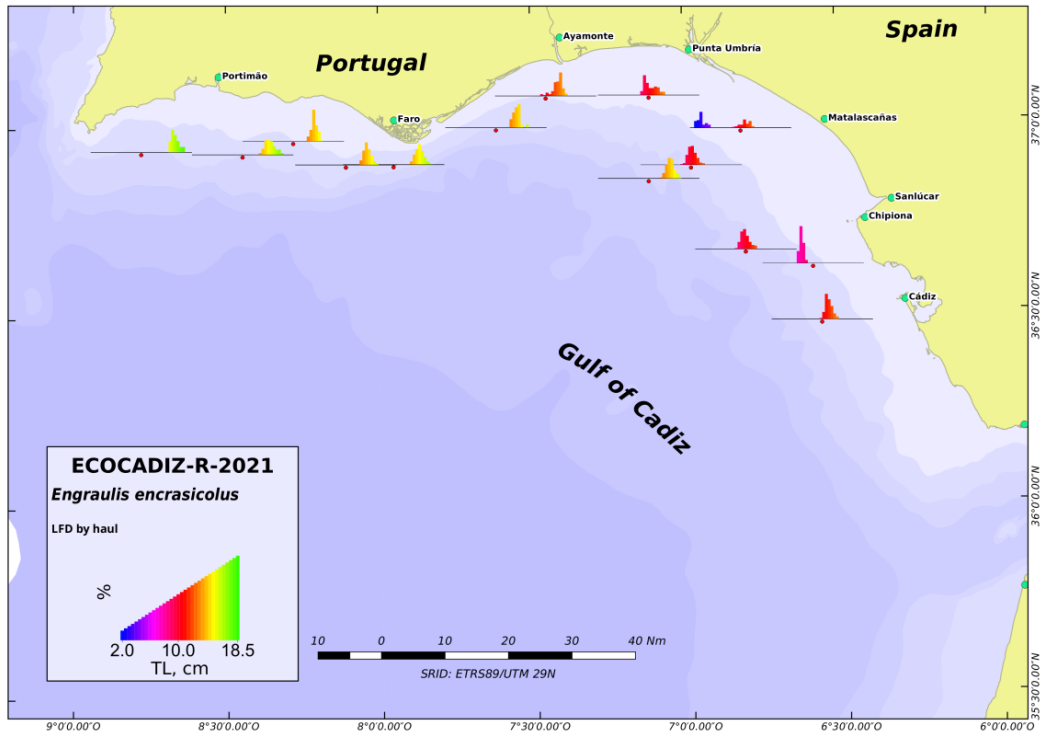
Figure 5. *ECOCADIZ-RECLUTAS 2021-10* survey. Anchovy (*Engraulis encrasicolus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
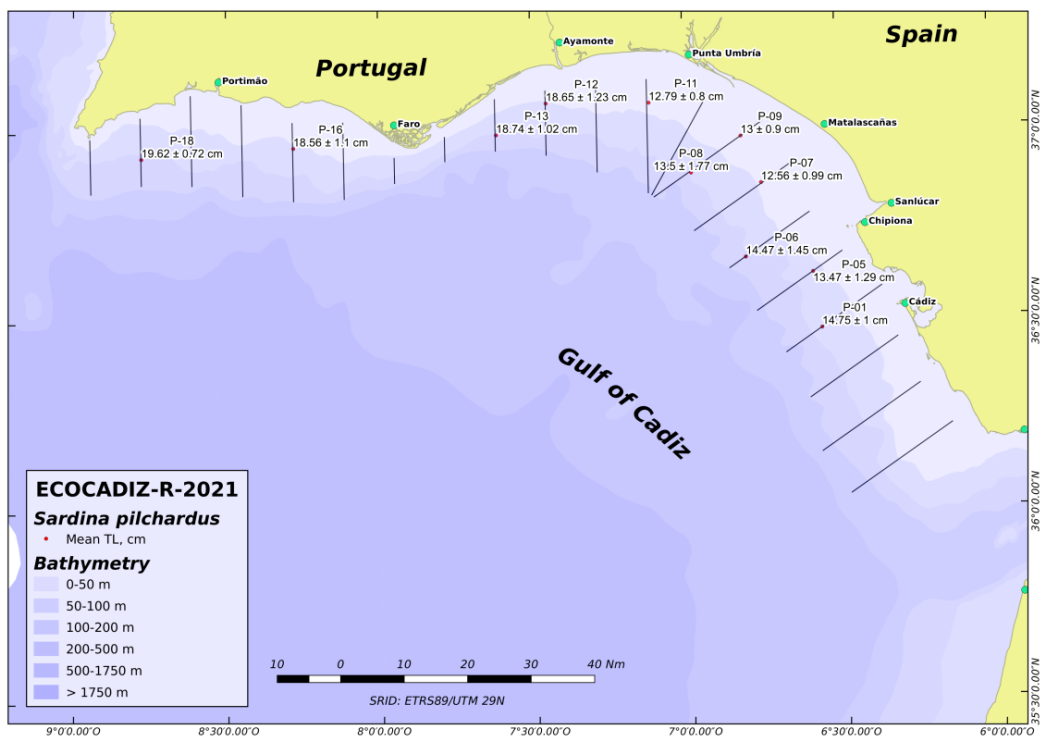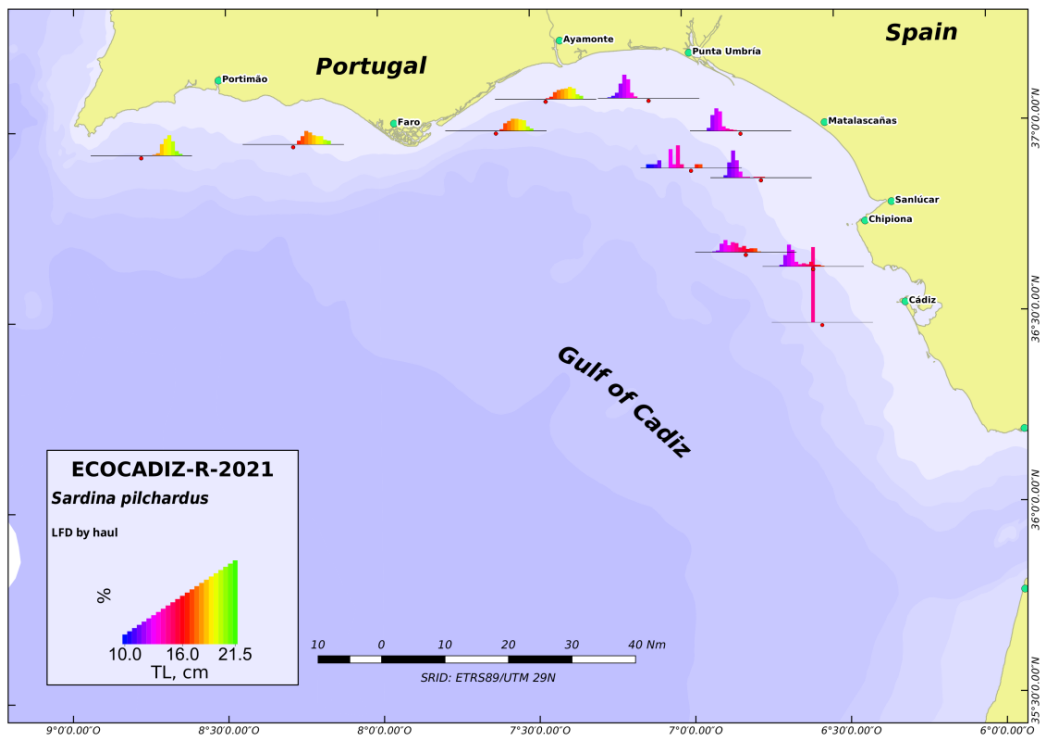
Figure 6. *ECOCADIZ-RECLUTAS 2021-10* survey. Sardine (*Sardina pilchardus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
