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WP3 - Proposal of coordinated subregional assessment, GES determination and monitoring strategy for cetacean bycatch.

Deliverable 3.4.1. Improvement of observer programmes

CetAMBICion

Coordinated Cetacean Assessment,
Monitoring and Management Strategy
in the Bay of Biscay and Iberian Coast sub-region

Workpackage 3 Subtask 3.4.1

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Coordinated Cetacean Assessment, Monitoring and Management Strategy in the Bay of Biscay and Iberian Coast sub-region (CetAMBICion).

The CetAMBICion project, coordinated by the Spanish National Research Council (CSIC) and which includes 15 partners from Spain, France and Portugal, aims to strengthen collaboration and scientific work between the three countries to estimate and reduce cetacean bycatch in the Bay of Biscay and Iberian Coast ecoregion, in close collaboration with the fishing sector. Until 2023, the project will work to improve scientific knowledge on population abundance, incidental bycatch and on mitigation measures of the latter.

The project is part of the European Commission's DG ENV/MSFD 2020 (Marine Strategy Framework Directive) call and the objectives are aligned with the Habitats Directive and the Common Fisheries Policy.

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Glossary

Cetacean bycatch observer programme: scientific programme on board the commercial fleet specially dedicated to the record of cetacean bycatch.

DCF at-sea sampling programme: scientific programme on board the commercial fleet belonging to the DCF pan-European programme, aimed at discard sampling, but which also includes the record of the bycatch of vulnerable species since 2017.

Domain: segment of the population for which separate statistics are needed. Here we used a combination of sampling strata (metier DCF Level 4) and ICES Division.

Drop-out: phase of the fishing operation with unintentional release of the catch from the fishing gear before it is fully loaded on board the fishing vessel.

Number of incidents: hauls with positive cetacean bycatch, regardless of the number of individuals.

Observation rate: ratio between direct observation by scientific observer in relation to total fishing activity. This includes the percentage of observed fishing phases, especially the "slipping" and "drop-out" phases, as well as the number of hauls directly observed.

Pair factor: specific ratio for pair trawlers. Consist of the division between the number of hauls directly observed by the scientific observer and the total number of hauls developed during the trip. This ratio is 0.5 in trips where the holds of both vessels are filled, but it is close to 1 in coastal fisheries where mostly only one of the vessels fills its hold.

Potential Biological Removal: limit to the allowable human-caused mortality of cetaceans; calculated as the product of a minimum population estimate, one-half of the maximum net productivity rate, and a recovery factor (Wade, 1998).

Pre-sorting: phase of the fishing operation in which catch is left on deck after the gear is brought on board without entering the commercial catch classification process.

Sampling coverage: percentage of number of sampled units in relation to total population. For PSU, number of vessels sampled divided by total, and for SSU, number of trips sampled divided by total.

Sampling effort: number of sampling units. i.e. number of sampled unique vessels (PSU) or sampled trips (SSU).

Slipping: phase of the fishing operation with intentional release of specimens from the fishing gear before it is fully loaded on board the vessel.

Sorting: phase of the fishing operation where classification of the catch on the deck, conveyor belt or classification platform is carried out.

Acronyms

BPUE: Bycatch per unit of effort.

CV: coefficient of variation.

d: dispersion index, calculated as variance/mean ratio of BPUE from the observed data.

DCF: Data Collection Framework (https://datacollection.jrc.ec.europa.eu/).

GNS: set gillnets fleet/métier (only large-scale set gillnets in this deliverable).

ICES: International Council for the Exploration of the Sea.

MOCL1: minimum sampling coverage level to achieve 95% probability of observing any bycatch when bycatch occurs.

MOCL2: minimum sampling coverage level to achieve a 95% upper confidence limit no higher than the mPRB of *Delphiuns delphi* when no bycatch has been observed.

MOCL3: minimum sampling coverage level to achieve an estimation CV of 0.3.

mPRB: modified Potential Biological Removal (PBR), which is the PBR control rule tuned to maintain a population at 80% of carrying capacity, with probability 0.8, within a 100-year period (OSPAR, 2021).

PSU: Primary sampling unit.

PTB: Pair bottom trawl fleet/métier.

R: free software environment for statistical computing and graphics (https://www.r-project.org/).

SRSWR: Simple Random Sampling with Replacement.

SSU: Secondary sampling unit.

Executive summary

The objective of Subtask 3.4.1 of the project CetAMBICion is the evaluation of the DCF at-sea sampling programmes enhanced in 2017 through the inclusion of the monitoring of by-catch of non-target protected species. More precisely, to analyse the adequacy of their design and protocols for the purpose of monitoring of by-catch of non-target protected species.

For this, a case study was chosen to compare the data provided by the Spanish DCF at-sea sampling programme to the ICES "Working Group on Bycatch of Protected Species" (WGBYC) with the new data collected by the Spanish cetacean bycatch observer programme, specially designed to correct the possible deficiencies of the DCF programmes in the monitoring of incidental catch of cetaceans. For this, the data of the new Spanish cetacean bycatch observer programme were analyzed to explore the following issues: a) representativeness of the sampling frame; b) estimation of bycatch per unit of effort (BPUE); c) sampling coverage; and d) optimization of the sampling protocol.

The results obtained allow to conclude that the current Spanish European DCF at-sea sampling programme (which include the sampling of by-catch of non-target protected species) and the cetacean bycatch observer programmes provide similar results of non-target protected species for some of the ICES Divisions and métiers monitored. However, the monitoring of marine mammal bycatch requires certain specificities that must be considered in the design of a DCF programme if it is to monitor by-catch of non-target protected species, such as: probabilistic sampling design with record of refusals to allow bias analysis; sampling effort calculated for each fleet or *métier*; quantification of direct observation rate to allow the coverage of each phase of fishing operation, as well as the actual coverage of the pair trawl fleet's activity; in addition, optimization of the workload on board, eliminating secondary tasks that are not priority.

In relation to achieving the high levels of sampling effort and/or coverage necessary for the proper estimation of the bycatch of rare events, it is necessary to deepen the combination of monitoring based on scientific observers at sea with other alternative methodologies, such as the use of electronic monitoring, improvement of recording of bycatch in official control logbooks, dedicated logbooks recorded by vessel crew observers and/or questionnaires by port observers (see Deliverable from task 3.4.3 of the project), as well as identify those periods or areas where sampling coverage should be intensified.

1 INTRODUCTION

The EU Technical Conservation Measures Regulation (Regulation (EU) 2019/1241), which repealed and replaced the Council Regulation on measures concerning incidental catches of cetaceans in fisheries (Council Regulation (EC) 812/2004), included three main objectives: (i) to minimise, and where possible eliminate, incidental catches of sensitive species so that fishery-related mortality does not represent a threat to their conservation status; (ii) to minimise negative impacts of fishing on marine habitats, and (iii) to put in place management measures to comply with the Habitats, Birds, Water Framework and Marine Strategy Framework Directives. The measures cited in the third objective shall ensure that bycatches of sensitive species do not exceed levels established in the Union legislation and international agreements. Furthermore, Member States (MS) are required to take the necessary steps to collect data on these species.

ICES, through its agreement with DG-MARE, is the organization in charge of providing annual estimates of the numbers of specimens of sensitive species (as defined in Article 6(8) of Regulation (EU) 2019/1241), caught incidentally in fishing activities in the EU, disaggregated by sea area and type of fishing gear. The work of the ICES Working Group on Bycatch of Protected Species (WGBYC) is driven mainly by this assignment.

The European Commission establishes multiannual programmes for the collection and management of biological, environmental, technical and socioeconomic data in the fisheries sector (Commission Delegated Decision (EU) 2021/1167; from 2022) in compliance with the Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy (namely the Data Collection Framework: DCF; Regulation (EU) 2017/1004). The collection of data on by-catch of non-target species, in particular species protected under Union or international law, by European fleets has been integrated in the DCF since 2017 (Commission implementing decision (EU) 2016/1251); thus, many MS have tried to improve their respective at-sea national sampling programmes to accommodate both goals.