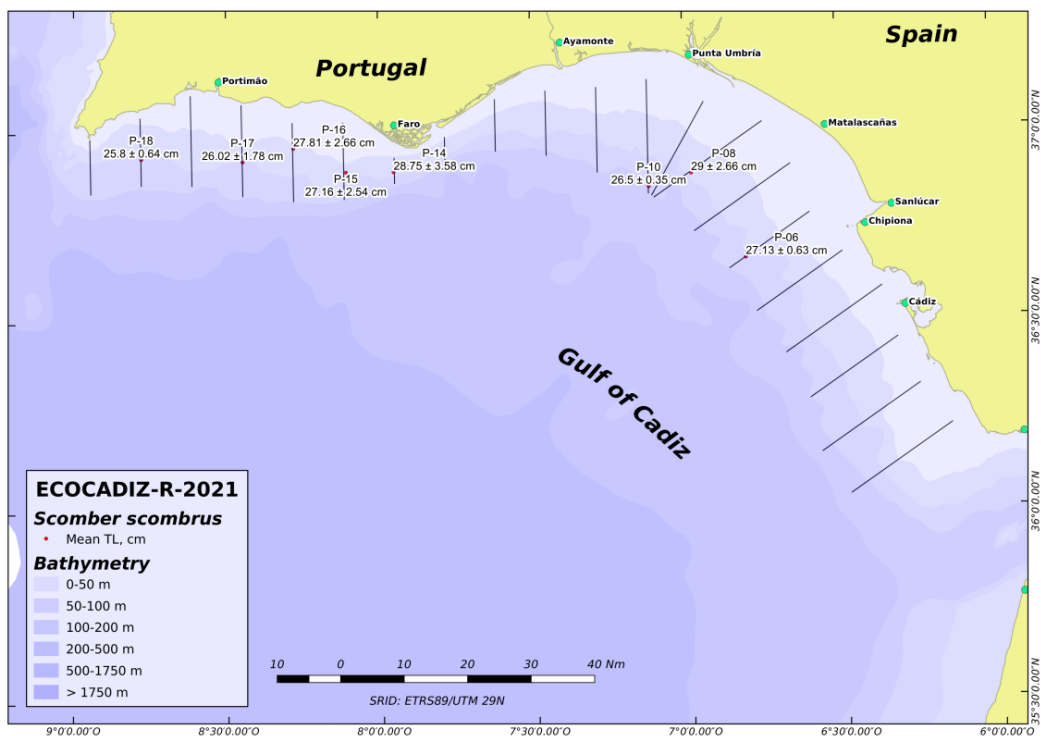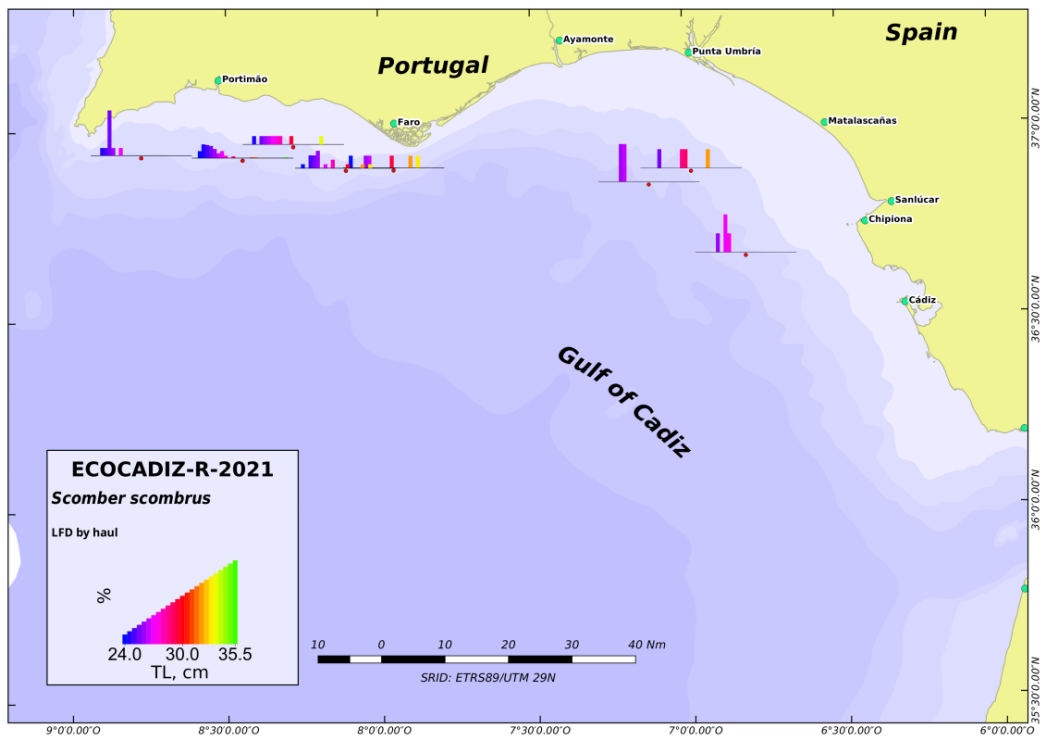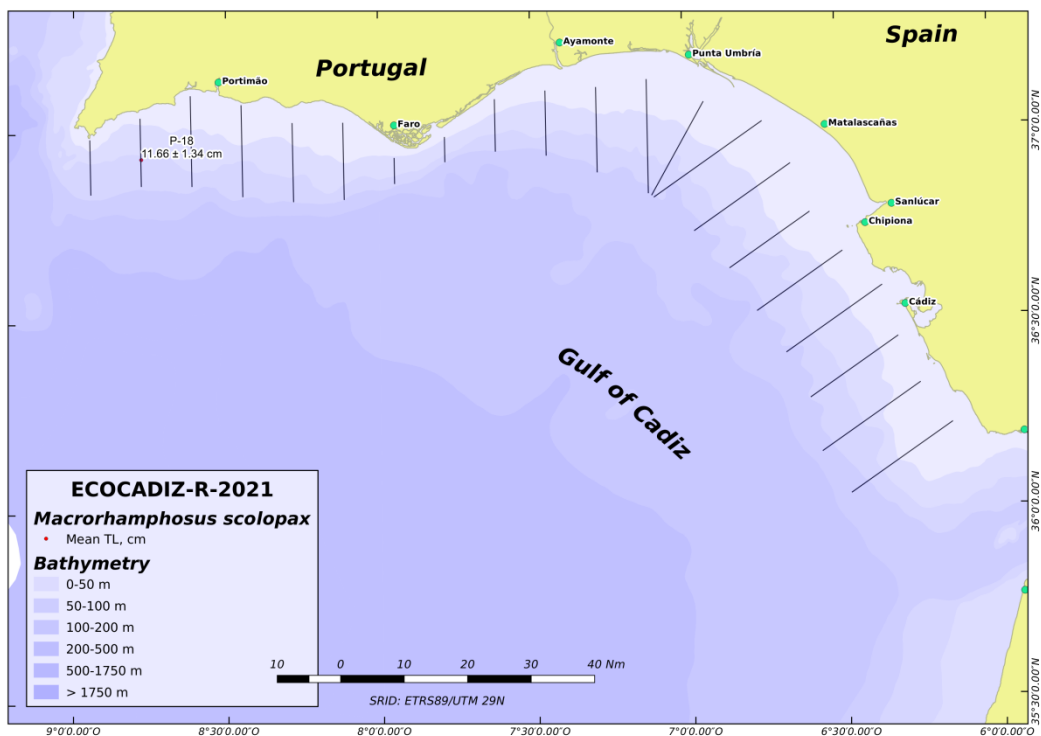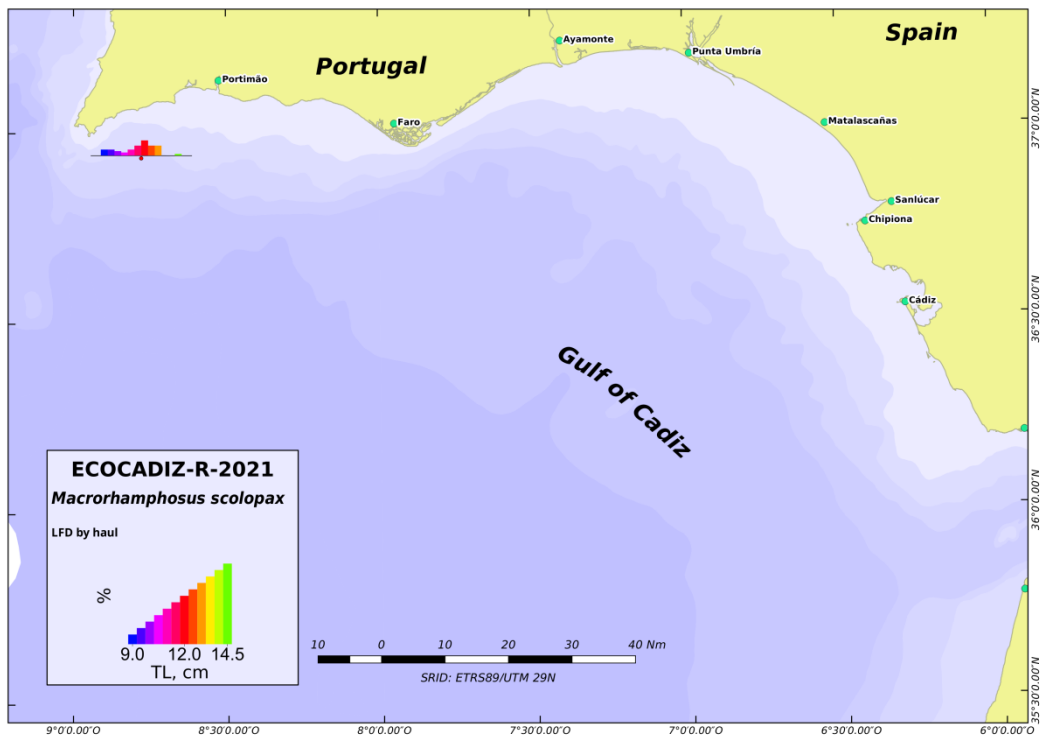
Figure 7. *ECOCADIZ-RECLUTAS 2021-10* survey. Atlantic mackerel (*Scomber scombrus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
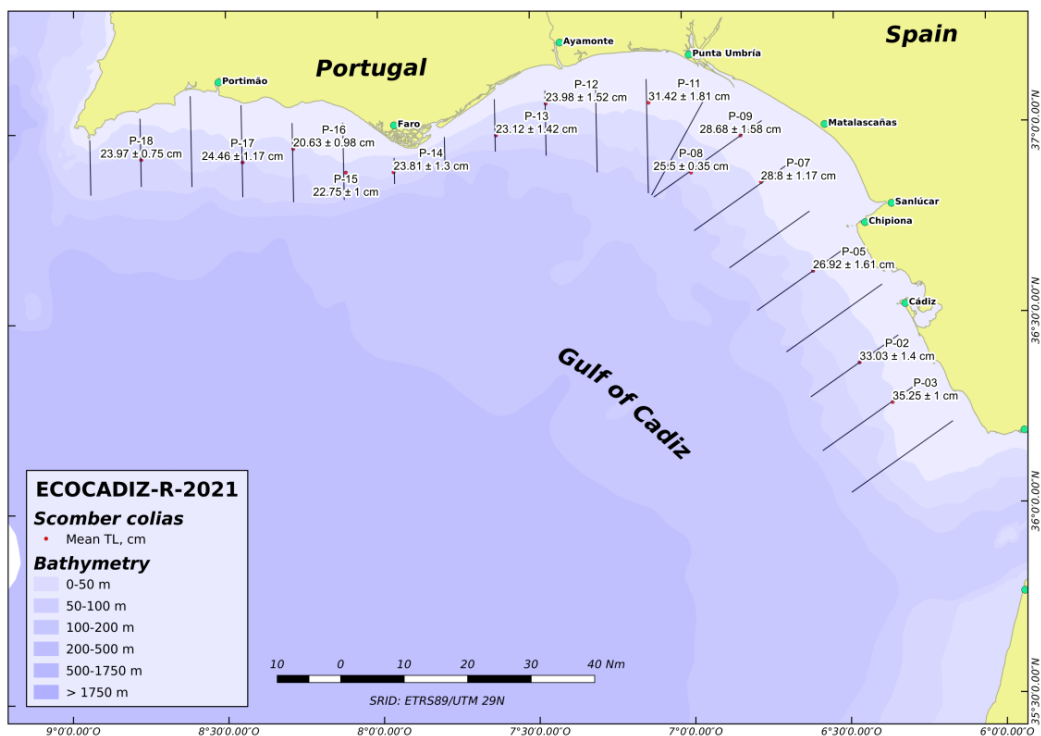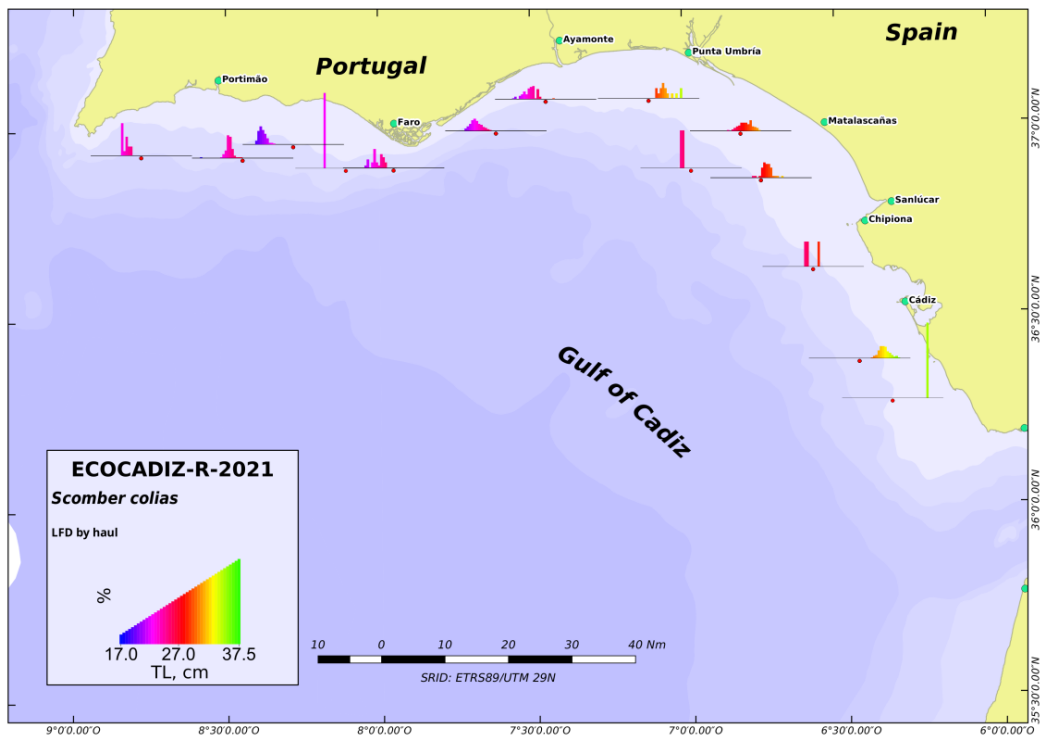