However, experts have criticized limitations of the at-sea DCF sampling programmes regarding monitoring of bycatch of protected species, as many elements of these programmes (*e.g.* objectives, sampling design, protocols, sampling effort, and sampling coverage are usually established focusing on discards and commercial catches requirements which may result in their inadequacy for monitoring of by-catch of non-target protected species (ICES. 2019). The only comparative analysis developed by ICES WGBYC showed great differences between the bycatch rates derived from DCF at-sea sampling

programmes and an UK observer programme dedicated to the bycatch of cetaceans [ICES, 2019], concluding that the bycatch rates derived from the former may be underestimated and unsuitable for proper estimations.

In Spain, the DCF at-sea sampling programme was enhanced in 2017 through the inclusion of the monitoring of by-catch of non-target protected species. And an at-sea observer programme specifically dedicated to cetacean bycatch is carried out since October 2020 in the Bay of Biscay on the same metiers as the ones covered in the DCF at-sea sampling programme. The objective of the Subtask 3.4.1 of the project CetAMBICion is the evaluation of the DCF at-sea sampling programmes, namely of the adequacy of their sampling design, protocol and effort for the purpose of monitoring of by-catch of non-target protected species. A comparison between the bycatch rates provided by the two at-sea sampling programmes currently ongoing in Spain was made: the DCF at-sea sampling programme aimed at monitoring discards of commercial species, which also includes the bycatch of non-target protected species (e.g. cetaceans), and the Spanish observer programme specifically dedicated to cetacean bycatch.

1.1 Description of the Spanish on-board observer programmes

The Spanish DCF at-sea sampling programme and the Spanish cetacean bycatch observer programme are described in Deliverable 3.1 of the project CetAMBICion, in Section 3.1.2 and Section 3.2.2.1, respectively.

The two referred programmes from Spain are based on similar statistical designs, with random selection of sampling units (vessels and trips) as well as record of sampling refusals. The primary sampling unit (PSU) is the vessel, which is randomly selected by Simple Random Sampling with Replacement (SRSWR) from the official lists of boats with fishing license. The protocol followed for the selection of the PSU includes the recording of responses to calls, with record of refusals. Once the vessel has accepted, the most immediate trip to be carried out is sampled, which constitutes the secondary sampling unit (SSU) (see Deliverable 3.1 of CetAMBICion project for more details). In terms of hauls, which constitute the tertiary sampling unit, all those that make up the trip are sampled in their entirety in both sampling programmes (except in cases of force majeure), with the exception of the pair trawl fleet, where the observer only has access to the hauls boarded on the boat where she/he is.

Regarding the sampling protocol on board, both sampling programmes contemplate the sampling of sensitive species, that is, taxonomic identification and biometrics of marine mammals, birds, reptiles and vulnerable fish. Obviously, the DCF at-sea sampling

programme also records the taxonomy and biometrics of non-vulnerable species. The most relevant differences of the programme dedicated to cetacean bycatch comparatively to the DCF sampling programme concern:

- Sampling effort and coverage: at least double of the sampling effort and coverage than in the DCF sampling programme (which covers around 1 % of the total trips of the objective metiers).
- Expertise of scientific observers: scientific observers are selected taking into consideration their ability to identify protected species.
- Dedicated observation: scientific observers are concentrated only on the bycatch of non-target protected species; sampling of commercial species is not included in the sampling protocol.
- Observation of all phases of the fishing operation: unlike the DCF sampling programme, where only two phases that occur on board after hauling of net are observed (namely "pre-sorting" and "sorting"), the dedicated programme also covers the previous hauling phase (here split into "slipping" and "drop-out" phases, depending on whether specimens are intentionally or unintentionally released by fishers before boarding, respectively), which were always completely monitored.

Apart from the registration of events of incidental bycatch of cetaceans, the Spanish cetacean bycatch observer programme also included cetacean sighting, bycatch of other species protected or vulnerable not targeted by the metier (birds, turtles and fish from Table 1D of Commission implementing decision (EU) 2016/1251) and marine litter. The quality of this information, as well as its possible scientific interest and usefulness, are also evaluated in this deliverable.

2 MATERIALS AND METHODS

2.1 Data description

The analysis is carried out for the period from October 2020 to September 2021 using data collected by the Spanish cetacean bycatch observer programme. The fleets and métiers targeted were the Spanish large-scale (above 12m length overall) set gillnetters and Spanish bottom pair trawlers operating in the Bay of Biscay and Iberian Coast ecoregion (ICES Subarea 8 and 9, respectively Bay of Biscay and Portuguese waters). The small-scale fleet has not been considered, which can use gillnets in addition to a wide variety of fishing gears (longlines, hand lines, pots, dredges, etc.), due to scarce conditions to allow the boarding of scientific observers. Thus, the subsequent analyses were carried out on two fleet strata according to the fishing gear (i.e. metier Level 4): large-scale set gillnets (GNS) and pair bottom trawlers (PTB). The expected sampling coverage (2%), calculated from the 2019 official logbooks, was 101 and 79 trips for GNS and PTB, respectively.

Geographically, both target fleets operate in two fishing grounds: mainly French waters of Bay of Biscay (ICES Divisions 27.8.a, 27.8.b and 27.8.d2 – respectively North, Central and Offshore of Bay of Biscay); and Spanish waters of Bay of Biscay (ICES Division 27.8.c – South of Bay of Biscay/ Cantabrian Sea) and of Atlantic Iberian waters (north of ICES Division 27.9.a). Technically, the Spanish set gillnet fleet comprises two DCF métiers, both targeting demersal fish by using different mesh sizes: GNS_DEF_80-99_0_0, directed to hake in ICES Divisions 27.8.c and 27.9.a, and GNS_DEF_>=100_0_0, directed to hake in Divisions 27.8.a, 27.8.b and 27.8.d2 as well as white anglerfish in ICES Divisions 27.8.c and 27.9.a. The bottom pair trawl fleet presents two métiers: PTB_ MPD _>=55_0_0, targeting a mixture of pelagic and demersal fish (blue whiting, hake and mackerel), and PTB_ DEF _>=70_0_0, targeting demersal fish (hake).

2.2 Methodology

The data obtained by the Spanish cetacean bycatch observer programme were analyzed with the aim of being compared with those obtained by the DCF at-sea sampling programme, which are yearly analyzed and published by the ICES Working Group on Bycatch of Protected Species (WGBYC). For this, the following issues have been considered:

- Representativeness of the sampling frame.
- Estimation of bycatch per unit of effort (BPUE).
- Sampling effort and coverage.
- Optimization of the sampling protocol.

2.2.1 Representativeness of the sampling frame

The selection of trips is a two-step process, in which the vessel is the primary sampling unit (PSU) and the trip is the secondary sampling unit (SSU). To analyze the representativeness of the PSU we compare the vessel length between the vessels from the sampling frame and the target fleet (total population), while to analyse the representativeness of the SSU we compare the total landed weight per trip between the vessels from the sampling frame and the total population based on official logbook data (Fernandes *et al.*, 2021). The Unpaired Two-Samples Wilcoxon signed-rank test was used in both cases, since both vessel length and total landed weight per trip presented non-normal distributions (Shapiro-Wilk test). Analyses were conducted in R (R Core Team, 2019).

When samples were found to be not representative, further analyses were done to detect the source of bias and attempt to correct for the bias a posteriori (Moore et al., 2021). Namely, the trips were sub-stratified according to home port, and for each sub-stratum we determined: percentage of responses from fishers to the selection of trips for onboard sampling; as well as percentage per each trip of the main target species of the fleet, to explore differences in fishing strategies. Then, a Kruskal Wallis test was applied on the trips (SSU) disaggregated by sub-stratum taking as explanatory variable the landed weight of the main target species of the fleet. Furthermore, we determined the number of sampled and total trips per each combination of home port and ICES Division. To balance the representativeness of sampled trips in relation to the total trips of the fleet within a Division we calculated a "bias-correction factor" for each port (or groups of ports that contrasted in terms of refusal rates and of fishing strategy), namely: first we divided the number of sampled trips in the port*Division combination by the number of sampled trips in the Division; second we divided the total number of trips in the port*Division by the total number of trips in the Division; last we divided the second ratio by the first ratio.

2.2.2 Estimation of bycatch per unit of effort (BPUE)

The bycatch mortality is the total number of non-target animals that die (or are expected to die) in a fishery from interacting with fishing gear (Moore *et al.*, 2021). A general point estimator of bycatch mortality for population *i* is:

$$\mu_{it} = N_{it}\, E_t\, c_{it}\, m_{it}$$

where the expected bycatch mortality in year t, μ_{it}, is the product of animal abundance in the population (N_{it}), total fishing effort (E_t), a scaling parameter referred to as catchability (c_{it}), and the bycatch mortality rate (m_{it}), *i.e.* the proportion of bycaught individuals that die,

whether immediately or eventually. N_{it} and c_{it} are correlated and in practice will often be difficult to estimate separately, so more typically the product $N_{it}\, c_{it}$ is estimated as a single parameter referred to as "bycatch per unit effort" (BPUE), which is calculated as:

$$BPUE_{it} = n_{it} / E_t$$

where n_{it} is the number of dead or injured individuals for population i in year t, and E_t is the total sampled fishing effort in the same period.

In relation to this last parameter, although the Spanish cetacean bycatch sampling programme provides several detailed fishing effort variables (e.g. number of trips, number of hauls, fishing hours), we have chosen to use fishing days to facilitate comparisons with ICES WGBYC estimates (ICES, 2021a). We consider that fishing days provide a more accurate measure of fishing effort than days at sea used by WGBYC, since not all days at sea include fishing activity. However, the differences are small in coastal fleets, which are the majority in this case study, where the ratio between fishing days and days at sea is 0.9 for both GNS and PTB. For the bycatch estimation, both sampling strata were subdivided into domains geographically disaggregated by ICES Division, in the same way as in WGBYC (ICES, 2021a) and WKMOMA (ICES, 2021b).

The sampling protocol of the Spanish cetacean bycatch observer programme includes the record of the observation rate. This consists of recording observed and non-observed hauls, as well as observed and non-observed phases of the fishing operation. Regarding the phases of the fishing operation, all the hauls sampled have been directly observed in its four phases: slipping, drop-out, pre-sorting, and sorting. However, the observation rate of hauls is especially relevant in the pair trawl fleet, since the gear is operated by two vessels and the observer can only make a direct observation of the hauls that are hauled on the vessel where she/he is onboard.

In pair trawl fleets, each haul is performed by the two vessels of the pair fishing unit but hauled only to one of them. In the case of the Spanish pair trawl fleet operating in distant French waters, trips last several days until the holds of both vessels are filled, and the observer only has access to a part of the hauls (the ones conducted in the vessel where she/he is onboard). However, in the Spanish pair trawl fleet operating in Spanish coastal waters, trips generally fill the holds of only one of the ships and the scientific observer can sample all hauls in that vessel. In order to parameterize these differences, we used the observation ratio to calculate a "pair factor", considering the ratio between the days with directly observed hauls and the total number of days of the trip. This pair factor was further used in the estimation of BPUEs.

When bias was detected in representativeness of the sampling frame, the bias-correction factor described in Section 2.2.1 was applied to the biased BPUE for correction and to obtain the standardized BPUE.

2.2.3 Sampling coverage

The statistical design of the Spanish cetacean bycatch observer programme considers the vessels and their trips as PSU and SSU, respectively, for which it determines the sampling effort (for PSU in number of sampled vessels, for SSU in number of trips) and sampling coverage (for PSU in number of vessels sampled divided by total; for SSU in number of trips sampled divided by total). However, the BPUE estimation uses fishing days as unit of fishing effort and not number of vessels or of trips, so that the final sampling coverage may suffer deviations with respect to the PSU and SSU sampling coverages due to the different duration of trips between fishing areas.

Regarding total fishing days of pair trawlers, the fishing days extracted from the logbooks collect the days twice for trips that fill both holds, that is, those days declared by vessel 1 and those days declared by vessel 2. However, this does not occur with coastal trips in which only the hold of one vessel is filled, because the second vessel does not declare any related landings. In this way, the official fishing days of the logbooks cannot be used directly (which would overestimate the effort), but neither can they be divided by 2 in a general way (which would underestimate the effort). To correct for this, we calculated a "pair factor" based on the observation rate of hauls in sampled trips: number of fishing days observed (with hauls uploaded to vessel 1, where the scientific observer is) divided by the total fishing days of the sampled trip (developed by vessels 1 and 2) by PTB domain. This factor is then applied to the total fishing days of the fleet by PTB-domain, as well as the sampled fishing days.

For the determination of total fishing days of the studied gillnet fleet, these are recorded by a single vessel, so it does not require the corrections described in the pair trawl fleet. However, the trips registered in logbooks only declare the trip destined for the collection of fishing gear, which entails the registration of catches. If there were previous trips to only set the fishing gear, these are not recorded as trips.

Small populations for which bycatch is an infrequent or rare event imply particular bycatch estimation challenges and require high sampling coverage levels to avoid severe biases due to small sample size (Moore *et al*., 2021). Curtis and Carretta (2020) developed a method and package in R "*obsCovgTools*" (R Core Team, 2019) that calculates coverage levels

required to meet user-defined bycatch estimation objectives in scientific fisheries observer programmes. These objectives include: (1) estimating the probability of observing bycatch when it exists in a fishery, (2) providing an upper confidence limit for bycatch, even if no bycatch is observed, and (3) estimating bycatch to a desired precision level. Estimates in all cases are based directly on or simulated from the corresponding Poisson or negative binomial probability distribution. An interactive version of this tool is also provided by the authors to be used online (https://kacurtis.shinyapps.io/obscov/).

Regarding the first objective, we calculated the sampling coverage needed to achieve 95% probability of observing any bycatch when bycatch occurs. Secondly, we determined 95% upper confidence limit no higher than the potential biological removal (PBR) of common dolphin (*Delphinus delphis*), the most common cetacean species in bycatch in the study area. Finally, the CV level was set to 0.3, considered a reasonable default input for the target precision (Wade, 1998; Moore *et al*., 2021).

Outputs were estimated from the total effort (fishing days) by domain (metier DCF L4 and ICES Division) and the dispersion index (*d*) obtained from the data provided by the Spanish cetacean bycatch observer programme. The dispersion index (*d*) by cetacean species was calculated as ratio of variance/mean of BPUE. More skewed data have higher *d*. According to the authors, a value of 2 is a relatively conservative default for rare event bycatch of marine mammals. However, higher *d* may be needed when variation among effort units is high.

To determine the PBR of common dolphin, we used the modified Potential Biological Removal (mPBR), estimated by OSPAR at 985 individuals for the Northeast Atlantic management unit (ICES, 2021b).

2.2.4 Optimization of the sampling protocol

The Spanish dedicated bycatch monitoring programme was designed specifically with the aim of registering the bycatch of cetaceans, however, it also included other potentially relevant information as cetacean sightings, bycatch of other protected or vulnerable species not targeted by the metier (birds, turtles and fish from Table 1D of Commission implementing decision (EU) 2016/1251) and marine litter.

The record of cetacean sightings was included in the Spanish cetacean bycatch observer programme to investigate the potential relation between presence of cetaceans and their incidental catch. The protocol instructed observers to record the observation time spent in this task before every lifting/hauling of the net out of the water as well as in navigation

between hauls. In each sighting, the number of individuals, taxonomic identification, latitude, longitude, sea state, wind speed, visibility and distance of the sighting were also noted.

The monitoring of by-catch of non-cetacean species includes information of the specimens by haul such as number of individuals, length, weight and condition at the time of catch and release. For the variable condition, 5 states were established: alive, damaged, dead, rotting and unknown. A specific table with the relevant species in the area (following Table 1D of EU Decision 2016/1251) was provided to observers. Regarding collection of morphometric data, three variables were specified: one common for all the taxonomic groups (total length), and a second and third specific by taxa (e.g. curved carapace length for turtles, body circumference in front of the dorsal fin for marine mammals, etc).

Marine litter data includes information recorded by haul and classified by category: A) Plastic, B) Metal, C) Rubber, D) Glass/Ceramics, E) Natural product, and F) Miscellaneous. Each category was subdivided into different subcategories to facilitate its coding, for example, category A allows differentiating between bottles, bags, caps, remains of synthetic fishing gear, etc.