Figure 8. *ECOCADIZ-RECLUTAS 2021-10* survey. Chub mackerel (*Scomber colias*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
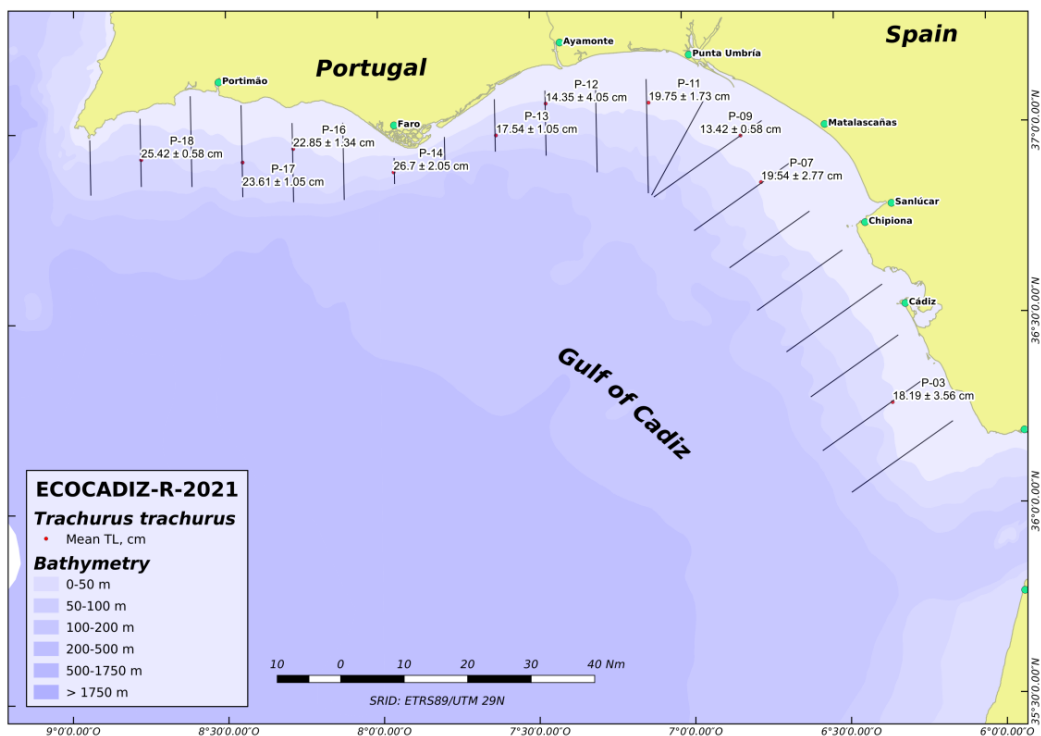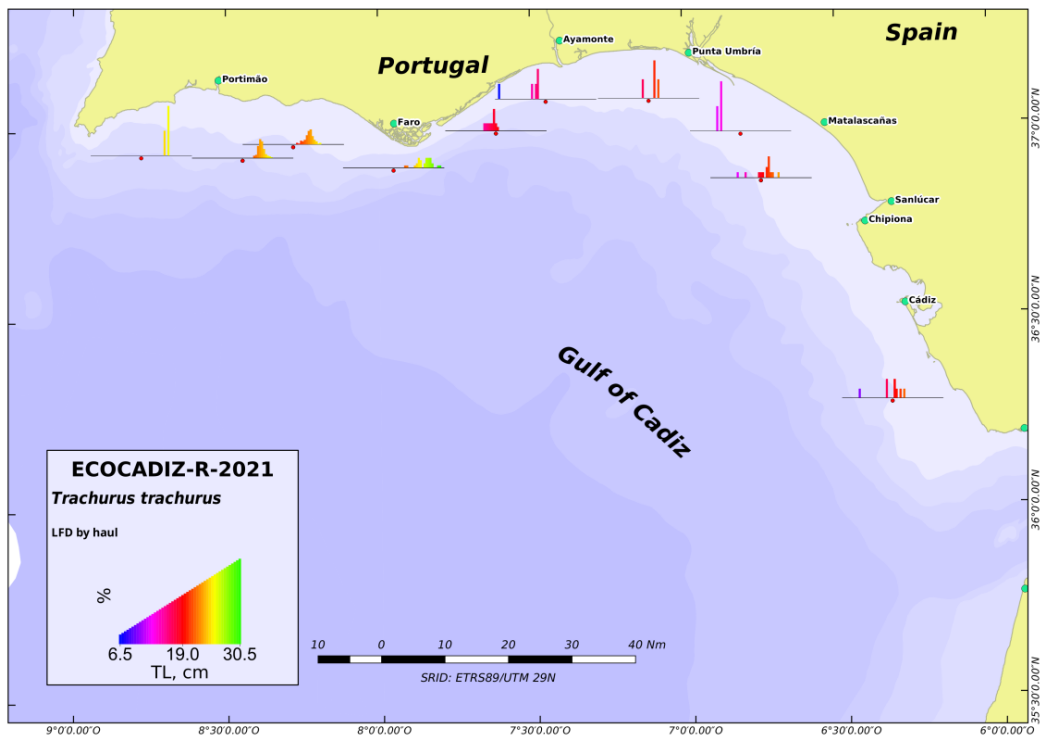
Figure 9. *ECOCADIZ-RECLUTAS 2021-10* survey. Horse mackerel (*Trachurus trachurus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
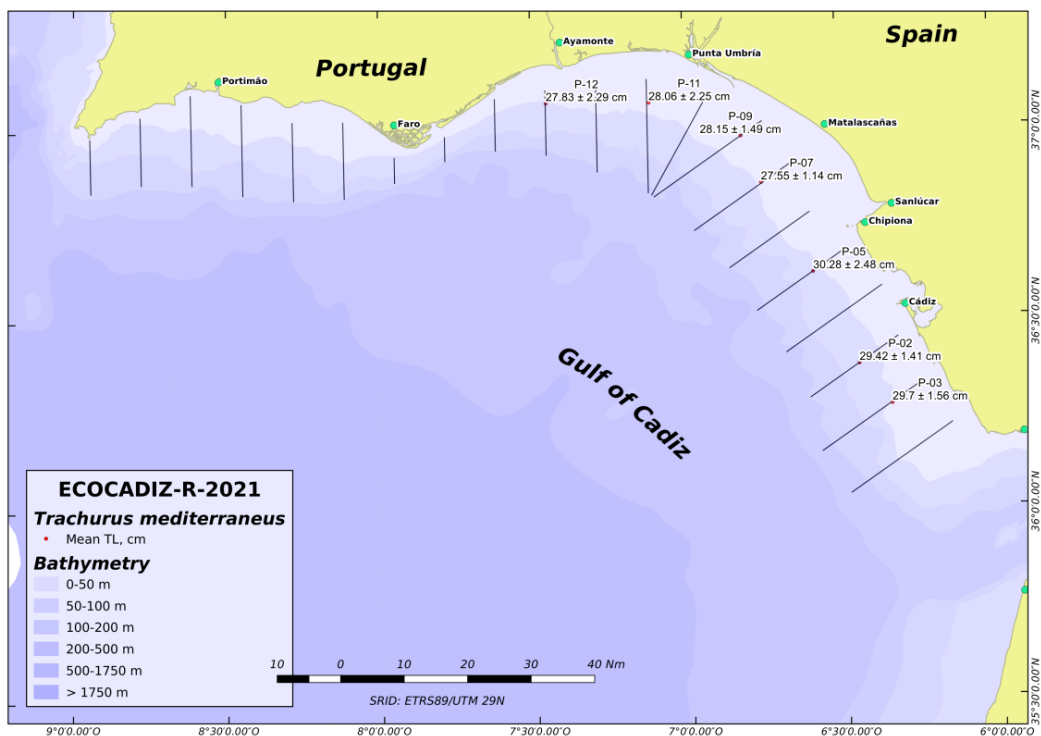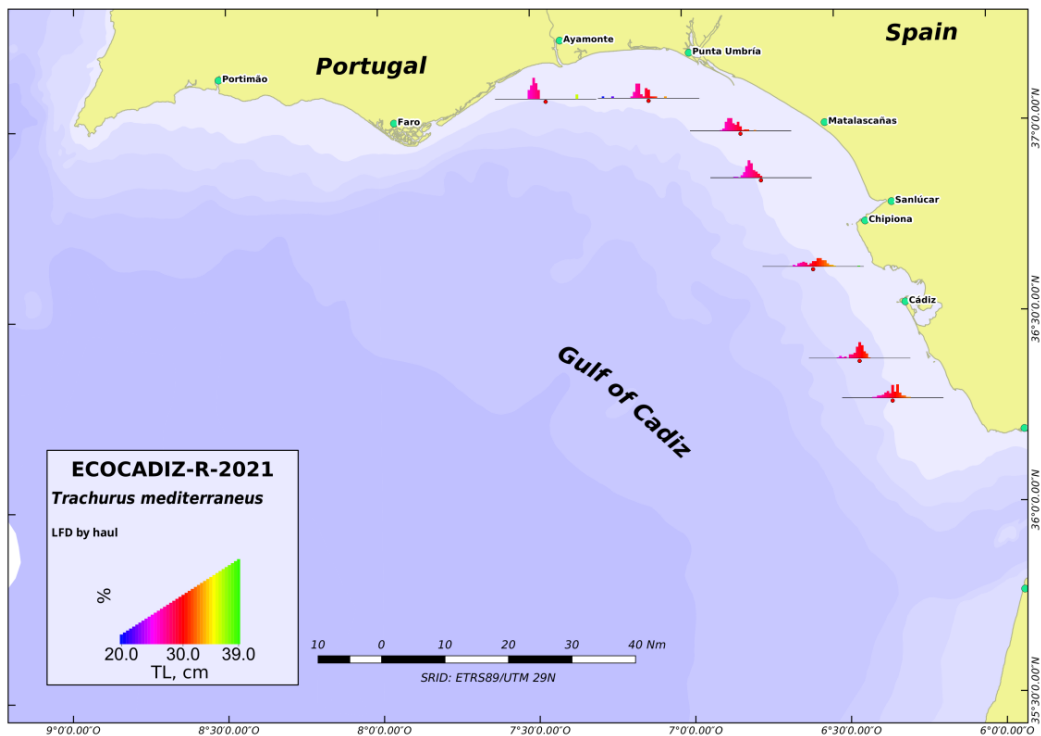