For these secondary tasks, a completeness analysis and a brief summary of the data collected was done to evaluate the appropriateness of their inclusion in at-sea sampling programmes dedicated to cetaceans. The completeness rate, *i.e*. the degree to which the observers have collected data as defined in the sampling protocol, was determined for each data type (1- cetacean sightings, 2- bycatch of non-cetacean protected or vulnerable species, and 3- marine litter). The summary of the data included shows the basic description of the data collected to determine the type of variables and the quality of the inferred parameters.

Lower completeness rate of a variable signifies a lower sample size, and can result in lower accuracy as well as reveal issues in sampling (e.g. time needed for collecting the data, the level of expertise required, the lack of collaboration from the vessel crew, unclear sampling protocol or insufficient training).

3 RESULTS

3.1 Representativeness of the sampling frame

Total sampling effort (n) of the Spanish cetacean bycatch observer programme between October 2020 and September 2021 was 55 unique vessels (primary sampling units) and 223 trips (secondary sampling units) (**¡Error! No se encuentra el origen de la referencia.**). Sampling coverage (%) was higher in PTB than GNS for both the primary sampling unit (unique vessels) and the secondary sampling unit (trips).

Table 1. Total and sampled primary (unique vessels) and secondary (trips) sampling units, as well as the corresponding sampling coverage of the Spanish cetacean bycatch observer programme, from October 2020 to September 2021.

Strata	Total Unique vessels	Total trips	Sampled unique vessels	Sampled trips	PSU (unique vessels) coverage (%)	SSU (trips) coverage (%)
GNS	65	4492	34	88	52.3	2.0
PTB	31	5033	21	135	67.7	2.7

Vessels from target fleet and from the sampling frame did not differ regarding their lengths in either of the metiers sampled (Two-Samples Wilcoxon signed-rank test; GNS: W = 1176, p-value = 0.61 6 with n = 34; PTB: W = 336, p-value = 0.85 with n = 21). No bias was detected in the GNS total landed weight per trip (W = 219209, p-value = 0.08 with n= 88); however, a significant difference is observed for the PTB total landed weight per trip, which was higher in the sampling frame (W = 271830, p-value = 0.00007, with n=135). Therefore, the primary sampling unit (unique vessels) from the sampling frame can be considered representative of the target fleet for both sampling strata, as well as the secondary sampling units (trips) for GNS but not for PTB trips.

To further explore the bias found in the total landed weight of the sampled PTB trips in relation to the sampling frame, we sub-stratified the PTB trips by home port, and we evaluated the responses of the fishers to the random selection of trips (**¡Error! No se encuentra el origen de la referencia.**). The percentage of PTB trips accepted for sampling exceeds that of all and any of the other responses (overall and in each port, except one where it is equal); however, refusals differed per base port, with port A having a much higher acceptance percentage (87%) than any of the other three ports (B, C, D, between 50 and 56%) (coded for confidentiality and geographically ordered from East to West).

Table 2. Responses (in percentage) of the Spanish pair bottom trawl (PTB) fishers contacted by scientific observers to request for sampling at sea, by base port and response.

Base port of vessel operating with PTB	Acceptance	Refusal	Unavailability	Observer refusal	No response	No contact details
Port A	87	0	9	0	4	0
Port B	50	0	50	0	0	0
Port C	56	0	44	0	0	0
Port D	53	29	18	0	0	0

An additional analysis of landings per PTB trip by port was made to detect possible differences in fishing strategies namely by comparing the percentage of the main target species of the strata PTB, per trip (blue whiting *Micromesistius poutassou*). The Kruskal Wallis test found significant differences in percentage of blue whiting by trip between base ports (chi-squared = 737.347, df = 3, p-value = 0) and the Pairwise comparisons revealed that they are significant between port A (lower percentage, mean 9.9%) and the remaining ports B, C and D (higher percentage, mean 82.6%) (Table 3).

Table 3. Kruskal-Wallis rank sum test among percentage of blue whiting by trip for PTB strata by base port. (*) significantly different.

	Port A	Port B	Port C
Port B	-16.61363 (0.0000*)		
Port C	-16.90359 (0.0000*)	-0.585091 (1.0000)	
Port D	-27.11982 (0.0000*)	-2.376509 (0.0524)	-1.523996 (0.3825)

To further explore the bias detected in the total landed weight of the sampled trips in relation to the sampling frame, we calculated the distribution of the total (and sampled) number of trips of PTB vessels by base port and ICES Division (Table 4).

Table 4. Total number of trips of Spanish PTB fleet from October 2020 to September 2021 by base port and ICES Division. The number of sampled trips is in parentheses.

Port	Division 27.8.a	Division 27.8.b	Division 27.8.c	Division 27.9.a
A	4 (0)	177 (26)	506 (15)	0
B	0	0	361 (13)	0
C	0	0	342 (11)	0
D	0	0	2097 (52)	1547 (18)

Vessels from port A operate in four Divisions, vessels from port B and C in only one (27.8.c) and from port D in two (27.8.c, 27.9.a.). Division 27.8.c is the only fishing area common to

PTB vessels from all four ports; therefore, this domain (PTB-8c) is the only one affected by the bias detected. Then, the Two-Samples Wilcoxon signed-rank test was applied to total landings of the target fleet and the sampling frame by port group (port A vs. ports B-C-D) in Division 27.8.c, in which no significant differences were found: port A (W = 4453, p-value = 0.51 with n = 15), and ports B-C-D (W = 92847, p-value = 0.08 with n = 76).

For Division 27.8.c we obtained a bias-correction factor of 0.93 for sampled trips of pair trawlers from port A, and a bias-correction factor of 1.01 for sampled trips of pair trawlers from ports B, C and D).

3.2 Estimation of bycatch per unit of effort (BPUE)

As stated in section 2.2.2, the estimation of bycatch per unit of effort (BPUE) was estimated using "fishing day" as effort unit. The Spanish cetacean bycatch observer programme sampled 313 fishing days (

Table 5): 115 in GNS (sampling coverage of 1.9%), and 198 in PTB (3.5%).

Both the set gillnet fleet and the pair bottom trawl fleet operating in ICES Sub-Areas 8 and 9 present their greatest fishing activity (% of fishing days) in Division 27.8.c: 77.6% for GNS and 65.2% for PTB. The sampling coverage, *i.e*. the percentage of the fishing days of the fleet that has been monitored by the scientific observers, was unequal by domain, from 0% (no sampling) in GNS-8b, GNS-8d and PTB-8a to 19.6% in domain PTB-8b (Table 5).

In relation to the BPUE by cetacean species, the highest value was obtained for common dolphin (*Delphinus delphis*) bycaught by PTB in Division 27.8.b (domain PTB-8b), which also presents bycatch of long-finned pilot whale (*Globicephala melas*). Although with a lower BPUE, *D. delphis* also appears as a bycatch of PTB in Division 27.8.c with 1 individual bycaught (domain PTB-8c), together with bottlenose dolphin (*Tursiops truncatus*). GNS in Division 27.8.c (domain GNS-8c) presented the incidental catch of 1 specimen of *D. delphis*. Domains GNS-8a, GNS-9a and PTB-9a were sampled but had no incidental bycatch events.

Table 5. Bycatch per unit of effort (BPUE) resulted from the Spanish cetacean bycatch monitoring programme developed between October 2020 and September 2021, by domain and cetacean species. Total fishing days taken from logbooks. Sampled fishing days and sampling coverage (in brackets) were calculated considering both vessels activity for pair trawlers (including the days when the observer did not have direct access to the haul when it was hauled to the other vessel in the pair).

Domain	Total fishing days	Sampled fishing days (%)	N. incidents	Spp.	N. individuals	BPUE (dedicated programme)
GNS-8a	599	11 (1.8%)	0	--	0	0
GNS-8b	204	0 (0%)	0	--	0	0
GNS-8c	4610	84 (1.8%)	1	*D. delphis*	1	0.012
GNS-8d	84	0 (0%)	0	--	0	0
GNS-9a	445	20 (4.5%)	0	--	0	0
PTB-8a	4	0 (0%)	0	--	0	0
PTB-8b	393	77 (19.6%)	10	*D. delphis*	32	0.416
			1	*G. melas*	2	0.026
PTB-8c	3702	102 (2.8%)	1	*T. truncatus*	4	0.039
			1	*D. delphis*	1	0.010
PTB-9a	1577	19 (1.2%)	0	--	0	0

The bycatch rates estimated by ICES with DCF 2017-2021 data (ICES, 2021a) have been summarized in Table 6 to facilitate its comparison with those provided by the Spanish cetacean bycatch monitoring programme.

Table 6. Bycatch rates estimated by ICES with DCF 2017-2021 data (ICES, 2021a).

Metier Level 3	Total days at sea	Total Observed Effort (%)	N. incidents	Spp.	N. individuals	Bycatch rate (DCF)
Nets-8a	468598	709 (0.2%)	9	*D. delphis*	9	0.013
Nets-8b	152198	476 (0.3%)	11	*D. delphis*	14	0.029
Nets-8c	27970	49 (0.2%)	1	*D. delphis*	1	0.020
Nets-9a	170840	434 (0.3%)	4	*D. delphis*	6	0.014
Bottom trawls-8a	512676	73 (0.01%)	4	*D. delphis*	21	0.288
Bottom trawls-8b	123485	164 (0.1%)	4	*D. delphis*	8	0.049
Bottom trawls-8c	14730	62 (0.4%)	1	*D. delphis*	1	0.016
Bottom trawls-8d2	5295	9 (0.2%)	1	*D. delphis*	4	0.444

The highest BPUE of *D. delphis* provided by the Spanish cetacean bycatch monitoring programme during 1 year (in 2020-2021) recorded in PTB-8b (0.416 individuals/fishing day) was of the same order of magnitude as the highest bycatch rate estimated for bottom trawlers (métier level 3) in the Bay of Biscay and the Iberian Coast ecoregion with 2017-2020 DCF data (ICES, 2021a): 0.444 individuals/days at sea in Division 27.8.d.2. However, the Spanish cetacean bycatch monitoring programme also provides bycatch rates for long-finned pilot whale (*G. melas*) that was not recorded by the 2017-2020 DCF programme.

The bycatch rate for *D. delphis* provided by the Spanish cetacean bycatch monitoring programme during 1 year (in 2020-2021) for PTB in Spanish waters PTB-8c (0.010 individuals/fishing day) was also of the same order of magnitude as the values estimated with 2017-2020 DCF data (ICES, 2021a) for bottom trawls: 0.016 individuals/days at sea in Division 27.8.c. However, the Spanish cetacean bycatch monitoring programme also provides bycatch rates for bottlenose dolphin (*T. truncatus*) that was not recorded by the 2017-2020 DCF programme. Neither of both at-sea sampling programmes recorded cetacean bycatch in Division 27.9.a for pair bottom trawlers.

For the set gillnet fleet (GNS), the Spanish cetacean bycatch monitoring programme during 1 year (in 2020-2021) only detected bycatch in Division 27.8.c (BPUE of *D. delphis*: 0.012 individuals/fishing day), while the 2017-2020 DCF data provides estimates for *D. delphis* in almost all Divisions of the Bay of Biscay and Iberian Coast ecoregion within the same order of magnitude: 0.013, 0.029, 0.020 and 0.014 individuals/days at sea respectively in Division 27.8.a, 27.8.b, 27.8.c and 27.9.a. Nevertheless, DCF data for GNS in Divisions 27.8.a, 27.8.b, and 27.9.a includes data from fleets of other countries collected by their respective DCF at-sea sampling programmes.

As explained in section 2.2.2, the Spanish pair trawl fleet presents different fishing strategies by ICES Division, regarding the filling of the holds of both vessels or just one. In the first case, the scientific observer has direct access to only half of the hauls made by the pair fishing unit, that is, to the hauls uploaded to the vessel in which she/he is. In the second case, the scientific observer has access to all the hauls made by the pair fishing unit. Taking the observation rate per hauls we obtain the following pair factors (number of fishing days directly observed/total number of fishing days by trip): 0.5 in Division 27.8.b; 0.74 in Division 27.8.c and 1 in Division 27.9.a. The first two values were used in Table 7 to estimate the total fishing days and the directly observed fishing days of the PTB domains with bycatch records.

Table 7. Bycatch per unit of effort (BPUE) for bottom pair trawlers (PTB) resulted from the Spanish cetacean bycatch monitoring programme developed between October 2020 and September 2021, by domain and

cetacean species. Total official fishing days and sampled fishing days were recalculated by applying the "pair factor" described in the text. Table only includes the domains which had incidental bycatch during the dedicated programme.

Domain	Total fishing days	Sampled fishing days (%)	N incidents	Spp.	N individuals	BPUE (dedicated programme)
PTB-8b	197	39 (19.6%)	10	*D. delphis*	32	0.831
			1	*G. melas*	2	0.052
PTB-8c	2740	75 (2.8%)	1	*T. truncatus*	4	0.053
			1	*D. delphis*	1	0.013

With the correction applied to the total and sampled fishing days, these two variables decreased and the BPUE increased proportionally. An annual incidental mortality calculated by multiplying BPUE and total fishing effort is equivalent between the two approaches (not corrected - Table 5, and corrected - Table 6).

To correct the bias detected due to the unbalanced sampling between the PTB trips of vessels from port A and the PTB trips of vessels from ports B, C, and D, we applied the bias-correction factors provided in Section 3.1 to domain PTB-8c, the only one affected by the bias detected in the previous section. The standardized BPUE decreased by one hundredth in both cetacean species (Table 8).

Table 8. BPUE corrected the applying the bias-correction factor calculated by stratifying the sampling coverages of domain PTB-8c by port group: port A vs. ports B, C and D together. Table only includes the domains which had issue with representativeness of the sampling frame.

Domain	Spp.	Biased BPUE	Bias-correction factor	Corrected BPUE
PTB-8c	*T. truncatus*	0.053	1.01	0.054
	D. delphis	0.013	0.93	0.012

The BPUE showed spatio-temporal patterns. Within the year, the highest bycatch rates are shown in winter for both PTB domains that have incidental catch of cetaceans (PTB-8b and PTB-8c; Figure 1). Geographically, 88% of cetacean specimens were incidentally bycaught in the easternmost part of the Bay of Biscay, to the East of 4° East longitude (Figure 2), corresponding to 86% of cetacean bycatch events.

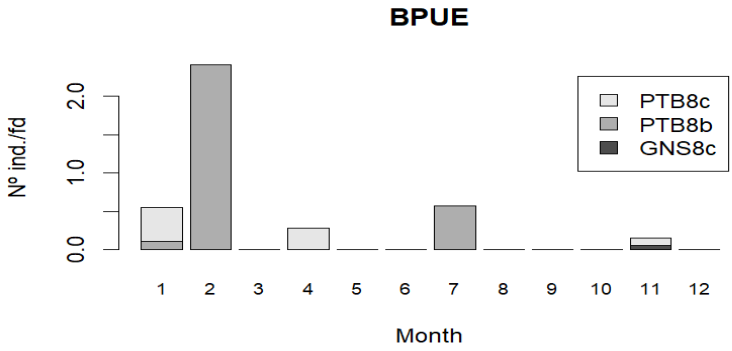

Figure 1. BPUE (number of bycaught cetaceans per fishing day) by domain and month, estimated with data from the Spanish cetacean bycatch observer programme developed from October 2020 to September 2021.

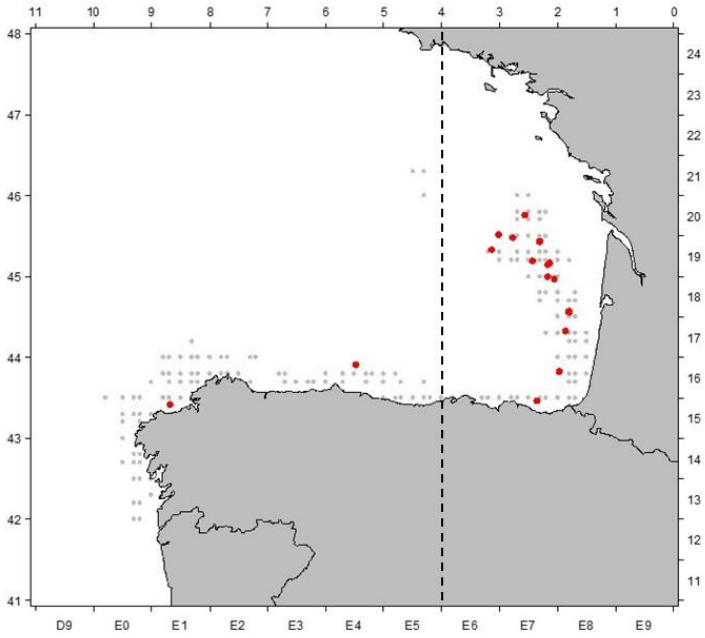

Figure 2. Geographical distribution of the total observed fishing days (grey) and events of cetaceans bycaught (red) in the Spanish cetacean bycatch observer programme developed from October 2020 to September 2021.