Figure 10. *ECOCADIZ-RECLUTAS 2021-10* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
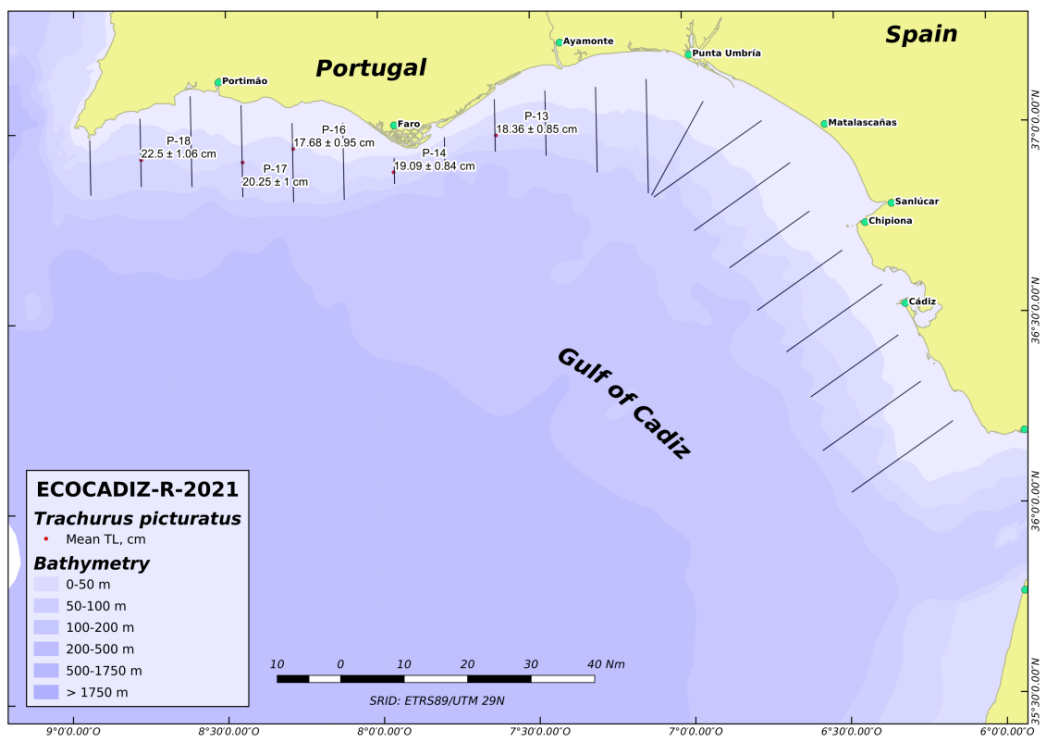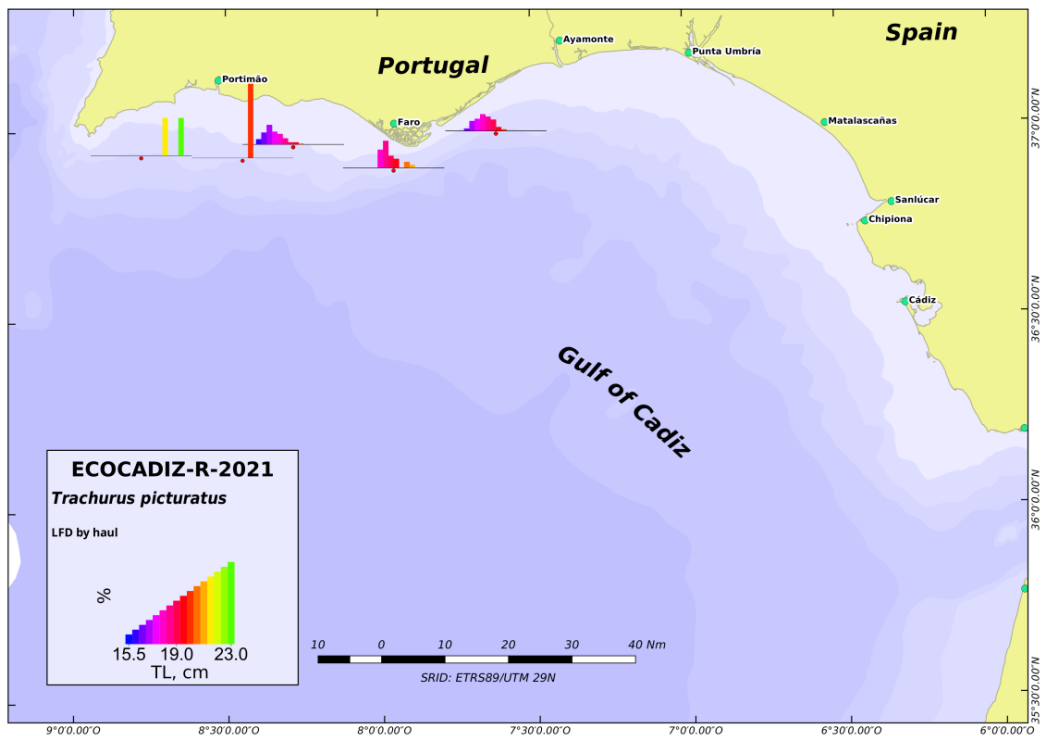
Figure 11. *ECOCADIZ-RECLUTAS 2021-10* survey. Blue jack mackerel (*Trachurus picturatus*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
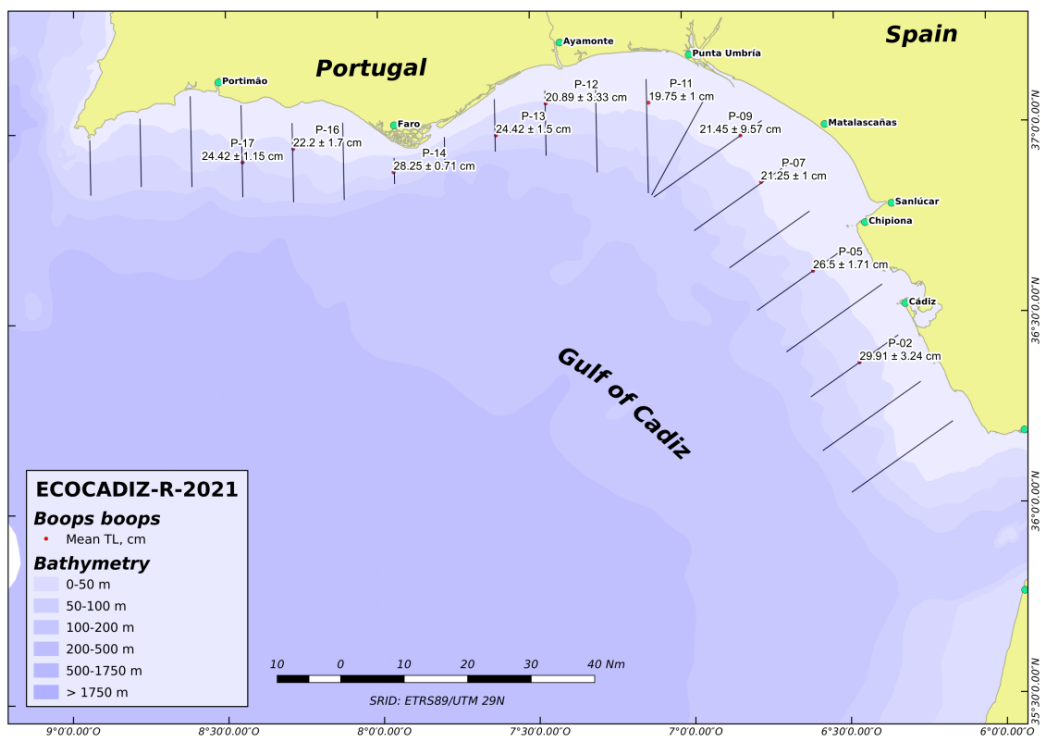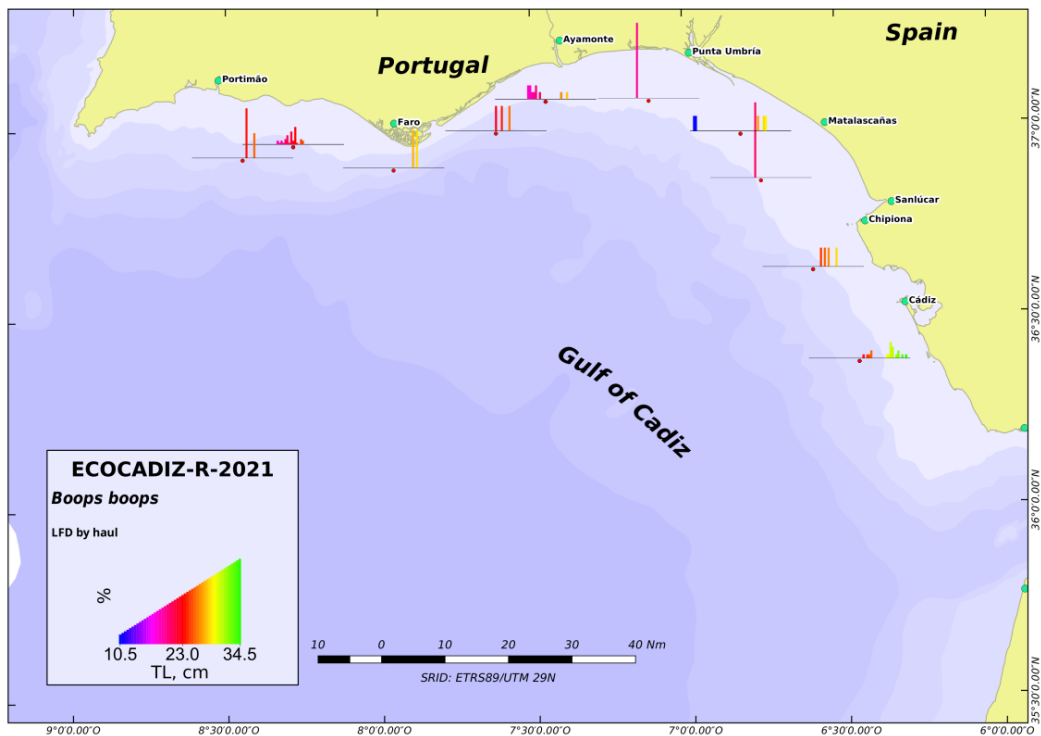