3.3 Sampling coverage

In the Spanish cetacean bycatch observer programme, the domains with bycatch of cetaceans had a sampling coverage (percentage of sampled fishing days relatively to total fishing days by domain) of 1.8% (GNS-8c), 19.6% (PTB-8b), and 2.8 (PTB-8c).

The sampling coverage calculator developed by Curtis and Carretta (2020) was applied to these domains with positive bycatch of cetaceans. The estimations provided by the "*ObsCovgTools"* calculator show that the coverage achieved by the Spanish cetacean bycatch

observer programme only reaches the second statistical objective (MOCL2) for the three domains (Table 9). MCOL2 refers to the sampling coverage needed to achieve a 95% upper confidence limit no higher than the modified Potential Biological Removal (mPBR) for common dolphin (*D. delphis*), estimated at 985 individuals in the Northeast Atlantic (ICES, 2021b).

The sampling coverage of domain GNS-8c should be enhanced to 5.6% to reach the minimum level that would allow reaching 95% probability of observing bycatch of common dolphin (*D. delphis*) (MOCL1), as well as to 16.8% to obtain a CV of 0.3 (MOCL3). For domain PTB-8b, the Spanish cetacean bycatch observer programme would have reached the MOCL1 goal; however, the sampling coverage would have to reach 32.0% of sampling coverage to satisfy the premise of not exceeding a coefficient of variation of 0.3 (MOCL3). For domain PTB-8c, the sampling coverage should be enhanced to 9.2% of total fishing days to reach 95% probability of observing *D. delphis* bycatch (MOCL1), and 25.3% to meet objective MOCL3.

Table 9. Minimum sampling coverage levels in percentage by domain needed to achieve the three statistical objectives analysed for the Spanish cetacean bycatch observer programme developed from October 2020 to September 2021: MOCL1 - minimum sampling coverage level to achieve 95% probability of observing any bycatch when bycatch occurs; MOCL2 - minimum sampling coverage level to achieve a 95% upper confidence limit no higher than the modified Potential Biological Removal (mPBR) of *D. delphis* when no bycatch has been observed; MOCL3 - minimum sampling coverage level to achieve an estimation CV of 0.3. Table only includes the domains which had incidental bycatch during the dedicated programme. Total fishing days are the total fishing days considering the pair factor correction.

Domain	Total fishing days	Sampled fishing days (%)	BPUE	d	MOCL1	MOCL2	MOCL3
GNS-8c	4610	1.8%	0.012	1	5.6	0.4	16.8
PTB-8b	197	19.6%	0.831	6.7	5.6	1.1	32.0
PTB-8c	2739	2.8%	0.012	1	9.2	0.5	25.3

3.4 Optimization of the sampling protocol

3.4.1 Cetacean sighting

The sampling protocol established the collection of cetacean sighting, but a total of 6,204 sighted individuals were recorded comprising not just cetaceans: 28 taxa, 12 families and 4 classes (Mammalia, Aves, Elasmobranchii and Actinopterygii) (Table 10) from 363 events registered in 70 sampled vessels and 178 sampled trips. These correspond to 2941 cetaceans sighted, of 12 taxa.

Table 10. Number of events and individuals observed by family. Number of taxa registered within each family provided.

Cetacean	Class	Family	Events	Taxa	Individuals
Yes	Mammalia	Balaenopteridae	26	3	31
Yes	Mammalia	Delphinidae	271	7	2901
Yes	Mammalia	Phocoenidae	1	1	6
Yes	Mammalia	Physeteridae	2	1	3
No	Mammalia	Phocidae	1	1	1
No	Elasmobranchii	Dasyatidae	1	1	1
No	Aves	Hydrobatidae	9	1	49
No	Aves	Laridae	22	6	3024
No	Aves	Procellariidae	6	3	16
No	Aves	Stercorariidae	4	2	9
No	Aves	Sulidae	19	1	162
No	Actinopterygii	Molidae	1	1	1

Among cetaceans, common dolphin was the taxa with the major number of sightings and of individuals observed (Figure 3).

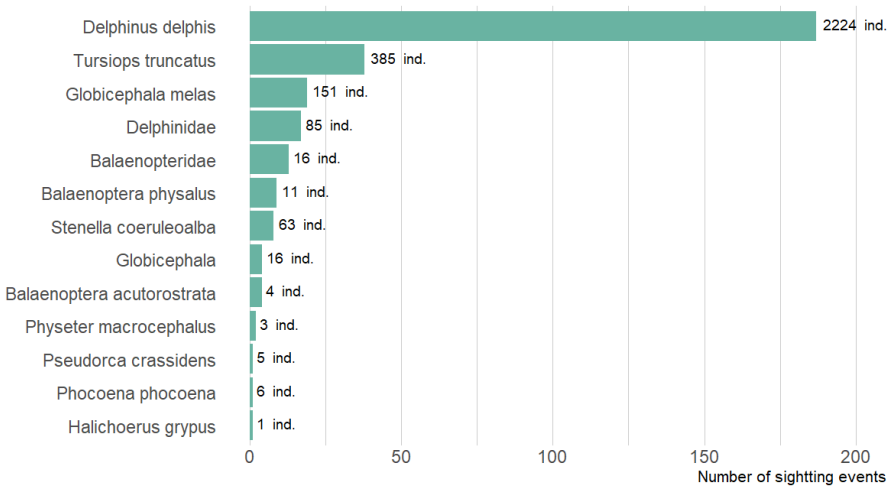

Figure 3. Number of sighting events (x-axis) and individuals (on the right of each bar) by taxa.

The data of cetacean sightings were not analyzed statistically to investigate the potential relation between presence of cetaceans and their incidental catch due to the difficult consolidation of the data and as this was not the aim in this deliverable. Much of the information of interest was collected in the "observations" field, consisting of qualitative descriptions, the parameterization of which will require extra work in future analyses.

3.4.2 Bycatch of non-cetacean species

A total of 87,457 individuals were recorded as bycatch from 237 taxa, 134 families and 23 classes other than mammals (Table 11). The number of individuals was not found in 13.8% of the records of non-cetacean bycatch whereas the weight was not found in 16.9%. A total of 3,400 events of non-cetacean species bycatch were recorded in 325 trips and 882 hauls (more events than hauls, since more than one species can be by-caught in one haul).

Table 11. Number of events and individuals observed by class. Number of taxa within each family provided.

Phylum	Class	Sum of events of each taxa	Taxa	Individuals
Annelida	Polychaeta	16	2	23
Arthropoda	Malacostraca	275	27	23905
Chordata	Actinopteri	438	69	11655
Chordata	Ascidiacea	24	2	916
Chordata	Aves	17	2	32
Chordata	Elasmobranchii	857	52	9931
Chordata	Holocephali	78	5	289
Chordata	Petromyzonti	5	1	5
Chordata	Thaliacea	106	2	10793
Cnidaria	Anthozoa	286	15	1850
Cnidaria	Hydrozoa	5	1	20
Cnidaria	Scyphozoa	6	2	18
Echinodermata	Asteroidea	339	6	5659
Echinodermata	Crinoidea	137	2	8722
Echinodermata	Echinoidea	226	7	2070
Echinodermata	Holothuroidea	149	4	516
Echinodermata	Ophiuroidea	194	3	8279
Mollusca	Bivalvia	12	6	26
Mollusca	Cephalopoda	88	14	486
Mollusca	Gastropoda	122	7	2213
Ochrophyta	Phaeophyceae	4	3	1
Porifera	Demospongiae	15	4	47
Porifera	Hexactinellida	1	1	1

Records showed more species than those indicated in the sampling protocol. On the other hand, the variable “condition” is not of interest for most part of species that were registered in this task. Therefore, the following analysis excludes commercial fish. For the non-cetacean species included in the sampling protocol, the completeness rate for sampling of

morphometrics varied from 97% for the first length in the protocol (total length applicable to all taxonomic groups), 42% for the second measure, and to 7.8% for the third measure in the protocol (Figure 4).

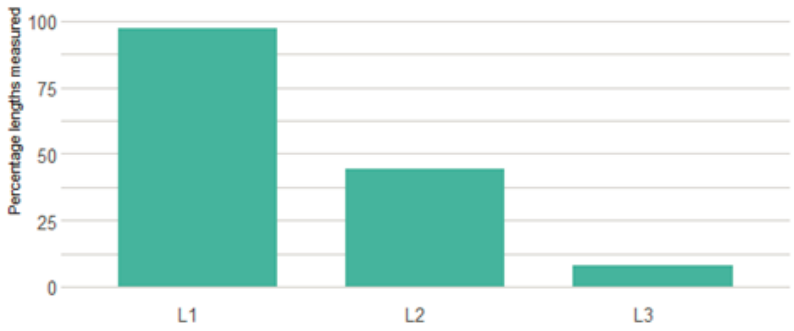

Figure 4. Percentage of lengths measures fulfilled by length parameter.

A total of 1,521 individuals were registered with at least one length parameter in 126 trips and 231 hauls. Elasmobranchii is the group with the highest number of records (Figure 5), followed by Actinopterygii. Minor representation of other classes, as Echinoid or Anthozoa, also appear.

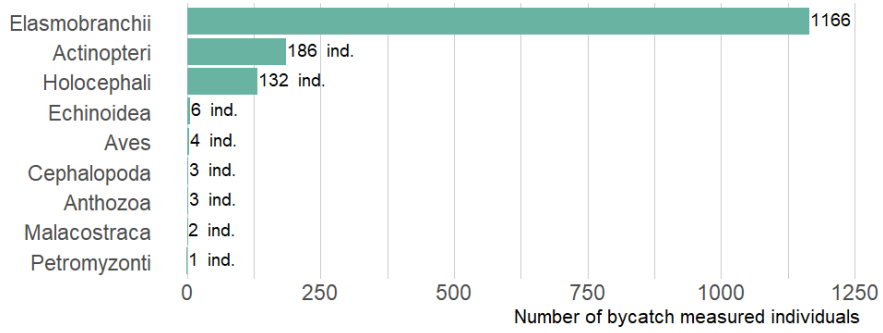

Figure 5. Number of individuals measured of non-cetacean bycatch.

3.4.3 Marine litter

The analysis of the marine litter data showed that they erroneously included the record of natural inorganic (stones or coal) and organic (rhizomes or seashells) items. ICES does not consider marine litter any natural remains (new guide not published yet).

Relevant variables as the category and sub-category were recorded in most cases under the field “Observation”, complicating quantitative analysis. Same issue is found for variables “Quantity” and “Size” where missing information is in several cases wrongly registered under the “Observations” field.

Marine litter was recorded in 62 sampled vessels, 153 sampled trips and 380 sampled hauls. A total of 1,274 items were found, distinguishing 35 different articles classes belonging to 8 marine litter types: Glass/Ceramics, Metal, Natural inorganic, Natural organic, Natural product, Plastic, Rubber and Miscellaneous. Natural inorganic marine litter was the most abundant type of “marine litter” in terms of number of items (Figure 6) and was in almost all cases composed exclusively by stones.

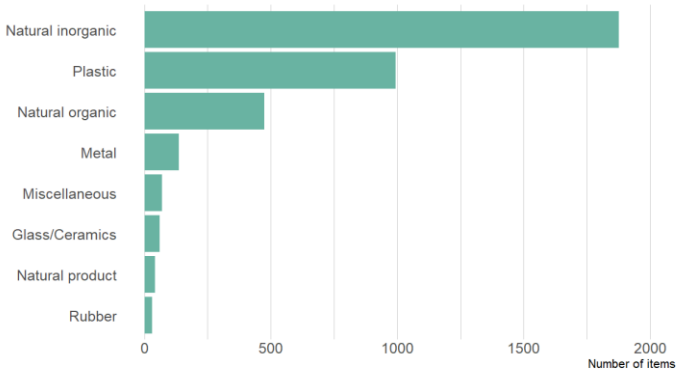

Figure 6. Total of items collected per marine litter type.

The second most abundant type of marine litter was plastics. Considering the presence/absence of marine litter types, plastics had the highest occurrence both by haul and by trip (Figure 7), appearing in the 78.4% of the hauls where some type of marine litter is registered.

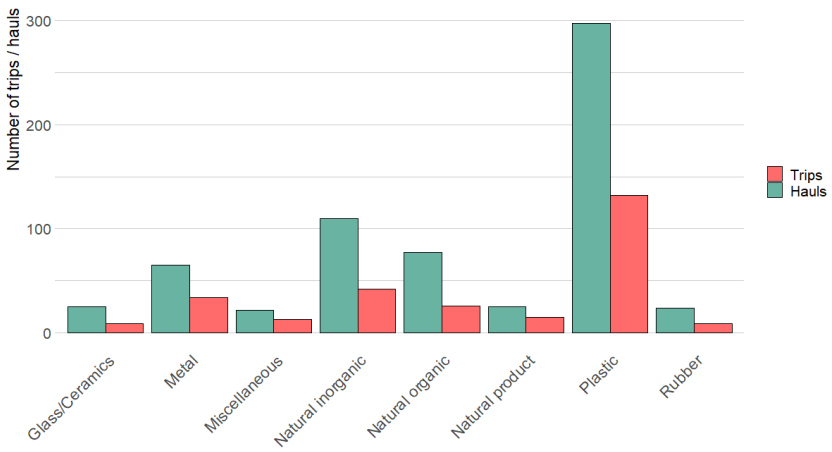

Figure 7. Presence of marine litter types in trips and hauls.

When registered, observation coverage is very high, with a mean of 94.4% and a median of 100%.

4 DISCUSSION

The BPUE (bycatch per unit of effort) for common dolphin *Delphinus delphis* obtained by the Spanish cetacean bycatch monitoring programme carried out in Spanish vessels operating with large-scale set gillnets and pair bottom trawl in the Bay of Biscay (ICES Divisions 27.8.a, 27.8.b, 27.8.c, and 27.9.a) in 2020-2021 provides support to the BPUE estimates derived by ICES (ICES, 2021a) from the Spanish DCF at-sea sampling programme 2017-2021, which included in the sampling protocol the bycatch sampling of vulnerable species since 2017. This question is of special importance when designing future sampling programmes on board the commercial fleet, as it reinforces the validity of the data from both programmes.

From the statistical point of view, the first issue that must be guaranteed in a sampling programme is the representativeness of the samples, otherwise biased estimates of the studied variable could be obtained. The two sampling programmes under consideration here (dedicated and non-dedicated to cetaceans), have a sampling design based on random sampling, in which all the elements of the target population have the same probability of being selected for sampling, but stratified by ICES Division and metier *i.e.* random selection of vessels and trips is performed with each stratum. However, the randomness in the selection of the samples can be altered due to deviations in the execution and implementation of the sampling plan, as evidenced in the present case study and as frequently occurs in DCF at-sea sampling programmes in several member states (provided to the European Commission in Table 4 of refusals in the Fisheries Dependent Information (FDI) data call). Therefore, it is recommended that an at-sea sampling programme, whether directed at commercial species or dedicated to the bycatch of cetaceans, integrate mechanisms that allow subsequent bias analysis. In this sense, it is recommended to establish as part of the sampling protocol the collection of responses from fishers that allow to identify the refused vessels/trips. This allows to parameterize the deviation and correct the estimates for which the sampling programme in question was established.