Figure 12. *ECOCADIZ-RECLUTAS 2021-10* survey. Bogue (*Boops boops*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
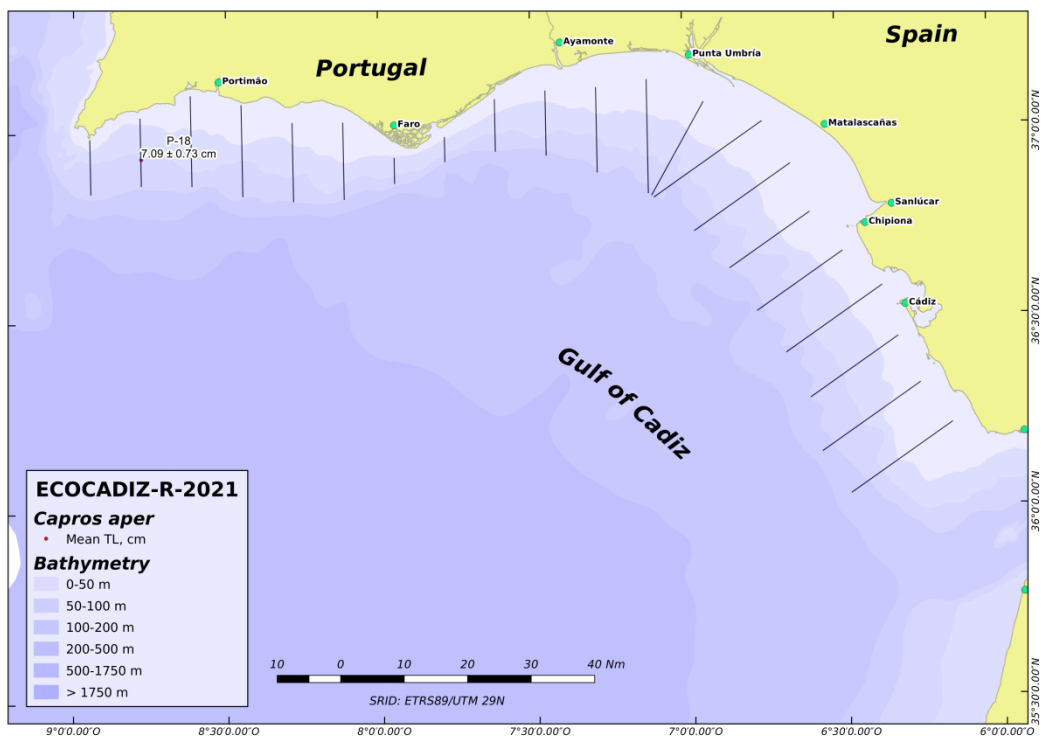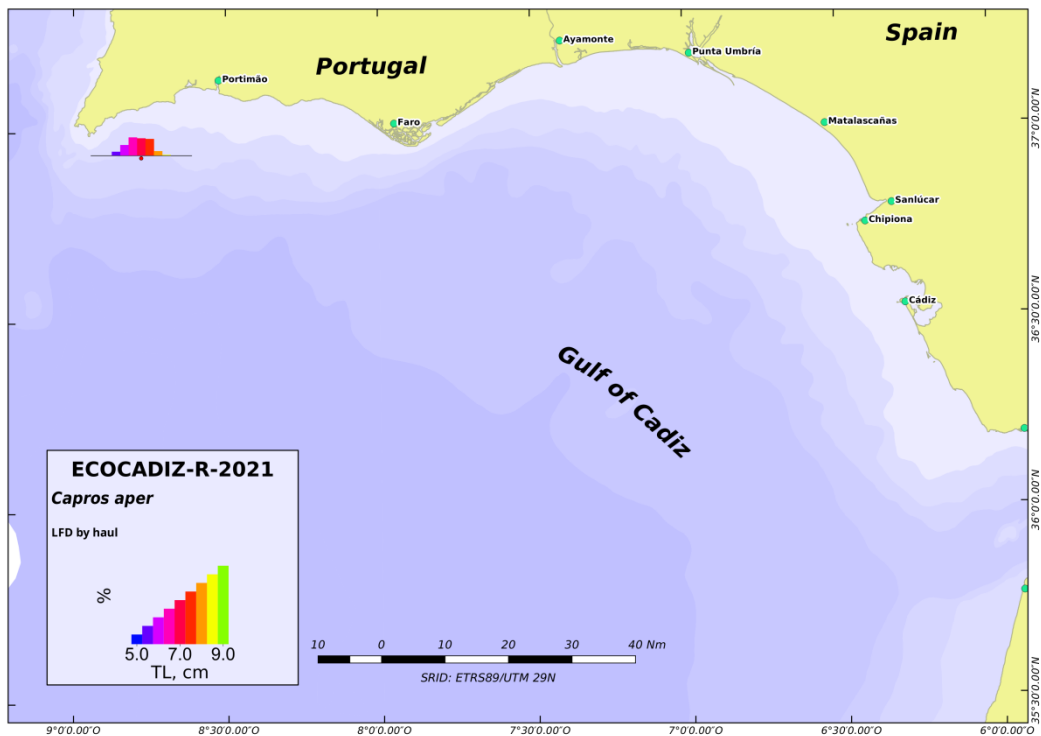
Figure 13. *ECOCADIZ-RECLUTAS 2021-10* survey. Boarfish (*Capros aper*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

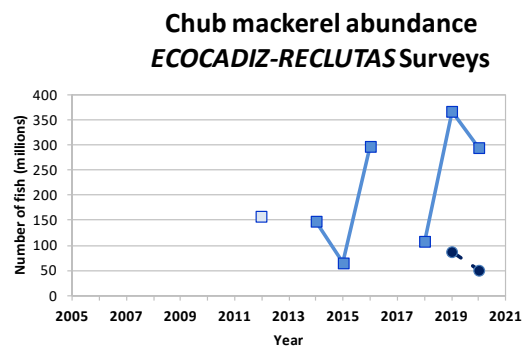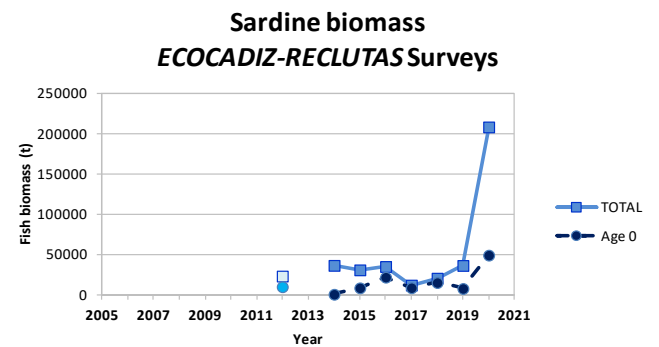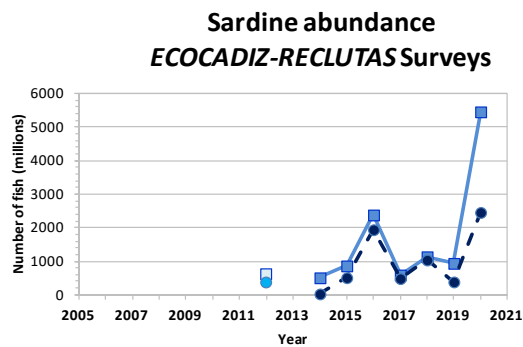**Figure 14.