Another fundamental issue is to determine the sample size required for the objectives of the sampling programme. The sample size depends on the characteristics of the study variable. Discards of commercial species are frequent events and can therefore be estimated with smaller sample size than less frequent or rare events such as bycatch of cetaceans. In this sense, the combination of both objectives in the same at-sea scientific programme will imply that the sample size would be determined by the limiting factor, which in this case is the cetacean bycatch sampling. Increasing the monitoring effort performed by scientific observers may be logistically and economically unfeasible in many fleets, and additional

monitoring methods may be needed be used to complement the monitoring effort by scientific observers (*e.g*. electronic monitoring, see Deliverable from task 3.4.3 of the project). As for trips sampled with both types of objectives, up to a certain point, the work of the scientific observer on board can be optimized and reduced to improve the implementation of the sampling protocol with both objectives (*e.g*. removing the record of secondary data with no application for the objectives of the sampling programme).

Furthermore, it is also important to determine the observation rate of the sampling programme at each hierarchical level in complex stratified sampling designs as is the case of the programme studied here and many other fisheries monitoring programmes. For instance in this study, there are primary sampling units (vessels), secondary sampling units (trips) and sampling units within them (such as several hauls within trips, and different phases of the fishing operation in each haul). When the coverage of the hauls, fishing phases or fishing days is not complete, the relationship between catch and effort is altered, altering the resulting BPUE. Moreover, end-users of by-catch data may need to consider units of effort common to the sampling programs of the different countries (*e.g*., trips, days at sea or fishing days).

The present analysis highlighted the relevance of how fishing effort and sampling effort are determined for the PTB fleet. In this fleet a pair of vessels operates a single gear and the net is hauled onboard of one of them which raises issues for the estimation of fishing effort (based on logbooks, since both vessels record the same trip to be able to allocate their respective catches) and for the determination of sampling effort (since observer can only monitor hauls that are hauled to the vessel where she/he is onboard). It is very important that this aspect is considered and dealt with appropriately when estimating BPUEs. For instance by ICES expert group WGBYC does not detail how this aspect was dealt with but from results it seems that sampled fishing days included all days of duration of the sampled trips regardless of whether they have been directly observed or not, whereas total fishing days of the whole Spanish pair bottom trawl fleet was divided by two. This precision is especially relevant since ICES estimates are being used as a basis for the proposal of management measures in the Bay of Biscay and Iberian coast (ICES, 2023).

The present analysis demonstrates for this case study how different approaches rendered similar outcomes in terms of BPUE: raw data of total fishing days and sampled fishing days, as well as corrected total fishing days and corrected sampled fishing days by applying the pair factor. This is so because both parameters are corrected in the same proportion; however, this is correct when calculating by Division, since the pair factors are specific to geographic area. In any case, if raw or corrected data are used, what must always be

respected is the use of directly observed bycatch. Since international data sources such as RDBES do not provide the estimation of the "observation rate" or the "pair factor", our proposal is to use the following available parameters:

A. Total fishing days as in logbooks (as supplied in the RDBES CL matrix).
B. Sampled fishing days (total, including with and without direct observation) (as supplied in the RDBES CS matrix).
C. Number of cetacean individuals bycaught directly observed (providing in the RDBES CS matrix only individuals bycaught in hauls monitored by scientific observers).

In our opinion, the most accurate way to compute total fishing days of pair trawlers is the one that involves the least manipulation of official records, that is, in the same way that the Spanish administration transmits them to RDBES and other international databases, *i.e*. the fishing days declared by each vessel of the pair. Similarly, to keep up the correspondence, the sampled fishing days should also correspond to the total days monitored, regardless of whether they have had direct observation or not, as in fact it is currently provided in the RDBES CS matrix. In this way, it is avoided to apply pair factors that can only be obtained by onboard sampling and that can vary between years as well as depending on the sampling effort exerted. Nevertheless, the number of cetaceans incidentally bycaught must only include those directly observed by the scientific observer.

Apart from the three sampling issues related to sampling design and its implementation (representativeness of the samples, sample size and observation rate), another relevant aspect of sampling programme is the optimization of its sampling protocol. The protocol should not include collection of information that will not be used, and should differentiate primary essential tasks from secondary optional tasks, which can be neglected if needed. In the case of this study primary essential tasks are concern cetacean bycatch, whereas secondary optional tasks concern cetacean sighting, non-cetacean bycatch, and marine litter.

Cetacean sightings are usually collected in scientific surveys by boat or plane following a sampling design based on transects that allows to make appropriate estimates of cetacean abundance. On the other hand, fishing vessels in which scientific observers do the monitoring operate in space and time according to their commercial interests, which does not provide a suitable sampling design for estimating the abundance of cetaceans (whether or not the programme is dedicated to cetaceans). It is also true that, in areas lacking scientific surveys the commercial vessels can serve as platforms of opportunity but this is not the case in the Bay of Biscay, where several scientific surveys based on transects and with long time series are carried out. On the other hand, the use of sightings to investigate

the potential relation between presence of cetaceans and their incidental catch needs further analyses to evaluate its quantification, modelling and eventual application in fishing advice.

Sampling of bycatch of non-commercial and non-cetacean species is routinely implemented in DCF sampling programmes, but these programmes generally do not collection biological information on cetacean species other than species, number and condition. Therefore, biological sampling (taxonomic identification, weight, size and condition) of vulnerable species is recommended in programmes that can accommodate it in the sampling protocol and that will then use the data. In this sense, the specific training of the observers on board is recommended, both in terms of the identification of species, as well as the collection of specific measures and the handling of live specimens for their release. On the other hand, the variable "condition" does not seem to be a useful variable for fish, which are generally dead after being hauled on board.

Collection of marine litter has been introduced in DCF at-sea sampling programmes of commercial fisheries because of their broad temporal and spatial coverage. However, marine litter sampling data is also collected in scientific bottom trawl surveys, which comply with requirements needed for estimation of marine litter distribution, such as accurate measurement of horizontal opening and the distance dragged to calculate the area covered, and appropriate geographical stratification of sample location is required for the weighting process.

The present study indicates that the Spanish cetacean bycatch monitoring programme and the Spanish DCF at-sea sampling programme could be merged into a single at-sea sampling programme. The idea of a single programme that meets the needs of sampling commercial catches together with the bycatch of vulnerable species has numerous advantages. On the scientific side, observer training, sampling protocols implemented, data collected and databases and data entered can be standardized which would facilitate the consolidation of data, statistical analysis and estimates. Logistically, observers enrolment on board fishing vessels would be centralized facilitating a better distribution of human resources. On the fishing sector side, contacts with fishers for a single program (rather than for two different ones) could result in higher acceptance rates.

5 CONCLUSIONS

The analyses carried out in task 3.4.1 of the project CetAMBICion allow drawing some conclusions which may be applicable to other fisheries that share characteristics of the case study analyzed here:

- The cetacean bycatch data provided by the European DCF at-sea sampling programmes, which include the sampling of vulnerable species, may be as useful and appropriate as those collected by dedicated at-sea monitoring programmes.
- When the previous point is fulfilled, the combination of both types of sampling programmes in a single at-sea programme can help optimize data collection and strengthen parameter estimation, as well as favour fleet collaboration.
- The main aspects to consider when defining an at-sea sampling programme incorporating cetacean monitoring programme:
    - Probabilistic sampling design: this allow the analysis of eventual biases, and is usually already the case in many DCF at-sea sampling programmes.
    - Sample size: rare events, such as incidental catch of marine mammals, require a larger sample size than for commercial species which occur more frequently; sample size must be calculated specifically for each fleet and species and for a specific objective in terms of data quality.
    - Observation rate: it is always necessary to indicate when a direct observation has been made at every level of the sampling design (trip, haul and phase of the fishing operation).
    - Distinguish primary essential tasks and secondary optional tasks, and do not include tasks that do not refer to the objectives of the programme and that do not provide data with sufficient quality for the purpose for which they are collected.

In relation to the high levels of coverage necessary for the proper estimation of the bycatch of rare events, it could be necessary to deepen the combination of on-board monitoring with other methods that could allow for higher coverage levels, as electronic monitoring or the improvement of bycatch recording in logbooks (see Deliverable from task 3.4.3 of the project), as well as identify periods / areas / métiers in which sampling coverage should be intensified (see Deliverable from task 3.2 on risk analysis of the project).

Although the objective of this deliverable is the improvement of observer programmes, and the estimation of BPUEs has only been used to facilitate comparisons with the DCF at-sea sampling programmes, it has been possible to verify that improvement in the data collection can considerably improve the bycatch estimation procedure.

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