** *ECOCADIZ-RECLUTAS 2021-10* survey. Longspine snipefish (*Macroramphosus scolopax*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
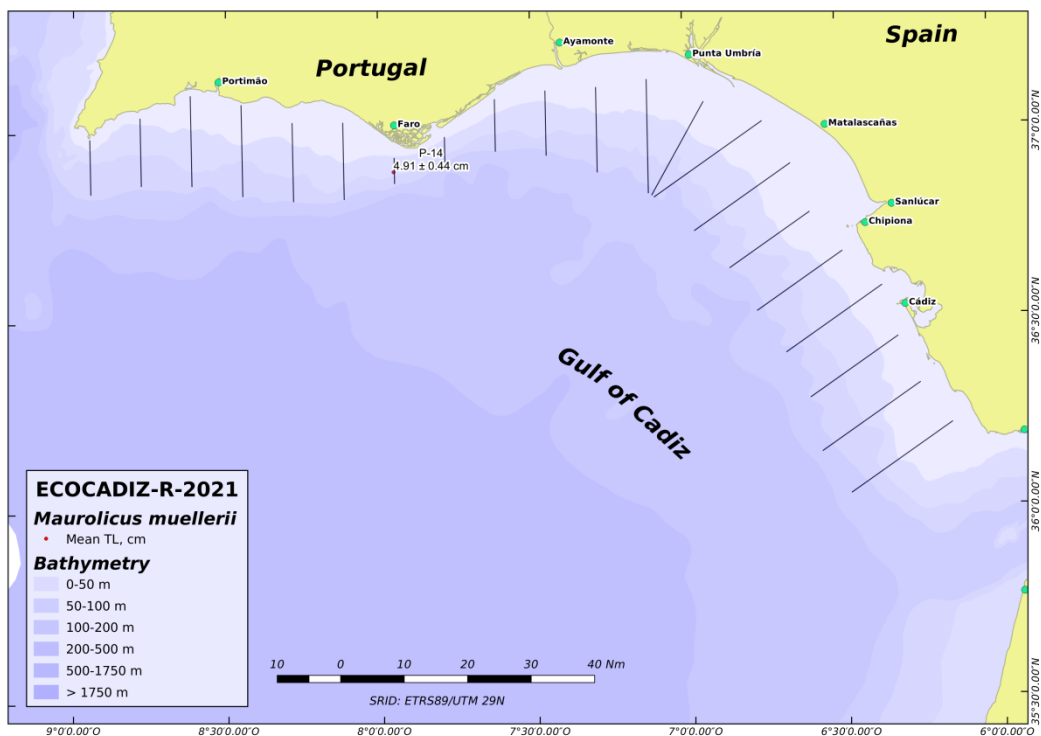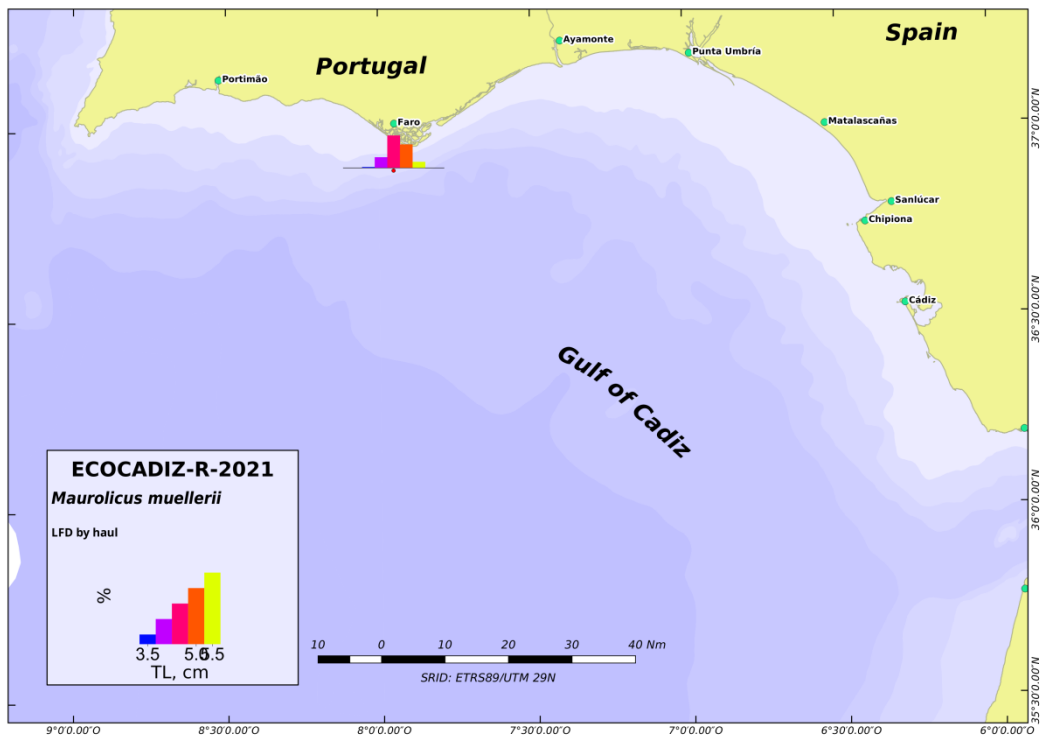
Figure 15. *ECOCADIZ-RECLUTAS 2021-10* survey. Pearlside (*Maurolicus muelleri*). Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.
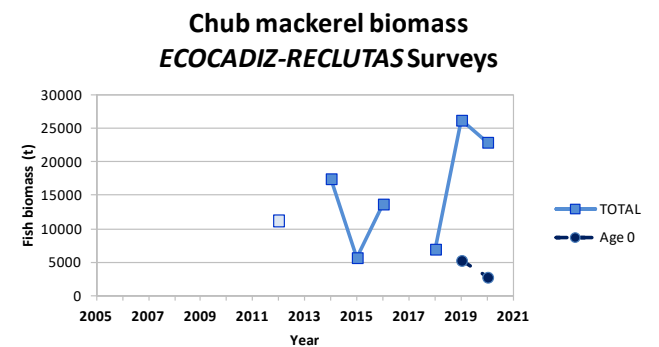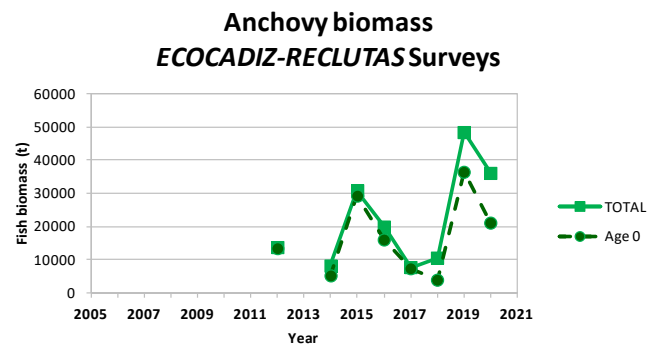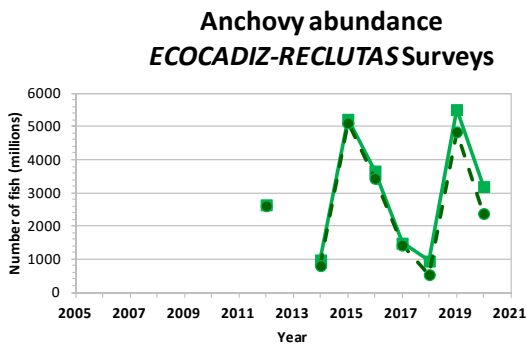
Figure 16. *ECOCADIZ-RECLUTAS* surveys series. Historical series of autumn acoustic estimates of anchovy, sardine and chub mackerel abundance (million) and biomass (t) in Sub-division 9.a South. The estimates correspond to the total population and age 0 fish. The 2012 survey only surveyed the Spanish waters. No survey was conducted in 2013. Although a survey was conducted in 2017, the survey was interrupted for a serious breakdown of the vessel's propulsion system and no estimates were computed. The 2018 estimates should be considered with caution because a possible under-estimation. Age data for chub mackerel started to be available since 2019 on. Estimates from the 2021 survey are not yet available.